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Transdisciplinary Engineering: A Paradigm Shift

Proceedings of the 24th ISPE Inc. International Conference on Transdisciplinary Engineering, July 10–14, 2017

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Preface

This book of proceedings contains papers peer reviewed and accepted for the 24th ISPE Inc. International Conference on Transdisciplinary (formerly: Concurrent) Engineering, held at the Nanyang Technological University, Singapore, July 10–14, 2017. This is the sixth issue of the newly introduced series "Advances in Transdisciplinary Engineering", which publishes the proceedings of the TE (formerly: CE) conference series and accompanied events. The TE/CE conference series is organized annually by the International Society of Productivity Enhancement (ISPE, Inc.) and constitutes an important forum for international scientific exchange on transdisciplinary concurrent engineering and collaborative enterprises. These international conferences attract a significant number of researchers, industry experts and students, as well as government representatives, who are interested in the recent advances in transdisciplinary concurrent engineering research, advancements and applications.

Developed in the 80's, the CE approach is based on the concept that different phases of a product life cycle should be conducted concurrently and initiated as early as possible within the Product Creation Process (PCP), including the implications of this approach within the extended enterprise and networks. The main goal of CE is to increase the efficiency and effectiveness of the PCP and to reduce errors in the later phases, as well as to incorporate considerations for the full lifecycle, through-life operations, and environmental issues. In the past decades, CE has become the substantive basic methodology in many industries (e.g., automotive, aerospace, machinery, shipbuilding, consumer goods, process industry, environmental engineering) and is also adopted in the development of new services and service support.

The initial basic CE concepts have matured and have become the foundations of many new ideas, methodologies, initiatives, approaches and tools. Generally, the current CE focus concentrates on enterprise collaboration and its many different elements; from integrating people and processes to very specific complete multi/inter/transdisciplinary solutions. Current research on CE is driven again by many factors like increased customer demands, globalization, (international) collaboration and environmental strategies. The successful application of CE in the past opens also the perspective for future applications like overcoming natural catastrophes, sustainable mobility concepts with electrical vehicles, and intensive, integrated, data processing. Due to the increasing importance of transdisciplinarity, the board of ISPE, Inc. has decided to rename the conference series in "Transdisciplinary Engineering".

The TE2017 Organizing Committee has identified 31 thematic areas within CE and launched a Call For Papers accordingly, with resulting submissions submitted from all continents of the world. The conference is entitled: "Transdisciplinary engineering: a paradigm shift". This title reflects the variety of processes and methods which influences the modern product creation. Finally, the submissions as well as invited talks were collated into 16 streams led by outstanding researchers and practitioners.

The Proceedings contains 120 peer-reviewed papers by authors from 27 countries. These papers range from the theoretical, conceptual to strongly pragmatic addressing industrial best practice. The involvement of more than 15 companies from many industries in the presented papers gives additional importance to this conference.

This book on ‘Transdisciplinary engineering: a paradigm shift’ is directed at three constituencies: researchers, design practitioners, and educators. Researchers will benefit from the latest research results and knowledge of product creation processes and related methodologies. Engineering professionals and practitioners will learn from the current state of the art in concurrent engineering practice, new approaches, methods, tools and their applications. The educators in the CE community gather the latest advances and methodologies for dissemination in engineering curricula, while the community also encourages young educators to bring new ideas into the field.

The proceedings are subdivided into sixteen parts, reflecting the themes addressed in the conference programme:

Part 1 contains papers in the theme Air Transport and Traffic Operations and Management addressing operational management and traffic control issues.
Part 2 contains contributions on Risk-aware Supply Chain Intelligence addressing operational and management issues in client-supplier relationships.
Part 3 illustrates some approaches to Product Innovation and Marketing Management. Papers included in this part address issues, like brand loyalty, consumer readiness, and consumer involvement in innovation processes.
Part 4, Human Factors in Design, an area with growing interest, contains papers on research into, for example, visualization, human behavior with products, and ergonomics.
Part 5, Human Engineering, contains papers, amongst others, on the design of intelligent devices like prostheses.
Part 6 addresses the theme Design Methods and Tools with papers on data and methods for specific design processes.
Part 7 contains papers on the theme Decision Supporting Tools and Methods. In this part subjects like methods and tools for mass customization are addressed including decision-making approaches.
Part 8 deals with the Concurrent Engineering. This part contains various approaches, methods, tools for planning, managing and executing a transdisciplinary engineering process.
Part 9, Knowledge-based Engineering, addresses a variety of approaches to capture, process, manage, use and disseminate knowledge in a transdisciplinary engineering process.
Part 10 is entitled Collaborative Engineering and contains papers on research into methods and tools for the initial phases of the design process in different application areas.
Part 11 contains papers on Engineering for Sustainability: cost-optimal, resource-efficient and eco-design and engineering.
Part 12 contains contributions in the area of Service Design, addressing the notion of systems, as well as the design of service systems and logistics.
Part 13 focuses on Digital Manufacturing with an emphasis on production processes, scheduling, maintenance, and work planning.
Part 14 addresses the topic of Design Automation, addressing topics like modeling automation, process automation, interoperability and data-driven design.
Part 15 contains papers on the theme Artificial Intelligence and Data Analytics with an emphasis on modeling.
Part 16 outlines the importance of Smart Systems and the Internet of Things. Special attention will be given to Cyber Physical Systems, Industry 4.0 and cloud objects.

We acknowledge the high quality contributions of all authors to this book and the work of the members of the International Program Committee who assisted with the blind peer-review of the original papers submitted and presented at the conference. Readers are sincerely invited to consider all of the contributions made by this year's participants through the presentation of TE2017 papers collated into this book of proceedings. We hope that they will be further inspired in their work for disseminating their ideas for new approaches for sustainable, integrated, product development in a multi-disciplinary environment within the ISPE, Inc. community.

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Transdisciplinary Engineering: A Paradigm Shift
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Component-Based Data-Driven Predictive Maintenance to Reduce Unscheduled Maintenance Events

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Abstract. Costs associated with unscheduled and preventive maintenance can contribute significantly to an airline's expenditure. Reliability analysis can help to identify and plan for maintenance events. Reliability analysis in industry is often limited to statistically based approaches that incorporate failure times as the primary stochastic variable, with additional strict assumptions regarding independence of events and underlying distributions of failure phenomena. This foregoes the complex nature of aircraft operations, where a whole range of operational factors may influence the probability of occurrence of a maintenance event. The aim of this research is to identify operational factors affecting component reliability and to assess whether these can be used to reduce the number of unscheduled occurrences (i.e. failures). To do so, a data-driven approach is adopted where historical operational and maintenance data is gathered and analysed to identify operational factors with a measurable influence on maintenance event occurrence. Both time-independent and time-dependent Proportional Hazard Models (PHMs), models which incorporate operational factors as covariates, are employed to generate reliability estimates. Results obtained from analysing historical data of a set of ten components with respect to unscheduled removals indicates that adopting new maintenance schedules, derived from the proposed reliability models, could reduce the number of unscheduled occurrences by approximately 37%. The potential benefits of adopting the proposed strategy are extensive. Nonetheless, numerous assumptions have been introduced to overcome challenges imposed by the complex nature of the data. To overcome these challenges, recommendations are made for future development of the proposed approach.

Keywords. Predictive maintenance, unscheduled maintenance, Proportional Hazard Model

Introduction

Costs associated with maintenance can contribute significantly to an airline's expenditure; historical estimates for maintenance cost range between 10 – 15% of the overall expenditure incurred by airlines [1]. Reliability analysis can help to identify and plan for maintenance events. Reliability analysis in industry is often limited to statistically based approaches that incorporate failure times as the primary stochastic variable [2]. Such approaches assume simple binary behaviour in terms of reliability: a component works or it does not. In addition, strict assumptions regarding

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(in)dependence of events and underlying distributions of associated failure phenomena are frequently made [3], which may be unwarranted in some cases. In relation to the aerospace domain, a major limiting factor of existing statistically-based approaches is that these forgo the complex nature of aircraft operations, where a whole range of operational factors may influence the probability of occurrence of a maintenance event. For instance, aircraft operating from hot, sandy airports or regions have very different conditions of use than aircraft operating from cold, wet airports, which leads to different failure modes and times for components.

The aim of this research is to improve statistical reliability assessment in aircraft maintenance by incorporating the effect of operational factors. To do so, operational factors affecting component reliability are identified and assessed for their capability to reduce the number of unscheduled occurrences (i.e., failures). A data-driven approach is adopted where historical operational and maintenance data is gathered and analysed to identify operational factors with a measurable influence on maintenance event occurrence. The identification of these explanatory variables constitutes the primary contribution to the state of the art. Additionally, both time-independent and time-dependent Proportional Hazard Models (PHMs) are employed to generate reliability estimates, as these statistical models do have the possibility to incorporate explanatory variables as covariates.

The structure of this paper reflects this focus. In Section 1, a brief theoretical context is given. In Section 2, the modelling approach is given, including a discussion of the method to identify relevant operational factors and formulation of the reliability models used in this research. The next Section provides results for a set of selected components. Finally, some conclusions and indications for future research are presented.

1. Theoretical context

Time-based reliability models use component age (time) to model reliability. In its simplest form its lifetime distribution function $F(t)$ and probability density function $f(t)$ are based on common statistical distribution functions (e.g. exponential, normal, log-normal). For more complex components where sequences of random variables are involved, such as repairables, statistical models can be reformulated to include a renewal parameter [3]. Research has shown that type II General Renewal Processes (GRP-II) generally provide better estimates than [Non] Homogeneous Poison Processes ([N]HPPs) and Renewal Processes (RPs) [4]. In GRP models the i^{th} failure is formulated using the previous failure time ($(i-1)^{th}$ failure) and with a renewal function, derived from the renewal parameter. Common weaknesses of time-based reliability models include a lack of capability to incorporate explanatory variables and a lack of representation of multiple degradation states.

Proportional Hazard Models, also known as Cox models, extend time-based models by introducing covariates [5]. The standard (time-based) statistical hazard function is reformulated to introduce covariates and corresponding parameters, as given in equation 1.

$$\lambda(t, Z \mid \theta, \beta) = \lambda_0(t \mid \theta) e^{\beta^T Z} \tag{1}$$

Z are the covariates corresponding to failure t, $\lambda_0(t)$ is the underlying hazard function (e.g. normal distribution), θ (θ_0, θ_1, ..., θ_i) denotes the unknown parameters of the underlying distribution function, and β (β_0, β_1..., β_j) denotes the unknown parameters corresponding to each covariate. This equation can readily be reformulated to incorporate time dependent covariates $Z(t)$, at the cost of computational complexity.

PHM models have been employed succesfully in research before, for instance in aerospace domain applications [6,7], but to a limited degree in practice. However, current developments in aircraft operations and maintenance – in particular with respect to increased storage and availability of sensor data to characterise operational conditions during flight – open up the possibility to revisit these models for a structured, automated application towards reliability estimation incorporating operational variables.

2. Modelling approach

The approach used to model and analyse reliability of components, including the effect of operational factors, is highlighted in Section 2.1. Subsequently, two steps in the approach are detailed further: identification of relevant operational factors (Section 2.2) and reliability modeling (Section 2.3).

2.1. General modelling and analysis approach

The general modelling and analysis approach adopted in this study is shown in Figure 1. As visualized, the modelling approach consists of five main blocks:

1) **Program initiation:** this step addresses importing fleet-wide maintenance and flight datasets, the identification of component-specific data in the wider maintenance dataset, the extraction of component-related flight data from the flight dataset, and, as a last and critical step, extraction and characterisation of component-related maintenance events. These events can be of type *Failure*, in which a component has failed unexpectedly and has required unscheduled corrective maintenance, and *Censored*, in which a component has been replaced according to schedule at a specified time interval.
2) **Flight identification:** flight identification helps to address the following hypothesis: *the heavier the operational use of components, the higher the probability of component failure*. Flight identification identifies flights which *may* have had an influence on unexpected component failure. A heuristic has been developed to identify *a set of flights* which can be associated with a particular failure event on a particular day, instead of an individual flight.
3) **Data analysis:** in step 3, two distinct approaches are used to identify operational factors of influence towards component failure: extreme value analysis and maximum difference analysis. These approaches are discussed in more detail in Section 2.2.
4) **Reliability modelling:** In step 4, a set of reliability models is applied to analyse the component dataset(s). A standard statistical approach (incorporating failure time as the single variable of interest) is employed to give baseline predictions, in accordance with current industry standards. In addition, two variants of the Proportional Hazard Model (PHM) are employed to account for the influence of operational factors, as identified in step 3. These variants are discussed in more detail in Section 3.3.

5) **Future predictions:** The final step in the approach concerns the generation of expected failure times using the reliability models established in the previous step. By predicting flight utilization and conditions, it is possible to estimate expected values for failure times for specific components, which can be used to adjust maintenance scheduling.

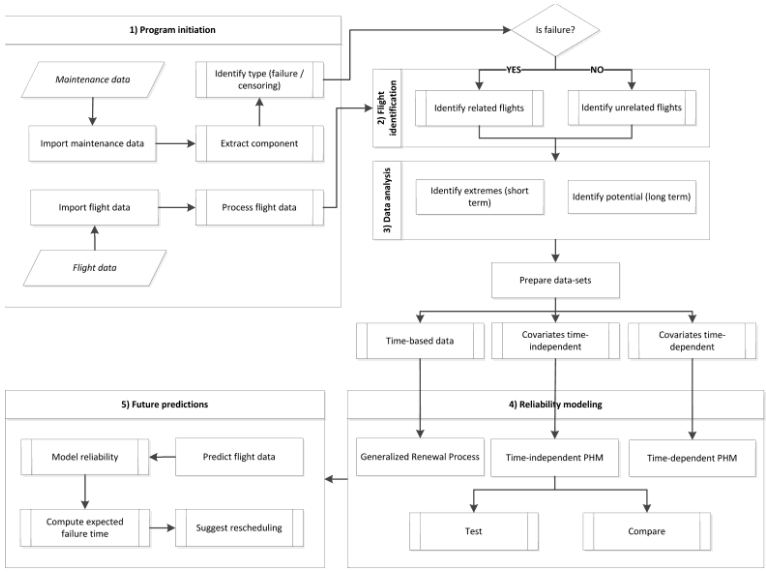


Figure 1. Modelling and analysis approach.

2.2. Identification of relevant operational factors

As mentioned in step 3 of the overall approach, it is critical to know which operational factors can have a measurable influence on component reliability behaviour over time. Given historical data regarding this behaviour, and operational data which can be linked to the component utilization over time, it becomes possible to identify which operational factors influence reliability. In line with the general approach, it is assumed that the identification of related flights towards a component maintenance event has been succesful, leading to a small subset of flights with potential relation to the event.

2.2.1. Extreme Value Analysis (EVA)

The focus of this module is to further narrow down the number of potentially related flights and assign one flight per failure event based on the occurrence of extreme values. In general terms, this module assesses (to a certain significance level) which operational factors were abnormally high. Extreme Value Analysis (EVA) optimises one flight variable at a time, searching for optimals in both the positive and negative direction. When optimising in the positive (negative) direction, flights with observation values x below (above) the mean μ were penalised by assigning a negative p value. This increases the probability that the selected flights experienced similar extremities in the operational variables. The optimisation problem is formulated as given in equations 2 and 3.

$$\text{Maximise } z_v^D = \sum_{i \in N} \sum_{j \in M_i} f_{ij,v}^D \times p_{ij,v}^D, \quad \forall v \in V,\ D \in \{-,+\} \tag{2}$$

Subject to

$$\begin{aligned} &\sum_{j \in M_i} f_{ij,v}^D = 1, \quad \forall i \in N, D \in \{-,+\} \\ &f_{ij,v}^D \in \{0,1\}, \quad \forall i \in N,\ j \in M_i,\ v \in V,\ D \in \{-,+\} \end{aligned} \tag{3}$$

With $f_{ij,v}^D$ being a decision variable which represent optimal flight selection for variable v in optimization direction D, where it should be noted that $f_{ij,v}^D$ is 1 if flight j corresponding to event i is the cause of failure, and is 0 if flight j corresponding to event i is not the cause of failure. Furthermore, $p_{ij,v}^D$ expresses a probability that variable v (representing an operational factor) in flight f_{ij} belongs to group C, which is the set of censored events (i.e., the events without failure). D is the optimization direction for variable v, where if D is negative (-), p values of variables v during flight f_{ij} are penalized if observed value $x_{ij,v}$ is above mean value μ_v, and if D is positive (+), p values of variables v during flight f_{ij} are penalized if observed value x_{ij} is below mean value μ_v .Furthermore, some sets are involved: N being a set of unscheduled maintenance events (i.e, failures), M_i being flights potentially related to failure event i, and V being a set of operational factors.

Finally, note that in the equations above, p is a positive value in the interval [0 1]. To specify an optimization direction D, all p values are computed such that, depending on the direction, observations $x_{ij,v}$ below (or above) μ_v are penalized. Hence,

$$p_{ij,v}^D = \begin{cases} D \times (1 - 2P(z > \left| \dfrac{x_{ij,v} - \mu_v}{\sqrt{\dfrac{\sigma_v^2}{n}}} \right|)) & \text{if } x_{ij,v} \geq \mu_v \\ -D \times (1 - 2P(z > \left| \dfrac{x_{ij,v} - \mu_v}{\sqrt{\dfrac{\sigma_v^2}{n}}} \right|) & \text{if } x_{ij,v} < \mu_v \end{cases} \tag{4}$$

2.2.2. Maximum Difference Analysis (MDA)

The maximum difference module is important for time-independent PHM models, which focus on mean values during a component's fail cycle (see Section 2.3). Its application is straightforward:

1. Compute mean (per operational factor) of all flights related to failure events (Group F).
2. Extract mean and standard deviation (per operational factor) of all flights related to censored events (Group C).
3. Compute probability (per operational factor) of F belonging to C using Z-test (large population size and known standard error).
4. Extract operational factors that are least likely to belong to Group C.

Successful execution of EVA and MDA produces a selection of flights associated with failure events along with a reduced list of operational factors that are likely to be the root cause of failures. Examples are given in Section 3.

2.3. Reliability modeling approach

The failure events and associated operational factors constitute essential input for the reliability models, as described next. In total, three distinct models are employed to estimate reliability:

1) **Generalized Renewal Process (GRP):** a GRP-II model is formulated to serve as a baseline estimate using failure and censor times only. No operational factors are included into this model formulation. GRP-II models employ the concept of virtual age. Various underlying distributions have been tested and assessed for goodness-of-fit, including the normal, log-normal, logistic, gamma, exponential and Weibull distributions. This is justified as multiple components, with multiple failure modes, have been considered. For parameter estimation, maximum likelihood estimation (MLE) has been employed. The MLE routines have been adjusted to take into account censored data and multiple serial numbers per governing part number. To maximize the likelihood function, numerical algorithms have been employed as a closed-form solution to the likelihood function was not available. In particular, the Nelder-Mead and BFGS algorithms have been used [8].
2) **Time-independent Proportional Hazard Model (PHM):** a time-independent PHM has been employed according to the formulation as given in equation 1. Again, underlying distributions for the hazard function include the normal, log-normal, logistic, gamma, exponential and Weibull distributions. In essence, the GRP time-based reliability models described above are extended by introducing time-independent covariates. These covariates – represented as mean values over one flight - are taken from the MDA analysis, but are limited in number using forward selection to keep the standard error (and associated confidence intervals) within reasonable bounds. MLE is used again to perform parameter estimation.
3) **Time-dependent Proportional Hazard model (PHM):** Equation 1 is adjusted to take into account operational factors which vary over time; Z becomes $Z(t)$. EVA analysis yields operational covariates, with values that can vary as a function of time. In time-dependent models the hazard rate for all flights related to a maintenance event is computed. Each observation (flight) is subject to some error. Ergo, it follows that the error of the computed reliability increases cumulatively. To limit the total error and omputational time, a

forward selection approach has been implemented with a maximum of two iterations (two covariates).

3. Results

The method outlined in Section 2 is applicable to any component. In this study, results are derived from ten components with the highest impact in terms of unscheduled removal rate. Maintenance data with respect to these components was collected and spanned a period from 2004 – 2015. In addition, operational data was collected, spanning a period from 2011 – 2015. Table 1 gives some key characteristics of the dataset for one particular component (blade assembly and bearing), as well as output of the flight identification, EVA and MDA modules.

Table 1. Key dataset characteristics for blade assembly and bearing example

Dataset attribute	Value
Number of components	1597
Number of flights (total)	548353
Number of operational variables (total)	1531
EVA output (relevant operational variables)	38
MDA output (relevant operational variables)	78

Figure 2 shows a visual example of the top operational factors influencing failures of blade assembly and bearing, following from MDA and EVA analysis. In the case of MDA analysis, a significant difference can be observed between the mean ambient pressure operating on failure event associated flights (as given in red) and the censored event associated flights (as given in blue). Similarly, for EVA analysis, the longitudinal acceleration (Accn_long_mean) is more severe for failure-associated flights when compared to flights associated with censored events (i.e., no failures).

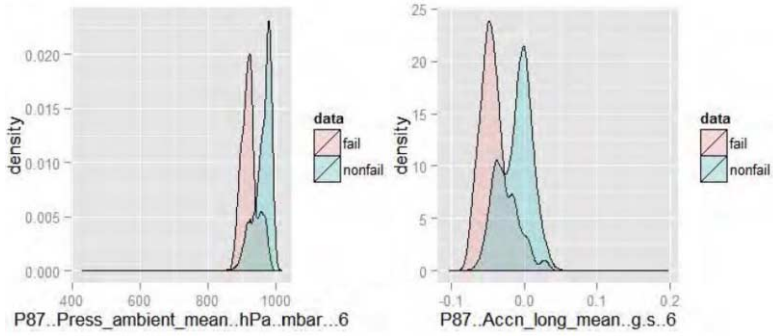


Figure 2. Top operational factor as identified by MDA (left) and EVA (right)

In terms of effectiveness of time-based reliability models versus PHM variants, Table 2 shows MLE output, computational time and goodness-of-fit characteristics (according to the NRR test) for a subset of underlying distributions and varying number of operational factors. A few observations can be made. Firstly, the MLE estimator value is most optimal for time-dependent PHM, outperforming the other two model types. However, goodness-of-fit is best for time-independent PHM, with the additional observation that incorporation of additional operational factors increases accuracy of forecasts. For other components and other underlying distributions, these findings will vary, but in general, either time-independent or time-dependent PHM models will

outperform time-based models, to various levels of accuracy. As mentioned, for the given example, the model accuracy increases when more operational factors are included into the analysis. This is however not a generalizable statement: the optimum number of operational factors will vary from component to component, and typically lies between two to five.

Table 2. Overview of GRP-II, time-independent and time-dependent PHM model results (MLE estimates; NRR goodness-of-fit test; computational time) for underlying exponential distribution

	GRP-II	**Time-independent PHM**				**Time-dependent PHM**			
# oper. Factors	N/A	1	2	3	4	1	2	3	4
MLE	-643.6	-632.3	-624.5	-618.6	-614.7	-582.3	-502.0	-425.1	-387.1
NRR	44.45	37.32	32.43	35.41	27.21	104.25	76.37	46.38	60.14
time [min]	<< 1	6.35	8.7	11.34	13.51	46.1	89.7	152.2	217.9

4. Conclusions

Results derived from analysing and modelling the top 10 components, in terms of URRs, show that it is feasible to identify operational factors that have a significant influence on failure probability. The subsequent use of statistical models incorporating operational covariates (the time-dependent and time-independent versions of the Proportional Hazard Model) are suitable to incorporate the effects of these identified operational factors into reliability estimation. Results show that these models tend to outperform time-based models in terms of accuracy.

Limitations to this study are as follows. First, it is difficult to make an a priori assessment of which underlying distribution and which number of operational factors should be included into relability analysis. Analysis of historical data should be executed regularly to verify any choices with respect to these model settings. Furthermore, any reliability forecasts should be validated using a separate set of maintenance event data to be able to quantify the efficacy of the proposed method in terms of failures prevented and costs saved.

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A Multi-Criteria Decision Making Framework for Aircraft Dispatch Assessment

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Abstract. The aircraft dispatch decision is a complex analysis based on many factors related to airworthiness regulations, aircraft health status, resource availability at current and future stop(s) and operational preferences of the operator. Within the turnaround time (TAT) a decision has to be made whether the aircraft can return to service, defects have to be deferred, operational restrictions apply, maintenance has to be performed, or if the aircraft is unable to safely perform the next flight. This paper presents a framework for automated dispatch decision support and, as a first step of implementation of the framework, a proof of concept for automated root cause identification by means of a case study on a Airbus A320 wing anti-ice valve. A decision tree algorithm has been applied to a synthetic dataset, representing historical failure data with associated root causes and observed symptoms, achieving correct classification of the root cause for 40% of the cases. Analysis of the results show that the accuracy of the method increases with an increasing number of symptoms associated to a root cause. Furthermore, the method cannot distinguish between root causes with similar symptoms. Although the use of synthetic data restricts conclusions that can be drawn from the results, the work shows a proof of concept for automated root cause identification and leads to initial findings that are essential for future implementation and optimisation of the method. Eventually, the framework will be operationalised in the form of a mobile tool to assist stakeholders in on-site aircraft dispatch decision support.

Keywords. Aircraft maintenance, aircraft dispatch, decision support, multi-criteria decision making, root cause analysis

Introduction

AoG, or aircraft on ground, is terminology used in aviation to indicate that a defect prevents the aircraft to continue scheduled flight operations. While AoG, the aircraft will not be generating revenue by transporting passengers or cargo. Therefore, airline operators aim to minimise AoG by carefully planning flight schedules and maintenance intervals. Because the regulated maintenance intervals are far from efficient with respect to remaining useful life (RUL), and because of the exponential growth of available data and computational power, the aviation industry is now moving towards more data-driven maintenance methods, like prognostics and health monitoring [1, 2]. Instead of performing maintenance at fixed time intervals, these methods use historical data and current health state to only perform maintenance when failure is expected in

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the near future, thereby exploiting more of the RUL. These methods aim to prevent unexpected failures that lead to AoG, but are unlikely to entirely avoid unexpected failures for highly complex systems such as aircraft.

In current airline operations, unexpected failures remain a frequent cause for flight disruptions and should be resolved swiftly to minimise AoG and operational impact. Line maintenance deals with resolving unexpected failures and other maintenance activities within the flight schedule. To avoid delays, all maintenance should preferably be completed within the turn-around time (TAT), which is the time required to complete all ground handling and have the aircraft ready for the next departure [3]. While most line maintenance activities are planned and thus are prepared for, unscheduled tasks following from unexpected failures often disrupt the flight operation, because they require troubleshooting followed by an assessment of the aircraft's capability to perform the next flight. This process is known as aircraft dispatch assessment. Based on the defect information an assessment has to be made if the aircraft can be 1) dispatched without restrictions; 2) dispatched with a component or system inoperative; 3) maintenance is required before dispatch, or that 4) the aircraft is incapable to perform the next flight. The aircraft dispatch assessment is a typical example of a Multi-Criteria Decision Making (MCDM) problem, having multiple alternatives and assessment criteria. In the MCDM domain many methods have been developed to assist the stakeholder to rank alternatives, and in general three main steps have to be performed [4]:

1. Determine relevant decision criteria and alternatives.
2. Attaching numerical measures to the relative importance (i.e., weights) of the criteria and to the impacts (i.e., the measures of performance) of the alternatives in terms of these criteria.
3. Process the numerical values in order to rank the alternatives.

However, determining the importance of a specific decision criterion for a given problem is hard, because the criterion itself can be difficult to assess due to lack of quantitative and reliable information (e.g., maintenance cost). Hence, to assess the stability of an optimal solution a sensitivity analysis of the decision criteria has to be performed in order for the MCDM method to be effective [5]. A stakeholder can make better decisions by knowing which criteria affect the solution the most. With many MCDM methods available, it is not straightforward to determine which method is most suitable for a specific problem. To assist in selecting the right MCDM method for a given problem the 11 most commonly used methods were analysed by Velasquez and Hester [6], listing their advantages and disadvantages. Multi-Attribute Utility Theory (MAUT) as an extension of Multi-Attribute Value Theory (MAVT), the Analytical Hierarchy Process (AHP) and Simple Additive Weighting (SAW) are frequently used methods, of which the latter is widely used because of its simplicity. The general trend in recent years is to combine multiple methods to overcome specific weaknesses of a particular method. The exponential growth in computational power over the last decades has significantly accelerated this trend and also provides the opportunity to exploit large amounts of data for better decision making.

However, before any MCDM method can be applied to the aircraft dispatch assessment problem, the root cause of the defect needs to be identified first in order to determine the appropriate corrective maintenance action. Only then the different dispatch scenarios can be properly assessed. Current research on the aircraft dispatch problem assumes that the root cause for the defect is known [7], but for most cases the

root cause still needs to be determined during the TAT. In some cases of unscheduled maintenance, when the defect is communicated in-flight, the troubleshooting department can try to determine the root cause beforehand. The troubleshooting procedure for aircraft maintenance is described in the Troubleshooting Manual (TSM) and entails multiple tasks with increasing complexity, ranging from simple tests and resets up until replacement of the defective component. Quick, accurate and automated root cause identification saves valuable time in the TAT that can be used for dispatch decision assessment and maintenance execution, reducing the risk of delay. With the root cause known, the right corrective maintenance task can be determined, the requirements and resources to perform that task can be established and then the alternative dispatch scenarios can be assessed. To this end, the objective of this paper is to 1) introduce a framework for automated dispatch assessment; 2) present a root cause identification approach which fits into this automated dispatch assessment framework and addresses the functionality mentioned above.

Given this focus, this paper first discusses the state of the art in aircraft dispatch decision making, followed by introducing the developed framework for automated dispatch assessment, including the definition of the alternative dispatch scenarios and a definition of the stakeholders involved. A case study for root cause identification using a synthetic dataset, representing a historical database of reported defects, is discussed next and the paper ends with the conclusions.

1. Aircraft dispatch state of the art

While research in the broader domains of operations research and decision support systems has progressed significantly in recent years, research focussing on the aircraft dispatch problem remains scarce [7]. Most studies focus on long-term operations, do not support dispatch decisions directly, do not assess relevant information simultaneously or do not take into consideration the limited time available within the TAT, and are thus not addressing the issues that line maintenance technicians face. Papakostas et al. [7] describe a short-term planning methodology for the line maintenance activities of an airline to increase fleet operability and reduce maintenance cost. Based on four criteria, being cost, operational risk, flight delay and remaining useful life (RUL), dispatch alternatives are calculated and ranked on utility by assigning weights to each criterion. The research introduces a novel method to support the aircraft dispatch decision, including a significant number of relevant criteria, but also has some limitations. Firstly, it is assumed that the root cause of a problem is known, while this is usually not the case. The process of troubleshooting and pinpointing the root cause can be a very time-consuming processes, time that is not available during the TAT. Secondly, the method only considers condition-monitored components, i.e., components for which the condition is assessed (near-)continuously on the basis of direct or indirect information, for instance from sensors. Based on the RUL of these components an assessment is made, but even in recently introduced aircraft many components that could lead to AoG are not condition-monitored. Finally, the research aims to reduce the number of unscheduled maintenance events by using data of condition monitored components and plan corrective maintenance before failure of the component occurs. This, however, does not provide a solution for truly unscheduled failures of (non-monitored) components that require reactive maintenance. In any case, even condition-monitored components can fail unexpectedly. More recent

work within the domain also indicates the research gap for operability assessment of the aircraft during its mission. Tiassou et al. [8] aim to develop a model to assess changes in the aircraft health status online to support mission planning, even during flight, and evaluate the probability that an aircraft can continue flight operations for a given period of time using a dependability approach. The model relies on accurate reliability data to assess successful mission completion and to plan maintenance activities, which might not always be available. Moreover, the model provides predictions of component failures and maintenance task durations for operational planning, but does not account for maintenance task execution or determining the root cause of a defect.

For industry, the state of the art is more difficult to analyse due to intellectual property restrictions and the use of generic marketing terminology in the specifications. Solutions provided by manufacturers like Airbus and Boeing are able to include data from many (on-board) sources and, combined with a well-developed user interface, are powerful tools to optimise aircraft operability and maintenance activities [9, 10]. They also offer support in maintenance task execution by providing related documentation, include the aircraft's maintenance history and troubleshooting assistance. The systems aim to reduce unscheduled maintenance activities through continuous real-time health monitoring and provide decision support based on that data, but do not mention direct dispatch decision support in case of an unforeseen event. Another issue is the fact that both new and modernised aircraft are equipped with extensive integrated health monitoring systems, but a significant part of the world fleet still operates with less advanced health monitoring capabilities and therefore is unable to fully benefit from these data-driven support systems. Another drawback of these systems is that they are vendor specific and are designed to work optimally, or even solely, for aircraft of a specific manufacturer, requiring multiple systems for mixed fleet operators. Unfortunately, the fragmentation of different information systems is currently one of the main headaches for operators. Maintenance, Repair and Overhaul (MRO) service providers like Mxi and Lufthansa Technik aim to overcome this problem by offering integrated maintenance support systems to operators that combine different data sources to optimise the maintenance operation from supply chain to prognostics and maintenance planning [11, 12]. Similar to the vendor specific solutions, these solutions focus on data-driven methods to prevent unscheduled maintenance occurrences and are not aimed for short-term unscheduled event resolution; direct dispatch decision support is not featured.

In short, both the academic and industry state of the art show that there is still a need for direct dispatch decision support to assist the stakeholders in aircraft line maintenance and minimise flight disruptions and the associated cost.

2. Framework for automated dispatch assessment

The objective of this project is to provide internal stakeholders with ranked dispatch alternatives in order to support them in decision making and reduce flight disruptions through optimised dispatch decisions. To get from a reported defect to a list of ranked dispatch alternatives a framework was developed to support this functionality. Figure 1 shows a schematic representation.

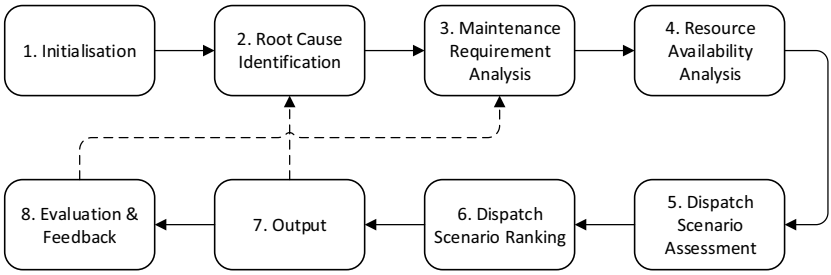


Figure 1. Schematic overview of the dispatch assessment tool.

The functionality of the steps in the framework is as follows:

1. **Initialisation**
   During the initialisation step all relevant information about the aircraft and the defect is gathered. The defect information includes data such as the error code, fault message or description of the problem. Based on the defect information the related troubleshooting procedure (TSM) is determined. The aircraft information includes data such as its registration mark, manufacturer, model, current configuration and location. The flight schedule, and in particular the estimated time of departure (ETD), is also essential information for dispatch option evaluation.
2. **Root Cause Identification**
   The TSM provides describes symptoms that are related to a root cause and the Aircraft Maintenance Tachnician (AMT) will register observed symptoms on a mobile device. Based on historical data of similar symptoms and root causes, the most likely root cause is determined. If the root cause can be determined with a specific predefined level of certainty, the system proceeds to the next step. When this level of certainty can't be obtained either an incorrect TSM task was selected, or insufficient data for classification was available. In the first case the AMT is asked to select the TSM task manually, for the latter case the a manual analysis has to be performed. All results are used to expand the existing historical database for future classification.
3. **Maintenance Requirement Analysis**
   With the root cause known the required maintenance action can be determined and subsequently the required resources for maintenance execution (e.g., man hours, equipment and spare parts).
4. **Resource Availability Analysis**
   In this step availability of the required maintenance resources (determined in step 3) at current and future stop(s) is checked. In some cases it is desirable to defer a defect, for example when there are better maintenance facilities at the next stop, or when there is already maintenance planned in the near future. Therefore, the dispatch option "dispatch by MEL" is evaluated, in which case the aircraft is dispatched with certain systems or components inactive. Constraints for flying with systems or components inoperative are detailed in the Minimum Equipment List (MEL). Currently inactive systems or components of the aircraft are listed in the Hold Item List (HIL), which must be compared with the MEL to verify that deferral of the current defect is compliant. Other resources, such as the flight schedule, flight crew limitations and the mission profile are included as well.

5. Dispatch Scenario Assessment

All possible dispatch scenarios are evaluated based on the requirements and resources available. Based on the input of industry experts and the dispatch definition by Tiassou et al. [8], a new dispatch scenario definition was developed, shown in Figure 2.

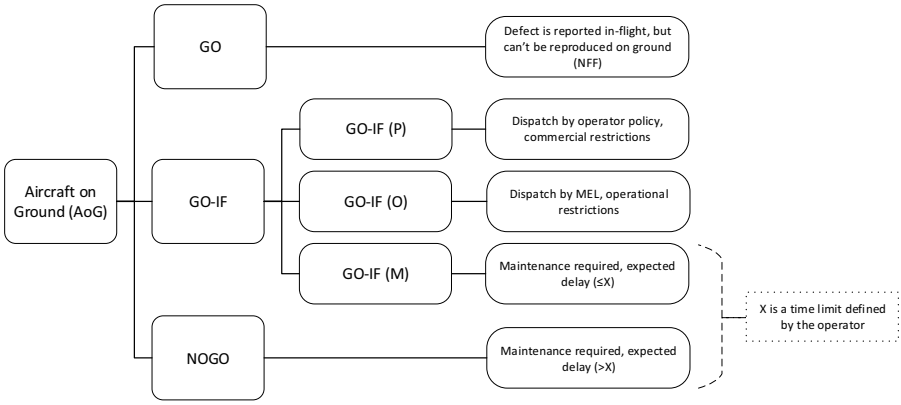


Figure 2. Modified dispatch scenario definition.

When an aircraft is AoG the following dispatch scenarios are defined (in order of operational impact):

- **GO**: the reported defect is not found, either because there is no defect or because the defect can only be observed while flying; known as No Fault Found (NFF). The aircraft is dispatched without additional restrictions.
- **GO-IF**: the aircraft can be dispatched with restrictions, or after a maintenance task is performed. GO-IF has the following subcategories:
  - **(P)**: the defect only leads to commercial restrictions, e.g., an operator can choose not to sell a seat with a defective table. The defective item can be deferred to a preferred maintenance opportunity. The aircraft is dispatched by operator policy.
  - **(O)**: the defect can be deferred in compliance with the MEL and doesn't conflict with the current HIL status. The aircraft is dispatched by MEL and operational restrictions may apply.
  - **(M)**: the defect requires corrective maintenance before dispatch. A delay will follow if the maintenance elapsed time exceeds the ETD. As the delay increases specific limitations can lead a NOGO, for example due to crew flight time limitations. After completion of the maintenance task the aircraft can be dispatched.
- **NOGO**: the reported defect can't be deferred or fixed before the ETD or maximum allowable delay (X in Figure 2) and the flight has to be cancelled. X is defined by the operator accordancing to their business model (e.g., low cost, high passenger comfort). The aircraft can't be dispatched and remains AoG.

6. **Dispatch Scenario Ranking**
   When the feasible dispatch scenarios are determined they are ranked according to specific criteria set by the operator (e.g., cost, time), integrated by a weight matrix for the decision criteria.
7. **Output**
   The output is a list of ranked dispatch scenarios presented to the AMT on a mobile device. The best ranked scenario is proposed to the captain and, when agreed upon, executed. If the captain doesn't accept the proposed scenario, the second best result can be selected, and so on.nWhen the chosen dispatch scenario requires the execution of a maintenance task, the AMT also verifies that the defect is resolved. Results are recorded in the historical database for root cause identification.
8. **Evaluation and Feedback**
   In the evaluation and feedback stage the actual outcome of the chosen dispatch scenario is evaluated with respect to the decision criteria, by comparing them to the outcome predicted by the system. This way, it can be verified that the system inputs (e.g., maintenance requirements and resources) were correct or require adjustment. Based on the evaluation the corresponding defect instance in the historical database for root cause identification can be classified to improve future classification.

With the framework explained, the development is initiated at step 2 by means of a case study for automated root cause identification.

3. Case study root cause identification

For this case study the wing anti-ice valve (WAIV) of an Airbus A320 is considered. The current troubleshooting procedure is described step-by-step in the TSM and includes execution of several maintenance tasks in the process. The TSM describes 18 possible root causes and 17 symptoms that may be related to a specific root cause for a defective WAIV. Symptoms are either indicated by on-board systems warnings, the flight crew or are identified by the technician.

With no current access to actual maintenance data, a synthetic dataset representing the maintenance history of an Airbus A320 fleet is created. The file contains 10000 entries, each representing a WAIV defect with one of the 18 root causes randomly assigned. Symptoms that are not related to a specific root cause according to the TSM always remain zero. For the symptoms that do relate to a root cause a value of 0 or 1 is randomly assigned using a uniform distribution, 1 representing a symptom that is observed (true) and 0 for the symptoms that are not observed (false). Many machine learning algorithms for root cause analysis (RCA) have been developed over the last decades and based on the work of Solé et al. [13], providing an extensive overview and classification of available RCA models, a decision tree algorithm is used to classify root caused based on the observed symptoms. The decision tree analysis is performed using Weka, a machine learning software tool developed by the University of Waikato in New Zealand [14], and more specifically the J48 algorithm is used. With the current synthetic dataset the algorithm can classify the root causes correctly for only 40% of the time, which is far from sufficient for use in a an operational environment.

The confusion matrix in Figure 3 provides a detailed insight on the classification performance, where the root causes are labelled **a-r**. On the diagonal the number of correctly classified root causes is given, marked in green. Root causes **f**, **l**, **m** and **n** (orange columns) are never classified at all, which can be explained by the fact that they all have just one symptom associated. Moreover, the symptom is shared with root causes **o** and **k** (blue columns), which are frequently incorrectly classified as root cause **f**, **l**, **m** or **n**. Root causes that have more symptoms associated to them also show these classification errors, most clearly shown for root causes that have a origin at both the right- and left-hand side of the aircraft. For example, root causes **e** and **i** are the wing anti-ice valve controllers on opposite sides of the aircraft and share exactly the same symptoms, leading to them being mixed up almost equally with their counterpart (red bordered cells). Figure 3 also shows that no other root cause has been classified incorrectly as **e** or **i**. Similar accuracy can be found for root cause p (aircraft wiring, green column). These root causes share the characteristic of having a high number of associated symptoms (i.e., 13 for **e** and **i**, 12 for the aircraft wiring).

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	
408	0	0	0	0	0	88	0	0	0	76	0	0	0	0	0	0	0	**a**
0	**197**	0	104	0	0	0	33	0	205	5	0	0	0	0	0	4	11	**b**
0	0	**424**	0	0	0	0	0	0	0	125	0	0	0	0	0	0	0	**c**
0	0	0	**283**	0	0	0	266	0	0	9	0	0	0	0	0	10	0	**d**
0	4	2	2	**247**	0	0	3	270	1	0	0	0	0	0	0	14	5	**e**
0	0	0	0	0	**0**	0	0	0	0	432	0	0	0	112	0	0	0	**f**
360	0	0	0	0	0	**95**	0	0	0	81	0	0	0	0	0	0	0	**g**
0	0	0	296	0	0	0	**225**	0	0	11	0	0	0	0	0	5	0	**h**
0	5	2	8	280	0	0	2	**244**	2	0	0	0	0	0	0	13	7	**i**
0	205	0	97	0	0	0	40	0	**187**	4	0	0	0	0	0	1	7	**j**
0	0	0	0	0	0	0	0	0	0	**480**	0	0	0	131	0	0	0	**k**
0	0	0	0	0	0	0	0	0	0	487	**0**	0	0	101	0	0	0	**l**
0	0	0	0	0	0	0	0	0	0	424	0	**0**	0	110	0	0	0	**m**
0	0	0	0	0	0	0	0	0	0	438	0	0	**0**	99	0	0	0	**n**
0	0	0	0	0	0	0	0	0	0	474	0	0	0	**107**	0	0	0	**o**
11	9	0	6	0	0	2	5	0	7	0	0	0	0	0	**482**	0	14	**p**
0	0	32	89	0	0	0	13	0	0	5	0	0	0	0	0	**389**	0	**q**
0	112	0	72	0	0	0	55	0	91	3	0	0	0	0	0	3	**232**	**r**

Figure 3. Confusion matrix for the decision tree classification

Because a synthetic dataset was used, these initial findings only provide an indication of the performance that can be achieved when authentic data is used. It is expected that authentic data will include stronger and more consistent underlying correlations between symptoms and root causes. However, the applied method shows a proof of concept and has led to the following observations that will be taken into account for future development; 1) root causes with only one or few associated symptoms lead to a low classification accuracy, 2) the method cannot distinguish between root causes with similar associated symptoms, and 3) the accuracy of the method improves with a growing number of associated symptoms.

Based on these observations, some recommendations are determined for the development of the automated root cause identification method. Firstly, root causes having only one or few associated symptoms require additional information for accurate classification. Secondly, for root causes that share the same set of associated

symptoms with other root causes it might be useful to aggregate them for improved accuracy. Both recommendation require intervention of an expert; the AMT. Finally, this initial case study also clarified the following factors:

- Unlike the assumption in the created data file, it is very unlikely that historical data will show evenly distributed root causes. In reality, some root causes will appear more frequently than others.
- Some symptoms will have more influence than others on the root cause classification, which can be incorporated by assigning weight factors to the symptoms.
- Subsequently, some symptoms will show to be irrelevant and can be removed for classification (i.e., apply feature selection).
- In reality it is infeasible to perform the entire troubleshooting procedure during the TAT, which would include replacing the component itself and result in a GO-IF (M) or NOGO without any dispatch assessment. Hence, it needs to be determined to what extent the troubleshooting procedure needs to be completed to provide sufficient information for dispatch assessment.
- With many methods available for RCA [13], it is worthwhile to evaluate the performance of other suitable methods.

4. Conclusions

When an aircraft faces a defect, a decision has to be made whether the aircraft can continue flight operations or not. This aircraft dispatch decision is complex due to the large amount of factors that have to be considered, the multiple stakeholders involved and a limited amount of time available before the next scheduled flight. To avoid costly AoG, current research mainly focuses on prognostics, health monitoring and preventive maintenance, but those methods cannot entirely avoid the occurrence of unexpected failures in a complex system like an aircraft. The need for direct dispatch decision support for unexpected failures and, additionally, the need for automated root cause identification was identified. This paper proposes a framework for automated dispatch decision support and initiates the implementation by the development of a method for automated root cause identification in a case study. The framework aims to automate the dispatch decision, starting from a reported defect up to providing ranked dispatch alternatives, using an eight-step approach. A crucial step in the framework is the capability to automatically determine the root cause of a defect, which is tried to be achieved by comparing observed symptoms with previous instances of that defect. A case study was performed on the Airbus A320 wing anti-ice valve, using a synthetic dataset. The J48 decision tree algorithm was applied using Weka and an overall accuracy of 40% for identifying the correct root cause was achieved. The confusion matrix showed that a root cause with one or few associated symptoms is rarely correctly classified, the accuracy of root cause classification increases with an increasing amount of associated symptoms and that root causes with similar associated symptoms can't be distinguished between. While the use of a synthetic dataset limits the conclusions that can be drawn about the performance, the case study showed a promising method for automated root cause identification and has led to several recommendations for future development.

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Effects of Information Availability on Workload and Situation Awareness in Air Traffic Control

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Abstract. To deal with the continous air traffic growth, air traffic controllers (ATCOs) are equipped with enhanced air traffic control (ATC) systems. The enhanced systems offer fully comprehensive aircraft information, such as plan view, speed, climb /descent rate, vertical information as well as the prediction of the aircraft parameters. Although increased information is often linked to the increase of situation awareness (SA), however, increasing the volume of information could also be detrimental to SA and workload. To what extend the aircraft information would benefit the ATCOs should be further investigated. This study aims to examine the effects of different information displays on ATCOs workload and SA. Thirty air traffic controllers (ATCOs) were divided into three groups corresponding to three display conditions: non-display, vertical, and trajectory display. The results revealed that the vertical display lowered ATCOs' workload and enhanced their SA as compared to other conditions. The workload and SA with the trajectory display were not different as compared to those in the existing ATC facility. It could be inferred that, on the one hand, with low information availability, ATCOs are required to interpret the airspace manually thus placing a cognitive burden on them. On the other hand, high information availability provided in the trajectory display condition, also hindered ATCOs from effectively using it due to the information overload. Here, the vertical display was found to provide sufficient information for ATCOs since it presents the information that was not depicted in the current radar system. Conversely, presenting information of all aircraft parameters was not necessarily valuable.

Keywords. Information availability, workload, situation awareness, air traffic control

Introduction

The continuous growth in air traffic has placed a challenge for air traffic control safety [1]. Given this increase, there will be a greater burden on ATCOs in performing the ATC tasks that include monitoring aircraft to obtain information about the call-sign, altitude, latitude, route and destination in ensuring that the aircraft are on the right path [2], as well as maintaing separation among aircraft.

To support ATCOs, a concept of additional display in ATC system has been proposed to provide more information about aircraft parameters such as plan view, speed view, climb/descent rate view, and vertical profile. On the one hand, the increase in information availability can be associated with the increase in SA. On the other hand, however, high information volume would also compromise SA [3].

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In this study, different levels of information display including vertical and trajectory displays were examined. The vertical display may be beneficial for ATC operations since it could help ATCOs in visualizing the 3D picture of the airspace that is important for safe and efficient traffic control. Moreover, ATCOs preferred vertical maneuvers for conflict avoidance [4]. In fact, almost all ATC facilities only provide aircraft altitude information in aircraft data-tag which is not intuitive in depicting spatial information.

In addition to the vertical display, trajectory display provides more comprehensive aircraft information. Detailed lateral positions, speed profile, and climb/descent rate as well as the prediction of these parameters are also available for ATCOs. These information may be valuable for ATCOs to meet air traffic and airspace constraints [5]. Furthermore, it could aid ATCOs in visualizing separation among flights.

A number of literature have suggested that displaying more information could enhance ATCOs' performance by reducing their mental computations thus lowering workload and increasing SA. However, the question "how much is too much" remains to be further investigated in determining appropriate volume of information in ATC.

Therefore, the main objective of this study was to examine how the presence of different information displays would affect ATCOs' workload and SA. In the experiment, the current ATC display (non-display condition) was constrasted with the vertical and trajectory displays. In each display condition, three conflict resolution aid (CRA) conditions were replicated. However, the effects of the CRA conditions were not the focus of this paper, hence, were not elaborated further. Two main hypotheses were tested in this study.

H1: The vertical and trajectory displays would generally reduce the workload relative to non-display condition. However, the workload would be further reduced with the vertical display.

H2: The vertical and trajectory displays would enhance the SA relative to non-display condition. However, the SA would be further enhanced with the vertical display.

1. Methods

1.1. Participants

Thirty (30) ATCOs from the Civil Aviation Authority of Singapore (CAAS) and the Republic of Singapore Air Force (RSAF) participated in the study. Their ages ranged from 24 to 62 years (Mean = 30.06 years) with the average work experience of 4.25 years.

1.2. Apparatus

A medium fidelity of ATC simulator, the NLR ATC Research Simulator (NARSIM) [6] was used during the experiment. It presented the standard instrument departure (SID) and standard arrival routes (STAR) of Singapore airspace. There were one ATCO's and two pseudo-pilot's positions set in the experiment. The ATCO participants were provided with four monitor screens that showed (i) the primary radar with short term conflict alert (STCA) feature warning ATCOs of a potential conflict (Figure 1), (ii) the flight progress strips, (iii) the vertical (Figure 2) or trajectory (Figure

3) display, and (iv) the CRA [7] that provides a resolution manuver to an ATCO two minutes prior to a conflict. The pseudo-pilots were provided with three monitor screens that display the primary radar, the blipper inputs, and the CRA feedback.

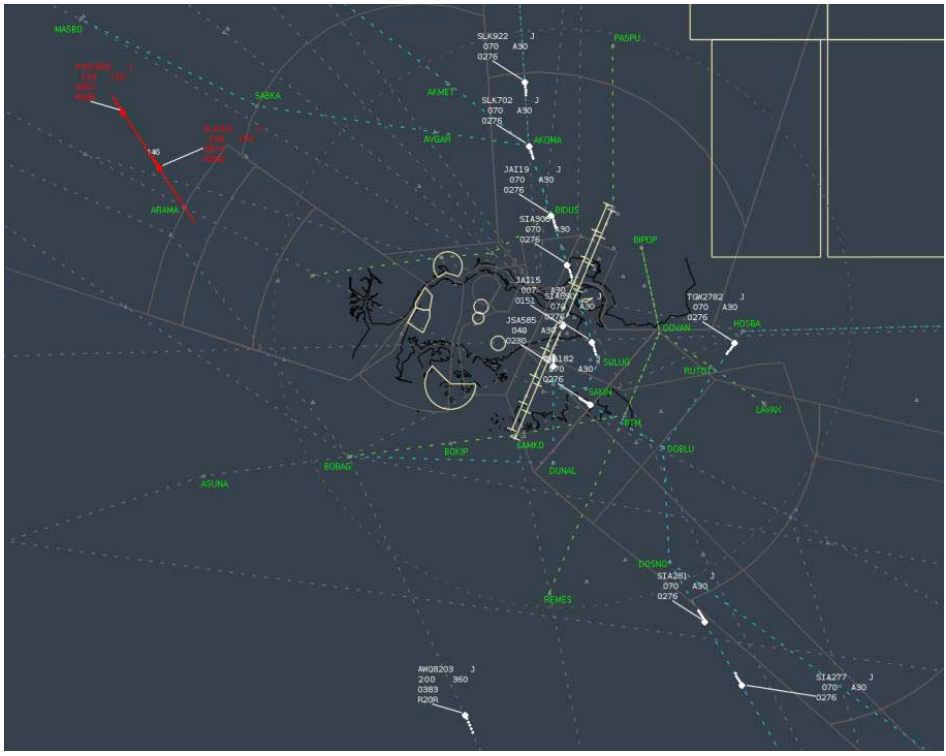


Figure 1. The Primary Radar Display. Dotted lines represent the airways.

1.2.1. The vertical display

The vertical display provides aircraft vertical profile showing the time and the flight level that will be achieved by the aircraft in every waypoint along its route. The aircraft profile was calculated based on the air traffic simulation (ATS) scripting in the NARSIM. A flight from the current radar position in the NARSIM was executed by following the route, constraints, and the script to its destination.

There are a few design features of the vertical display (Figure 2) used in this study. First, it shows the waypoints as indicated by the triangles to increase the cognitive linkage [8] between the vertical display and the primary radar display. Next, ATCO participants were able to only display the vertical profile of a selected aircraft. This "detail in demand" feature [9] allowed them to reserve their cognitive resources from other traffic aircraft that did not need immediate actions. To display the vertical information of a certain aircraft, ATCOs could select the aircraft call-sign on the display panel to activate the required information. They could reselect the respective call-sign to remove the information.

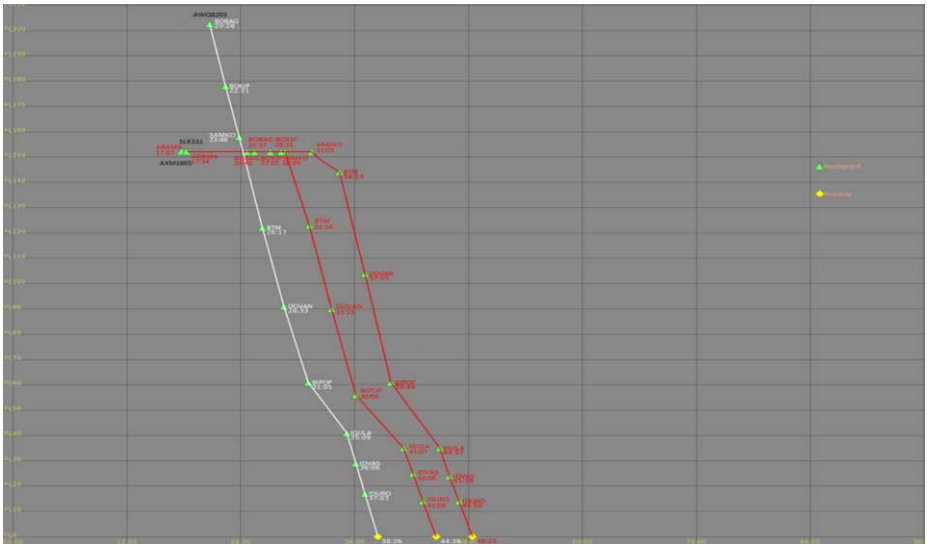


Figure 2. The Vertical Display.

1.2.2. The trajectory display

In addition to the altitude information as provided in the vertical display, the trajectory display (Figure 3) also showed other aircraft parameters in terms of heading and speed.

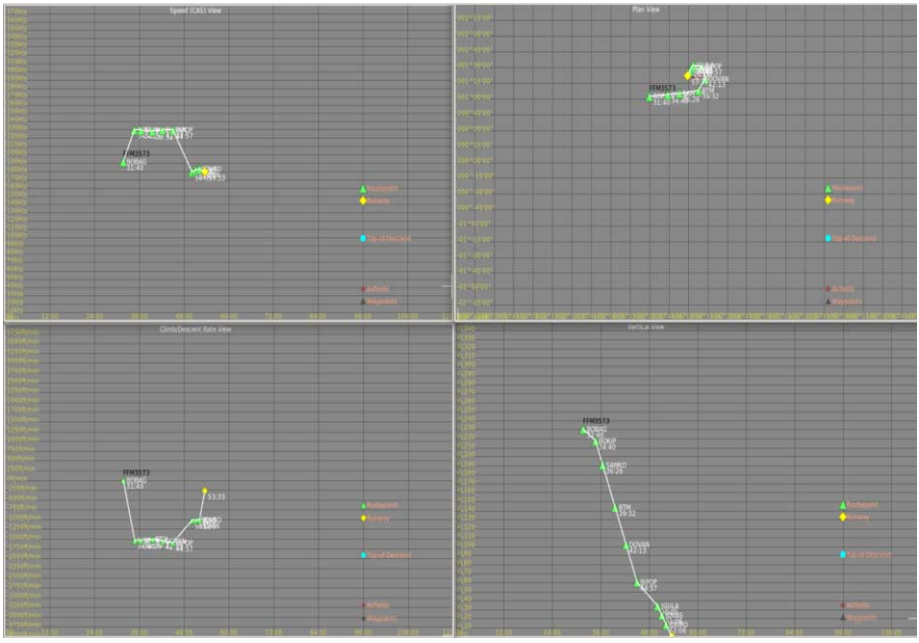


Figure 3. The Trajectory Prediction Aid.

Four aircraft paramaters were displayed along the waypoints. First, speed view was provided to display the aircraft speed profiles along the time axes (top-left corner). Second, plan view was displayed to show the aircraft lateral and longitudinal positions

(top-right corner). Third, the climb/descent rate view was displayed to show the climb and descend courses in feet per minute (bottom-left corner). Lastly, vertical view was also displayed to provide the aircraft altitude information (bottom-right corner).

1.3. Experiment design

Two factors were examined in this study: CRA and display conditions. The CRA and display conditions were within- and between-subjects factors, respectively. The CRA conditions include three levels: reliable, unreliable, and manual conditions. The ATCO participants were assigned to three display conditions: trajectory display, vertical display, and non-display conditions.

In the trajectory display condition, the participants were provided with the four aircraft parameters information in an additional display. In the vertical display condition, only vertical profile information was provided. Whereas, no additional information was provided in non-display condition.

1.4. Procedure

The experiment consisted of a briefing and three experiment sessions. Participants performed ATC tasks including accepting and transferring the incoming and departing aircraft to and from their sectors, respectively, controlling the air traffic within their controller area, as well as maintaining separations among aircraft with the traffic density of 60 aicraft. In addition, participants were also requested to respond to the SA probes during the experiment. The CRA and the different displays could be utilized whenever available. The participants communicated with the pseudo-pilots verbally and the pseudo-pilots keyed in the respective commands to the ATC simulator. Moreover, the NASA-TLX questionnaire [10] was administered upon completion of each experiment session.

1.5. Analysis

A 3 (CRA conditions: reliable, unreliable, and manual) x 3 (display conditions: trajectory display, vertical display, and non-display) mixed-design ANOVA was performed for the workload and situation awareness (SA) measures, respectively. The mean (M) as well as the F and p values reflecting the significance of the factors are provided in Section 2 accordingly. Post-hoc comparisons were also performed to closely examine the effects of each display on the workload and SA. The effects of CRA were not reported since it was not the factor of interest in this paper. The workload measure was obtained from NASA-TLX rating (ranging from 0 to 100). The SA data were derived from the percentage of correct responses [11].

2. Results

2.1. Workload

In general, the workload was lower with the trajectory and vertical displays than without any additional information displays as shown in Figure 4, $F(2, 27)= 3.31$, $p=$

0.05. However, the post-hoc analyses revealed that there was no significant difference in the workload between trajectory (M= 67.36) and non-display (M= 73.69) conditions (p= 0.18), although there was a trend of lower workload with the trajectory display. However, the workload was significantly reduced with the vertical display (M= 61.89) as compared to the non-display condition (p= 0.02).

The trajectory display was beneficial only when the CRA was available [12] and it showed the same cost as the non-display condition when ATCOs worked manually. However, this interaction was not significant, F(2, 44)= 1.45, p= 0.23.

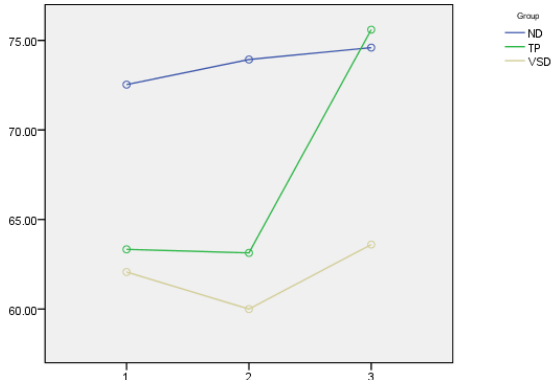


Figure 4. Workload Level across Conditions (1: Reliable, 2: Unreliable, 3: Manual Conditions; ND: Non-Display, TP: Trajectory Predictor, VSD: Vertical Display).

2.2. Situation awareness

There was a marginally significant effect of information display on SA, F(2, 23)= 2.79, p= 0.08. Furthermore, the post-hoc analyses (LSD) revealed that the SA was generally higher with the vertical display (M= 71.85%) than the trajectory display (M= 57.14%), p= 0.05 and the non-display (M= 58.80%), p= 0.06 conditions. No difference in SA between the trajectory display and non-display conditions (p= 0.82).

3. Discussion

In the existing ATC facilities, ATCOs mainly perform their work with the 2D primary radar display that provides aircraft status on the digital data-tag. Most of ATCOs would initially refer to the radar display and review the flight progress strips (FPS) to obtain required information. The process of checking and integrating the actual traffic information into the mental model is necessary for setting ATCOs' mental picture of current traffic conditions [13]. The maintenance of mental picture could enhance ATCOs' capability in efficiently controlling the air traffic [14]. To maintain their mental picture, however, ATCOs have to continuously perform accurate mental computations, including the updates for speed, altitudes, and headings changes, as well as the influences of the changes on the ATC operations.

In the present study, ATCOs were equipped with the additional displays that support them in obtaining the information of speed, altitude, and heading as well as the

changes of every single aircraft along the flight paths. The displays including vertical display and trajectory display were evaluated using human-in-the-loop simulation and were contrasted with the current ATC facility. Prominently, our results generally showed that providing more information regarding aircraft status in a more intuitive format did benefit ATCOs.

The results revealed that workload was generally higher in the existing ATC setting as compared to the vertical and trajectory display conditions. Although the trajectory display led to lower workload than in non-display condition, the workload between the two conditions failed to reach significant difference. However, workload was significantly lower with the vertical display than the workload in the existing ATC setting, showing that H1 was upheld. These findings suggested that information displays could assist ATCOs in performing their mental computations thus lowering their workload.

Moreover, the SA was enhanced with the vertical display but not with the trajectory display. The ATCOs' SA was not different between the trajectory display and the existing ATC conditions, indicating that H2 was partially supported. This finding might be due to information overload [15] that could in fact hinder the ATCOs to effectively use the trajectory display.

Collectively, the vertical display did offer benefit for both workload and SA more than the trajectory display did. The vertical display was beneficial since it provides a contextual information [16] of vertical profile (Z axis) and updates that are currently not available on the primary radar display. It helps ATCOs to maintain their mental picture of air traffic situation without essentially burden their cognitive resources with high volume of information [3].

This derives practical safety implications in developing and using new ATC systems. A little information would require ATCOs to use higher cognitive resources to obtain aircraft and airspace information as well as to perform mental computations for the necessary information changes and updates. Yet, if too much information is presented to the ATCOs by new systems, ATCOs would also need more time and effort for interpreting the information [17]. An interactive display that presents "appropriate volume" of information and allows ATCOs to have control over the information interface would be recommended.

There are few limitations in this study. First, the environmental factors such as weather were not taken into account during the ATC simulation tasks. Next, longer training period should be allocated to make ATCOs more familiar with the additional displays. Yet, the findings of this study has outlined the display design principle for the development of new ATC systems in dealing with the air traffic growth.

4. Conclusion

This paper evaluated different information displays in ATC and provided an empirical evidence of the benefits of displaying appropriate volume of information. The findings also highlighted the provision of vertical display as a promising technology in ATC to provide sufficient information for ATCOs in dealing with the increasing air traffic. This display is also expected to support various concepts of future ATC operations such as continous climb and descent, user-preferred route, and trajectory based operations although it still deserves continually careful investigations. Particularly, scanning of the information display, flight delay, advance conflict notification time, communication

time between pilots and controllers, and aircraft fuel consumption may be quantified in future research to validate the display use for the future ATC operational concepts.

Acknowledgment

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Unstable Approach: Intervention and Prevention

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Abstract. This research aims to investigate the occurrence of unstable approach from teamwork process via situation awareness, and shared-situation awareness. 9 pilots were recruited for a one-hour interview to identify critical themes. The results depicted that, under congested airspace derived from peak hour and unexpected weather, in order to consume excessive aircraft in the terminal area, ATCOs were prone to issue instructions which sacrificed aircraft's safety margins to squeeze the current air traffic flow. Therefore, aircraft may be too high or too fast during approach. For team process, pilots will actively identify ATCOs intention from TCAS, radio channel, and given instructions. As a result, they will be able to predict the coming steps and make preparation in advance. To conclude, in order to balance the needs of both ATCOs and pilots. ATCOs may have to consider not only separation but the appropriateness of vertical profile. Other than that, during the team process, critical and short information should be provided to make sure both parties comprehend each others intention mutually in seconds.

Keywords. Unstable approach, system risks, team process, situation awareness, shared situation awareness, shared mental model

Introduction

Landing safety has long been an issue which receives intensive attention from researchers. Aside from the technical failures or unexpected weather condition, for most of the occurrence of landing accidents, human errors were involved [1]. To achieve proper landing stability, several landing criteria have to be fulfilled, otherwise, the approach can seem as an unstable approach. [2, 3], which may lead to severe accidents, including runway excursion, runway incursion, or hard landing. [4] According to the related research, the unstable approach and failure of go-around were responsible for the major part of aviation accidents, in 2011, 68% of the aircraft accidents happened in these two phases. [2, 5, 6].

Some research blamed the occurrence of unstable approach for pilots' situation awareness, and decision-making errors. However, based on the perspective of critical resource management (CRM), a proper system will be able to detect and address potential risks and threaten in advance [7]. Therefore, to achieve effective and radical risks reduction, not only the operators who got involved the unsafe act, but also the corresponding team work performance. Specifically, the manoeuvers of the aircraft will be determined by the air traffic controllers' (ATCOs) instructions based on the requirement of air traffic flow management, after that, pilots will follow the

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instructions to operate the aircraft accordingly. Accordingly, two aspects will affect the quality of ultimate landing, one is the appropriateness of the given instructions, another is the quality of team coordination and communication [8, 9]. Firstly, ATCO's instructions will be issued based on air traffic flow management and conflict resolution. However, the instructions, sometimes, failed to fit both parties' requirement. For example, excessive airspeed, late descent, or improper vectoring may make the pilots unable to fulfill standard landing criteria within safety margin, increasing the probability of unstable approach [8]. Secondly, at this moment, proper coordination and communication are required to eliminate potential risks [10, 11]. For dynamic landing scenario in the aviation industry, due to unequal information sharing, and highly heterogeneous working types, sometimes, it makes challenging for both parties actively supplement each other immediately. [3, 9]

Apparently, to investigate whether a system is able to achieve required performance and flexibility, the examination regarding the interaction among team members is compulsory, especially for the complicated system like aviation industry [12]. In terms of the current research about unstable approach. Firstly, most of the current research put more emphasis on the individual performance. Relevant research investigates how the pilots operated, and coped with the instability during the landing phase [2, 3], or how ATCOs provided proper instructions which facilitate landing stability [8]. Other than that, little research explores the dynamic process of communication during approach. With limited research, [9] investigated the break down during the communication process, indicating that 52% of communication conflicts occurred in approach phase. Furthermore, the mismatch of operation requirements was the most prevalent type of conflicts, which was derived from the difference between subjective priority regarding required performance.

From the perspective of the human factor, to achieve seamless teamwork within a complicated system."Shared situation awareness (SSA)" is a critical role which can be defined as the extent to which all individuals in a team hold the same value regarding the required team performance [11, 13]. And it determines whether all the works from each of the team members are able to achieve a "holistic" team performance. Based on the literature above, obviously, the mismatch of operation requirement and the difference between two parties' priority regarding performance showed that, sometimes, pilots and ATCOs failed to hold the same value and figure out a proper solution which fit both sides' requirements during the communication. Relvant research indicated that it also connects to the unwanted ultimate team performance, even though each of the team members has fulfilled their responsibility. Since an individual may not able to predict and provide necessary resources which others need [13, 14]. Therefore, the aim of this research is to uncover the root cause of the occurrence of unstable approach from the perspective of teamwork process. Specifically, this research will examine the results of team process, and clarify the corresponding decision making and communication gaps between pilots and ATCOs from the perspective of SSA.

1. Literature review

1.1. Situation awareness (SA) & Shared situation awareness (SSA)

Situation awareness (SA) has received intensive attention, especially within the aviation industry, as it is used to explore how operators make their decisions. SA

represents how a person perceives different elements in the environment, how they comprehend the meaning, and how they project the status to the future [1, 15]. For level 1 SA, one perceives the critical cues from the environment. For level 2 SA, one comprehends the meaning of a situation pattern through a mental model created based on training or experience. Finally, for level 3 SA, one projects the current situation to the near future to anticipate what will happen. After a series of mental processing, the final goal and ultimate decisions can be determined. SA serves as a basis for high quality of performance, and decision-making, numerous research have indicated the importance of possession of proper SA, especially for landing. [3, 4] As in landing phase is the most dynamic situation within the whole flight trip. It's compulsory for both ATCOs and pilots to stay sharp about the probable changes.

However, SA is mainly adopted to explain an individual's decision-making process. With complicated systems in the modern aviation industry, highly heterogeneous work distribution is common to cope with the extremely dynamic environment. Therefore, SA has been further extended to the perspective of the team and examines how numerous team members integrate their work and achieve required team performance, which can be called shared situation awareness (SSA). And it can be defined as the extent to which individuals in a team hold the same SA regarding the required SA [11, 13]. And two different types of shared mental models including (1) task-related mental model, and (2) team-related mental model, have been identified by relevant research. [16]

1. The task-related mental model includes two aspects: (1) technology/equipment and (2) task/jobs. First, the task-related mental model of technology and equipment, it means the shared knowledge which enables an individual to understand the technology they are interacting with, like equipment functions, and system limitation. On the other hand, shared mental model regarding task/jobs determines whether an individual possesses sufficient shared knowledge about team task-procedure, and correspondingly strategies regarding ultimate team goal. Basically, it will not affect the quality of individual performance. However, task-related may act as a "filter" to eliminate those "proper" individual decisions, however, which is not appropriate for overall team performance. Thus, task-related mental model determines whether a team member is able to achieve "individual performance which fits team requirement".

2. Team-related mental model represents the shared knowledge about how the team members interact with one another and how other members behave during the tasks. Three different dimensions, includes: (1) coordination, (2) communication, and (3) cooperation. For the first item, it examines whether team members possess the proper strategic knowledge to actively locate the critical need of the current state [17]. For communication, it unfolds whether team members hold the shared understanding about what information is critical to provide, and how the information is conveyed. For the third dimension, it investigates whether team members are able to cooperate with each other well, including items like team spirit, and interpersonal relationship.

In this research, to achieve a better clarification about potential gaps regarding the possession of SSA, operatos mutual belief will be also uncovered. Relevant research indicated that human is able to simulate other's mind based on the mutual belief, further, enabling proper interaction without completely information exchange [18]. The results also showed that, under the fighter jet simulation, two persons who are able to

simulate each's mind achieve better score [19]. However, one thing worth noting is that the possession of shared mental model doesn't directly affect the ultimate team performance. Instead, it will be mediated by the execution of team process, including coordination, communication, and cooperation [17] [14]. Accordingly, the quality of the execution of team process is determined by the required SSA of team members, which affect the ultimate performance. Thus, this research will not only investigate operators' SSA and mutual belief to examine the potential SAA gaps, at the same time, the quality of team process will be also examined to identify the current state of team communication and coordination.

1.2. Agent-based model during landing stage

To achieve a more comprehensive and detailed examination regarding to how ATCOs and pilots coordinated each other during dynamic approach phase, agents-base model (ABM) will be applied, which is a reasonable tools to unfold interaction among stakeholders, system, and procedure Although, ABM is a qualitative approach which applies computational simulation to examine how a system functions under certain environment [20]. It can still serve as a structure which fits the rich data from descriptive decision theory like mental model [21]. Therefore, an agent-based model during approach is developed, and details are shown in Figure 1 below.

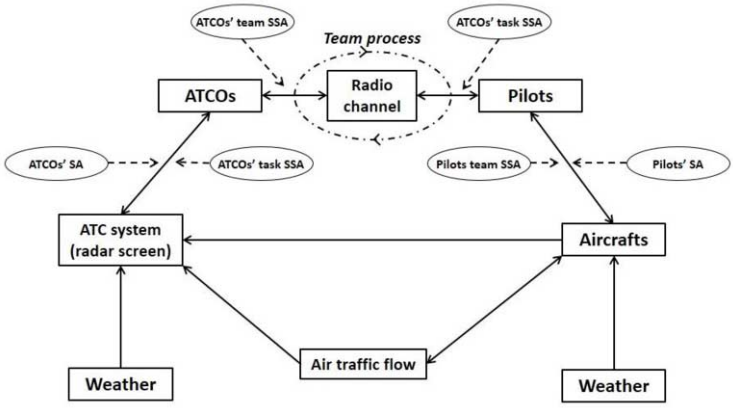


Figure 1. Agent-based model regarding communication between ATCOs and pilots during approach.

For the current system structure, ATCOs are located at a higher hierarchical level than pilots; therefore, ATCOs will check the weather and current air traffic flow from the radar screen, then issuing corresponding instructions to pilots through the radio. After pilots receive the instructions, they will either execute the instructions accordingly or provide alternatives and feedbacks to coordinate with ATCOs, making sure the instructions fit both sides' requirement. In terms of mental capabilities, respective SA is compulsory for each sides' main tasks (ATCOs for air traffic control, pilots for aircraft maneuver). On the other hand, to achieve seamless radio communication, corresponding team-related SSA are needed for them to provide critical information, and identify critical need during the team process. Ultimately, for task SSA, it determines whether team members are able to fulfill their work which fit system's requirement and strategies.

2. Methodology

2.1. Structure and participants

For the methodology, the SA and SSA will be elicited by the critical decision method, which is the event-based approach used to investigate challenging events [22]. Nine pilots were recruited and asked to provide experience regarding unstable approach. Two parts will be identified to fully explore the teamwork during the landing phase, including: (1) Given instructions from ATCOs, and the approaches pilots applied to evaluate them, and (2) following team process after instructions provision. After that, the content analysis will be carried out to categorize several critical themes which will be essential to explain the occurrence of unstable approach. For the prerequisite of the recruitment, to investigate the potential risks in the system interaction, participants pilots are required to be at least first officer with at least one-year working experience. With the possession of descent experience and skill, participants can pinpoint the underlying breakdown which may harm the landing safety effectively.

2.2. Interview questions

Two aspects will be covered in this research, including (1) Given instructions from ATCOs, and the approaches pilots applied to evaluate them, and (2) following team process after instructions reception. Corresponding probes will be applied to uncover the SA and SSA.

1. ATCOs' instructions & pilots evaluation:
   - What were the instructions you have received from the ATCOs during the unstabilized approach?
   - Please describe the state of the aircraft, how you comprehend the state, and how did you evaluate the appropriateness of the instructions? (pilots' SA)
2. Team process:
   - Please describe the team process during approach.
   - How you actively support team supplementary?What is the critical information needed to be provided? What is the vibe of cooperation?
   - To facilitate team supplementary, what kind of aspects do you think is necessary for ATCOs to possess? What kind of information do you think is necessary for ATCOs to provide? What attitude do you think is necessary for ATCOs to possess?

3. Result:

In this interview, 9 pilots were recruited, including 4 first officers (FO), and 5 captains (Capt). The participant's profile is shown in Table 1 below. And for the results of content analysis, 16 sub-themes has been converged to 33 themes. The themes which are no more than 5 frequency will not be displayed here. And these themes will be separated into two parts, including: (1) ATCOs' instructions & pilots evaluation (5 themes, and 12 sub-themes), and (2) corresponding team process (11 themes, and 21 sub-themes).

Table 1. Participants profile.

Participants	1	2	3	4	5	6	7	8	9
Age	31	32	40	60	52	25	50	52	57
Position	FO	FO	FO	Capt	Capt	FO	Capt	Capt	Capt
Flying hour	1900	2000	3000	22000	30000	1450	18000	9000	12000

3.1. The reception of ATCO's instructions

This section consists of two parts, including (1) the instructions from ATCOs, and (2) the approaches pilots applied to evaluate given instructions. The overview of the codes and themes are shown in Table 2 below. Firstly, for the provision of instructions from ATCOs, two themes were identified, including the scenario background, and instructions content. As for the scenario background, congested airspace which was based on either peak hour or bad weather was frequently mentioned. On the other hand, for instructions content wise, high-speed instructions were frequently issued, other than that, ATCOs also squeezed the aircrafts sequence for better airspace utilization. Relevant instructions include taking short cut, and late descent.

As for the approaches pilots applied to evaluate the instructions, excessive airspeed, altitude were the frequently mentioned cues (SA level 1) for landing instability. Then, the remaining track miles is a critical indicator of safety margin, accordingly, the three-time rule will be applied to evaluate the current state and the window for instability elimination (SA level 2). For prediction (SA level 3), pilots are able to know the available window to eliminate instability. And it's critical to predicting 10 nautical miles ahead.

Table 2. ATCOs' instructions & pilots evaluation.

The instructions from ATCOs		
Theme	Sub-theme	Description
Scenario background: Congested airspace (41)	Peak hours (18)	ATCOs will try to consume congested air traffic flow as soon as possible (9) and manage multiple aircrafts simultaneously (4). Moreover, the communication channel will be clogged up due to frequent instructions provision (5).
	Unexpected weather (12)	Unexpected weather compressed the available airspace, leading to congestion (7), also the condition of the runway will be significantly affected (5).
Instructions content: Instructions sacrifice safety margin for better utilization of air space (43)	Maintain high speed (18)	Requested pilots maintain high speed for faster consumption of air traffic flow, which made pilots unable to decelerate on time (18).
	Unsafe sequence management(20)	Sequencing instructions which may sacrifice pilots' safety margin to consume the flow faster. Relevant instructions includes take short cut (9), late descent (7), and increase air speed for separation (3)
The approaches pilots applied to evaluate instructions (SA)		
SA Level 1: Excessive airspeed and altitude were the most common cues which pilots concerned. (33)	Either too fast or too high on LOC (14)	Excessive airspeed (8) or excessive altitude (6) when pilots intercepted the localizer.
	Too fast and too high on LOC (6)	Both airspeed and altitude were excessive when pilots intercepted the localizer (6).
	Excessive altitude due to track miles reduction. (9)	Excessive altitude because ATCOs cut down the available track miles (9).
SA Level 2: Remaining track miles is critical for coming energy management	Remaining track miles act as the margin for energy dissipation (43)	Remaining track miles and three-times rules served as the indicator of remaining safety margin (30). And it determined whether the aircraft were able to decelerate and descent in time (13).

and dissipation (75)	Deceleration will be firstly executed before descent (11)	The airspeed should be decreased to a certain gate first, preventing from high-speed descent. (11)
	The direction of the winds affected the ultimate state of the aircraft (12)	Wind direction around the terminal area is a factor which affects the results of deceleration. Head wind is preferred to help decelerate.
SA level 3: Based on the results of prediction, pilots are able to know the available window to eliminate instability. (25)	Predicted that remaining track miles were not enough for energy dissipation. (14)	Pilots realized that remaining track miles was not able to dissipate excessive altitude (4), air speed (4), or both of them simultaneously in time (6).
	Proper prediction is compulsory (4)	It's critical to predicting the state of aircraft 10 nm ahead.

*the number in the brackets represents the frequency mentioned.

3.2. Team process

This part consists of three parts to uncover the current state of team process, including (1) team process, the results of communication and coordination, (2) pilots' SSA, and (3) ATCO's required SSA from pilots' perspective. The overview of the codes and themes are shown in Table 3 below. First, for the result of team process, to coordinate properly, it's critical to actively identify each other's intention and constraints. Pilots will check TCAS, and other pilots' communication on the radio to actively identify ATCOs' intention, which helped them to determine coming steps accordingly. For communication wise, providing coming steps directly to decrease the time consumption is important. It's waste of time to elaborate the cause-result interaction.

For pilots' SSA, regarding team SSA, to achieve proper coordination, pilots will apply various approaches to achieve proper coordination, various approaches will be adopted to identify and anticipate ATCOs' intention. The mostly used approach is TCAS checking, through examining the flow of surrounding aircraft. Other than that, pilots will also listen to the communication of other pilots. All of which enable pilots to collect relevant cues, and simulate how ATCOs executed their job. In addition, to decrease the time consumption under critical scenario, pilots emphasize the direct provision of next course of action, instead of the reasoning of current state. As for task SSA, pilots also manage the air traffic flow partially, which is achieved by maintaing aeparation between the aircraft ahead, and try not to slow down too early, helping ATCOs to manage the flow easier.

For ATCOs' required SSA from pilots' mutual belief, regarding team SSA, in order to facilitate a better coordination efficiency and results, it will be better for ATCO's to express their intention directly, which facilitates pilots to actively get engaged in the team process. Furthermore, the provision of remaining track miles and assigned airspeed from ATCOs during communication also provide cues for pilots to identify ATCOs' intention. For example, more track miles than the usual might represent congested air traffic flow ahead, so pilots will prepare to decelerate in advance. As for required task SSA, ATCOs should consider the appropriateness of vetical profile, and capabilities limitation. Since, sometimes, ATCOs may over-focus the seperation maintenance, ignoring whether the aircraft are stable or not. And the appropriateness of vertical profile is the item mostly frequently mentioned, which leading to excessive potential energy state. Furthermore, different rate of deceleration among different weight of aircraft should be also taken into consideration to prevent the potential impact regarding seperation maintenance.

Table 3. Team process and corresponding SSA.

Team process		
Theme	Sub-theme	Description
Coordination: it's critical to identify each other's intention and constraints (23)	Actively identify each other's intention (15)	Both parties actively identified each other's intention. Pilots will check surrounding aircraft via TCAS (3), and aircraft current state (4) to figure out the intention of ATCOs. For ATCOs, they will actively check pilots' acceptability regarding instructions (5).
	Passive coordination (6)	Sometimes, both parties fail to reach consensus, then pilots executed the instructions directly.
Communication: information provided should be critical yet short (42)	Keep communication short and clean (11)	It's critical to keep the communication short and clean. Excessive information will congest radio channel.
	Provide coming course of actions directly to each other (24)	For both parties, it's critical to provide the information regarding to current constraints and corresponding actions directly. E.g: pilot will request extra track miles (one orbit) for operate directly where necessary.
Cooperation: professionalism matters (20)	Professionalism and training facilitate the vibe (10)	The good impression regarding ATCOs' professionalism will increase the confidence of cooperation
Pilots' team SSA		
Coordination: pilots actively anticipate and examine ATCOs' instructions (40).	pilots will apply various indirect approaches to anticipate ATCO's intention (27)	Pilots will try to actively anticipate ATCOs' intention via checking TCAS (9), the aircraft state (9), other pilots' communication from the radio (2), and information in given instructions (5).
	Pilots possess critical thinking to examine the instructions (8)	Pilots should possess critical thinking to eliminate potential risks, instead of blindly following ATCOs' instructions
Communication: The provision of coming step is critical (13)	The provision of pilots' own coming step is critical (9).	It's important for pilots to provide the next step directly (9). E.g." unable to hold due weather, is it possible to do a left-hand pattern instead of right ?"
	The alternatives should be short (3).	Pilots try to keep information short and critical to decrease the consumption of time
Cooperation: respect the instructions as possible (12)	Pilots will respect ATCO's instructions at first place (8)	Pilots will respect and follow ATCO's instruction as possible, as long as the landing safety was ensured. Since the communication takes reciprocal help.
Pilots' task SSA		
Pilots will fly the aircraft in a way which supports ATCOs requirement regarding air traffic flow management (36).	Make preparation for coming instructions (10)	Pilots will make preparation in advance for coming instructions, which is based on the current state of aircraft. (10)
	Try to actively maintain separation, among aircraft (11)	Pilots actively maintain the separation (5 nm) among aircraft to support ATCOs requirement.
	Not decelerate too early to fit ATCO's requirement (5)	Pilots will try not to slow down too early to fit ATCO's requirement regarding air traffic flow management. (5)
Required ATCOs' team SSA from the perspective of pilots		
Coordination: expressing intention helps pilots engaging the coordination (11)	It's better to express intentions during communication (4)	It's better for ATCOs to express intention via instructions. For example, due to runway change, heading to 350 degree
	The constraints of pilots should be set as priority (6)	ATCOs have to adapt themselves to the pilots' need and find another solution to sort out the situation.
Communication: surrounding information and remaining track miles are critical to	It's better to provide the state of surrounding (5)	When providing the instructions, it's better to provide the relevant surrounding instructions, like the state of air traffic flow ahead.
	Track miles and required speed are	Track miles and assigned speed are critical information which is needed to be provided, which helps pilots

being provided (21)	needed to be provided (9).	identified ATCOs' intention, and tailor their flight plan to ATCOs' need.
Required ATCOs' task SSA from the perspective of pilots		
ATCOs should comprehend the performance constraints and consideration of pilots (32)	ATCOs should ensure the appropriateness of aircraft state (11)	For ATCOs, the consideration of the appropriateness of vertical profile is compulsory, instead of over – focusing separation.
	ATCOs should know the capabilities difference among aircraft (19)	ATCOs should know the capability difference among different types of aircraft regarding declaration rate for better management of sequencing and avoid the sudden change.
	ATCOs should realize pilots' care regarding remaining fuels (9)	During vectoring the aircraft (go-around/ holding), the consideration of remaining fuel is necessary, avoid fuel emergency.
The way ATCOs issue instructions has to adapt current state of air space (8)	The instructions should be tailored to the air space (8)	ATCOs have to actively adapt to the compressed air space due to bad weather, changing the way of vectoring.

*the number in the brackets represents the frequency mentioned.

4. Discussion and conclusion

Based on the results above, it's apparent that the occurrence of unstable approach is highly connected to the appropriateness of given instructions. For ATCO's responsibilities, they have to consume the airspace congestion as fast as possible, which makes acute changes common. However, it may conflict pilots' consideration regarding landing safety, while gradual operations are preferred. As a result, how to balance the requirement for both ATCOs and pilots is critical. Accordingly, team process serves as a safety net to detect and eliminate potential landing risks, which requires both parties to actively engage in. However, due to different information sharing and the lacking of the regular form of information delievery, sometimes, it's hard for both parties to identify each other's intentions and constraints within a short period. If team process fails to achieve the required performance, the responsibilities of landing risk elimination will totally rely on pilots' experience and skill, which bring excessive mental workload.

Overall, the landing risks derived from inevitable goals conflicts are common, while they can detect and cope with proper team process. Based on the current approach, voice communication is still the major way to communicate each other. However, in the future, data-link will be applied to replace the current way [23]. All the trajectory data can be dynamically exchanged between pilots and ATCOs. However, relevant research indicated that data-link is unlikely to be implemented in the terminal area [9] Since approach phase is too dynamic to spend extra time to key in extra data to communicate, which has been mentioned by two captains in this research. However, based on the results of this research, both pilots and ATCOs have possessed required mental model to identify the overall situation with limited cues, like remaining track miles and assigned speed. Hence, as long as we can identify ATCO's mental model, and how they comprehend pilots' constraints in the future research. Then the point where both parties converges can be used as a critical basis for the development of the future supplementary system.

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Study on Impact of Separation Distance to Traffic Management for Small UAS Operations in Urban Environment

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Abstract. Unlike manned aviation operating in non-segregated or controlled airspace where separation distance between aircraft is well defined, the safe separation distance for UAVs operating in urban environment in segregated or uncontrolled airspace have yet to be established. There are many confounding factors affecting the safe separation distance for UAV. These include but not limited to exogenous factors such as wind, rain and birds. In this study, the aim is to derive the relationship between separation distance and the number of conflicts. As a preliminary study, direct flights for UAVs are considered. This is because from a UAS operator's point of view, a direct flight to destination is always preferred. However this may not be allowed due to the potential increase in conflicts due to multiple UAVs operating concurrently in the airspace. If the airspace density is sufficiently low, one expects the conflicts between UAVs to be reduced accordingly, thus making direct paths feasible. On the other hand, a high density would nonetheless increase the number of conflicts, rendering a controlled and managed airspace necessary, either by altering the flight paths or through speed control. It is then postulated that there should be a particular threshold whereby such transition from a free flight path to a non-free flight path will take place. With this aim in mind, the number of conflicts, defined by the loss of separation, between the UAVs is investigated for two scenarios: (1) direct flight path to destination and (2) direct flight path with speed control. In both scenarios, the UAVs will enter the airspace simultaneously towards different destination points, simulating the maximum possible number of UAVs entering the airspace at the same time. The number of conflicts is also then computed for different values of distance separation distance separation for each scenario. These results will then give a preliminary hint on the threshold conditions for the transition.

Keywords. Traffic Management, Unmanned Aircraft Systems, Unmanned Aerial Vehicles

Introduction

With the projected growth of the global market of the unmanned aircraft systems (UAS) at CAGR of 9.83% from 2016 to 2021 [1], the airspace will soon be filled with

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UAS that are fulfilling different purposes and missions, such as delivery, surveillance and aerial photography [2,3]. This will then potentially spur a demand in the usage of UAS and thus the traffic management of large number of UAS in the urban airspace will then be one that is necessary, similar to the early days of manned aviation. The safe and efficient traffic management of the UAS (TM-UAS) will then be a critical enabler for these operations to take place effectively, which will in turn drives the industry towards greater innovation and benefits. Various organisations such as National Aeronautics and Space Administration (NASA) [4] and Netherlands Aerospace Centre (NLR) [5] are currently studying and developing the traffic management for UAS operations. However, there are currently little studies in the area of traffic management for UAS operations in urban environments. Integrating UAS in the urban environment poses additional challenges whereby one now has to consider its potential interaction with the high density urban population and buildings. In addition, the airspace has to be purposefully re-designed to enable large scale multiple mode operations in the urban environment.

In view of the airspace design, the study of separation distance for UAVs operating in urban environment becomes a critical area of R&D which will enable the urban airspace to be traffic managed efficiently and safely. Furthermore, unlike manned aviation operating in non-segregated or controlled airspace where separation distance between aircraft is well defined, the safe separation distance for UAVs operating in urban envirnment in segregated or uncontrolled airspace have yet to be established.

1. Airspace Phase Transition

The traffic management in the urban area can be considered as one that is of competing needs and requirements. The UAS operators, with the aim to increase its own efficiency and reducing its own cost, will demand to finish its mission in the shortest time possible and in the most direct path whenever possible. However, from the traffic management perspective, this may not be always feasible, since the flight paths may cross each other and this may lead to potential incidents or collisions between the UAS. As a result, the operators in turn have to be made to follow sub-optimal structured waypoints so as to ensure maximum safety. Yet, on the other hand, if the flight density is sufficiently low such that any potential incidents may be avoided, an UAS flight with direct route should then be made permissible.

As a result, one can introduce the so-called concept of airspace phase transition (APT) [6] in the management of the urban airspace. The main idea of such concept is as follows: given the real-time conditions (such as density and performance of the airspace, degree of human activities under the airspace etc.) of the urban airspace, one should be able to dynamically configure the airspace structure from one that is structure-less (i.e. direct routes) to one that is fully structured (i.e. with fixed waypoints), similar to the phase transitions in condensed matter. As a result, an airspace phase transition threshold (APTT) has to be defined for transition of one structure to another. Eventually, the capacity of the urban airspace at each airspace structure can be established, so that the demand can be better managed.

However, to quantify the APTT is a multivariable problem, and highly non-trivial. In order to aid the research in this direction, the conditions in which a phase transition will be necessary are studied. In particular, the effects of distance separation between UAS on direct routes will be studied in this work. By increasing the distance separation

between UAS, one effectively reduces the density of the UAS within the airspace and this may potentially reduce the number of possible conflicts between the UAS. By understanding the relationship between number of conflicts and distance separation between UAS, this gives one a better insight on threshold condition that could be defined.

2. Methodology

The simulation and modelling was performed using System Tool Kit (STK) developed by AGI [7]. The operating environment for the simulation study is a urban area of 0.185km2. The urban town consists of many high rise buildings that are under 100 ft and this is chosen so that a direct route analysis can be performed over its airspace. An urban town in Singapore was selected for the simulation. The area is configured with 6 entry points that allows the UAS to fly from all directions, with the main criteria being that the entry points are unobstructed by any buildings (See Figure 1). 3 designated landing points based on the urban topography were also selected. One should note that while the choice of entry points and landing points may be arbitrary, the analysis that follows may be easily extended to other cases and more complex scenarios. It is also assumed, for simplicity, that the UAS mission is considered to be completed once it arrives at its designated landing point.



Figure 1. Flight paths of the UAS.

In the case of the scenario considered in this work, only a single flight level is considered. This is justified as in order to enable large scale full mixed UAS operations in urban areas in short to mid-term, the airspace has to be restricted to one that is segregated from any manned aviation, and this typically covers only airspace up to 200 ft. Assuming that the buildings in the urban areas are around 100 ft, this hence allows only a single flight layer to be set up within the limited urban airspace.

Furthermore, for simplicity, the same model of UAS is used for all the flights. While realistically one would anticipate the airspace to be filled with UAS of varying performance specification, one would foresee that the future ConOps to restrict a minimum performance for UAS at any enroute flight levels, thus the dynamics and kinematics of the flight level will be dictated by the UAS with the least performance specification in the airspace during the timeframe of interest. Therefore, the choice of the model may not that critical, since all the UAS have to follow the same speed within the flight path.

The variable of interest here is the number of conflicts between the ith and jth UAS, which is defined as the loss of minimum separation between the two UAS, $|Di - Dj| < D_{min}$. The choice of this metric stems from the idea of complexity in manned aviation, where they are typically defined by the density of the airspace, interaction between the planes and the velocity of the planes [8]. An airspace of high complexity will correspond to a high workload to air traffic controller and should be avoided. As mentioned in the preceding paragraph, since there is only a single flight layer, a simplified metric will suffice for the analysis of the complexity of the airspace. Any UAS that comes sufficiently close to each other on the same flight level ought to be resolved.

The UAS will be sent into the area simultaneously through the 6 entry points in 3 waves separated by a fixed time interval, with each wave of UAS travelling to a particular landing point. This is to simulate the maximum concurrent flow of the UAS traffic into the area. The distance separation τ (in ft) is chosen based on the assumption that each UAS are already separated by a fixed distance before entering the area. One would intuitively expect that as the distance separation increases, the number of conflicts should decrease accordingly, since a sufficiently large distance separation will reduce the density of the UAS in the area, lowering the probability of a potential conflict. One would then even further expect that for extremely long distance separation, the number of conflicts should tend to zero. However, for reasons discussed in the following section, even for long distance separation, one will not able to completely reduce the number of conflicts to zero.

In order to benchmark the complexity of the airspace, two configurations are compared. The first configuration involves the UAS flying directly to the designated landing points in a straight path. Such a configuration was previously considered [6], and it was found that the complexity of the airspace will increase in a polynomial fashion with respect to the number of UAS introduced into the airspace. This configuration will form the baseline analysis for the complexity of the airspace.

As a comparison, a second configuration extends the first configuration by introducing a speed control algorithm such that whenever two UAS experience a loss of separation, the speed control algorithm will be activated to slow down the UAS until the loss of separation is resolved. It is assumed that every UAS is able to acquire the position and velocity of other UAS in its proximity via certain sensing technology, for instance, ADS-B to achieve detect-and-avoid (DAA). Therefore, the speed control method only addresses collision avoidance. As its name suggests, speed control method

tunes only the magnitude of the velocity by accelerating or decelerating the UAS. The philosophy is that the impact to the whole UAS traffic due to the collision avoidance maneuver of a single UAS can be alleviated since the routes of all UAS will not be changed. It is also to note while that speed control is not necessarily the optimal method for collision avoidance, such study is one of the first to incorporate the technology aspect of UAS (i.e. DAA) into the traffic management of multiple UAS in urban airspace.

3. Results

Figure 2 shows the effect of distance separation on the number of conflicts for different values of UAS introduced into the area. In this case, the number of conflicts displays a general decreasing trend with respect to the distance separation. This is not too surprising as the increasing the distance separation reduces the density of the UAS in the airspace concurrently at any point of time, thus reducing the probability of UAS coming into conflict. Furthermore, during the process, some of the UAS might already have completed the mission and thus further reducing the concurrent number of UAS in the area. However, it is also noticed that as the distance separation increases, the number of conflicts in fact do not tend to zero. This can be explained by the following: since the UAS are introduced into the area in waves distance separated by τ, therefore increasing τ will reduce any conflicts between UAS that arrived in different waves. On the other hand, any conflicts that arise from UAS from the same wave can never be resolved by distance separation. This hence explains why there is always a finite number of conflicts within the area.

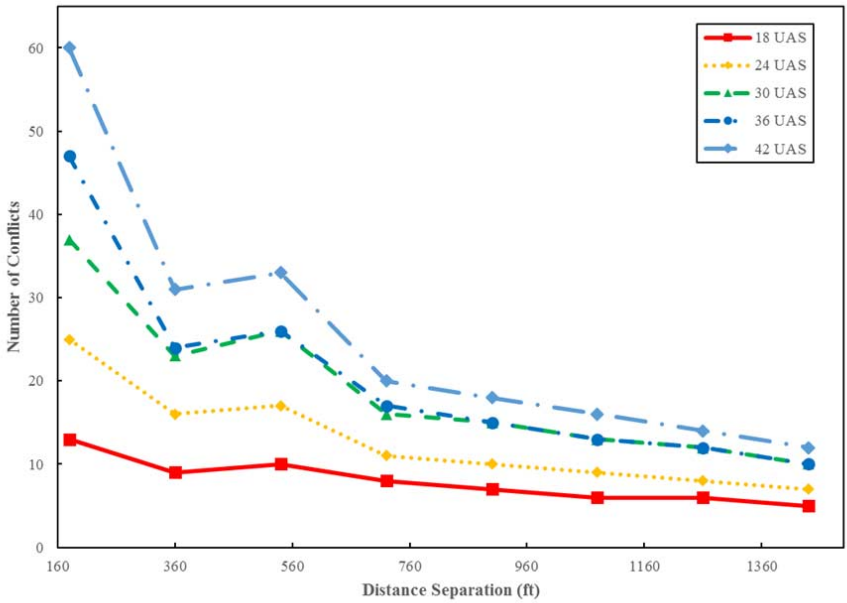


Figure 2. Number of conflicts with respect to the distance separation.

Figure 3 shows the second configuration whereby the speed control algorithm is introduced. Due to computational challenges of the algorithm in computing for large amount of UAS, the maximum number of UAS investigated is capped at 36 in this configuration. Similar to the first configuration, the number of conflicts decreases with increasing distance separation, as well decreases for small number of UAS introduced into the area, which should be expected. What is notable is that by introducing the speed control algorithm, the number of conflicts can be completely reduced to zero for the 18 and 24 UAS cases. For higher number of UAS, the number of conflicts can be completely reduced to zero when the distance separation is 1080 ft.

The main source of conflicts can be attributed to three different factors. Firstly, many of the conflicts arises close to the landing points. This is expected as the landing points are the converging points for all the routes and thus many of UAS may reach the landing points at similar times, generating conflicts between the UAS. Even with the implementation of speed control algorithm, this sometimes may not completely resolvable when multiple UAS arrive at almost the same time. While the algorithm attempts to control the arrival of the UAS sequentially by decelerating the UAS, the decelerated UAS may still be too close to the landing point and may not be able to remain well clear with the UAS that arrives before it, thus resulting in conflict. This hence is an indication that similar to manned aviation, the management of the traffic at landing and take-off points are just as crucial, and one may have to design a holding pattern for multiple UAS near the landing and take-off points, and this will be the discussion of the future work.

Furthermore, since some of the flight routes passes through the landing points at close distance, hence these UAS will pass by areas with multiple UAS converging, thus generating additional conflicts. For the speed control algorithm, since the UAS can only decelerate at a fixed rate, this may sometimes lead to a traffic jam while the UAS decelerates in order to avoid the conflict. The UAS, however, may be unable to resolve the conflict completely due to the fixed deceleration, especially for cases where the density is high due short distance separation.

Lastly, the design and the configuration of the entry and landing points contributes to the conflicts. As observed in Fig. 1, there are many points of intersections due to the different direct routes passing from entry to landing points. This is however inevitable due to the positions of the entry and landing points. While one could attempt to resolve this problem by ensuring that the UAS fly through the points of intersection at different time, this is a daunting problem due to the sheer number of intersections and the numbers of permutations that have to be computed in order to resolve all the conflicts along every single intersections. For this reason, the trend in both configurations do not show a pure monotonic behaviour, but instead display a sudden increase at particular points where the UAS happen to be at the same point at the same time.

Additionally, while the speed control algorithm successfully resolve a large number of conflicts, it may sometimes introduce additional conflicts due to the following:

Firstly, the deconflicting of the UAS may lead to ripple effects, i.e. the deconfliction between the 1st and 2nd UAS may introduce additional conflict with the 3rd UAS that was flying into the flight path. This additional conflict sometimes may not be resolvable as the 1st or 2nd UAS was already initiating the deceleration protocol and it cannot be stopped suddenly, or that the 3rd UAS just simply do not have sufficient time to react and initiate the speed control procedure.

Secondly, since the initiation time for the speed control procedure is set at a fixed value (10s) before the conflict, ideally the UAS in conflict should be in safe separation range of each other's route before the initiation. However, given that some routes have swallow intersecting angles and are close to being parallel, the UAS will already be less than D_{min} right from the onset, thus generating conflict even as the UAS starts to decelerate and eventually hovers. For the speed control algorithm, this mechanism is in fact responsible for most of the conflicts.

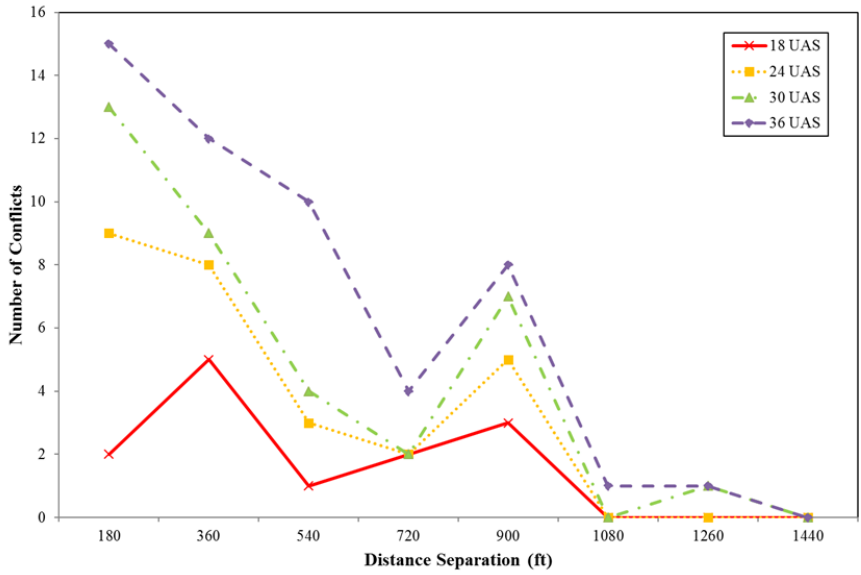


Figure 3. Number of conflicts with respect to distance separation with speed control algorithm.

Comparing between the two configurations, one can observe that by introducing an additional algorithm, the number of conflicts can be reduced drastically, thus permitting the direct route paradigm to occur at higher density of UAS. This hence serves as one possible (relatively simple) mechanism for airspace management. However, it is also observed that such mechanism fails fairly quickly for shorter distance separation and this may potentially be one of the factors in deciding if APT should take place. A potential application of these results will be to define the APTT conditions using the distance separation and number of UAS in the urban airspace as one of the parameters.

4. Concluding Remarks

The paper study the relationship between separation distance to number of conflicts for UAS operations in urban airspace. The results show that with increasing separation distance, the number of conflicts (violating the constraint of minimum collision distance of 100 ft) reduces. While the inclusion of speed control of UAS will further reduce the number of conflicts significantly, it is still unable to completely resolve all the potential conflicts at short separation distance. Nonetheless, this study serves as a first study in establishing the minimum separation standard required to ensure safe and efficient UAS operation in the urban environment.

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Research on On-Board Head-Up Display Design Based on Distracted Driving

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Abstract. This work will be designed for the driver's distraction driving condition during driving, which aims to improve the driver's spatial awareness and response time. In order to meet these requirements, we analyze and apply the relevant theories such as visual selection and cognitive capture to find out the necessary function of the head-up display interface. Omnidirectional recognition, presenting information when necessary, information division, intelligent braking and call disconnection are five features in the design. In order to prove the effectiveness of the design, we designed the experimental prototype and eye movement experiment to test the design. Overall, this work discusses a huge challenge of Human-machine interface, elaborates many new features of the car interactive interface, and introduces the outcome of user trails that contrast the interface with our design and without our design.

Keywords. Head-up Display; Distracted Driving; Visual Selection; Cognition Capture

Introduction

According to survey, over one fifth of road traffic accidents were resulted from distracted driving [1]. With the increase of navigation system and on-board mobile devices, drivers face a bigger safety challenge when driving. All kinds of car manufacturers are also developing their exclusive head-up displays to cater to the general public's pursuit for high technology. The invention of many on-board recreation equipment are also catching people's eye. But it's noteworthy that as a symbol of status and identity, cars can also bring massive pain for a number of families during traffic accidents while showcasing buyer's flavor. Speed and stimulation will bring danger and information overloading will cause potential threats to drivers.

1. Analysis of drivers's braking process

According to the principle of cognitive psychology, driver's braking process is a very complex recognition process (Figure 1). At first, drivers have to perceive and identify road condition. The input of information is mainly achieved by visual selection and identification. Then, after the information has entered driver's brain, the brain has to absorb and estimate it to predict idea trace and speed. Driver's estimation is based on

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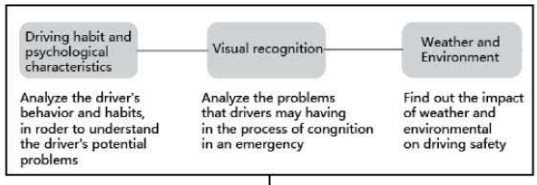
the perceived road condition, and then he has to response to the received information by offering feedback during operation. It transforms recognition process to behavioral process which is also the stage when substantial effect takes place and the braking process finishes. However, during the operation, traffic accidents caused by human factors often occur at the recognition and estimation stage. Although there are specific situations like driver's age can cause delay of action, this paper doesn't focus on this aspect. So problems like these are excluded from this research. This paper will mainly talk about the recognition and estimation stage. For example, drunk driving accidents mainly rise from cerebral palsy caused by heavy drinking which weakens driver's perceptional and analytic ability. Distracted driving as analyzed in this paper also concerns weakened perception、 distraction and delay of estimation caused by behaviors like answering mobile phones which bring potential threats to drivers.



Figure 1. Analysis of Driver's Braking Process.

2. Analysis of reasons for distracted driving

Distracted driving is very commonplace in daily life. Under many circumstances, it is defined as man-made mistake because of driver's distraction during the operation. But drivers should take all the blame. According to Gibson's direct recognition theory, outer environment can be of great meaning for people. All things in natural environment have their "values and meanings" that waiting for people to discover them. People respond to environmental information out of their instinct because environment can lead and control human beings [2]. As a result, information from on-board interface and outer environment is of great importance for drivers. Here reasons causing distracted driving can be divided into three categories: outer environment、on-board interface and the driver himself (Figure 2).



Content / Results	Diving habits and psychology characteristics	Visual capture	Weather and Environment
Common problems	Driving for a long time and old hands' carelessness	An increase in the number of the equipment in the car	Visibility is poor due to the fog or haze and the road is slippery in the rain or snow
analyses	Attention is not concentrated, which is easy to cause traffic accidents	It is easy to cause driving distraction, which will lead to accidents	Brake time is extended, which cause the driver difficult to take actions promptly in an emergency
Design opportunities	warning in an emergency	warning only in emergency situations	data analyses, brake time and distance measurement and cauculation

Figure 2. Analysis of reasons.

2.1. Outer environment

During the process of driving, as the outer environment keeps on change, drivers have to continuously perceive the outer condition so as to make correct judgments. However, outer environment often misguide drivers which can leads to false operation. Huge vehicles on the road and constant whistles can distract drivers, weather and road condition can also cause false judgment. They are all related with driver's obsession with these circumstances. For example, under environment of low visibility caused by heavy moist, drivers often make mistakes when measuring distances which leads to lack of understanding of the entire environment. When sudden danger occurs, they do not have adequate time to make preparations so accidents occur. Smooth road surface and streets with sharp turns can also have the same problems.

2.2. On-board interface

Today with the rapid change of technology, on-board mobile devises are on the constant rise. This is also a unique feature brought by the information technology. All of these products are rising from designers' good will to bring convenience to our life, but the information overloading in the surrounding environment will distract drivers. As a result, drivers will be able to concentrate on useful information which can produce serious consequences.

2.3. The driver

The driver himself is a significant factor for distraction and also the research focus for this paper. By probing into individual drivers, we can help them to deepen their understanding of outer environment and on-board interface so as to promote the overall improvement and development.

2.3.1. Visual selection

Drivers' interaction with and response to outer environment originated from the input and identification of visual message. It's a complex to process from noticing to responding and then to acting. During the whole process, visual selection is one of the important bases. The process of visual selection can be divided into an early stage (bottom up) and a later stage (up down) [3]. At the first stage, large amount of outer information will stand out from all particular ones which can raise visual attention but does not require any reasoning process. While at the second stage, drivers have to form understanding to stimulation by processing information [4]. Drivers' perception and thinking influence all the things that they can see. Drivers' early visual selection is stimulated by environmental information. Here it refers to outer environment as well as on-board interface. Later visual selection is a concept consists of drivers' ability、experience and the corresponding design model. So when conducting interface design for on-board head-up display, designers need to stress and process all urgent information according to different levels to inform drivers of potential danger and prompting them enter into later visual selection stage quickly and behavioral stage earlier.

2.3.2. Cognition capture

Recognition capture means distraction from a variety of stimulation. Here simulations mainly refer to visual ones. However, other sensory stimulation like hearing also play an important role. Stimulation's influence on drivers depends on brain load intensity brought by information.

Visual stimulation is the most frequent one when people are driving. Overloaded information will occupy drivers' attention sources and dilute key information during the driving task [5]. HUD directly represents information on the front windshield which can help drivers to acknowledge contents on the display. But it will overlap with information from outer environment and thus weaken the distinctiveness of actual road condition. As a result, it will be difficult for drivers to notice the overall situation. Moreover, with the further development of on-board equipment, many drivers can answer their phones by eye-tracking or speech recognition instead of using their hands. But experiments showed that compared with mobile phones, speaker phones can not reduce the effect on drivers' responsive time. It is because that while the whole process doesn't involve hands or eye, the calling and answering stage will still occupy their brains so to reduce their attention to driving task and weaken their response to emergency [6].

2.3.3. Time interval

Working memory refers to preservation of relevant information and constraint of useless ones. Research found that the difference in the time interval between memory objects and researching sequence will lead to the difference in processing information [7]. The longer the time it needs, the coding of memory subjects will be more precise. So time interval can enhance the processing and understanding of visual contents to make better response. During presentation, information has to be unique, easy to identify and also has particular presenting time to help drivers to process coding correctly and make corresponding response. Nelson once put forward a "ten-minute rule" which said that new drivers have to study all the interface functions within then minutes. If drivers fail to do so, it means that the interface design is too complicated [8]. But it's noteworthy that while drivers can understand all functions, there will still be difference in making response and interpreting information as drivers have to constantly interact with the environment. So it's very necessary to setting a time for information presentation.

2.3.4. Information processing and analysis

After getting to know the road condition, drivers have to make response and take actions according to their knowledge and experience. Many new drivers are not familiar with the entire operation so they need to finish driving tasks by a long-term accumulation of experience so as to minor the influence by changeable road conditions and driving speed. So after observing the road condition and acquiring key information, drivers' understanding of information will become especially important. But for skilled drivers, there may also be accidents rising from overconfidence or misjudgment. Skilled drivers often become obsessive with low driving load. This kind of low driving load bears relationship with outer environment, which mainly comes from drivers' psychological recognition. When driving on open and flat roads, drivers confront with low driving load which requires little attention. But on the contrary, it can also exert

influence on drivers' over recognition which may lead to carelessness and reckless driving. When there are sudden changes in the surroundings, they will face difficulty in making prompt response. As a result, this design hopes to classify information into different levels according to their emergence which can in turn regulate drivers' attention and enable them to make judgments of the danger of the road condition.

3. Response time

Setting response time is also an important focus for this design. It includes perception time、judgment time and operation time. Operation time can further be divided into the time for the feet to leave the accelerator pedal and to tread on brake pedal. While drivers' age also affects vehicle's braking length and time needed for them to take response. So it is obvious that the setting of reminder time can be influenced by many factors. It's very difficult to form a standard. Due to consideration of security, this design set a loose reminder time. According a research conducted by Malko Green, drivers need 0.7 second to take response when anticipating potential dangers (0.5 second for response and 0.2 second for movement). But under unknown sudden danger, 2.5 seconds is an appropriate time for taking response as stipulated by the American Association of State Highway and Transportation Officials. So we set an alarm 3.6 seconds in advance with the aim to convey potential threats to drivers and to provide time for a second-level alarm and delay the urgent braking time for 1 second in order to avoid accidents caused by lack of time for action [9]. It's due to the fact that drivers have to take response within 0.7 second so 1 second is already a very urgent state which can cause accidents at any given time.

4. Design

Contact analogue Head-Up Displays (cHUDs) are considered to be the development of HUD technology,which emphasizes the combination of icons on the HUD interface and the real scene. It avoids the driver's disengagement from the real driving scene due to the information displayed on the screen. Boris Israel [10] has carried out detailed technical aspects of our design, so it is not further described in this article.

This work is designed based on the cHUDs. According to theories of visual selection、averted vision and visual capture, we desire to make a design which will be convenient for drivers to identify and take action. This design with the aim of avoiding distraction which may further lead to traffic accidents has the following 5 features: Omnidirectional recognition，presenting information when necessary, information division, intelligent braking and call disconnection. As for dangerous cars appearing on the front windshield, this system will set a contour and encoding it with different colors. As for dangerous cars which do not appear on the front windshield, it will label these cars with different symbols to inform direction and emergency level.

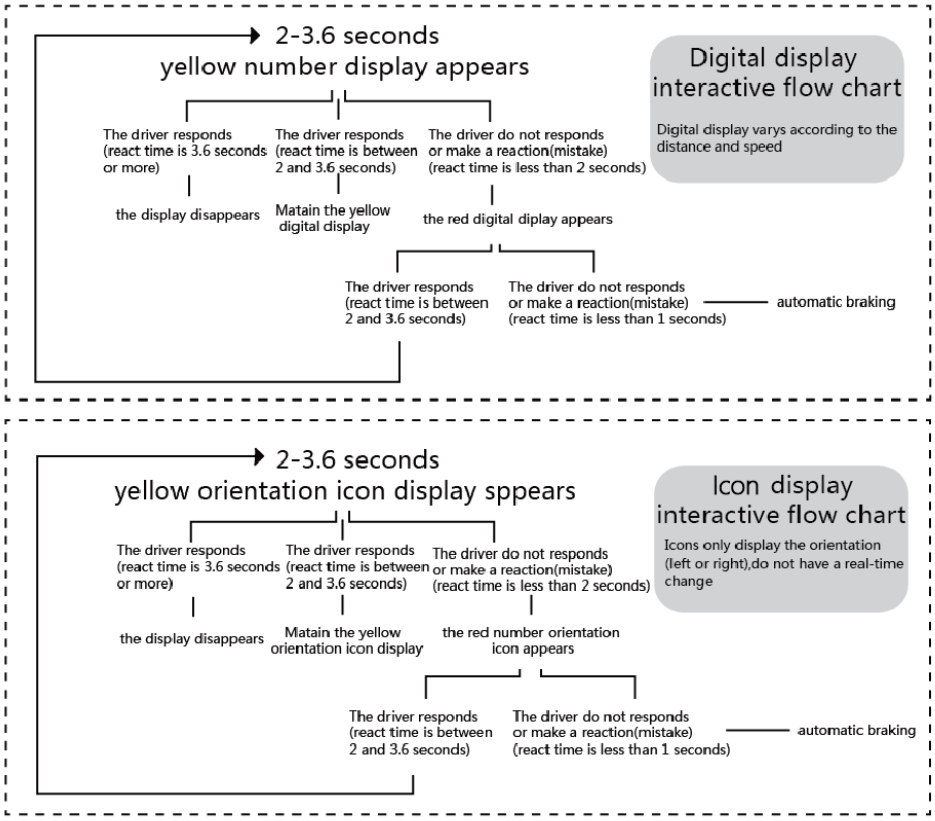


Figure 3. Interaction Diagrams of Digital Presentation and Icon Presentation.

4.1. Ominidirectional recognition

Drivers usually focus on the front of vehicles. They pay less attention to conditions on two sides and the back. If sudden changes happen, it will be difficult for them to take prompt response. So this design intends to enable on-board head-up display to extend the scope to all directions. By combing laser and ultrasonic technology, this system will explore the directions and speed of cars in the surroundings and predict their further movements so as to inform drivers of potential threats (Figure 4).



Figure 4. Informing Drivers of Road Conditions on Both Sides to Help Them Take Prompt Response.

4.2. Presenting information when necessary

In order to address problems like information overloading and attention capture, this design aims to simplify on-board head-up display interface to reduce the information burden on display. So only when there are potential dangers and will pose real threat the reminder function will actually operates. Moreover, as drivers need time to possess information, there will be time intervals on interface display to enable drivers to take effective response on the surrounding conditions.

4.3. Information division

Information division can have different displays according to urgent levels of information and strengthen stimulation on drivers by encoding with different colors. This can help drivers to understand the current danger and take corresponding response. General emergency information is encoded by yellow color while very urgent one is encoded by red color. Information division can not only emphasize important information but also be a psychological suggestion to drivers as well as providing buffer time for braking when emergency occurs (Figure 5 and 6).



Figure 5. Yellow Encoding Informs Drivers of articular General Danger so Drivers can have Adequate Time to Response.



Figure 6. Red Encoding Informs Drivers of Emergency so with the Less Response Time, it can Prompt Intelligent Braking.

4.4. Intelligent braking

The research found that it takes 0.7 second for drivers to notice the alarm and take action so we can assume that it's difficult for drivers to get rid of danger within 1 second. When two cars come into collision, if drivers do not take action, methods like

intelligent braking are needed to help drivers to get rid of danger. This call also apply to drivers who struggle to make correct directions under emergency.

4.5. Calling disconnection

By exploring the theory of attention capture, we can find that although the emergence of many on-board devices renders it impossible for drivers to answer phones by their hands, the process of answering can also occupy their attention. When it's impossible to prevent drivers to answer phones, this design will magnify the ability of human intelligence to make judgments and predictions on the surroundings so as to identify the danger of answering phones. When there is no threat, the connector will interact with both sides of conversation to inform callers in advance.

5. Experiment

In addition to the theory, the design is also tested to verify its effectiveness by experients. The experiments were carried ot in the Engineering Experiment Center of Nanjing University of Science and Technology. the main experimental instrument is eye tracking, and the user selected for the experiment are the 25-35 years' people who have the driving license and have driven the car at least one year up to now. the number of the tester is 8, and male to female ratio is 1:1 (Figures 7 and 8).



Figure 7. the scene of eye tracker experimental.

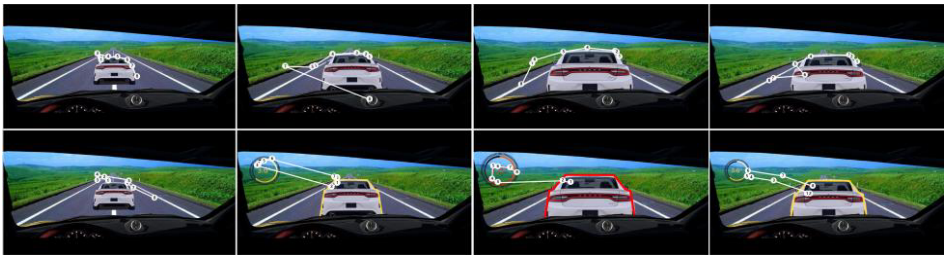


Figure 8. contrast of human visual trajectory measured by eye tracker. (the last four drawings show the absence of the design, and the next four are for the design).

In the experiment, The dynamic videos are used to simulate situations of the driving process. Testers are asked to wear the Eye tracker glasses sitting in front of the screen to watch the the videos when the Eye tracker records tests' eye movement. We

used screen capture to intercept the recorded videos at intervals of 2 seconds in order to compare the interface with our design and without our design, which is shown in Figure 8.

By comparing the visual trajectories of the two cases, it is found that when the icons are not present, the driver's attention is concentrated around the front vehicle, but a little scattered. When the front vehicle enters the range of general warning, the visual response to the two cases shows a striking difference. In the absence of our design, the driver focuses on the front car at first, but his attention gradually distracted from it. In the case of the icon, the driver's attention focus on the front car and left upper tips moving back and forth between the two objects. When the vehicle is in the emergency warning distance, the driver pays more attention to the front car than the general situation before two seconds, but the attention is still in a discrete state.

In the marked case, the driver is attracted by the front car and the top left icon at first , and then attention is still focused on the top left icon and the number. At this time, the driver is very concerned about the front car. When the situation changes to general dangerous situation, in the case without our design, the driver's attention no obvious changes, compared with the state 2 seconds before. But in the case of the interface with icon display, the driver's attention changes a lot, compared with the previous two seconds. The driver's attention is converted elsewhere, which shows the driver is relaxed, has been realize the situation out of the critical state of emergency.

Based on the experiments, it can be found that our design plays a big role in attracting drivers'attention through the digital display icon and the umber. Divided design and color can serve as a warning to drivers in different emergency situations. However, it is worth noting that this experiment is only a preliminary experiment. The following experiments will also be carried out in diversiform environments. In addition, the driving simulator will be used in the experiment as a device to ensure that the simulated scene is closer to the driver's real driving state.

6. Discussions

In recent years, with the rapid development of technology, many of them will be created、developed、improved and publicized in the near future. However, this design still faces many problems for further research. First of all, drivers have to assess dangerous vehicles by the way of information division in order to emphasize the most dangerous one. But during complex environment, the presentation of the most dangerous information may cause drivers to ignore other potential threats. So it’s still a big concern for research to make choice of various kinds of dangerous information. Then in terms of technology, this design can not guarantee the preciseness of presentation. It’s easy to have problems like delay or stall which are crucial during operation. As a result, the design requires the synchronization between information acquisition and reality. Moreover, hearing plays a significant role for people to take response and make judgments. During the following research, we will take consideration of hearing and further explore it in the process of interaction between on-board head-up display and people to stimulate driver’s different senses.

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A Preliminary Study of an Augmented Reality-Based Solution for Composite Aircraft Inspection Aiding

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Abstract. With the increasing usage of composite materials in the aerospace industry, the maintenance, repair, and overhaul (MRO) of aircraft has become a major challenge. MRO operations for composite aircraft are complex because there are a variety of types of damage that can happen to the composite materials, and there are numerous corresponding inspection and repair methods that may be chosen. For new aircraft that use a significant amount of composites materials such as the Airbus A350 and Boeing 787, cost and cycle time of maintenance are significantly affected by the efficiency and effectiveness of composite materials joining and repair process and inspection. However, current repair and inspection methods are primarily labor-intensive and time-consuming manual operations. In this study, a new method for assisting in composite aircraft inspections based on a vision-based technique was proposed to improve the aircraft maintenance process. An image-based recognition method and a 3-D augmented reality method will be conceptualized. In the experimental phase, a simulated aircraft component with underlying structures was fabricated with 3-D printing, and a test of identifying the underlying structures was conducted to validate its accuracy. The preliminary results of validation of 3-D augmented reality are provided.

Keywords. composite aircraft, inspection, non-destructive evaluation, augmented reality

Introduction

Composite material is used to build aircraft, wind turbines, bridges, and automobiles, and more. As the awareness of greenhouse gas emission and climate change grows, the use of composites has increased because they can lower emissions by decreasing the

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weight of structures like aircraft [1]. Fiber composites also significantly improve structures in different ways such as weight reduction, lower acquisition cost, stronger stiffness, and higher temperature tolerance [2]. The use of carbon fiber composites in aircraft structures has increased in recent decades. The latest passenger aircrafts such as the Boeing B787 or the Airbus A350 are made with over 50 % of composites. All is not perfect in the world of composites usage, however. Damage to composites happen through regular use of the aircraft and during servicing or grounding. Structural strength can be impacted by the fragility of composites. Most damage to composites occurs from some sort of impact [3], but not every damage incident is visible. For instance, a low-velocity impact can cause what's called barely visible impact damages (BVID), which may appear as only a small indentation on visual inspection, but the delamination inside the materials can threaten the structure of the aircraft over time [4]. Therefore, the adoption of non-destructive evaluation (NDE) is essential during the maintenance life cycle.

Various types of damage may occur on composite aircraft such as delamination, disbonding, moisture ingression, impact damage, etc. The corresponding NDE techniques are also different. Ultrasonic techniques can be used for deep delamination or disbonding; thermography can be used for detecting core damage; and shearography can measure surface deformations [5]. Despite which NDE technique is adopted, there are still issues in addition to operating NDE tools in the field. For example, some of the composite damages are so minor that they may not need to be repaired immediately, but should be treated for safety's sake after a few trips of in-service flying. The Federal Aviation Administration (FAA) uses a graded aircraft maintenance scale as follows: Type A Check, Type B Check, Type C Check, and Type D Check [6]. Flight hours and calendar time determine which type of maintenance check is needed. Inspection for any type of structural damage is especially important for composite aircraft. Impact damage can result in various types of damage [7] such as delaminations, dents, or punctures, leaving the composite structure fragile due to fiber breakage or matrix checks in the fiber composites [1]. For these reasons and more, the ability to track potential damages is the key to improving the efficiency of maintenance and repair.

A favorable technology for assisting technicians in the maintenance process is Augmented Reality (AR). AR offers advantages because it combines the real and the virtual, and offers real-time interactivity, and three-dimensional contents [8]. One of its greatest attributes for aircraft inspection is the ability to display virtual information in the real world. Technicians can access AR information with head-worn displays (e.g. smart glasses), handheld displays (e.g. tablet PCs), or projective displays [9]. Tablet PCs can replace lots of paperwork, and smart glasses can provide hands-free AR operation in the workplace. Henderson and Feiner [10] designed an AR-based solution for armored carrier turret maintenance, where head-worn displays allowed a hands-free environment. Gibert [11] indicated which technologies can be used in AR applications for the US Air Force: tablets, projections, glasses, and VR visors. In 1993, Feiner [12] proposed a structure of knowledge-based AR aimed at maintenance and repair tasks. Additionally, augmented reality technology is also introduced in applications like design, manufacturing, and training [13, 14, 15, 16, 17].

Automation has been one of the primary ways to achieve effectiveness and efficiency in industrial processes. Augmented reality may be the next technology to improve on current issues affecting composite aircraft inspection. According to the collaborating partner, the problem they have been facing is that it takes technicians and inspectors a lot of time to record and identify damages, extending an already lengthy

maintenance cycle. A novel technology needs to be inserted into the maintenance process to automate inspection and recording of damages. This project investigates using a vision-based (image & AR) technology to achieve automated inspection to decrease maintenance cycle time, reduce cost, and improve reliability. However, this study is not meant to replace current inspection methods (i.e. non-destructive evaluation), but rather assist technicians in identifying and tracking structural damages of composite aircraft. In this paper, the concept of a vision-based solution will be demonstrated, and the preliminary results of an AR application will be given.

1. Vision-based solution for composite aircraft inspection

According to the collaborating partner, the following problems plague them: current maintenance methods depend on the capabilities of maintenance technicians, which introduces human error into the process [16] and makes reliability and quality hard to control; and identifying the underlying aircraft structures during the curing process is time-consuming because technicians have to use tools like ultrasonics. For these reasons, augmented reality was regarded as a favorable approach to improve performance in the field.

1.1. Concept of aiding in recording the history of damage and repair

Considering that aviation safety is directly related to how well an aircraft performs during operation, damage inspection and assessment is critical. However, as mentioned, there are levels of damages from minor to severe. While all damages must be repaired, minor ones that do not affect safety or quality of flight can be scheduled for a future date to avoid too much downtime. To make the maintenance cycle more efficient, it would be helpful to have a method for keeping a record of all damages to an aircraft, even minor ones. Currently, this is usually done by repeatedly inspecting the plane, but in doing so it is difficult to know which are old or new pieces of damage.

Our concept in aiding in tracking damage and repair involves using a 2-D image-based methodology and transferring the data to a database accessible by an AR device. The conceptual idea is shown in Figure 1. First, technicians have to use NDE tools to identify the damage and mark it on the aircraft surface. The system will recognize and analyze the markers and store the data as CAD models. The markers are stored with additional information such as date, damage type, and status. The AR technique can allow technicians to see the real aircraft structure and to simultaneously read the recorded virtual information. By keeping damage and repair information and analysis up-to-date and accessible, technicians can work more efficiently.

The specific procedure of 2-D image recognition is: (1) read the target image into RGB values; (2) convert the RGB values into grayscale; (3) find points/makers have RGB value; (4) use K-means clustering to group the points into the nearest clusters and find the centroid coordinates of each cluster; (5) sort the clusters with respect to x-coordinate of the centroids (ascending); (6) plot all the clusters and read information from the text file as the legend; and (7) the coordinates of all 2-D marks will be stored in case if a CAD drawing needs to be created. All the markers are able to store information, such as damage size, position, date discovered, or inspector's comments, which are used to help technicians to review in the next cycle, if needed. The algorithm is shown in Figure 2.

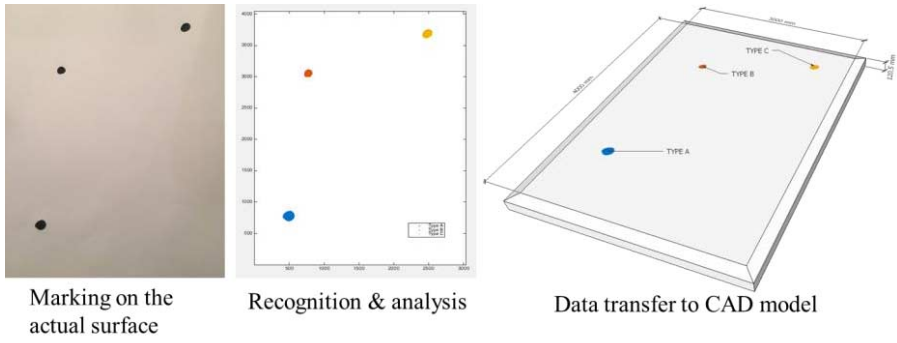


Figure 1. The concept of damage and repair tracking aid.

Finding Points and Markers

```
//Bitmap srcBitmap = new Bitmap("C://Users//RD11//Desktop//image_1");
OpenFileDialog openFileDialog = new OpenFileDialog();
Bitmap srcBitmap = null;
openFileDialog.Filter = "all files|*.*";
if (openFileDialog.ShowDialog() == DialogResult.OK)
{
    srcBitmap = (Bitmap)Bitmap.FromFile(openFileDialog.FileName, false); //reading image
}
ArrayList temp_point = new ArrayList();
srcBitmap = (Bitmap)Bitmap.FromFile(openFileDialog.FileName, false); //reading image
pictureBox1.Image = srcBitmap;
Color srcColor;
int wide = srcBitmap.Width;
int height = srcBitmap.Height;
for (int y = 0; y < height; y++)
    for (int x = 0; x < wide; x++)
    {
        //get RGB value
        Points newpoint = new Points();
        srcColor = srcBitmap.GetPixel(x, y);
        byte temp = (byte)(srcColor.R * .299 + srcCo
        if(temp < 50)   //RGB > 50
        {
            newpoint.X = x;
            newpoint.Y = y;
```

K-means clustering

```
public int[] Cluster(double[][] data)
{
  int numTuples = data.Length;
  int numValues = data[0].Length;
  this.clustering = new int[numTuples];

  for (int k = 0; k < numClusters; ++k)
    this.centroids[k] = new double[numValues];

  InitRandom(data);

  Console.WriteLine("\nInitial random clustering:");
  for (int i = 0; i < clustering.Length; ++i)
    Console.Write(clustering[i] + " ");
  Console.WriteLine("\n");

  bool changed = true; // change in clustering?
  int maxCount = numTuples * 10; // sanity check
  int ct = 0;
  while (changed == true && ct < maxCount)
  {
    ++ct;
    UpdateCentroids(data);
    changed = UpdateClustering(data);
  }

  int[] result = new int[numTuples];
```

Figure 2. Partial algorithm of the damage and repair history tracking aid.

1.2. Concept of applying 3-D augmented reality in composite aircraft maintenance

Being able to interact between the "real" environment and a "virtual" one is the predominant advantage of AR, which has been applied in maintenance, manufacturing, and training. The display of virtual contents can take various forms like a static image, 3-D animation, text, video, or audio. In this case, the proposed AR application uses images, animations, and text to provide technicians with complete information about the aircraft's damages, history of repairs, and tutorials on how to make repairs. Images are used to indicate previous damages, animations can provide repair tutorials, and information about damages, etc. appears in a textual format (shown in Figure 3).

In this project, the capabilities of the AR application should be able to: (1) virtualize the input damage and repair history; (2) display the stored information at the exact position on the aircraft structure; and (3) identify the underlying structure for the technician. A marker-based technique is selected to guarantee a higher level of accuracy for identification. The accuracy of identifying the underlying structure is critical and, therefore, will serve as the validation in the next section. The AR mechanism relies on a pattern comparison, and the virtual content will be displayed upon the identified target. After that, technicians can follow the tutorials to complete the tasks.

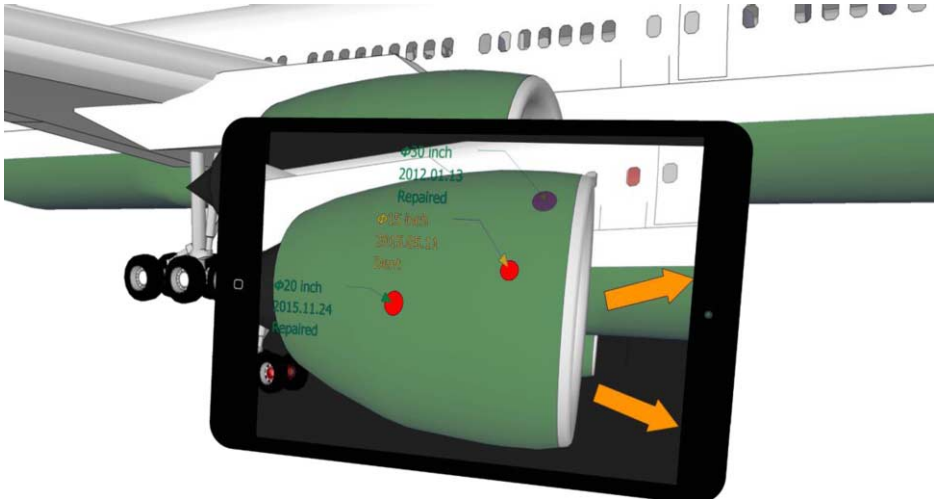


Figure 3. Augmented reality for tracking damage and repair history.

2. Experiment

Currently, augmented reality programs are mostly focused on entertainment, gaming, product demonstration, etc. For these applications, the accuracy of identification is usually not a critical issue like it is for the aviation industry.

In this study, an experiment was conducted to validate the accuracy of using AR to identify underlying structures. Five people with engineering background from the Georgia Institute of Technology, GA, USA, were recruited. All of them have experience in using AR applications, three of them are graduate students, and two are full-time researchers. The average age is 30 (SD = 2.7) years old.

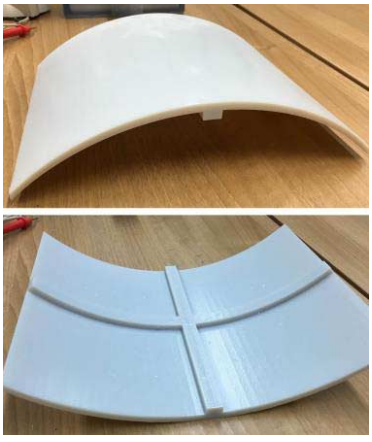


Figure 4. 3-D printed underlying structure.

3D printing was used to fabricate the demonstration article with underlying structures. The 3D printed structure is 28.21 cm in length and 20.32 cm in width. At the

backside of the printed part, a cross measuring 1-cm wide was designed as the underlying structure. The actual structure image is shown in Figure 4. For consistency, we used the same model to recreate the 3-D object for AR, which has the same dimension as the actual one. The intervals of fasteners are between 2.54 cm to 3.47 cm, and the diameter of each fastener hole is 0.6 cm. Participants had to operate the AR system and point the location of fastener holes. As shown in Figure 5, the 3-D animation was generated and the task begun (a), and participants then point the fastener holes (b) by viewing the real-time animation (c).



Figure 5. Using AR to identify the underlying part.

3. Results and discussions

In order to validate the accuracy of AR technology in this experiment, a traditional method was also provided for participants. Other than the AR method, they had to refer to the printed hard copy of the blueprint to accurately identify the location of fastener holes and their dimensions. A total of 18 fastener holes needed to be discovered in both methods, 10 holes are in the horizontal direction, and 8 holes are in the vertical direction. Figure 6 shows the results of AR method and blueprint method.

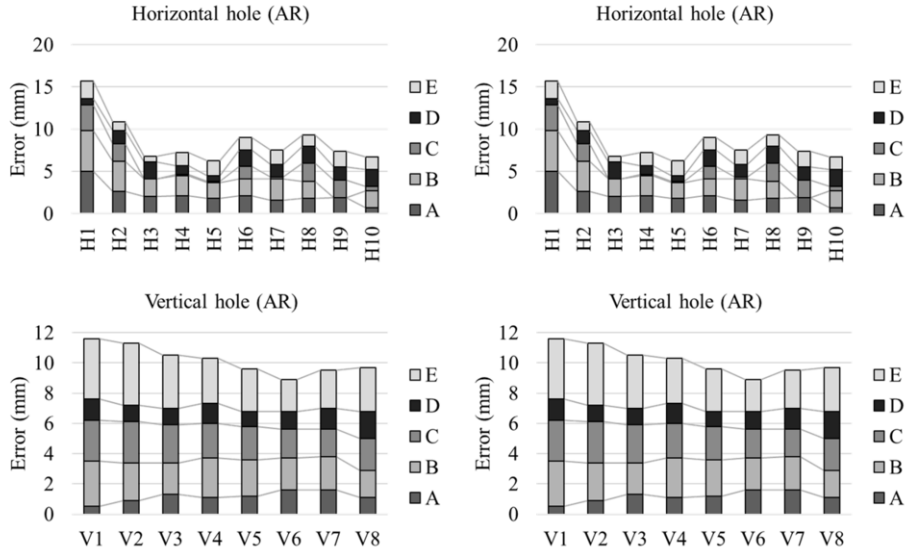


Figure 6. Illustrations of measurement deviation of 5 participants .
(AR = augmented reality; Traditional = printed blueprint; H1-H10/V1-V8: no. of fastener; A-E: participants)

The overall measurement deviation of using AR is 1.87 (SD = 0.94) mm, and the overall measurement deviation of using blueprint is 1.35 (SD = 0.98) mm. As for 10 horizontal holes, the measurement deviation for AR is 1.74 (SD = 1) mm, and the measurement deviation for blueprint is 1.26 (SD = 0.85) mm. And for 8 vertical holes, the measurement deviation for AR is 2.01 (SD = 0.83), and the measurement deviation for blueprint is 1.46 (SD = 1.07) mm. Task completion time was also measured during the experiment, and the average time used for the AR method was 361.6 seconds and 536 seconds for blueprint method.

In accordance with the results, the measurement deviation of the AR method shows greater than the traditional one. In the dimension of the printed underlying prototype, the diameter of each fastener is 6 mm, and the underlying cross is 10 mm in width. However, the measurement deviation using AR is 1.87 mm, which is even greater than the traditional one (1.35 mm). That is, the accuracy may not be good enough for doing such delicate tasks.

As shown in Figure 6, the performance of pointing out vertical fastener holes was much more stable than the performance of pointing out horizontal ones. Even though the average measurement deviation is greater in vertical holes. The reason for the unstable accuracy for horizontal holes might be caused by the arc-shaped underlying part, which is an uneven surface for the AR mechanism. Although the performance of AR seems worse than the blueprint method, the task completion time of AR is less than the blueprint method. In short, AR technology has the potential to improve efficiency, but the accuracy is still a challenge.

4. Conclusion

The proposed solution is not to replace the existing inspection methods like non-destructive evaluation, but rather to improve the overall reliability and efficiency during the maintenance cycle. In addition, the damage and repair history tracking system aims to assist technicians in tracking historical information about damages and repairs. By taking advantage of AR, this concept is considerably more intuitive and immediate, compared to original methods (e.g. paperwork). And last, the accuracy of AR was quantified with the experimental investigation, where the preliminary results show the measurement deviation is slightly greater than the blueprint method.

Thus, no matter which concept is realized via AR functions in the field, the accuracy is a problem that needs to be fixed. The contributions of this study are: (1) noted the issue of the efficiency and accuracy of composite aircraft maintenance and repair; (2) proposed a vision-based solution for the issue; (3) validated the accuracy of AR.

Future work

In the future, further validation will be conducted for the damage and repair history tracking system. When it is fully developed, the entire system will be tested by actual maintenance technicians. The ultimate goal is to create an effective inspection and maintenance technique for aircraft maintenance and other related applications.

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Part 2

Risk-Aware Supply Chain Intelligence

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Transdisciplinary Engineering: A Paradigm Shift
C. Chen et al. (Eds.)

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Zachman Framework in the Agile Digital Transformation

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Abstract. Emergent behavior is behavior of a system that does not depend on its individual parts, but on their relationships to one another. Such behavior exists in biological systems, physical systems as well as in the human performance. It is an inherited nature of a System-of-Systems (SoS). A suitable framework is needed to guide the development of SoS architecture, which includes emergent behavior. Enterprise architecture (EA) is a discipline driving change within organizations. Aligning and integrating business and IT thereby belongs to strategic management. The management of EA change is a challenging task for enterprise architects, due to complex dependencies amongst EA models, when evolving towards different alternatives. In this paper, various architecture frameworks are explored for an application on SoS architecture. The use of Zachman Framework to guide the architecture development is described in step-by-step details in this paper. The agent-based simulation is recommended to develop the SoS architectural models following the Zachman Framework guidance. Ultimately, SysML and UML should be integrated with the agent-based model. An example with the collaborative engineering services for the global automotive supply chain is hereby described.

Keywords. Agile Digital Transformation; Architecture Reference Model; Systems of Systems Engineering; Engineering Collaboration; Zachman Framework

Introduction

There are numerous instances of literature describing the existence of emergent behaviors in human performance, physical systems, biological systems and economics [1]. Emergence is when some totally new phenomenon emerges out of the collective behavior of much simpler parts where the individual simpler parts are responding through simple rules to their local environment. The emergent behaviors exist in global grids due to Scale, Communications Locality, Element Simplicity, Feedback and Element Autonomy [2]. Change made to behavior in individual components could have pervasive and unexpected effects on global behavior. Emergent behaviors arise from the cumulative actions and interactions of the constituents of a System-of-Systems (SoS). The behavior and/or performance of the SoS cannot be represented in any form that is simpler than the SoS itself [3]. Understanding and harnessing these (emergent behavior) effects is crucial to success of SoS [4].

Digital transformation has multiple definitions. A broader one defines it as a consistent networking of all economic sectors and as adaption of actors to new

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circumstances of the digital economy [5]. The ability to adapt quickly to change also stands out as an important capability. Experts have told, that agility is more important than technology skills. The 21st century is about agility, adjustment, adaptation and creating new opportunities [6]. The main finding of this study says that maturing digital businesses are focused on integrating digital technologies, such as social, mobile, analytics and cloud, in the service of transforming how their businesses work [7].

There are discussions and research about how to model and develop a SoS architecture including the emergent behavior. The architecture framework will have to be chosen first prior to modeling the SoS architecture. This goal is demonstrated by a use case from engineering collaboration with a high level of agility, which comprises impact from strategy, technology and global market [8].

The remainder of this paper is organized as follows. The section 1 gives the comprehensive overview of the most relevant commercial applications of the architecture framework, in particular in the Zachman framework for emergent behavior. The application of the agile digital transformation of a global supplier portal is described in section 2. Conclusions and outlook close the paper in section 3.

1. Commercial Applications

All the frameworks are applicable to a single system, but not all the frameworks are suitable for the SoS. The applicability of architecture frameworks to a SoS need to be explored.The most popular architecture framework is DoDAF (Department of Defense Architecture Framework) [9]. It is a sophisticated and well-defined framework with three views with its own products. The requirements of these products are detailed and structurally described. It leads to limited ways and means to comply. Emergent behavior is non-linear as explained above. “Interface” is closely related to integration that the missing of a system, subsystem or component will make the integration impossible. Thus, “Interface” is not applicable to the SoS with emergent behavior. For these reasons, DoDAF is not suitable as an architecture framework guide for the development of a SoS architecture.

MODAF (Ministry of Defense Architecture Framework) is an extension of DoDAF by adding the Strategic View and Acquisition View. The strategic view is to support the capability management process. The six (6) products are text, phasing, mapping to deployment and operations, and descriptions of the relationships between capabilities. They can be modeled for a single system or SoS. MODAF is not suitable as an architecture framework guide for the development of a SoS architecture.

The TOGAF (The Open Group Architecture Framework) Architecture Development Method (ADM) is flexible in that it may be used with a set of deliverables from another framework, or it may even be used in conjunction with the Zachman Framework [10][11]. The TOGAF ADM is designed to allow tailoring by an individual organization. It is intended that users of the TOGAF will use the TOGAF ADM as a guide in designing their architecture. Rather than being a restrictive method and forcing extraneous tasks to be performed, the TOGAF ADM allows an individual organization to choose to bypass, or tailor, any part of the process as required. The ADM is a generic method for architecture development, which is designed to deal with most system and organizational requirements. This suits well with loose coupling and emergent behavior characteristics of a SoS environment.

Zachman Framework is suitable for complex systems, such as SoS. Architecture is relative and there is a set of them, organized around the points of view taken by various players. They included (1) the planner or whoever is setting the agenda and strategy for an organization, (2) the owner who runs the organization, (3) the designer who wants to represent the business in a disciplined form, (4) the builder who applies specific technologies to solve the problems of the business and (5) the subcontractor. Each represents a perspective as a row in a matrix. Columns in the matrix represent the kinds of things people should be looking at. These include functions and data, as addressed by most methodologies. In addition, columns represent locations where business is done, the people and organizations involved, events, which cause things to happen, and the motivations, and constraints, which determine how the business behaves.

Is Zachman Framework suitable for developing a SoS architecture? It will be explored here. The Zachman Framework is a classification schema to organize "primitive" architectural information; no specific models, no methodology and no notation. The Zachman Framework can be used to describe any complex entity. It is product neutral and not like DoDAF and MODAF prescribing specific products. These basic features are advantages for developing SoS architectures with emergent behavior since the architecture developer will have the freedom to incorporate the latest modeling technique of emergent behavior.

The Systems-of-Systems (SoS) architecture is a layered architecture model which allows different developers to work in parallel and insure that changes in one layer of the protocol do not interfere with operations above and below that layer. Thus, layered architectures implement loose coupling between the services that makes up the overall SoS. System design including hardware and software will be based on architecture models in different levels. The first-layer is SoS level, the second-layer is component system level, the third-layer is subsystem level, and the fourth-layer is subsubsystem level, etc. There is only one first-layer for a single SoS but there are more than one second-layers depending on how many component systems etc. The layers are propagated in one-to-many relationships to the last layers. The first-layer of the Zachman Framework for a SoS is shown in Figure 1 [12].

2. Digital Transformation of a Global Supplier Portal

Canges in automotive supply chain lead to over 70% of the R&D shifted from OEMs to partners. This results in a big investment and development of R&D capacities [13]. System suppliers and joint ventures are thus growing in the innovation and value added networks into a new strategic role [14][15]. The creational performance of an OEM basically isn't measured by means of its own internal capabilities anymore. It depends on a collaborative SoS built from concert of its internal domains as well as these of its supply chain partners. These shifts essentially require partners to significantly expand their cooperation capability both vertically and horizontally, to redefine their strategic role within network structures and to speed up time-to-market of an underlying automotive SoS [16]. Efficient data communication in all phases is prerequisite for lean, agile and flexible collaboration; it is required to concentrate on differentiating strongly on development and technology competence [17]. Automotive suppliers that supply system components for a number of different OEMs or tier-1 suppliers are facing multiple challenges e.g. to ensure that they make components available according to customer-specific requirements and with a high level of resilience and reliability.

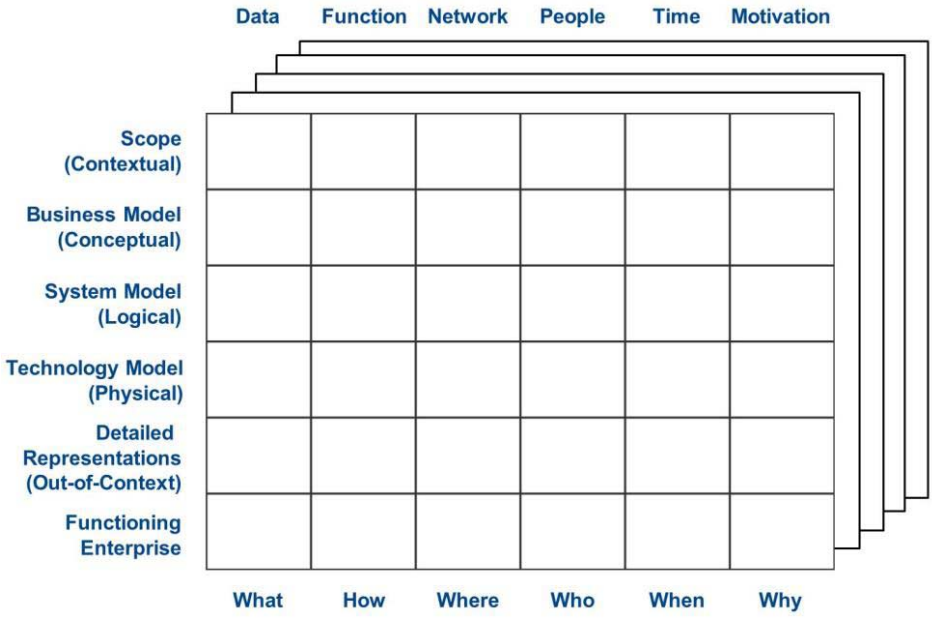


Figure 1. Zachman Framework in Layers.

As far as engineering data communication is concerned, automotive suppliers have to take numerous requirements into consideration that are not always easy to reconcile [18]. Multi CAD collaboration requirements are thereby specific for each development request coming from their various OEMs (Figure 2). On a collaboration perspective, each design change not only requires a comprehensive data conversion in each direction for identical product representations delivered to multiple OEMs. It involves taking multiple aspects into account related with substantially customized data, process, milestones, sites and tools aiming at improving the specific OEM collaboration experience; which very often are hardly available on premise. Any design iteration in change management extrapolates in requirements to managing the data exchange.

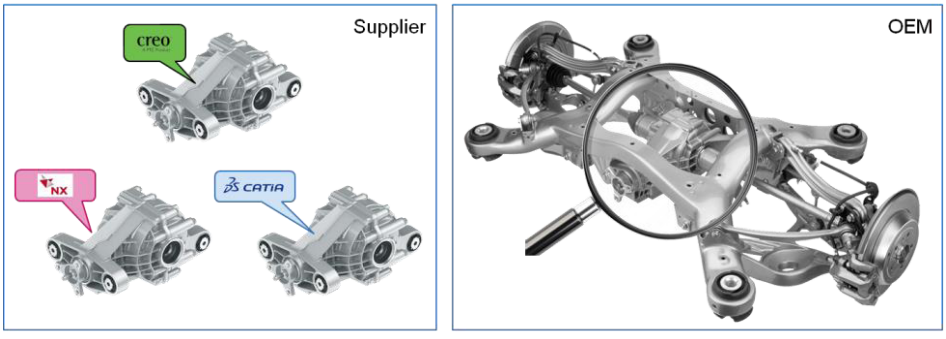


Figure 2. Multi CAD collaboration requirements [19].

OpenDESC.com is an industry-focused portal for engineering collaboration with features serving especially automotive throughout an extended enterprise. It is a holistic service, which includes both (1) translation of engineering data into a custom environment and (2) secured provision of engineering data to partners in an automotive

SoS. The conception shown below describes a high-level architecture of the platform on the perspective of 6 selected layers of the Zachman Framework (Table 1).

Table 1. High-Level Zachman Framework for OpenDESC.com.

	What	**How**	**Where**	**Who**	**When**	**Why**
Scope	Engineering product data provided by a customer or its partner are submitted according to specific constraints	Translation and exchange are thereby offered as cloud service	Global: All engineering sites of the involved parties are affected	OEMs and tier-X system suppliers of a customer	At each design change from an involved party	Achieve enterprise cross-collaboration without need for an infrastructure on premise
Enterprise Model	**Entity**=Business Organizations placing Order having Engineering Data and Tracing collaboration activities based on Report **Relationship**= Contract (SLA)	**Process**=Change Mngmt, On-boarding, Data Transmission, Data Reception, Support	**Node**=Business Locations (mostly engineering) **Link**=Connection	**People**= Sales, Design Department, Service Provide **Work**=Service Level Agreement, Process Order	On Data Submission, On Data reception	Enable engineering organizations to realize fast, easier and reliable communication demand
System Model (Logical)	**Entity=** Electronic DataSets contained in a Job submitted to Users in Organizations having a contractual Agreement **Relationship=**Person In Organization	**Process=** Set Up, Export Data, Import Data **I/O=**Web All parties must be registered to the platform and enabled to use services.	**Node**=see Figure 3 **Link**=Web Portal, OFTP over ISDN/ENX	**People**=Sales Person, Designer, Administrator, Sender, Receiver **Work**=Engineering Design, Send, Receive Data, Manage Services	On request	A party may be requested to provide, on a given date, data in a particular configuration to a customer.
Technology Model (Physical)	Model based Physical Data models with diagrams of the technology architecture, control structures, definitions and descriptions are realized using UML techniques. Users are interfacing directly with the service using (1) a web front end or (2) by means of an application programming interface for machine to machine communication. The UI is thereby described using graphical mock ups.					
Detailed Representations	By using templates, each customer of OpenDESC.com is easily set up as a node with its specific characteristics based thereby. Each node is logically separated from other customers in order to fulfill stringent security requirements. The operation of a node is conducted over an administration and operation interface, which allows an update of the node database.					
Functioning Enterprise	Each authorized user can create communication relationships, define rules for exchange, timing, quantity, desired data quality, level of detail and protection of intellectual property, add required metadata, distribute data sets to multiple users etc.					

Organizations who work together with different OEMs and tier-1 suppliers have to constantly cope with new requirements relating to exchange partners, data formats, system environments to be supported, quality and security requirements, etc. This

involves considerable administrative overhead in terms of time and money, which can on occasion have a negative impact on quality and adherence to deadlines [20]. Online collaboration is a big challenge in the field of international product development in a cross-language environment. It serves two aims: cross-language translation and design requirement clarification [21]. Scenarios are defined using planning techniques [22].

Aim of OpenDESC.com is to connect organizations within the extended enterprise, in a way that enables transfer and translation of engineering data submitted by a sender to a recipient based on specific-requirements of the receiver. The service is provided as cloud offering at global scale to customers and their OEM and tier-x partners anytime, when change orders are processed and handed over to partner [14]. Collaboration with OpenDESC.com is an alternative to not only cut costs but also facilitate making the exchange processes uniform and ensures a higher level of reliability, without having to invest in infrastructure. The results of research in the construction industry show that people collaborating using IT communication, at worst are as effective as people working face to face and are probably slightly more effective. This is a surprising result as IT communication lack rich and valuable non-verbal aspects of communication [23].

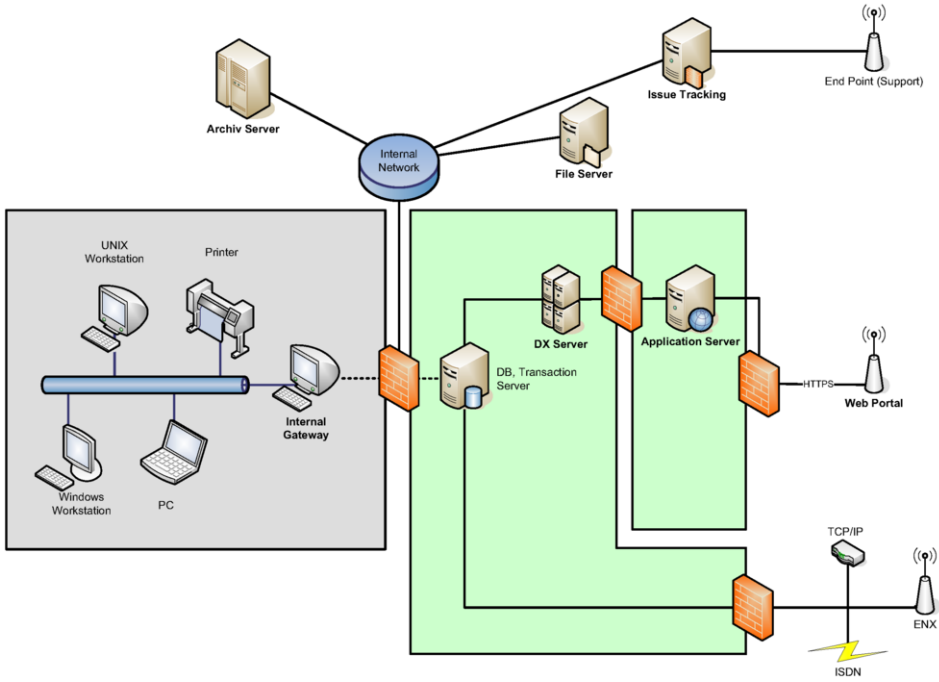


Figure 3. The platform conceptual architecture.

On a business model perspective OpenDESC.com allows business entities to process orders between development sites. The service offering is thereby governed by a Service Level Agreement (SLA) that covers processes like on-boarding new partners, transmitting and receiving data as well as support levels and decommissioning of registered users. Strategic agility remains the key factor in this contract. Having this in place, connections can be setup between engineering parties based on mechanisms and networks such as the European Network Exchange (ENX), the Odette File Transfer Protocol (OFTP) or by means of engineering portals just to name a few.

Each party in the collaborative SoS is provided with a platform on pay by use basis, enabling users to achieve fast, easier and reliable communication on demand, when an order is submitted [24]. The system model is built of users and units, the offering and jobs performed between users granted to use the service. Auxiliary infrastructure belonging to customers and OEMs are docked to this offering in a network realizing a system of collaborative systems in the various departments.The technology model of the platform is implemented with a redundant infrastructure taking stringent security aspects into account regarding access, data management and processing (Figure 3). On the user side, it provides a number of user frontends to services as well as machine-to-machine communication for an automatic processing of collaboration workflows [25]. The UI is described using graphical mock ups to visualize results at any stage.

Model based physical data models with diagrams of the architecture, control structures, definitions and descriptions are realized using UML. Use of node templates enable each customer of OpenDESC.com to be set up easily as a node instance with its own specific characteristics. Each node is logically separated from other customers in order to fulfill stringent security requirements. The operation of a node is conducted over an administration and operation interface, which allows its overall management. Each authorized user can create communication relationships, define rules for exchange, timing, quantity, desired data quality, level of detail and protection of intellectual property [26], add required metadata, distribute data sets to multiple users etc.

3. Conclusion

Emergent behaviors exist in biological system, physical system, human performance and economics. Emergence can be beneficial, harmful, or both. These behaviors exist in complex systems or SoS. Emergence is the primary mechanism for both operational success and operational failure in SoS. Success in SoS requires recognition, effective management, and exploitation of emergence. An accurate and complete system architecture model for a SoS is required to measure the existence, type, and level of emergent behavior of the SoS.

At the present time the Zachman framework is best suitable for developing a SoS architecture with the inclusion of emergent behavior. TOGAF and FEAF are also suitable since they are either adaptable to using and already include the Zachman framework features, respectively. DoDAF, MODAF and similar frameworks are not suitable to develop a SoS architecture including the emergent behavior.

Customized service-oriented value chains, which incorporate environment and social values, can be designed according to different conditions. Also, this system engages the advantages from both product-oriented and service-oriented companies to build a more comprehensive value network. Such a solution can serve as a decision support and benchmarking system because decision makers can develop different value networks according to various emphasized values [27].

Digital technologies, such as cloud computing and mobile apps, have the potential to transform significantly the way businesses run. The role of enterprise architecture is seen as important, especially in communicating business plans across the organization and defining a comprehensive framework. It could potentially be a good fit as one of the tools to be utilized in the latter stages of the Digital Transformation model (e.g. selecting one of multiple service offerings, [28]) but isn't definitely a solution to all of the different challenges, such as forgetting about the needs of the customer.

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A Resilient Model of Yard Template Generation for Minimizing Yard Overflow Risk Under Container Volume Fluctuation of Shipping Route

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Abstract. With the continuous development of the global container liner transportation, container terminal operation receives more and more attention. However, many uncertain situations still bring considerable risk to the operation of container terminals, such as the container volume cyclical fluctuation of shipping route, which brings the overflow risk in the yard area and challenges the terminal consecutive operation of the original yard template plan. This paper considers the cyclical fluctuation characteristics of different shipping routes, and proposes a resilient model (an MILP model) of yard template generation. The proposed model aims to minimize the expected overflow number of containers during the planning period and makes the operation of yard space allocation implemented more efficiently and orderly. Numerical experiments are performed to validate the effectiveness and efficiency of the proposed model.

Keywords. Port operation, yard template generation, yard overflow risk, resilient model, fluctuation of shipping route

Introduction

The yard template generation (YTG) plays a significant role in yard storage allocation in container terminal. The yard template is a normal concept applied in container terminals, especially in transshipment hubs, that utilizes consignment strategy [1]. The yard template planning problem is to determine which subblocks should be reserved to which vessels so as to optimize some certain objective functions, which could be the minimization of the number of used subblocks, and the route length of all the transshipped container flows in the yard [2].

However, many uncertain situations still bring a considerable risk to the implementation of the yard template plan, such as the container volume cyclical fluctuation of shipping route. The container volume cyclical fluctuation of shipping route makes difficult to determine the accurate number of sub-blocks for shipping route in the terminal yard. If the maximum value is employed, too much yard storage space is

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wasted, it seems impracticable since the yard space resources have become one of the most valuable resources in the terminal.While, if the minimum value is employed, container overflow risk will cause to yard template changed frequently, and challenges the terminal consecutive operation of yard template plan.

Based on space sharing strategy (for a comprehensive overview, we refer readers to the works given by Jiang et al. [3]), this paper considers the cyclical fluctuation characteristics of different shipping routes and proposes a resilient model of yard template generation. The proposed model aims to minimize the expected overflow number of containers during the planning period by means of shipping route optimal pairing, decreasing the yard management difficulty, and makes the operation of yard space allocation implemented more efficiently and orderly.

The remainder of the paper is organized as follows. Relevant literature is reviewed in Section 1. Section 2 presents corresponding mathematical model. Computational experiments are conducted in Section 3 to evaluate the effectiveness of the proposed model. Conclusions are given in the last section.

1. Literature Review

The concept of yard template was first mentioned by Moorthy and Teo[4] when their study on berth allocation planning. Lee et al. [5] studied how to optimize the yard storage space allocation with a yard template generation plan is given. Subsequently, Han et al. [6] and Jiang et al. [3] attempted to optimize the yard template and the yard storage allocation plans simultaneously, and they proposed a space sharing strategy to improve the yard space utilization of container terminal. Zhen [7] investigated the influence of yard congestion in the yard template optimizing, a mixed-integer programming model that minimizes the total expected travel time of moving containers around the yard is proposed. It is worth to mention that all these papers are researched the yard template generation under a deterministic situation.

Zhen [8] studies yard template planning for transshipment hubs under uncertain vessel berthing time and position, a mixed integer programming model and a corresponding solution method are proposed in this paper. Zhen [2] extended the above work, in this paper, a model is proposed for yard template planning considering random numbers of containers that will be loaded onto vessels that visit the port periodically.

Jiang et al. [3], Lee et al. [5], Han et al. [6] and Zhen [7] provided many useful methods to solve yard template generation. However, when it comes to many uncertain environments, these methods seem incapable. Zhen [8] assumes the numbers of unloading and loading containers are deterministic. Although the container fluctuation loaded onto vessels is considered in Zhen [6], but this paper solved this problem by set up some special sharing space(sub-block) in the yard, and the objective of this paper still simply concerned on yard operation cost.

2. Model Formulation

2.1. Assumptions

The following assumptions are made in the mathematical model:

1. All the shipping routes arriving at the terminal adopted liner transportation pattern, and all the routes have the same cycle time as well;
2. The berthing position and operating windows of shipping routes are given and fixed. Hence, once the shipping route assigned to the sub-blocks, the minimum container transportation distances are determined.
3. The space sharing strategy is applied in the yard, which it means that the one sub-block space can be shared with the neighboring sub-block(s).
4. Once the yard template is generated, the containers of shipping routes are allocated equally among the specific sub-blocks.

2.2. Notations Definition

1. Indexes	
i	index of shipping routes arriving at terminal;
v	voyages (cycles) index of shipping route;
s	index of sub-blocks;
b	index of yard block;
r	row index of yard block;
t	index of time periods in each voyages.
2. Sets:	
A	set of shipping routes, $A=\{1,2,...,N^a\}$, N^a equal to the number of shipping routes;
V	set of voyages of shipping route, $V=\{1,2,...,N^v\}$, N^v equal to the number of voyages;
S	set of sub-blocks, $S=\{1,2,...,N^s\}$, N^s equal to the number of yard sub-blocks ;
B	set of blocks, $B=\{1,2,...,N^B\}$, N^b equal to the number of yard blocks;
R	set of block rows, $R=\{1,2,...,N^r\}$, N^r equal to the number of yard block row;
N_s	set of neighboring sub-block(s) of sub-block $s\in S$, $N_s\in S$ and $\lvert N_s\rvert\le 2$;
B_r	set of blocks belong to row $r\in R$, $B_r\in B$;
S_b	set of sub-blocks belong to block $b\in B$, $S_b\in S$;
T	set of time periods in each voyages, $T=\{1,2,...,N^t\}$, N^t equal to the number of time periods.
3. Parameters:	
w_{iv}	containers number in voyage v of shipping route i (TEU);

d_{is}	transportation distance (loading and unloading) if route i is assigned to sub-block s (km);
h_{it}	handling parameters of shipping route i, if route i is in loading or unloading in period t, $h_{it}=1$; otherwise, $h_{it}=0$;
λ	storage capacity of sub-block(TEU), equal to 120 TEU in this paper;
δ^b	maximum amount of YCs enabled operating in the yard block, equal to 2 in this paper;
δ^r	maximum amount YCs enabled operating in the yard row, equal to 6 in this paper;
ρ	maximum amount of overflow containers in one sub-block among three consecutive voyages, equal to 120 TEU in this paper;
c	inner truck transportation cost, equal to 15 ¥/km·TEU in this paper;
M	a sufficiently large positive number;
ε	a sufficiently small positive number.
4. Decision Variables:	
x_{is}	1, if shipping route i assigned to sub-block s; 0, otherwise;
y_{sv}	the overflow containers of sub-block s in voyage v;
z_{iv}	transportation cost of shipping route i voyage v;
ϕ_i	the number of sub-blocks assigned to shipping route i;
g_{sv}	auxiliary decision variable, equal to 1 if the containers storage in sub-block s in voyage v; otherwise, equal to 0.

2.3. Mathematic Model

2.3.1. Objective Function:

$$\text{Objective 1:}\quad f_1 = \text{Min}\sum_{s\in S, v\in V} y_{sv} \tag{1}$$

$$\text{Objective 2:}\quad f_2 = \text{Min}\sum_{i\in A, v\in V} z_{iv} \tag{2}$$

The objective for the decision problem on yard template generation contains two parts: the minimum overflow containers (as expressed in formula (1)), and the minimum container transportation cost as expressed in formula (2). Since the mathematical model is a multi-objective optimal model, and the dimensions and quantities of two objectives are totally different, hence a compositive transformation is needed. Define α as the weight coefficient of yard container overflow, and note that $f_1^{\max}$ and $f_1^{\min}$ are the independent maximum and minimum value of f_1 respectively,

$f_2^{\max}$ and $f_2^{\min}$ are the independent maximum and minimum value of f_2. Therefore, the integrated objective function can be expressed as follows:

$$F = \text{Min } \alpha(f_1 - f_1^{\min})/(f_1^{\max} - f_1^{\min}) + (1-\alpha)(f_2 - f_2^{\min})/(f_2^{\max} - f_2^{\min}) \tag{3}$$

In the formula (3), the coefficient could be set as 0, 0.1, …, 1.0 with a step size of 0.1. This step could be adjusted manually according to problem size and terminal operator's preference. By changing the value of , different sets of solutions can be obtained. In other words, when is smaller, the solutions are more cost-saving. On the contrary, with the increase of , the solutions are more risk- minimizing.

2.3.2. Constraints:

$$\sum_{i\in A} x_{is} = 1, \quad \forall s \in S \tag{4}$$

$$\sum_{s\in S} x_{is} \geq \lceil \min\{w_{iv}\}/\lambda \rceil, \quad \forall i \in A, v \in V \tag{5}$$

$$\sum_{s\in S} x_{is} \leq \lceil \max\{w_{iv}\}/\lambda \rceil, \quad \forall i \in A, v \in V \tag{6}$$

$$\sum_{i\in A} x_{is} h_{it} + \varepsilon \sum_{i\in A} \sum_{s'\in N_s} x_{is'} h_{it} \leq 1, \quad \forall s \in S, t \in T \tag{7}$$

$$\sum_{i\in A} \sum_{s\in B_s} x_{is} h_{it} \leq \delta^b, \quad \forall b \in B, t \in T \tag{8}$$

$$\sum_{i\in A} \sum_{b\in B_r} \sum_{s\in S_b} x_{is} h_{it} \leq \delta^r, \quad \forall r \in R, t \in T \tag{9}$$

$$\sum_{v-1\leq v'\leq v+1} y_{sv} \leq \rho, \quad \forall s \in S, v \in V, 2 \leq v \leq (N^v - 1) \tag{10}$$

$$\sum_{s\in S_b} \sum_{i\in A} x_{is} w_{iv} / \phi_i \leq \lambda |S_b|, \quad \forall b \in B, v \in v \tag{11}$$

$$y_{sv} \geq [(\sum_{i\in A} x_{is} w_{iv} / \phi_i + \sum_{i\in A} \sum_{s'\in N_s} x_{is'} w_{iv} / \phi_i) - \lambda(1 + |N_s|)] - (1 - g_{sv})M, \quad \forall s \in S, v \in V \tag{12}$$

$$y_{sv} \leq g_{sv} M, \quad \forall s \in S, v \in V \tag{13}$$

$$g_{sv} \leq 1 + (\sum_{i\in A} x_{is} w_{iv} / \phi_i - \lambda)\varepsilon, \quad \forall s \in S, v \in V \tag{14}$$

$$g_{sv} \le 1+(\sum_{i\in A} x_{is} w_{iv} / \phi_i - \lambda)\varepsilon, \quad \forall s \in S, v \in V \tag{15}$$

$$\phi_i = \sum_{s\in S} x_{is}, \quad \forall i \in A \tag{16}$$

$$\sum_{i\in A} \phi_i = N^s \tag{17}$$

$$z_{iv} = \sum_{s\in S} x_{is} d_{is} c w_{iv} / \phi_i, \quad \forall i \in A, v \in V \tag{19}$$

$$y_{sv} \in N, \; g_{sv} \in \{0,1\}, \quad \forall i \in S, v \in V \tag{20}$$

$$z_{iv} \in N^+, \quad i \in A, v \in V \tag{21}$$

$$\phi_i \in N^+, \quad i \in A \tag{22}$$

The constraints of the proposed model are composed of four parts: the basic constraints of yard template generation, the constraints of yard container overflow, the logical constraints and the variables range constraints.

Formula (4) to formula (9) are the first part of constraints: formula (4) limits that each sub-block should be allocated to one shipping route during the entire planning horizon; formula (5) and formula (6) state that the space (sub-blocks) allocated to shipping routes should in a reasonable range; formula (7) states that when one of the sub-block is in loading or unloading status, the route(s) handling window assigned in the neighboring sub-block(s) should not conflict with each other; formula (8) and formula (9) are the limitations of YCs operating in the yard block and yard row. Formula (10) to formula (13) are the second part of constraints: formula (10) limits the amount of overflow containers among three consecutive voyage must in a reasonable range, too much containers overflowed in a short-term may seriously affect the normal operation of container terminal; formula (11) states although the container overflow of sub-block is allowed, but the containers assigned in each block should not excess the block storage capacity; formula (12) to formula (13) states the overflow containers in the yard. Formula (14) to formula (18) are the third part of constraints: formula (14) and formula (15) are the constraints of to ensure the value of g_{sv}; formula (16) and formula (17) state the relation of ϕ_i and x_{is}; formula (18) is the expression of container transportation cost. Formula (19) to formula (22) are the last part of constraints, which define the range of decision variables.

2.4. Linear Transformation

As for formula(11), (14), (16), (17) and (18) include a division expression between two decision variables, a linear transformation operation is applied. Define $\psi_{is} = x_{is} / \phi_i \geq 0$, and $\varphi_i = 1/\phi_i$, then:

$$\psi_{is} = x_{is}\varphi_i \tag{23}$$

Therefrom, the formula (23) can be transformed as follow:

$$\psi_{is} \leq \varphi_i \tag{24}$$

$$\psi_{is} \leq x_{is} \tag{25}$$

$$\psi_{is} \leq Mx_{is} + \varphi_i \tag{26}$$

$$\psi_{is} \geq \varphi_i - M(1 - x_{is}) \tag{27}$$

3. Numerical Experiments

To evaluate the effectiveness of the proposed model, small scale experiments are conducted. The terminal yard configuration is shown in Figure 1, the shipping routes fluctuation characteristic is shown in table 1, the shipping routes other information are shown in Table 2.

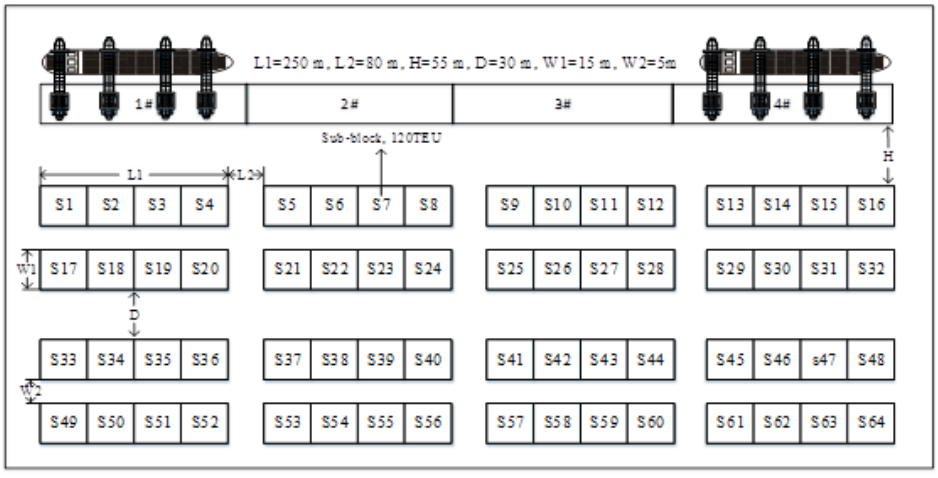


Figure 1. Terminal yard configuration

Table 1. Container fluctuation of shipping routes.

w_{iv}	1	2	3	4	5	6	7	8	9	10	11	12
R1	1280	1300	1350	1360	1420	1500	1410	1340	1280	1190	1130	1060
R2	1510	1400	1300	1210	1170	1060	1120	1200	1260	1300	1380	1500
R3	1250	1230	1200	1160	1100	1050	1120	1190	1250	1290	1360	1490
R4	1240	1290	1350	1400	1460	1530	1450	1420	1380	1320	1260	1200
R5	1020	1140	1230	1290	1360	1400	1430	1340	1280	1190	1130	1060
R6	1300	1270	1210	1130	1060	1000	1070	1130	1200	1250	1300	1360

Table 2. Shipping routes information in numerical experiments.

Routes	Estimated operating windows	Preference berthing position
R1	[1-4]	Berth 1#
R2	[5-7]	Berth 2#
R3	[8-12]	Berth 3#
R4	[13-16]	Berth 4#
R5	[17-21]	Berth 2#
R6	[6-9]	Berth 3#

The problem designed in this section is solved by optimization engine based on CPLEX within 5 minutes, all the computation experiments are conducted on a CPU 2.0 GHz, RAM 8.0 G computer. The experiment result is shown in Table 3, and the detailed yard template plans are shown in Figure 2 and Figure 2. As showed in Table 3, the risk-minimizing pattern (coefficient $\alpha = 1$) can decrease container overflow risk effectively, although it will cause the rising of transportation costs.

Table 3. Yard template generating results.

Patterns applied	Transportation costs	Overflowed containers
Cost-saving pattern	¥ 1 650 934	1 787 TEU
Risk-minimizing pattern	¥ 2 194 611	68 TEU

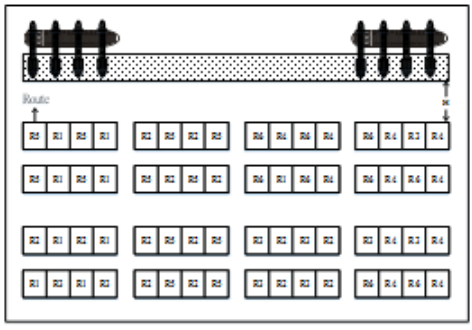


Figure 2. Yard template of cost-saving pattern..

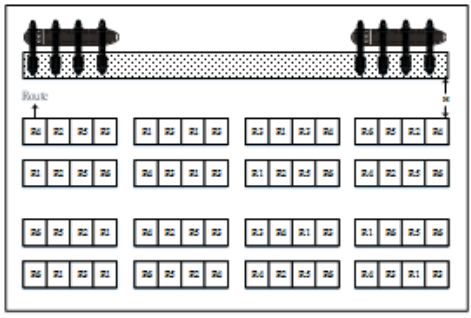


Figure 3. Yard template of risk-minimizing pattern.

4. Conclusions

This paper researches the yard template generation problem in container terminal, utilizes the cyclical volume fluctuation characteristic of shipping routes, aims at decreasing container overflow risk in terminal. A resilient model is proposed, and numerical experiments are conducted. The experiments results show that the proposed model can reduce the container overflow risk, and this model can provide a new direction for future researches.

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Omni-Channel Sales and Smart Logistic Service Framework – As-Is and To-Be Paradigms

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Abstract. E-commerce (EC) has fundamentally changed retail business models. Mobile devices (or m-commerce) and social networks drive retail innovations by better enabling data transfer and communications between EC participants (buyers, sellers, intermediaries). Many suppliers or intermediaries have invested in building virtual channels. Omni-channel sales integrate resources of different channels and provide consistent and satisfactory shopping experiences to potential customers. This research analyzes the retail industry's as-is omni-channel sales across social, legal, economic, policy, and technological (S.L.E.P.T) views. The research presents the to-be model of smart logistic services for omni-channel sales and distribution. The Internet-of-Things (IoT) enabled solutions supporting smart logistic services for omni-channel sales are the focus of the research. Finally, the as-is and to-be logistic process models are benchmarked with respect to their performance indices including operating costs, times, and required human resources.

Keywords. Omni-channel, S.L.E.P.T, smart logistics

Introduction

Modern customer demand requires that traditional stores and channels include (and in some cases are replaced by) virtual channels and e-commerce. A company will lose its competitiveness if it cannot take advantage of omni-channels to satisfy fast-moving market customers using both cyber space and physical stores.

Omni-channels were introduced in 2009 to enable businesses to interact with consumers through multiple channels, rather than the single point of contact. The omni0channel concept has evolved from single-channels, multi-channels, and cross-channels [1,2]. The greatest difference between omni-channel sales and traditional sales is that the former integrates the services and resources of more than two sales channels. Combining the sales date with intelligent methods, sellers can analyze the behavior of customers and develop an appropriate sales strategy to achieve consistent shopping experiences with high satisfaction for customers. To accomplish this task, sellers must

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provide a variety of logistics storage and distribution methods that likewise satisfy the customers' service and delivery demands [3,4,5,6].

Therefore, this study defines omni-channel sales for suppliers or sellers integrating more than two types of sales channels. Channels which are co-dependent provide a flexible and seamless shopping experience for both online or offline customers. This study provides a clear and complete definition of omni-channels to serve as the basis for subsequent research. The research analyzes omni-channel sales using logistics models, cash flows, and information flows for both domestic and cross-border sales. The application of strategic analysis and planning provides a feasible smart logistic model and integration system. The as-is and to-be models are compared and benchmarked with respect to their performance indices that include operating costs, time, and required human resources.

1. Current (as-is) omni-channel logistic model

SLEPT analysis is a method used to analyze five external factors that include social, legal, economic, political and technological factors that affect business operations. This section analyzes the current (as-is) SLEPT omni-channel logistic service environment. By analyzing the business and operation models of the logistic service providers and the manufacturing industries involved, the current operation model of omni-channel logistic operation model is created.

1.1. The analysis of S.L.E.P.T

This section includes relevant discussion of creating the as-is logistic model including social, legal, economic, policy, and technological factors. The analysis of these factors create the benchmarks for defining to-be improved model and its challenges.

1.1.1. Social environment

The social environment has significantly changed the behavior of consumers. Innovations such as social networking and near ubiquitous Internet usage has greatly enhanced e-commerce (EC) popularity. The models of consumer behavior using omni-purchasing channels are quite different from the traditional simple sales approach. In order to improve the social environment for omni-channel EC activities, environmental changes with ICTs are needed [7]. For instance, a cloud sharing system can provide dynamic trading information between suppliers and customers, suppliers or intermediaries. Further, data mining and analytical approaches must be applied to model the ever changing demands. These data assist suppliers to rapidly dispatch and fulfill orders for all channels in socially accepted processes. Figure 1 demonstrates the social environment with omni-channel sales integrated with smart logistics.

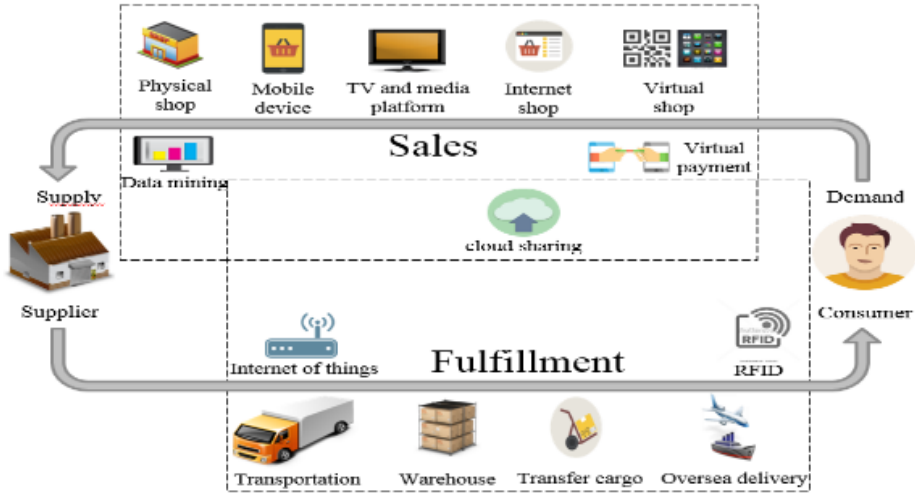


Figure 1. The social environment of omni-channel sales.

1.1.2. Legal environment

The concept of Retail 4.0 was proposed in 2015 [8]. With the vigorous development of Internet-enabled e-commerce, O2O (online to offline), and O2M (online to mobile), companies must integrate virtual (cyber) and physical sales channels must provide competitive business models to win and maintain customer loyalty. Governments must pass relevant laws to provide a regulated and protected environment that allow the fair and ethical operation of omni-channel sales and distribution across the global environment. For example, governments created intellectual property (IP) laws to protect IP rights and avoid infringement of trademarks, patents, business processes, and designs during commercial operations. Firms that introduce new technology to build an exclusive omni-channel model require IP law protection. Governments also regulate the return and replacement of goods and other rules to prevent customers from entering into disputing sales channel disputes. Further, with the liberalization and opening of global markets, the international trade environment must be restructured to include the smart logistics industry [9]. The seven day grace period is often enforced by government regulation for commodity trades using EC channels for both domestic and cross-border sales. Due to the limitation of cross-border transactions and regulations, a 7-day grace period is used to protect consumers. Provisions must be made to expedite returns without physically inspecting the merchandise.

The relevant laws and the legality of omni-channels are still developing as new innovations to services and channels are introduced. Governments must create laws and regulations to build trust and protect the marketplace for the expansion of omni-channel smart logistic practices.

1.1.3. Economic environment

Changes in the economic environment require companies to continually re-evaluate their competitive strengths and their business processes. The service delivered via the processes such as the logistics sales channel, build brand equity and consumer loyalty.

Companies that fail to re-configure their business processes lose strategic competitive advantage and are faced with the inability to better manage inventories and lower costs.

Retailers connect with new customers through many channels. These channels are also known as touch points and include Internet sales. Retailers experiencing low sales growth via omni-channels are facing operational inefficiencies that increase costs and lower profit margins. increasing cost and reducing the margin was inevitable. Customers often use virtual channels to gain greater visibility of their order status. The limitation is the increased customer dissatisfaction if the omni-channel order processes and fulfillment are poorly integrated and do not provide the services promote [10].

1.1.4. Policy environment

Omni-channels and smart logistics are significant foundations for the creation of government policies to promote national economic growth [11]. China, with a large land mass and a widely dispersed population centers, emphasizes the integration of consumer shopping behavior through Internet sites, social media, mobile devices, and online advertisements. Taobao and Alibaba are leading industries that have created a retail revolution across China by implementing omni-channels.

Industry 4.0 was promoted by Germany government in 2011 as a means to create and stimulate the use of smart factories. The technology of the smart factory is based on IoT and IoS. The implementation of the technology require horizontal integration of the value network, vertical integration of the manufacturing network, and communication linkages with workstations and cyber-physical systems (CPS) [12].

The 2013 Japanese industry revitalization plan was proposed to facility investment in R&D for equipment to revitalize the manufacturing and retail businesses. The objective of the R&D was to improve the interaction between machines in the factory to improve supply chain flows. By developing new sensors, control and drive systems that use cloud computing and artificial intelligence, the Internet linked robot machines become the core of Omni-channel smart logistic system development. PARCO, a Japanese department store, creates a unique consumer experience through the application of information technology and robots. Pepper, the robot receptionist, displays a large number of goods using digital signals based on customer requests.

Productivity 4.0 was proposed in 2015 by Taiwan government [13]. The policy emphasizes applications of new information and communication technologies for networking, cloud computing, big data analysis and the creation of artificial intelligence for domestic and global value chains. Retailers can use ICTs (big data, IoT, cloud services, ect) to facilitate the development of Omni-channels. The application of new types of automation technology improves logistic efficiency for transportation and distribution.

1.1.5. Technology environment

Supplier and firm collaborations are required to introduce related technology for the omni-channel and smart logistics model. Technical standards play an important role to enable collaboration, integration, inter-changiability in technology environment. Some key technologies are described in this section.

The cloud system enables Internet of Things (IoT) technology to monitor and exchange the commodity and sales information. Consumer behavior is better monitored in real-time and demand, preferences, attitudes, and opinions help create a very fast-moving and competitive environment. The voice of the customer is clearly heard and

quick adaptations to products and preferences can be made to enhance loyalty to the brand. Further, firms collect customer data using RFID sensors embedded in products. This is one example but sensors are deployable throughout the supply chain on machines, products, transport systems, and retailer systems. The omni-channel data collected are modeled and analyzed using big data computer software. The analysis yields information about consumption behavior, preferences and helps predict customer demand. The results help retailers and all members of the supply chain modify marketing strategies and provide greater customization. Finally, Cyber-Physical-System (CPS) is deployed as a smart trading platform, including micro shops to optimize customer purchase experiences and accelerate the efficiency of commodity trading.

1.2. Current model for logistic industry

This section includes the business models of logistic industry. This study analyzes this industries to find out the predicament.

Nowadays, in order to satisfy customer demands, most of the domestic logistic industry have demonstrated the efficiency of transfer goods, warehousing and distribution.Besides, the logistic industry must to set up warehouses and transport vehicles widely; however, the SMEs don't have enough funds to improve hardware equipment such as refrigeration equipment. It must be resolved by the logistics industry that delivers goods to the customer on time.

In an omni-channel environment, the distribution of goods for the logistics industry are mostly short-term products. How to store and distribute these timeliness products have taken the challenge for the logistics industry, so they should cooperate with suppliers and channel business to integrate good orders and provide uniform warehousing and distribution service. In next section, the study will induce how feasible model and methods for the logistic industry in an omni-channel environment.

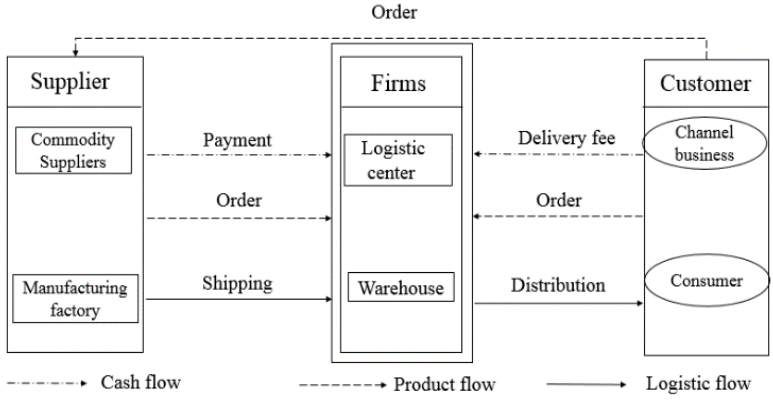


Figure 2. The current model of logistic industry.

2. Improved (to-be) omni-channel smart logistics model

Domestic SMEs still have many problems to build an omni-channel. The research hopes to use the existing technology and resources to build a new Omni-channel smart

logistics model and support SMEs to solve problems on developing omni-channel model.

2.1. Feasible model for logistic industry

By analyzing as-is model , the study plans the feasible methods to improve efficiency, cost, time and personnel in To-be model.

From the feasible model, SMEs logistic industrial can through the information Server system to analyze the channel sales condition. Formulate appropriate short-activities schedule for the channel, to increase the enterprise marketing ability. Provide supplier analysis information, to strengthen they inventory management and production scheduling skill. This is how B2B works, the cooperation enterprise will solve customers' problem independently under this B2B construction, and deal out each transport by the corresponding channel. Regarding the information flow, logistic companies should import data mining system from their e-commerce platforms, physical channels, stores, and all kinds of other channels. And through the information streaming, the subject would be sent back to customers and even the whole supply chain to facilitate the operation of logistic companies. After receiving the order, the distributor will deliver the commodity to the clients in their designated way.

Logistic industrial was the bridges between B2B, their objective is to facilitate storage and distribution. The above- mentioned platforms could not only secure personal information but also simplify the paying process. Most importantly, the customers could be expanded from regional to global scales.

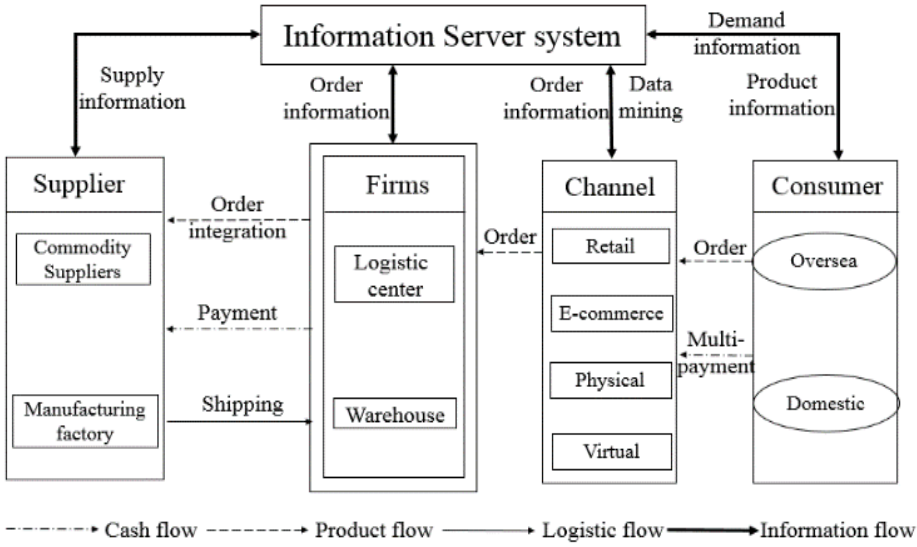


Figure 3. Feasible model of logistic industry.

2.2. Smart logistics application for omni-channel

The study suggests that SMEs can import relevant technology such as sensor technology, robot, big data, RFID and IoT device. And then, the customer orders, goods location, logistics demand, inventory and the information of vehicles can be

updated immediately. Those technologies can support firms to grasp the instant trends and strengthen the retailer marketing skill. For example, the logistic industry can import RFID and IoT tools, which can provide customer and manufacturing firm with efficiency logistic, transaction, production and storage. Manufacturing industry can import robot to strengthen the classification and handling of warehousing goods.

There is much different thinking with traditional in industry 4.0. SMEs must focus on customer relationship management (CRM), products classification, distribute problems and digitals data. Logistic industrial must analyze the trend and demand of the market, and make a suitable marketing model and suitable product classification which based on the technological way. Therefore, the research provided a feasible model and suitable technology. To let SMEs improve their integration skill. And in the smart logistics environment, firms still need to integrate the supply and demand information data upload to the cloud to share information for everywhere related logistics service.

From above of introducing intelligent technology, logistics process can be further analyzed and improved. Also, the overall logistics service level will be promoted to build a complete Omni-channel smart logistic model environment.

2.3. Benchmarking analysis

The section shows that what different between as-is and to-be models. Besides, the study uses quantitative simulation (INCOME) to analyze to-be improvement in time, cost, and personnel savings.

2.3.1. Logistic services

The study tries to import smart logistic technology such as RFID, electronic storage, data mining, and IoT to improve the efficiency of logistic process in to-be model. For example, firms can use E-storage and robot in storage and package process to increase the efficiency. At the same time, the cost of manpower will reduce because labor is replaced by the smart logistic technology.

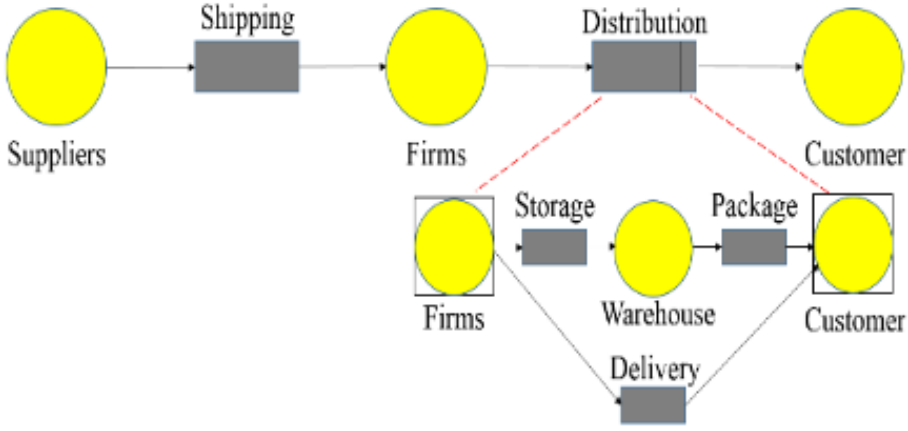


Figure 4. As-is model- logistic service process.

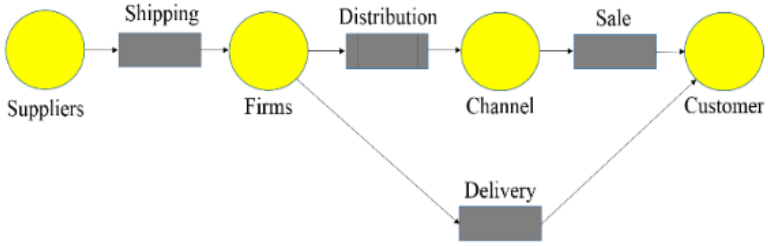


Figure 5. To-be model- logistic service process.

2.3.2. Cash transaction and add-value service

SMEs can corporate with the bank using e-wallet or online payment. The cash transaction process is too complex for customers in the as-is model. In to-be model, customers just induct machine by some virtual device and then, the order will be confirmed. Then invoice and transaction record data will storage in the cloud to simplify the transaction process and let customer track transaction record more convenient. Table 1 shows the key differences between as-is and to-be models.

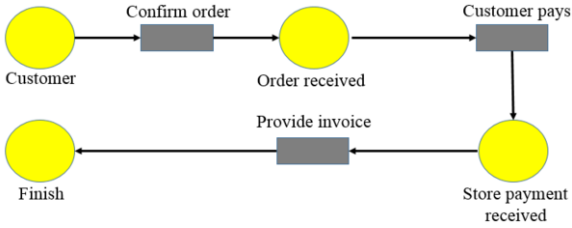


Figure 6. As-is model- cash transaction process.

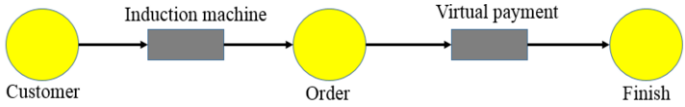


Figure 7. To-be model- cash transaction process.

Table 1. Main differences between as-is and to-be models in key categories.

Model Category	**SMEs industrial**		
	As-is	**To-be**	***Improvement**
Logistic Service	Warehouse Distribution Package	RFID, robot, UVN, electronic storage, data mining, IoT	T: 33,2 % P: 40 % C: 32,7 %
Information Integration	ERP, POS, MPS		
Add-value Service	Fee for difference of supplier and channel	Forecast demand, Sales planning, Order integration	T: 53,1 % P: 50 % C: 25 %
Cash Transaction	Cash in hand, Credit card	Electronic wallet, Virtual bank	

*Time (T), Cost (C), Personnel (P)

3. Conclusions

In the process of introducing omni-channel sales into various industries, the feasible models should be adjusted according to the industry and product characteristics. Many SMEs are facing challenges for omni-channel implementations due to limited resources and lacking technical capabilities. For these companies to solve the technical and resource problems, this study suggests that they can cooperate with enterprises which have constructed multi-channel platforms successfully. To create the virtual channels to draw customers and increase sales, the companies should seek expanding their own sales channels. Stuying the to-be omni-channel models and cooperating with other platforms are important steps for omni-channel implementation. If the information from customers and suppliers are uploaded to the cloud system from the platforms, they can be shared and fully analyzed. In the environment of smart logistics, the information of customer orders and sales data will be integrated and analyzed for business intelligence. With advanced smart technologies, such as service robots or UAV services, business can be conducted without the restrictions of time, location, and environment in the future. In order to achieve the goal of building successful omni-channel commerce, enhancing services of smart logistic integration becomes necessary.

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Implementing a Platform-Service Based on the Sharing Economy for Supply Chain Operations of Small and Medium Enterprises

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Abstract. Nowadays, more and more people choose the possibility of sharing goods and services. This trend is on the one hand utilized by the possibilities given through the digitalization and on the other hand forced by restricted resources and environmental issues. This development already caused significant changes in many markets and businesses but has not yet been holistically established in the field of supply chain management of small and medium enterprises (SMEs). This paper aims to evolve a strategy to integrate the main idea of the sharing economy and its platform-based business model into the supply chain management of SMEs. Therefore, the requirements of SMEs among their supply chains are classified and the idea of the sharing economy is implemented and evaluated. This research presents the applicability and contribution of the principals of the Sharing Economy to the sector of supply chain management in SMEs. This will empower SMEs to improve their current market value.

Keywords. Supply Chain Management, SMEs, Sharing Economy

Introduction

Nowadays an enormous amount of data is transferred via the internet or other wireless services. People all over the world have the possibility to communicate and exchange data over thousands of kilometers. Together with the increasing influence of the digitalization, the sharing economy is developing in more and more sectors and industries. The most popular and well-known examples are in the public sector like Uber and Airbnb. They provide services for transportation and accommodation without owning a single car or estate by themselves. The trend and the idea of sharing resources is driven by environmental topics, sustainability and a change in mindset.

The possibility to communicate and share data via online services is the driver for the sharing economy. With further development in terms of digitalization, the potential of the sharing economy for all kinds of industries can be imagined. Nevertheless sharing economy and supply chain management (SCM) in the original sense haven't come together so far, especially in the sector of SMEs which are often fallen behind in

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terms of innovation and adapting to new technologies and trends. The fact that SMEs represent the major part in industries worldwide (In Taiwan more than 97% of companies [1]) justifies the interest in this sector.

The aim of this paper is to bring the mindset of a sharing economy and the SCM with focus on SMEs closer together, to transfer the success of reducing the consumption of resources and gaining new resources in this sector. Therefore, a comprehensive investigation of the problems and deficits of SMEs in current supply chains is made in order to discuss the relevance of the principals of a sharing economy in this field. Subsequently, inspired by existing platform services in the public market, a platform model that implements the sharing economy in a B2B (business to business) supply chain network will be introduced. The potential of improvement is shown through three different scenarios. The idea is to improve the current business model of SCM in SMEs by implementing a platform based B2B (business to business) model. The expected results will be a contribution to environmentally friendly, customer friendly and sustainable Supply Chains due to higher utilization of resources and the appearance of new resources in the current supply chain environment.

1. Literature Review

1.1. Sharing Economy

The sharing economy or shared economy is defined as an activity induced by humans to generate a public value. This new form of economy is based on a horizontal organization with a mindset of usage rather than ownership [2]. Peer-to-peer economy and the collaborative economy both refer to the sharing economy and all involve the sharing of physical ownership and services among people or organisations. Value is added to these systems or rather communities by participating in the enabling platforms, both by consuming or providing [3].

Botsman and Rogers present a set of guidelines in their book to make the sharing economy a success. These guidelines name the four principles of collaborative consumption: including trust between strangers, idling capacity, critical mass, and belief in the commons. They claim that each principle is weighted evenly but might be more or less critical depending on what is being shared and who is part of the sharing. Naturally many applications of the sharing economy require a certain degree of trust among the participants or members of the community [2]. The intermediation is therefore mainly achieved via internet platforms. These intermediation platforms connect people, services, and even things in ways that have been unthinkable so far. These platforms essentially rely on the same structure. In the beginning, they collect enormous amounts of data. This data is either gained from the outside world or through social networks hosted by the platform. An important remark is that this data is never produced by the platform itself but by the people, services and things around it [3].

The application of platforms can be mainly found in start-up companies like Airbnb or Uber as well as in large enterprises with a “modern” mindset like Google, Apple or Microsoft.

1.2. Supply Chain Management of SMEs

The Supply Chain Management (SCM) has gained relevance in recent years, SCM has gradually emerged from the logistics into a comprehensive concept that covers all the business activities within and between partners in supply chains [4].

Nowadays the trend of SCM is devolved to collaborative supply chain clusters and is heading towards the sustainability in supply chains [5].

In all industrialized countries, SMEs contribute substantially to the total industrial output and are distributed in all industrial and service sectors. The majority of companies all over the world can be assigned to the SMEs. According to the International Finance Cooperation SMEs account for about 90% of businesses and more than 50% of employment worldwide. This represents the importance of SMEs for all industries, which is the reason why looking for new methods and technologies to enhance the efficiency of those is essential [5].

Depending on different countries the definition for SMEs might vary. According to taiwanese specifications a SME is a company which conforms to the criteria that a paid-in capital of less than NT$ 80 million (US$2.42 million a sales revenue of less than NT$100 million (US$3.03 million) per year musst occur depending on the industry [1].The main obstacles faced by SMEs are mainly individual, relational and organizational. The individual level reflects obstacles corresponding to a lack of competencies. The relational level refers to the relationships between the different components of the supply chain and the organizational level includes obstacles that deal with management's involvement in the supply chain organisation and commitment to SCM [6].

SMEs can serve the roles of suppliers, distributors, producers and customers within a supply chain [7]. It is important to mention the fact that SMEs are part of almost all supply chain networks but their supply chain strategy is mostly determined by their big customers within the supply chain. So although the trends of the SCM has been devolved into collaborative supply chain clusters the use of this concept among SMEs playing a self-determined role in a collaborative network has not yet been established [5].

2. Methodology

The purpose of this research is to address the current requirements of SMEs concerning SCM via the application of sharing economy. The methodology that approaches this problem can be divided into three phases. Phase I introduces current problems and difficulties in SMEs. Further on, the reviewed problems are summarized and categorized regarding the SCM context. Derived from the stated deficits phase II presents the main requirements to improve the SCM of SMEs. Phase III is dedicated to the approach of the requirements through the integration of the idea of the sharing economy, presented by three use-case-scenarios introducing a platform service to address the requirements.

2.1. Phase I: Classification of difficulties of SCM in SME

According to several publications focusing on the performance and deficits in SMEs, most SMEs around the world face the same problems.

Different surveys that have been executed over the last decade identified that a lot of problems for SMEs are centralized in the fields of SCM, manufacturing and information flow [8–10]. More detailed, the problems in the SCM field are concentrated to a lack of transportation flexibility including on-time-delivery, information accuracy between supply chain participants, difficulties developing partnerships, poor administrative processes in SCM and problems in stock control and warehousing [8,9]. SMEs also tend to face obstacles when it comes to competitive change over time and in general improving operating technologies [8]. Other difficulties SMEs need to face can be summarized as forecasting [8] and workforce ability [10]. Due to missing accuracy in forecasting market demands, many problems arise among the value creation, with impact to the supply chain performance.

The problems and deficits in SMEs stated before are all directly or indirectly referable to SCM. According to the main sectors of a supply chain network, the difficulties in SMEs are categorized into the fields of Warehouse and Inventory, Procurement, Information flow, Distribution, Management, and Forecasting, [11]. The appearing difficulties are correspondingly clustered into these categories. Based on quantity the categories are sorted by relevance as shown in figure 1 [8–10,12].

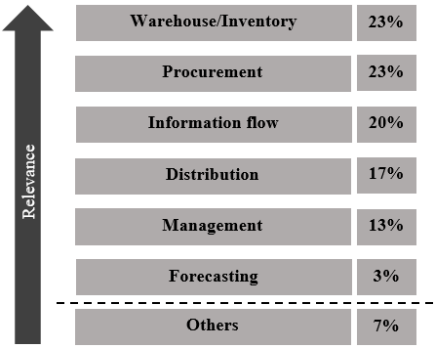


Figure 1. SME problem field classification in terms of SCM.

2.2. Phase II: Derivation of requirements to Improve SCM of SMEs

The previous section points out the fields of supply chain management or rather supply chain performance where SMEs can find themselves having the most deficits. Since SMEs are mostly determined by their customers within the supply chain they are controlled by the larger companies instead of managing their own supply chain strategy [13]. Hence as an outcome they merely just respond to changes within their supply chain network, than following a complete SCM strategy. Overall this induces, that SME supply chain requirements are heavily based on their customer requirements [12]. Without specifying the customer requirements for a certain supply chain or industry six requirements can be generally defined. These are receiving the right product, in the desired amount, at the right place and time, with the requested quality to the right price [14]. A study of SMEs in the UK has shown that their highest priorities are in quality, reliability, and price, topics as e-commerce and innovative elements are on the bottom of this list [13].

Thus, leads to a focus on operative SCM requirements rather than strategic. To address the field with the most deficits in the SCM of SMEs, the warehouse and inventory sector in an operational way with respect to the customer requirements and SME priorities, more transparency among the partners and the reduction of uncertainty is required. Together with flexible warehouse options, the current deficits in warehousing and inventory could be improved. When focusing on the customer requests the distribution plays a significant role and works hand in hand with the warehouse and inventory sector. To face this deficit and to improve the distribution

performance, more transportation options are essential. Transparency and a high-quality information flow together with a high reliability in transportation and manufacturing will obtain the requested performance.

The information flow is a crucial obstacle for SMEs and the improvement of the information flow is a requirement for itself. To achieve improvement in this sector it is necessary to enable new information technologies and provide easy access for the companies. The same applies to the forecasting, with improving the forecasting the uncertainties will decrease and transparency will increase. So, improved forecasting also represents a requirement. The management is also claimed to be a problem factor in SME regarding supply chains. Because deficits in this category mostly refer to management operations in the strategic timeframe it is not further discussed in this paper.

2.3. Phase III Addressing the requirements via the Sharing Economy concept

Phase III of this methodology presents the possibilities for SMEs to improve their supply chain performance via the sharing economy concept. Different scenarios of how to fulfill the requirements through a platform-service are introduced.

Recently more and more businesses are shifting to a platform structure to benefit from the interactions a platform provides. They connect with each other via the platform and utilize provided resources. On the one hand this generates missing or additional resources for one company and on the other hand it extracts extra value out of idling capacities [15]. This characteristic addresses the requirement of more available resources through the sharing aspect, by simultaneously generating value.
Stephany pointed out that sharing economy is not just about sharing resources and information, but that communities of users engage with each other beyond their transactional need. The platform users shift from a supply and demand motivated interaction to a community, which increases transparency and builds up trust [15]. The platform therefore provides a decrease of uncertainties. Because platforms are easily accessible tools, their implementation is addressable for SMEs although their priority towards e-commerce and innovative elements is low[13]. In the following, three use-case scenarios are presented.

2.3.1. Scenario 1: Transportation Sharing

Suppose that company A and B are using the platform to share idling capacities in transportation. Both are located in the same city and need to deliver their products to different customers. To enhance the utili-zation of transportation, company A offers available space in its truck via the platform. Since company B needs to serve a customer in the same area as A, a request to use that capacity is sent. The companies utilize the platform to share trans-portation capacities.

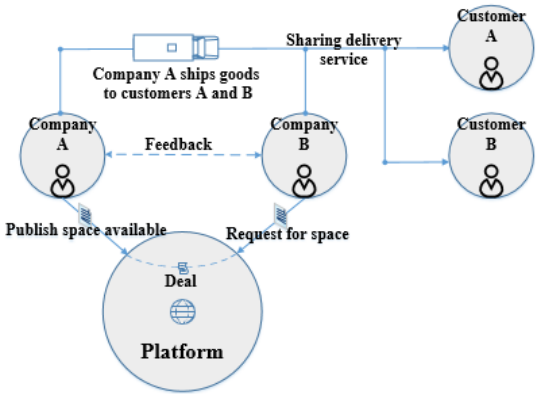


Figure 2. Scheme of the information and service flow via an integrated platform for sharing transportation resources.



Figure 3. Scheme of the information and service flow via an integrated platform for sharing warehouse resources.

2.3.2. Scenario 2: Warehouse Sharing

In this scenario the companies C and D run similar businesses. In this case, company C uses the platform to offer free storage in its warehouse. Company D which is expanding and growing has some clients in the city of company C. Via the platform D requests the free capacity in the warehouse offered by C. The companies agree to share the storage, which adds value to both companies.

2.3.3. Scenario 3: Community benefits of a platform

As another use of the platform, the companies represented in figure 4 can look at the profiles of other companies that are part of the platform community. This with the objective to look for new options of suppliers or by the simple fact of doing business with other SMEs can address the procurement problem of SMEs. Such as in the case of company E which is looking for new suppliers, so as it was mentioned, it reviews the profile of relevant companies. Thus, leads to obtaining new alternative suppliers such as company K is specialized in selling the raw material of the company E. This scenario could also be applied to the reverse scenario, where company K offers its services to other companies to generate new customers.

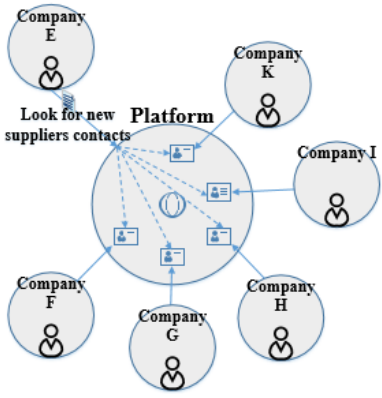


Figure 4. Scheme for the community benefits of the platform.

During this research a prototype application for the use in existing networks or to build up networks among SMEs has been developed. The following figure shows the usage of this web based platform.

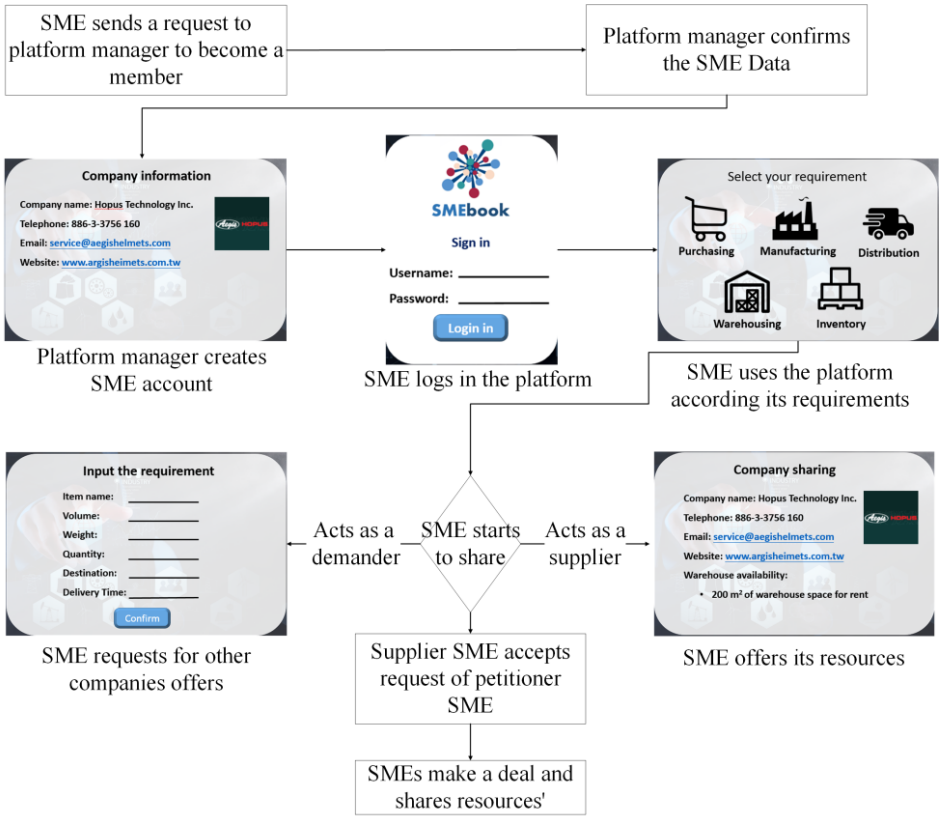


Figure 5. Flowchart of platform usage.

3. Conclusion

This paper addresses the integration of the sharing economy idea by presenting a platform model in the SCM field of SMEs to enhance their overall performance and market position as important players in wordwide industries.

Analysing former publications lead to current requirements and priorities of SMEs. The aproach via a platform service is visualized through the three use-case scenarios and shows the benefits for SMEs being part of a platform induced network. Although reviewed research results show a minor interest of SMEs in e-commerce and innovation adoption the aproach to better supply chain performance through a platform seems to be accessible for broad levels of industrial players as the integtration of comprehensive IT systems is not mandatory.

By utilizing former investigations about SMEs this research points out their deficits and priorities categorized into the relevant SCM sectors. The derived requirements and how the idea of the Sharing Economy, represented by a service platform, can benefit the SMEs is shown in the methadology part. The scenarios indicate the potential of the Sharing Economy idea for this industry sector. Besides addressing the detailed requirements stated in the methodology, SMEs solve their main problem of low resource access in all fields by implementing a simple tool in their business. Especially the practical contribution for the companies itself is very high and lets them, on one hand, overcome their limitations due to their size and on the other

hand creates value out of idling capacities. The platform generates win-win relationships for all companies that are part of the platform community and will improve their position in the market.

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An Investigation of Cross-Border E-Commerce Logistics and Develop Strategies Through SCCOM Framework and Logistic Service Risk Analysis

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Abstract. Cross-border e-commerce has become popular recently, so the importance of cross-border logistics has been enhanced. Because foreign buyers have high demand for logistics time, strengthening the logistics is an important key to increase sales. Only to enhance the ability of logistics can accelerate the cycle of the entire sales chain. By accelerating the recovery of capital can also increase the company's profits. However, the cost of logistics is the largest online cost of foreign trade expenditures. Cross-border distribution service errors would cause significant losses. Logistics risk management is relevant to improve the integration of strategic flows, but the contributions to cross-border logistics risks in literature seem limited. Therefore, this study is based on five steps of "Supply Chain Continuous Operation Management" (SCCOM) to help us analysis service risk for cross-border logistics. The main content of five steps include understand the SCCOM background, define SCCOM scope and objectives, operational impact analysis, continuous operational risk assessment, and continuous operational strategy. In case study, we take "Double 11"of Taobao in Taiwan area for example. Let consumers of China buy high-quality goods in Taiwan Taobao, and then send goods from Taiwan to China as the logistics risk analysis before the phase of cross-border services. The result indicates that cross-border logistics are most affected by "information system instability" and "maritime customs clearance anomalies". We develop the strategies that aim at the two factors above and propose some ways to reduce logistics service risk. Through the analysis results of this paper, cross-border logistics industries can take it as a basis for the development strategies. By this way, industries will reduce logistics risk, increase logistics capacity and smooth, and then improve the overall profit of the foreign trade industries.

Keywords. Cross border e-commerce, International supply chain management, Risk analysis

Introduction

In recent years, the global e-commerce retail sales grew rapidly. Cross-border e-commerce could make distance shorten between product and market. Cross-border e-commerce has great significance promoted the sustainable development of the domestic economy to meet the needs of foreign consumers [1]. From experts forecast, retail sales

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might reach 3400 billion dollars. The Cross-Border E-commerce is main power of growing up, increasing price over than 27%. It represents that the global consuming market has transferred.

The rapid growth of cross-border e-commerce transaction scale not only becomes the strong momentum of import and export trade, but also lengthens the value chain of the e-commerce industries and the logistics industries. Besides, cross-border e-commerce also provides multi-business models innovation opportunities. A series of advantages include cheap price, ensure genuine, multi-products. However, the development of export cross-border e-commerce has made many problems such as shortages and logistic problems [1]. We want to find the truly factors that affect the entire cross-border logistics.

The e-commerce industries said that cross-border e-commerce tax has reformed in the New Deal. The model to compete discount is not suitable for cross-border e-commerce now. The competitions shift to supply chain and logistics abilities.

Furthermore, customers and e-commerce companies have new requirements for logistics. They want faster, more accurate and more efficient logistics across the border trade. We analyze cross-border logistics involved in overseas warehousing, package, air transportation, customs clearance, domestic distribution and many other complex processes. The information comes from the opinions of e-commerce and logistics professional business time.

Logistic is the main foreign trade expenditures. E-commerce companies should take care of logistic risk more because any mistake maybe causes significant losses. Cross-border e-commerce logistic risks include damage or loss of goods during transit, customs confiscation inspection, not through aviation security, poor communication, risks during transportation, customs clearance and so on. Therefore, logistic risk analysis plays a critical role for a cross-border trade. Reducing the risk of logistics can avoid a lot of unnecessary costs. Doing supply chain management and controlling risk are concerned. So, It is time to evaluate trends and change drivers that are reshaping the current and future business environment around global supply chains [2].

This study aims to find the root causes of affecting cross border e-commerce logistic smooth. By improving these root causes, we can reduce the loss of time and cost. In other words, strengthening the abilities of logistic, e-commerce enterprises can accelerate the recovery of capital and increase profits.

1. Literature review

International e-commerce is called cross-border e-commerce. The raising of Internet accelerates cross border e-commerce and enables enterprises to develop global trade [3] [4]. Merchants use the internet technology to build e-commerce platform for trading and payment, and distributing goods by cross-border logistics. Customers can buy commodities from online and the merchants are located in other countries and jurisdictions [5]. Cross border e-commerce becomes an important trading patterns now. It not only breaks the barriers between countries and causes great changes of global trade but also enhances many new e-commerce business models [6]. Cross border e-commerce has three characteristics including all day, all directions and zero distance. It has changed the original e-commerce trade and rebuilt the supply chain of international trade. The rapid development of cross-border e-commerce relies on internet and international logistics provides new channels for enterprises' overseas marketing. It has

broken through the original thought of "business district" and increased the profit margin of foreign trade [7]. Cross-border e-commerce has injected new vitality to e-commerce, but it also exist some problems of cross-border logistics and distribution system [8]. So, management and controlling risk are also be concerned.

E-commerce had developed for a long time in western countries, mainly in Europe and American like Amazon. Cross-border commerce is developed faster by its environment [9]. Logistic mode in western is more mature than eastern world. We find that the exist research are mainly focus on the importance of E-commerce service quality and single-country delivery way of E-commerce management [10]. The Internet let present enterprises to make profit by their merchandise via cross border E-commerce. However, present works not focus about the logistics service risk for cross-border logistics. Therefore, this paper works on risk analysis of cross border E-commerce [9]. Main difficulty and problem of cross border E-commerce in China could summarize in three parts [10]. First, policy support of cross border E-commerce in China is in absence. Second, present development speed of international logistics is not match to giant E-commerce need in China. Third, the fundamental facility need upgrade much. The era of cross border E-commerce is relative short in China, but the development speed is super-fast. Total amount of double 11 increases every year, amazes global E-commerce manager [10]. The following approaches can help in the identification of potential supply chain risks: supply chain mapping, checklists, event tree analysis, fault tree analysis, failure mode and effect, etc.

Risk analysis can be defined in a number of ways, depending on how risk analysis relates to other concepts. Risk analysis can be described as risk communication, risk characterization, risk assessment, risk management, and policy relating to risk, to public- and private-sector organizations, in the context of risks of concern to individuals, and to society at a local, regional, national, or global level. We are concern about the risks in cross-border logistics like risks of damage or loss of goods during transit, customs confiscation inspection, not through aviation security and so on. Risk can be represented quantitatively in totally different ways, but usually due to consequence of undesirable events and the frequency or probability. In order to understand more thorough concept of the risk, we shall concentrate on a general risk model [11]. Risk is composed of three elements, vulnerability, threat and consequence [12]. Risk analysis can also be classified as three types: simplified risk analysis, standard risk analysis and Model-based risk analysis [13]. We focus on standard risk analysis. It could be defined as a more formalized procedure in which recognized risk analysis methods are used, such as Hazard and Operability study (HAZOP), coarse risk analysis and so on. There are several ways about risk analysis. For example, risk matrices are usually used to express the results [14]. The fault tree is a common method to find the problem [15]. Fault tree analysis is a deductive reasoning approach used to identify failures before their occurrence and as investigative tools to ascertain failures, to analyze accidents [16]. The FMEA is a powerful design tool that provides a mean to compare, from a risk point of view, alternative logistic service system [17]. Quality function deployment (QFD) is used as a powerful tool for improving product design and quality, and procuring a customer-driven quality system [18].

Although the cross border e-commerce is prevailing now, lots of risks exist in logistic service process. There are rarely investigations in this domain, so this research wants to analysis the logistic service risk of cross border e-commerce. We combine several methods to develop Supply Chain Continuous Operation Management (SCCOM) framework, which help us develop strategies for foreign trade industries.

2. Method

We would like to utilize Supply Chain Continuous Operation Management (SCCOM) to analyze this issue. According to the five steps of Supply Chain Continuous Operation Management (SCCOM) includes understanding the SCCOM background, defining SCCOM scope and objectives, operational impact analysis, continuous operational risk assessment, and continuous operational strategy. Taobao double eleven festival update the single-day transaction amount record every year. In Taiwan area, we let China customer buy product in Taiwan and sending to China properly. We do the risk analysis in cross-border E-commerce, especially in logistics. Based on the definition of SCCOM, we analyze logistics service risk for logistics transit mode.

You must understand the relationship of logistic system and supply chain management, and the potential impact. The purpose of supply chain management and influence of interruption, preference of risk decision maker, related regulation, expectation of customer and manager also played an important role in SCCOM. In Taobao case, customer in China could choose two system deliver their product to Taiwan, cross border home delivery logistic and cross-border convenience store delivery logistic. Based on the delivery destination, cross border home delivery service will send to China customer through delivery companies like Hsinchu corperation and T-cat corperation. It is quite similar between cross-border convenience store delivery logistic and cross-border home delivery logistic. Main difference depend on different supply chain member.

In this step, you must define the scope of your analysis. For example, main product activity, export airport or port, accepted operation and service level. We evaluate the potential factor of service system fragility, the case will go on with Taiwan seller in Taobao. The seller may send their product to China local port by convenience store. In this situation, the way from Taiwan to China might face much service mistake, for example, missing and destroy in delivery process. That will lead to logistic service mistake. Therefore, we have to define the potential factor and analyze it in next part.

We can reach two goals by operational impact analysis. First, it identifies the impact on industry supply chain activities. Second, it confirms the maximum time of tolerable interrupt service. In supply chain of logistic service, the most important performance is that achieve the service requirement from customers. We interview experts to know the realistic situation of cross border logistic step by step. By their practical experience share in detail, we can collect some error service contents of cross border logistic. And then we will do further classification and analysis by the information. We apply QFD and Cause & Effect/Fishbone Diagram to find the technical requirement needed that impacts distribution logistics service system by integrating experts' viewpoints and error service contents. After that, we design the questionnaire to measure the weights of these technical requirements. Final, we get the most important requirement.

At this step, we need to identify the risk which might occurred, also risk analysis and assessment is demanded.

Ask the relevant department experts, stakeholders according to brainstorming, literature review conclusion to identify all possible risk factors, then define the risk factors severity of the impact of the possibility.

We make use of fault tree analysis and FMEA. The first step is to look for all events that cause the top of the direct cause. The second step was to find each of the above direct reasons for all the direct causes, sequentially, until the most direct cause of

the most basic (bottom event). Then we might get some reasons of this service fault. Just like the store staff fault, transporter fault and so on. We find some events cause this fault, as loss of storage of goods, goods missing in the store and not leaving, etc. Then we can put in the figure and identify what kind of event it is then make decisions. FMEA (failure mode and effective analysis) is a step-by-step approach for collecting knowledge about possible points of failure in a design, manufacturing process, product or service. The main purpose of FMEA focus on three parts, the weakness of this system, the worst case if something wrong happened, how to prevent the bad situation. In our work, we analysis the failure mode in eight part, and evaluate the failure effect, failure reason, exist control policy. Depend on expert's opinion, we give it weights in S(severity), O(occurrence) and D(Detection). The RPN value is calculated by SOD value. All these symbols have totally different meanings and are able to be divided into two types: event symbols and gate symbols simply as Table we describe distinctly. Due to the consequence of the risk analysis, we can recognize the most dominant variables. We can develop continuous operational strategies and complete all the step of supply chain continuous operation management.

3. Case study

3.1. Understanding "Double 11" of Taobao logistics background

Taobao gives a platform for Taiwan's online sellers and serve customers to buy goods from Taiwan. Then goods are transported from Taiwan to anywhere in China according to logistics distribution system and the services could be separated into two ways: cross-border home delivery service and cross-border convenience store service. The service of delivery from Taiwan FamilyMart store and pick-up from the Shanghai delivery store, the sender in Taiwan could send goods to FamilyMart store, then the goods going are transported by shipping to China. After about 10 working days, the person who ordered can pick up the goods from delivery store. The supply chain members who responsible for this cross-border logistics service also need to integrate the information of logistics of Taiwan and China.

The logistics service process designed can divide into seven processes, sequentially, "Sender sends items from country A", "Logistics goods collection in country A", "Tally and labeling in country A", "cross-border cargo collection and transportation operations", "Tally and labeling in country B", "Distribution operation in country B", "Pick-up in country B". 4.2 would explain details of this process. There are two different logistic service process. Figure 1 is service process of convenience store delivery. It consolidates cargo service by Taiwan's convenience store. And Figure 2 is service process of home delivery. It consolidates cargo service by home delivery logistic of Taiwan.

3.2. Defining SCCOM scope and objectives on cross border logistic service

We evaluate the potential factor of service system fragility, the case will go on with Taiwan seller in Taobao. The seller may send their product to China local port by convenience. We collect the opinion of much experts to understand the structure of E-commerce industry, operation mode and logistic service process. We summarize the main reason in seven parts and it will presented as follows:

1. Seller sending: The seller packaged the product and go for sending at delivery multiple store or convenience store, and delivery fee is necessary.
2. Logistic process in Taiwan: The delivery corporation gather the product and check the detail and total amount of the goods. Once the checking is proceed, goods will leave the gathering place.
3. Labeling work in Taiwan: When all goods arrived to the logistic corporation, check the amount first, then labeling it. Then sealing it if no error is happened.
4. Cross-border logistic work: All goods will send to the port, separate by grade and x-ray checking is necessary. Then put the goods to the China-end logistic center.
5. Labeling work in China: When all goods arrived to the China logistic corporation, check the amount first, then labeling it, classifying it by destination.
6. Delivery process in China: The goods will send to local logistic center, buyer's place or convenience store. Message and your ID is necessary for getting your goods. Any receipt will keep in case product problem and tracking.

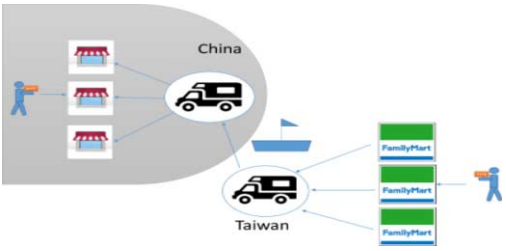


Figure 1. Service process of convenience store delivery

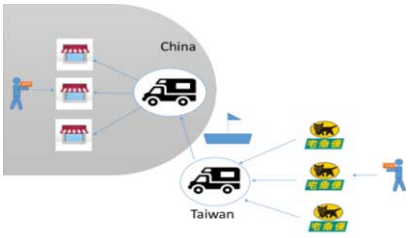


Figure 2. Service process of home delivery

3.3. Operational impact analysis on cross border logistic service

Cross border logistic service supply chain exists lots of risk. Through experts' opinion and literature collections, we generalize the content of cross border logistic service faults. We classify service faults into two types, "information flow error" and "logistic error". Table 1 shows detail contents of cross border logistic service errors. Figure 3 is "Cause & Effect/Fishbone Diagram". It is method that discover the root cause of questions.

Table 1. Cross border logistic service errors.

Types	Service error content	Service error reason
○,1 Logistic	○,3 Store employees errors	○,11 Input wrong information
		○,12 Product missing
		○,13 Delivery sheet missing
		○,14Product not meet delivery regulations
		○,15 Wrong Package
	○,4 Delivery employees errors	○,16 Delay (ex: traffic jam, weather, car accident, etc.)

Types	Service error content	Service error reason
		○,17 Product damage
	○,5 Tally employees errors	○,18 Wrong Classification in logistic boxes
		○,19 Unboxing damage
		○,20 Product damage
	○,6 Cross border delivery errors	○,21Delay(ex: weather, vehicle, custom)
		○,22 Product damage
	○,7 Consumers	○,23 Wrong pick-up
		○,24 Leave wrong Information
○,2 Information flow	○,8 Store information errors	○,25 Consumers information loss
	○,9 Information connect errors	○,26 Out of synchronization
	○,10 Tally information errors	○,27 Wrong classification of foreign products and domestic products

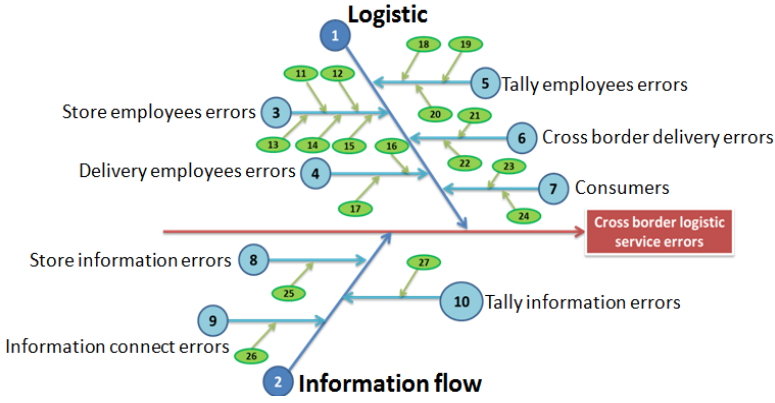


Figure 3. Cause & Effect/Fishbone Diagram

QFD emphasizes multifunctional teams required for integrating all corporate functions to be responsive to the customer's requirements so that product planning, product design, process planning, and production planning provide a coherent response to CNs [16]. But in our research, we apply Quality Function Deployment as Figure 4 to transfer the cross-border logistics border into technical engineering requirement. The customer requirements are from Service error content (Table 1).The symbols meaning and the weights applying in QFD. According to the QFD diagram, we find there are two technical requirements which have high weight value. “Avoiding logistic error” ability and “information synchronization”, their value are respectively to be 106 and 71. And the value is coming from multiple technical requirement and the expert importance of every errors, then add together to be the weight value. It’s much higher than the others. From these two, we can develop some strategies at 4.5- Continuous operational strategy on cross border logistic service.

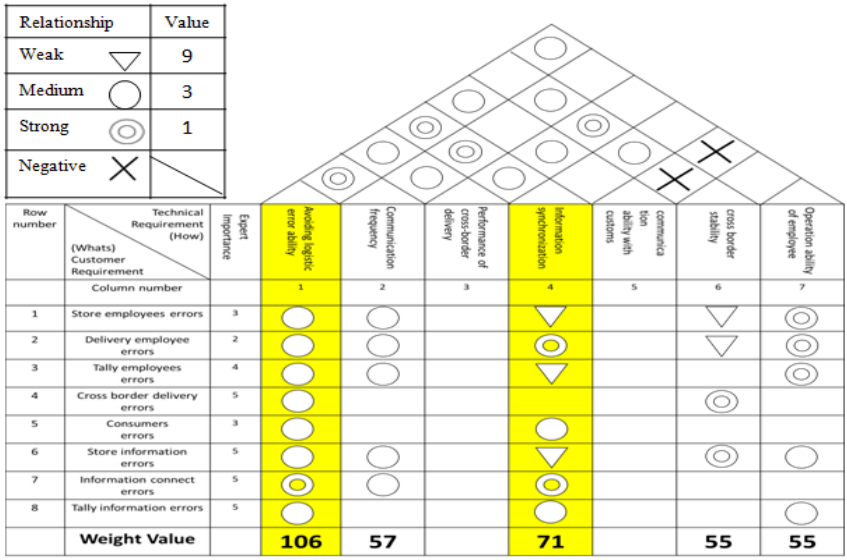


Figure 4. Quality Function Deployment

3.4. Continuous operational risk assessment on cross border logistic service

In this step, we use FMEA as Table 2 to implement logistic risk analysis. The FMEA is a formalized but subjective analysis for the systematic identification of possible Root Causes and Failure Modes and the estimation of their relative risks [15]. By the FMEA mode analysis, once the value is high means it is the weakness in this system. The SOD in Table 2 represent severity, occurrence and detection respectively. The logistic corporation have to manage the policy to conquer the factor. In this case, we found the highest value in FMEA mode is cross border delivery errors and information connection errors. Therefore, we manage the policy strategy in following part in communication frequency and information out of synchronization.

Table 2. Risk Priority Numbers.

	Failure			**Cause**		**Detection**		**Action**	
Item	Failure mode	Failure effect	S	Failure reason	O	Exist Control policy	D	RPN	Advise
Logistic	Store employees errors	Input wrong information	5	Product missing, Delivery sheet missing	5	Process regulation	4	100	More employee training
	Delivery employees errors	Delivery Delay	6	Product damage	3	Delivery corporation regulation	4	72	More driver training
	Tally employees errors	Wrong Classification	7	Unboxing damage, Product damage	2	Delivery corporation regulation	6	72	Double checking

	Cross border delivery errors	Delivery Delay	8	Product damage	5	Related law between countries	3	120	Strict standard at custom
	consumers	Carefulness	6	Wrong pick-up, Leave wrong Information	4	Receipt keeping	4	96	Sign and checking in receipt
Information flow	Store information errors	Data loss	5	Consumers information loss	4	Computer management	4	80	Database back up
	Information connect errors	Data link failure or loss	6	Out of synchronization	6	Computer management	4	144	Database back up
	Tally information errors	Wrong packaging or missing	7	Wrong classification of foreign products and domestic products	3	Logistic system	4	84	Strict training

Then, we use Fault Tree Analysis as Figure 5 to identify that the fundamental factors caused cross border logistic service errors. This analysis extends from Table 1 at 4.3. We employ some symbols as we introduce at 3.4 from the fault tree analysis. The purpose of using this diagram is to realize the relationship between an event to another and the most influential factors clearly. By Fault Tree Analysis, we can find the root causes of cross border logistic trade. So it makes this part more competed and powerful. Then we could refer this diagram to purpose the strategy at 4.5.

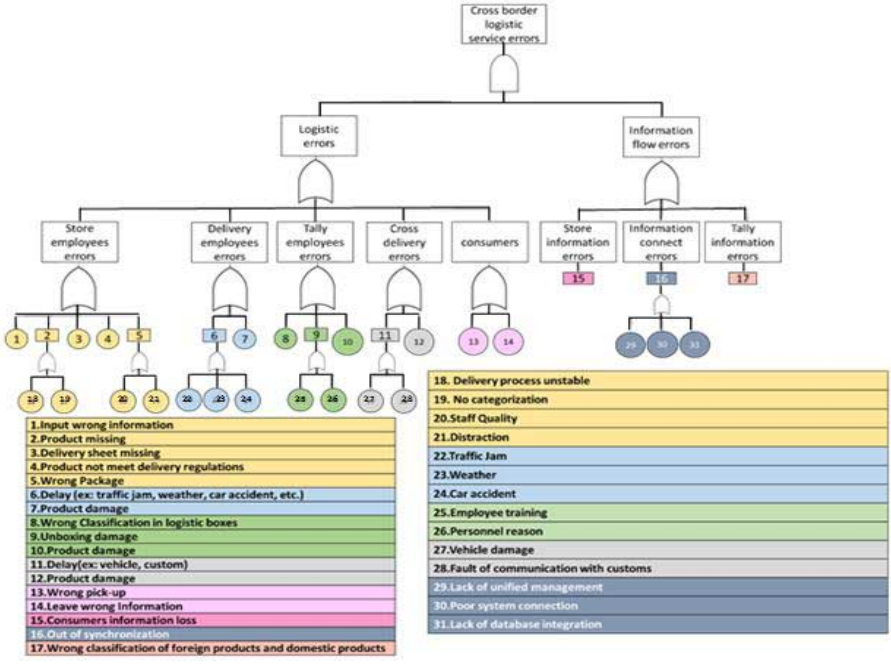


Figure 5. Fault Tree Analysis on cross border logistic service

3.5. Continuous operational strategy on cross border logistic service

From the previous QFD and FMEA, the first and second important technical requirements of the enterprise go to 'Avoid logistics errors ability' and 'Information synchronization.' First, Information synchronization means we have to set a stable system. Information system connects all related data between supply chain members, so it plays a crucial role in logistic system. To unified information system, we have to formulate a serious regulation. Then push all staff follow the regulation, education on such lesson. Also, tight standard on any system mistake, once something wrong happened, we think that enterprise could implement total quality management to manage efficiently. Second, avoid logistics errors ability is absolutely essential according to QFD. And we know cross border delivery might be key point in this technical requirement. So we conclude the frequency of weekly meeting in cross border supply chain is important, once there is bottleneck or emergency situation, the meeting will become frequent. During the meeting, we might have week review and prospect, then the manager review some fault in this week, then discuss what to do next week. Not only it could apply in this requirement, but also could use in lots of aspects.

4. Verification

We use INCOME to simulate the process we expected. There are two processes: as-is model and to-be model. The two processes are the same. We suppose that if the enterprise avoids the risk caused by "out of synchronization" and "cross border delivery", then the cost of transportation might decrease. Then we compare as-is model with to-be model, we could see that the time of this logistics process decrease from 604892 seconds to 578972 seconds. The decease rate of time is about 4.386%. And the cost is decrease from 290 to 268. The decease rate of time is about 7.587%. Figure 6 shows the result of comparison As-Is & To- Be. After analyzing, we identify the risk, then we apply INCOME to simulate that if the enterprise involved in this logistics process avoid these risk, then the cost and time will decrease certainly.

As- Is Activities	C...	Execution...	Resource...	Value Add...	Times (Sec...
manage order	1	10	0	0	10
Details of the goods (EDI)	1	2	0	0	2
examinate success 1	1	1	0	0	86,400
Seizure	0	0	0	0	0
pick up	1	0	0	0	3
transport by ship	1	100	0	0	345,600
examinate success 2	1	1	0	0	1
seizure 2	0	0	0	0	0
Domestic transport (Taiwan)	5	78	0	0	86,438
Domestic Transport (China)	5	98	0	0	86,438
Sum	16	290	0	0	604,892

To- Be Activities	C...	Execution...	Resource...	Value Add...	Times (Sec...
manage order	1	10	0	0	10
Details of the goods (EDI)	1	2	0	0	2
examinate success 1	1	1	0	0	86,400
Seizure	0	0	0	0	0
pick up	1	0	0	0	3
transport by ship	1	90	0	0	345,600
examinate success 2	1	1	0	0	1
seizure 2	0	0	0	0	0
Domestic transport (Taiwan)	5	73	0	0	69,158
Domestic Transport (China)	5	91	0	0	77,798
Sum	16	268	0	0	578,972

Figure 6. The result of comparison As-Is & To- Be.

Figure 7 below is the process of this cross-border logistics. Figure 8 is drill down of domestic transportation (Taiwan) and (China).

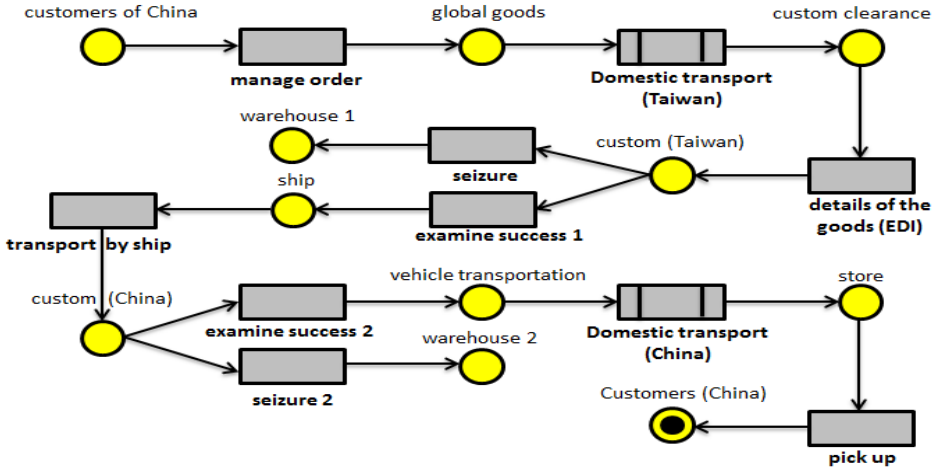


Figure 7. the whole process of cross-border logistics.

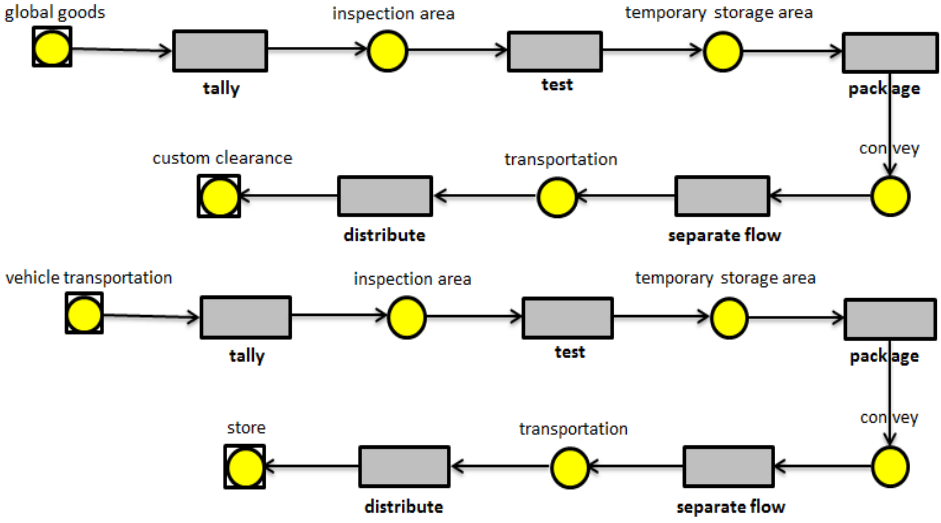


Figure 8. The drill down of domestic transportation (Taiwan) and (China).

5. Conclusion

In our work, the research is based on the rapid growth of cross-border e-commerce transaction, we complete research about cross border e-commerce logistic service risk. In Taobao case, we successfully use five steps of "Supply Chain Continuous Operation Management" (SCCOM), FMEA and Fault Tree Analysis to help us analysis service risk for cross-border logistics. In section 3, we introduce the method we proposed in this paper, SCCOM, QFD, FMEA and fault tree analysis. In section 4, the scope of SCCOM is defined and operational analyzes on cross border logistic service are

presented in this paragraph. We interviewed several experts in logistic and finished our questionnaire, it is the background of our work. Depend on the survey, it has been transfer into QFD and FMEA, we found several factors play a crucial rule in logistic system. By risk analysis in our work, 'Communication frequency' and 'Information out of synchronization' is the main reason to make the system unstable. We develop the strategies that aim at the two factors above and propose some ways to reduce logistics service risk. Also we propose the strategy against the weakness. Also we apply fault tree analysis to find the primary risk to deal with from all risk factors. Through the analysis results of this paper, cross-border logistics industries can take it as a basis for the development strategies. Furthermore, by this way, it will reduce logistics risk, increase logistics capacity and smooth, and then improve the overall profit of the foreign trade industries. In further work, we will do application of our analysis in real case. If our analysis is proved helpful to real logistic company, the era of cross border logistic will prosperous faster in near future.

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Analysis of Workshop Production Scheduling Considering Risk Factors

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Abstract. In the process of workshop production scheduling, many risk factors can affect the reliability of production. The factors influencing the production scheduling include time, quality, equipment failure and so on. The stability is critical in the flow shop, so the risk factors related to the production scheduling should be considered in the workshop production. Workshop scheduling is taken as the research object in this paper. Along with the rapid development of database technology, the process of workshop production scheduling also involves the record and statistics of many historical production data. So data analysis technology will be used to analyze the risk factors in the process of workshop scheduling firstly inthis paper. Secondly, the simulation model for production scheduling integrated with the risk factors will be built. The aim of the model is to balance the flow shop plan and improve the production efficiency. Finally, an example is given to show that the risk factors selected in this paper and the model are effective for solving the risk problem of workshop production scheduling.

Keywords. production scheduling, flow shop, risk factor, simulation

Introduction

The production scheduling regulates the activities of production, preventes the possible deviations during production, adjusts the activities which are away from the original production process, ensure effective regulation, the number of products and the production progress to reach the production target successfully. Production scheduling is complex, and there are risk factors in it. With the development of production technology, more and more enterprises have introduced advanced production organization method by information technology. A large amount of historical data in the database of production, so the useful information can be found from these data to assist decision making effectively.

Ensuring the reliability of production effectively in the production scheduling is an urgent problem. Finding the risk factors which affects the production scheduling from the historical data to improve efficiency of production plan is a strong support for the completion of the production plan successful.

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1. Literature review

Workshop production scheduling is concerned frequently. In the aspects of using traditonal method to solve production scheduling problem, Youichi Nonaka et al. [1] use the method combined with mathematical programming and tabu search to find the best workshop production scheduling machine allocation rules and process routes. Chen H X et al. [2] select Lagrange relaxation algorithm to study the job shop scheduling problem. In the aspects of using artificial intelligence method to solve production scheduling problem, Rui Zhang et al. [3] proposed a genetic algorithm based on local search module to solve the production scheduling problem. Xueni Qiu, Henry Y.K. Lau [4] establish a model for multi-objective problems, and use hybrid artificial intelligence method of artificial immune system (AIS) and priority scheduling rules (PDRs) to solve it. S.H. Chung et al. [5] proposed a modified genetic algorithm to solve the DS model. In the aspects of using data mining to study workshop scheduling, some researchers [6-12] use the fuzzy set theory and genetic algorithms, use multivariate analysis of variance method based on adaptive network fuzzy inference system, and use the scheduling rules whinch are gotten by data mining to solve these problems.

From these research, we can not find solving the workshop production scheduling from the view of risk. This paper will study the problem considering risk factors which gotten by using the method of data mining.

2. Study framework

In order to consider the risk factors in the production scheduling, we need to find the main risk factors in the production process, and it can adopt the method of data mining. In this paper, we will use the method of cluster analysis to find out the main risk factors from the historical data. On the basis of the classical production scheduling model, the simulation model is used to simulate the production, and the risk factors are applied to the simulation model to optimize the production scheduling. The main framework is shown in Figure 1.

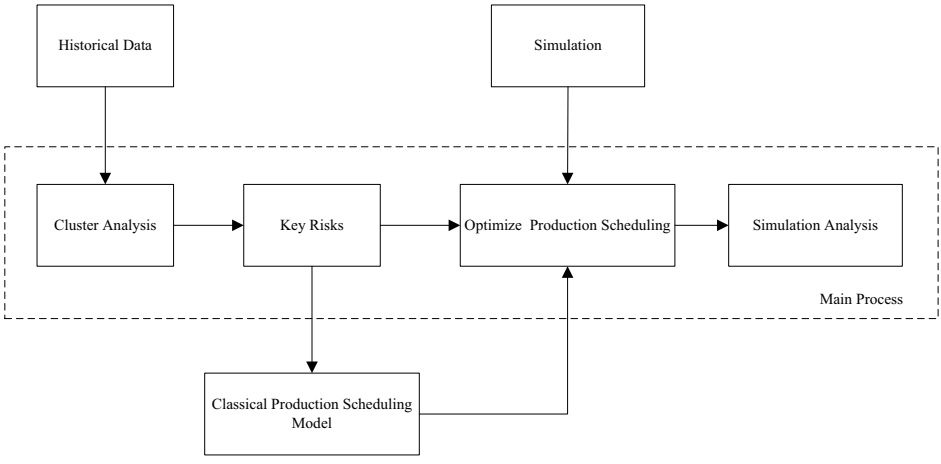


Figure 1. Diagram of study framework.

3. Risk factor study based on association analysis

3.1. Data selection

The risk factors in production scheduling need to use the method of data mining, so the data tables which is relating to the production scheduling should be found from the database. Different companies have different databases, so the main data items should be found through the analysis of the process of production. The special data tables need to be rebuilt which are connected with the original database. The main tables which are used in the next analysis is shown in Figure 2. According to the clustering index selection as well as the structure of the data tables, the SQL statement is used to statistical summary for association analysis.

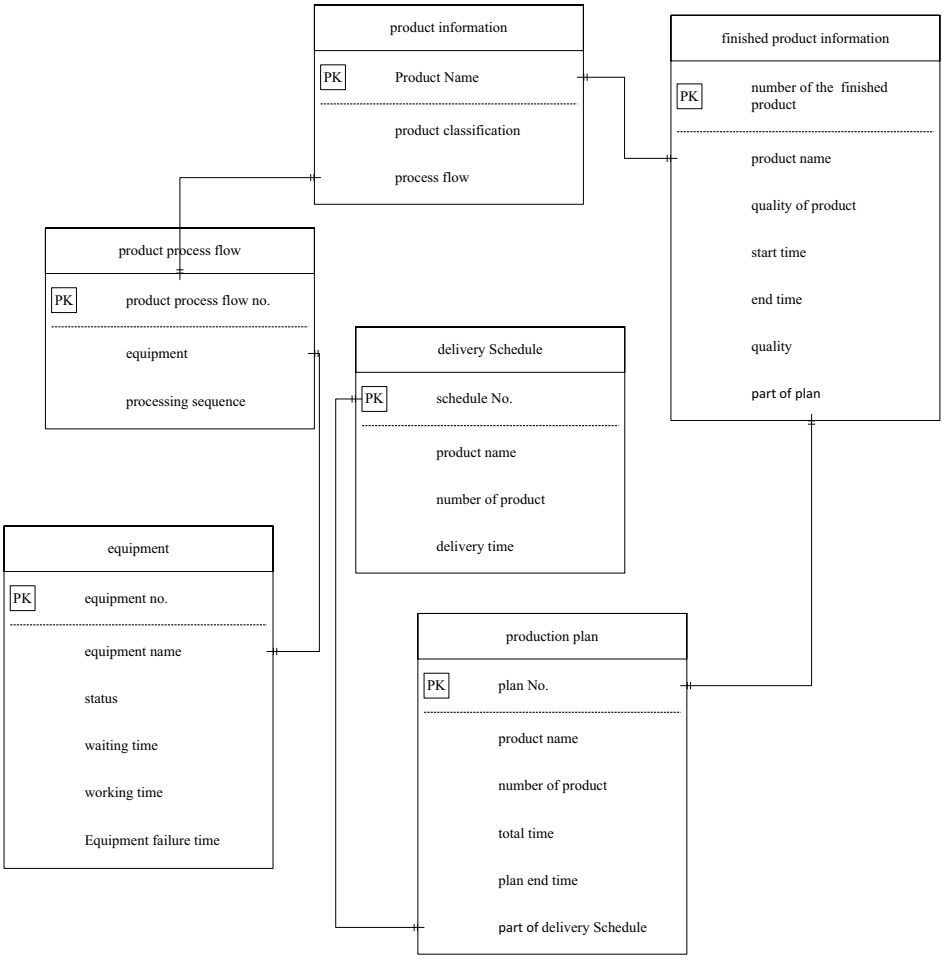


Figure 2. Diagram of data tables.

The data in the database can not be used for analysis directly because some data is irregularities and anomal. So some advanced processing of data should be made before using. The main flow is shown in Figure 3.

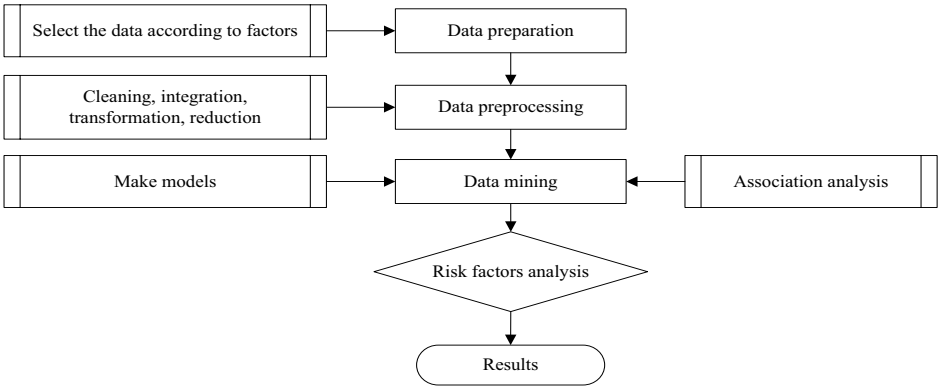


Figure 3. Process of data selection.

3.2. Association analysis

Through the cluster analysis of the data items to get the factors which influence the production scheduling, we can get the key risk factors. Considering the advantages and disadvantages of various algorithms for association analysis, fuzzy C-means clustering is choosed in this paper.

In the fuzzy C-means clustering for the clustering progress of risk factors, we need to find $y_1, \ldots, y_c$ as the center of c clusters. The objective function is defined as follow. Figure 4 shows main flow chart of the fuzzy C-means clustering to search the key risk factors.

$$I_f = \sum_{j=1}^{n}\sum_{i=1}^{c} x_{ij}^{\beta} d_{ij}^2; z_i \in R^n, 1 \le i \le c \tag{1}$$

The meaning of the parameters in the equation (1) is defined as follows.

1. x_{ij}: the value of the membership degree matrix
2. $d_{ij} = \|z_i - x_j\|$: Euclidean distance between the *i-th* cluster center z_i and the *j-th* data point x_j
3. β: fuzzy control parameter

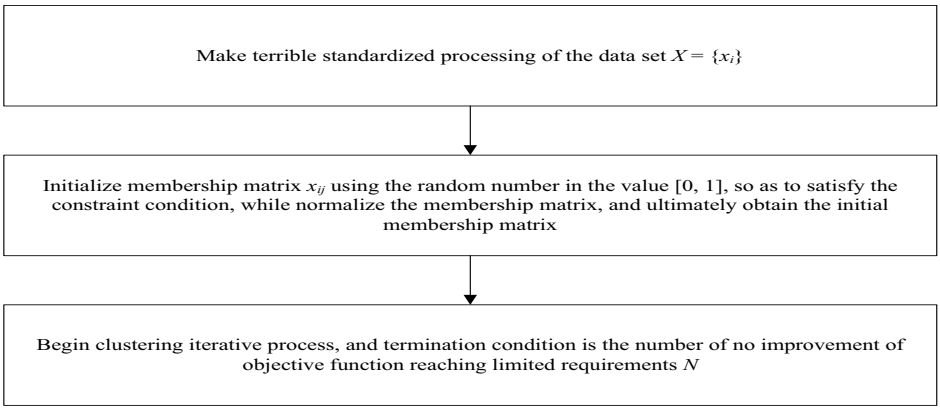


Figure 4. Flow chart of the fuzzy C-means clustering.

Through using the method above and the amount of historical data, the key risk factors inculding risk of time, risk of quality and risk of equipment can be found.

- Risk of time means that production scheduling needs more time for the processing.
- Risk of quality means that the unqualified product needs to repair.
- Risk of equipment means that the failure of equipment affects production.

4. Simulation optimization

The plan is achieved by simulation in this paper, and three key risk factors are constructed in the simulation system. The object of the model is to ensure the completion of production plan, and the risk probability is the basic judgement to resume the plan. The occurrence of the risk is stochastic, and the probability of completion of the original plan will be calculated. The rules below should be used in the simulation.

- *IF* the probability of completion of the original plan is less then or equal to 70%, *THEN* new plan should be created.
- *IF* the probability of completion of the original plan is greater than 70%, *THEN* continue to carry out the original plan.

The flow chart of simulation is shown in Figure 5.

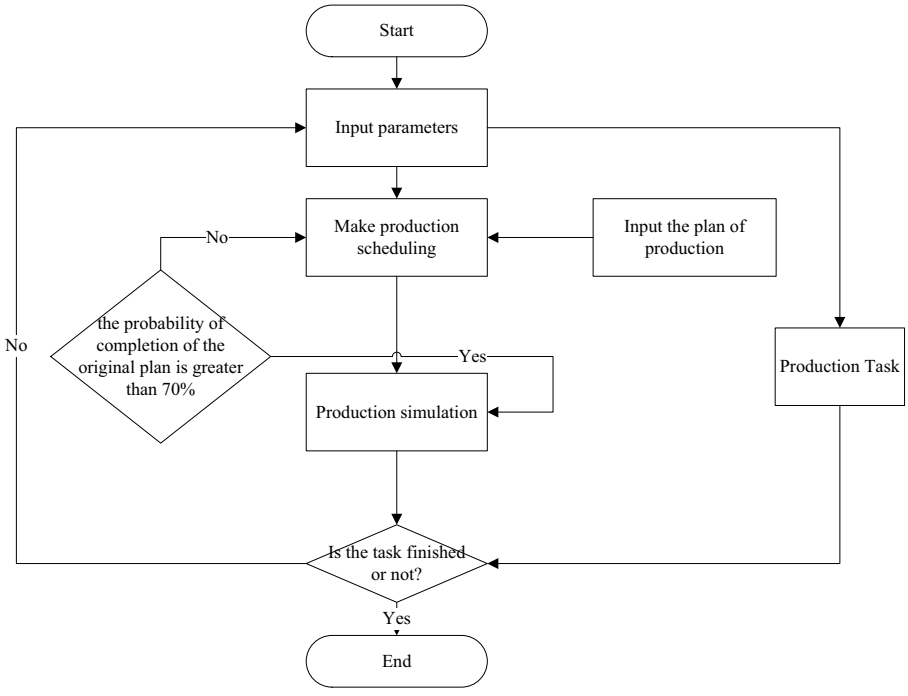


Figure 5. Flow chart of simulation.

5. Case Study

This paper uses the actual data of a workshop as a case study. The simulation model of in this paper is established by eM-Plant8.1, and the simulation model is shown in Figure 6. The initial parameter conclude the production task, equipment status, production process of the product and processing time.

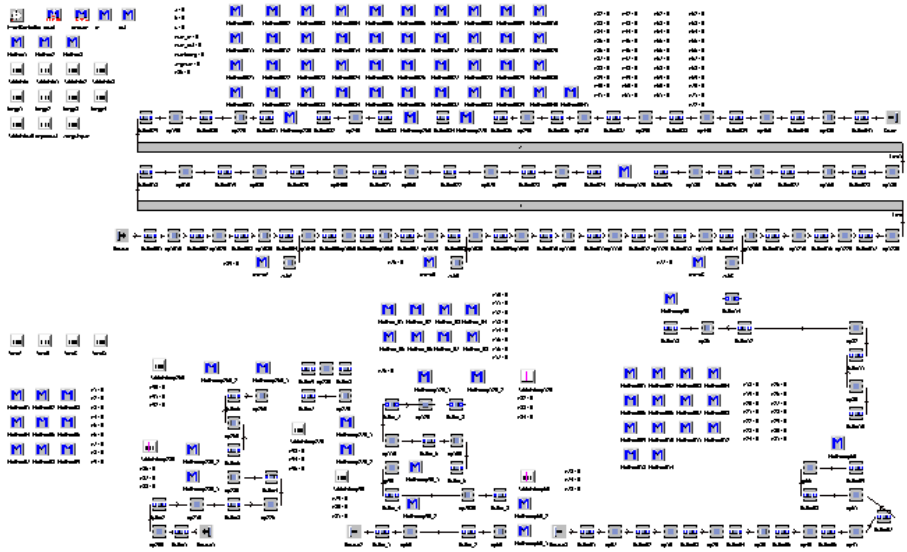


Figure 6. Simulation interface of production system.

The simulation has been run two times. First time, the risk factors is considering in the simulation, and it is not considering in the second time.Through the comparison of twice simulation, the processing efficiency is shown in Figure 7.

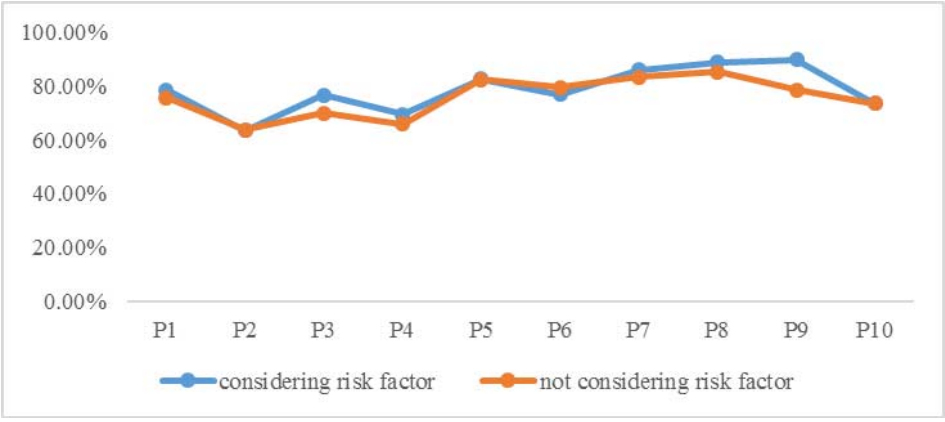


Figure 7. Comparing of simulation results.

It can be seen from Figure 7 that the production efficiency which considering the risk factors is higher than another one, so it is feasible to consider the risk factors in the production scheduling.

6. Conclusion

By using the association analysis, the main risk factors in workshop scheduling have been found, including risk of time, risk of quality and risk of equipment. Simulation is used to model the workshop scheduling considering risk factors in this paper. A typical case is provided to illustrate the risks found in this paper is correct, and the production efficiency can be improved if these risk factors are considered in making the workshop scheduling.

Acknowledgement

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Improved Classification Algorithm Based on Genetic Programming and Its Application in Process Monitoring of Additive Manufacturing

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Abstract. This work presented a defect classification methods based on improved classification algorithm in additive manufacturing process. To make the algorithm be applicable in process monitoring tasks, a method of optimizing the evolution process in GP evolution was raised in this work. A series of specific functions and their linear combinations were introduced to represent the GP classification model. The evolution process in this strategy is designed to optimize the coefficients of these functions and the offset. The advantaged in GP are also completely inherited. Comparing with GP alone, the improved strategy could reach higher classification accuracy in engineering application, i.e., process monitoring of additive manufacture.

Keywords. Classification algorithm, Genetic Programming, Additive manufacture, Process monitoring;

Introduction

Additive manufacturing (AM) has matured rapidly in recent years due to the development of AM processes, materials and a greatly increased understanding of the underlying design philosophies [1]. With AM, arbitrarily complex geometries, such as intricate internal features, lattice structures, and honeycomb structures, can be produced directly from a 3D CAD model [2]. Various materials such as polymers [3], ceramics [4], metals [5], can be fabricated directly with AM. AM also enables the reduction of material waste, part consolidation, and the ability to produce parts directly without further expensive part-specific tooling. However, many technical challenges continue to hamper the widespread adoption of AM and achieving its full potential [6]. One of the key technological barrier that prevents manufacturers from adopting AM technologies is the lack of assurance of quality with AM parts. To date, there is still a significant lack of mathematical and statistical models and algorithms to model the monitored process variables and fully utilize this invaluable data to detect process anomalies at early stages and conduct predictive control to improve part quality. To

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overcome this challenge, much emphasis has recently been placed on the monitoring of AM processes.

For example, for the laser power bed fusion (PBF) process , Van Elsen lists over fifty and experimental studies which have been widely undertaken to link energy density, traverse speed and hatch spacing with the part build quality in order to reduce observable material discontinuities [7]. Wang et al. have utilized acoustic emission sensors placed at each end of the substrate, in order to identify the position of the crack and its generation time in powder direct energy deposition (Power DED) [8]. Liu et al. built a correlation between the results of spectroscopic analysis and the clad quality of Inconel 625 laser hot-wire welding, such as surface appearance, clad dilution, hardness and microstructure[9]. Edwards et al. investigated the transmission and enhancement of laser generated surface waves with surface breaking angled cracks, wedge-shaped samples and branched cracks in wired direct energy deposition (Wire-DED) [10]. Brian et al. reviewed the dimensional accuracy and surface roughness for fused deposition modeling (FDM) and similar extrusion-based AM process [11]. It is noticed that part quality are highly influenced by process parameters. Thus, process monitoring of AM is essential if higher prototyping quality is required.

Among all the research topic concerning process monitoring of AM, one of the most important issue is to classify the abnormal from normal state, i.e. crack, residual stress, and identify them from various process parameters. Classification is the process to identify the belongings of categories (sub-populations), on the basis of a training set of data containing observations (or instances) whose category membership is already known [12]. Classification technology has been developed into a quite important research area in artificial, machine learning and pattern recognition. Human beings and animals could recognize objects by multiple times study of the properties or appearances. For the computer processes, with the training set of data which contains the observations whose category membership is already known, the task for learning process is to find the inherent rules underling in it. There are various well-known classification algorithm, such as neural network classifiers, SVMs (support vector machines), Naive Bayes, C4.5, and instance-based nearest neighbor classifiers. With different learning strategies, these algorithms have been widely applied in classification.

Among the above-mentioned classification algorithms, genetic programming is one of the most flexible. Proposed by Koza [13], and after decades of developing, GP has bloomed into a practical approach for the outworking classification problems [14-19]. Function set is one of the GP elements in encoding individual tree. An individual tree is composed of two kinds of symbols, which are function symbols and terminal symbols respectively. With the terminal symbols, leaf nodes of individual tree are encoded, while the other nodes are encoded using function symbols. Generally, function selection operation is necessary before GP algorithm is conducting. It is necessary to consider the strategy of the function symbol selection. In general, the function set are consisted of plus, subtract, multiply, and divide. The outcome could be markedly different with different function sets. The influences of chosen different function sets are thoroughly discussed by Wang et al. [20]. Since the selection of function sets are not the main topic in this work, interested readers could refer [19] for more information.

Using tree structure as individual encoding strategy, GP algorithm keeps the population constantly optimizing. On the other hand, crossover, mutation and fitness selection operations make GP flexible and adaptable for various problems. However,

after several generations, a lot of repeating works will be encountered most of the time. For example, new individuals with non-functional code will be created repeatedly and have to be kicked off for the bad fitness. This procedure is called code growth in [21], in which Soule et al compared various controlling methods of removing non-functional code and selective pressure. However, improving selective pressure will significantly increase the computational complexity, the evolution procedure will become more and more difficult.

To address this issue, an optimized algorithm based on GP for classification tasks is proposed in this work. During the optimization process, function symbols were specified and fixed. The major contribution of this work is

With those functions, better training model and less generation could be obtained. The proposed algorithm is successfully applied in the process monitoring of AM processes.

1. Methods

In real classification works, it is time-consuming to carry out trail-and-error procedure in function set selection using GP. Therefore, in this section, a solution for the selection of different function set was proposed. Using this method, GP solutions can be treated as functional parses. For ordinary dataset, a generic method should be found.

Taylor formula: If function $f(x)$ has the $(n+1)^{\text{th}}$ derivative in the neighborhood of x_0, function f(x) can be represented as this formula:

$$\mathrm{f}(x) = f(x_0) + f^{'}(x_0)(x - x_0) + \frac{f^{''}(x_0)(x - x_0)^2}{2!} + \cdots + \frac{f^{n}(x_0)}{\mathrm{n}!}(x - x_0)^n + R_n(x) \quad (1)$$

Taylor formula depicts the method of using x and its power function to substitute the original function. When condition holds, any function could be substitute by the accumulation of variants power function. To multiple dimension, it can be treated as multiple variant independent combination. On this basis, the function selection can be solved as follows.

GP algorithm always encodes individuals as trees. Besides, GP algorithm decodes individuals as function parses. Thus, the results obtained using GP can be treated as addition of serials of its variants and their power functions. Therefore, the only thing to be considered is the coefficients of each components. If the right coefficients of the components was obtained, result could be obtained the same as GP. In this approach, the major work transformed into the optimization of the component coefficients. In order to address this issue, we absorbed the idea of GP associating ANN strategy (GPN). The optimization direction was constrained using error calculation. The coefficients was updated using feedback mechanism. The structure of the algorithm is shown in Figure 1.

In the structure illustrated in Figure 1, the “in” symbols represents different sample dimensions, which are designated as input layer. $f_1, f_2, \cdots, f_5$ in median part represent functions of x, x^2, x^3, x^5 respectively, which are designated as median first layer. s_1, s_2 and s_3 represent the kernel function, which are designated as median

second layer. 'Output' is the output layer which defines the final result of the network. A serials of coefficient number was designed for each node.

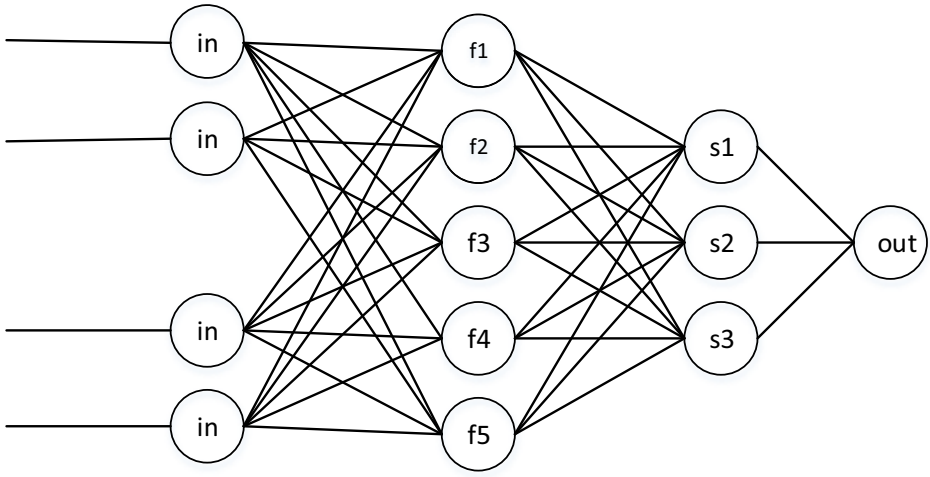


Figure 1. Structure of improved GPN algorithm.

In Figure 1, solid lines represent information transiting process. From left to right, samples were designated as input data one by one. Each dimension of one sample is transformed to individual node in median first layer. The median first layer firstly calculates the summation of the transformed data which are multiplied by the coefficients. The results will be transformed into the median second layer and treated by kernel function mapping into different distributions. Finally, using election operation, the final classes of the input samples are determined. The whole procedure are illustrated in Figure 2.

2. Experiments and results

To verify the algorithm proposed in the previous section, experiments were taken to classify abnormal state in laser cladding processes, i.e. micro cracks. Micro cracks are commonly encountered in laser cladding, due to the fact that laser cladding involves severe thermal cycling. Micro cracks could induce serious failures of the parts and should be avoided in laser cladding. This work was trying to monitor the micro crack defect using acoustic emission sensors and the proposed GP method. The schematic illustration of experimental setup is presented in Figure 3. Acoustic emission sensors and pyrometer were utilized for process monitoring. Micro cracks was obtained through adjusting of laser process parameters, such as laser power, laser beam diameter, and laser scanning velocity.

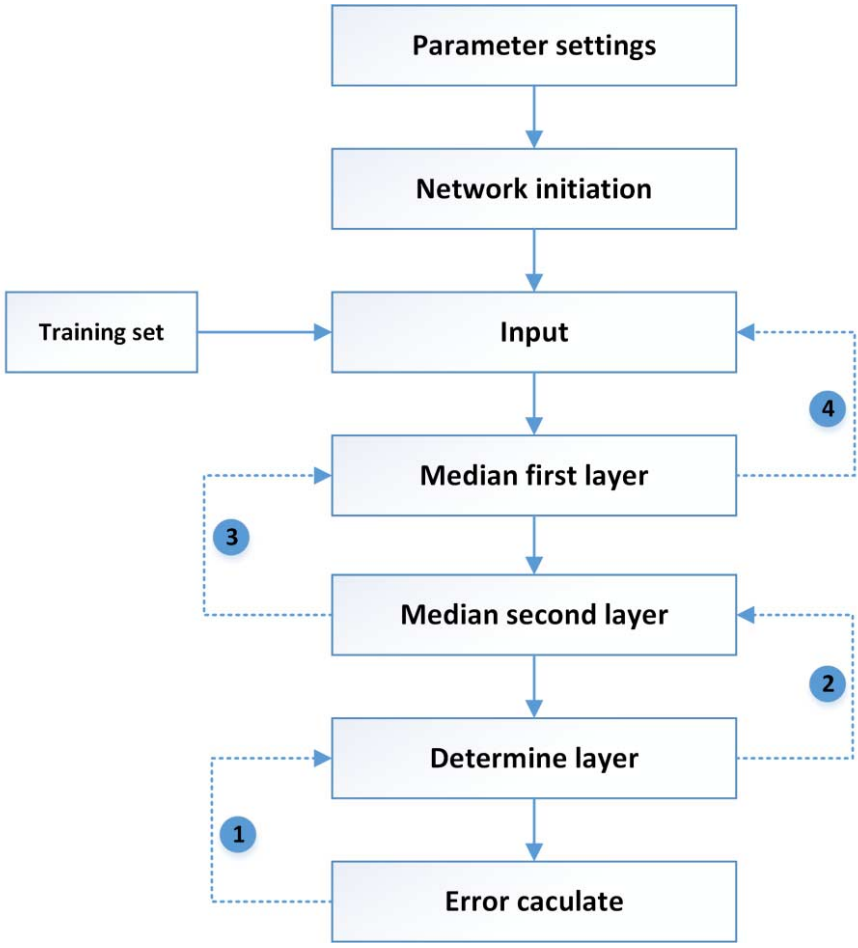


Figure 2. Procedure of improved GPN algorithm.

Both signals under micro crack and normal conditions were collected and their mean value, RMS value were chosen as input parameters. Sigmoid function was chosen as the node of the median second layer, the number of median second layer is set as three; the feedback times for one sample are set as three. With 20 independent experiments, the micro crack classification results are shown in Table 1.

Table 1. Classification accuracy of laser cladding cracks using GPN and GP.

Dataset	GPN	GP
RMS value	0.8530±0.04	0.7532±0.05
Mean value	0.8151±0.03	0.6924±0.02

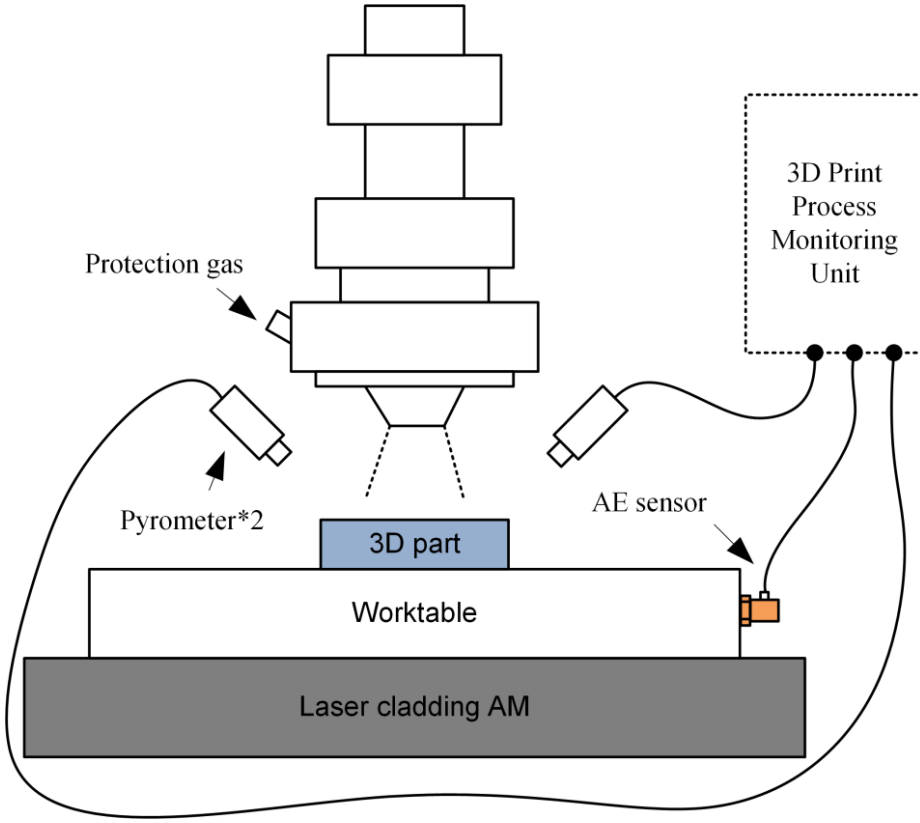


Figure 2. Experimental setup.

3. Conclusions and future work

This work presents an improved classification algorithm combined with GP and neural network. To make the algorithm be applicable in data mining tasks such as classification of AM process defects, a method of optimizing the evolution process in GP evolution was raised. Structure of input layer, two median layers, determining layer and final output layer was designed. The input layer is used to determine the dimension of signal feature datasets. Median layers are designed using four different power-functions and sigmoid function. The determining layer uses mean method to determine which class the sample belongs. To verify the effectiveness of the algorithm, experiments were carried out on a laser cladding machine. The aim of the experiments was to classify crack defects using acoustic emission features and temperature features. With 20 independent experiments, the crack classification results were promising. Results demonstrated that the proposed algorithm could reach better solutions comparing with GP.

Acknowledgement

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Cross-Border E-Commerce Risk Analysis Platform Based on SDN and Cloud Virtualization Technology

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Abstract. In recent years, Cross-Border e-Commerce has rapidly become popular in our daily life, and continuously causing some problems. Therefore, it is necessary to identify problems or risks using information technology. This study proposes a platform based on Software-defined Networking (SDN) and cloud virtualization technology. This platform can be the tool for a Cross-Border e-Commerce risk data analysis. The platform provides high flexibility and reliability, in line with the future development of large data risk analysis.

Keywords. Cross-Border E-Commerce, Risk Analysis, Virtualization

Introduction

Traditional computer network constructions are static and fixed, and the network topology is coupled to the physical network. Therefore, introducing new services and adjusting the network service chain involves a complicated configuration process, potentially may affect the original network connections, and affecting the services that were already being provided. Therefore, traditional network service supply has been unable to deliver many network services. With the rapid development of Internet and cloud technology, future network may be established in the Network Function Virtualization (NFV) environment. NFV enables decoupling of the network topology from physical network so that network topology and physical networks can be separated, allowing networks to be deployed more dynamically and flexibly [1][2][3][4]. This study is concerned with the provision of computing and network services that meet the needs of users when limited resources are available. In this work, service function chain technology is utilized to connected the required service functions, and proposed methods and mechanisms are used to provide computing and network function services.

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1. Background Knowledge

1.1. Software-defined Networking

In recent years, industry and academia have been actively involved in Software-Defined Networking (SDN) research. The operation and management of network systems have been extensively developed. In implementing a new protocol or experimenting with a new approach to doing test, traditional networks are not easily adjusted. Therefore, the SDN organization developed a network device that can be programmed through software under centralized management. SDN features include the control message and a separate data forwarding layer, centralized control and use of a defined interface for programmatic management of the network. As the Cloud and data centers store more data, processing must be mad faster and more efficient, requiring the virtualization and SDN to improve data transmission, network control, data center control and management efficiency [5][6][7].

1.2. Virtualization

Virtualization is a resource management technique that transforms the physical resources of a computer such as the processor, memory, disk space, network, and others into virtual resources. Virtual resources can be divided and combined to establish one or more computer environments, allowing the computer resources to be used more effectively and flexibly [8][9].

1.3. Network Function Virtualization (NFV)

NFV is an emerging technique. At present, the NFVrelated standard agreement is mainly driven by the European Telecommunications Standards Institute (ETSI). The construction of an environment that provides a complex and diverse network of functional services requires the preparation of many pieces of equipment to provide those services. Problems of compatibility arise among various devices, so network construction is not easy, and is prone to human error. NFV was developed to solve these problems. The main process in NFV is virtualizing hardware-based network devices to enable network functions to be changed using software. NFV, through standard virtualization, can change network functions from hardware-based to software-based. Replacing the hardware-based system reduces spending on hardware equipment and the amount of space occupied. Virtualized network functionality operates through a high-capacity and high-performance server. NFV is operated in software, which can be installed on any standard server, dramatically reducing network construction costs [10]. Network functions can be installed or uninstalled to meet the needs of users anywhere on the network, facilitating network construction, reducing the incidence of human error, and helping the network administrator easily maintain and manage the network environment [11][12].

1.4. Network Service Function Chaining (SFC)

Following the development of the Internet and cloud technology, networks are providing a wide range of network services. End-to-end devices usually requires various service functions to provide corresponding network services. End-to-end service functions are sequentially provided in a Service Function Chain (SFC) [13][14]. The SFC is used to provide orderly integration of network service functions. When a flow of network or packets are incoming from source to destination, the classification will guide them to the corresponding SFC [15][16][17].

2. Proposed System Architecture

This study proposes a platform for a cross-border risk analysis platform. Owing to the large amount of data involved and the need to operate complex procedures, the scheduling of computer resources and network management functions significantly affect performance. This work proposes an operations, administration, and maintenance platform for computer and network resource management, which is shown in Fig. 1. The platform consists of four layers. The first layer is the physical resource layer, which is responsible for the management of entity hardware-based resources, including computing, memory storage and network devices. The second layer is the virtual resource layer, which is mainly responsible for managing virtual resources, including virtual computing, memory storage and network services. The third layer is for operations, administration, and maintenance and accepts various applications and resource requirements from the upper level. It also assigns tasks to computing resource through resource adjuster and network function controller components. The fourth layer is the application platform for analyzing risk of cross-border electricity business, and is responsible for providing various application services.

2.1. Resource Adjuster Component

Today, service requirements change rapidly, and traditional physical hardware allocation has not been able to meet demand, so physical resources have been virtualized. This work integrated SDN to provide programmable and flexible network management and configuration. Relevant computer resources are virtualized to reduce the complexity of service construction; to solve the problem of compatibility of the original equipment, and to improve the efficiency of resource configuration.

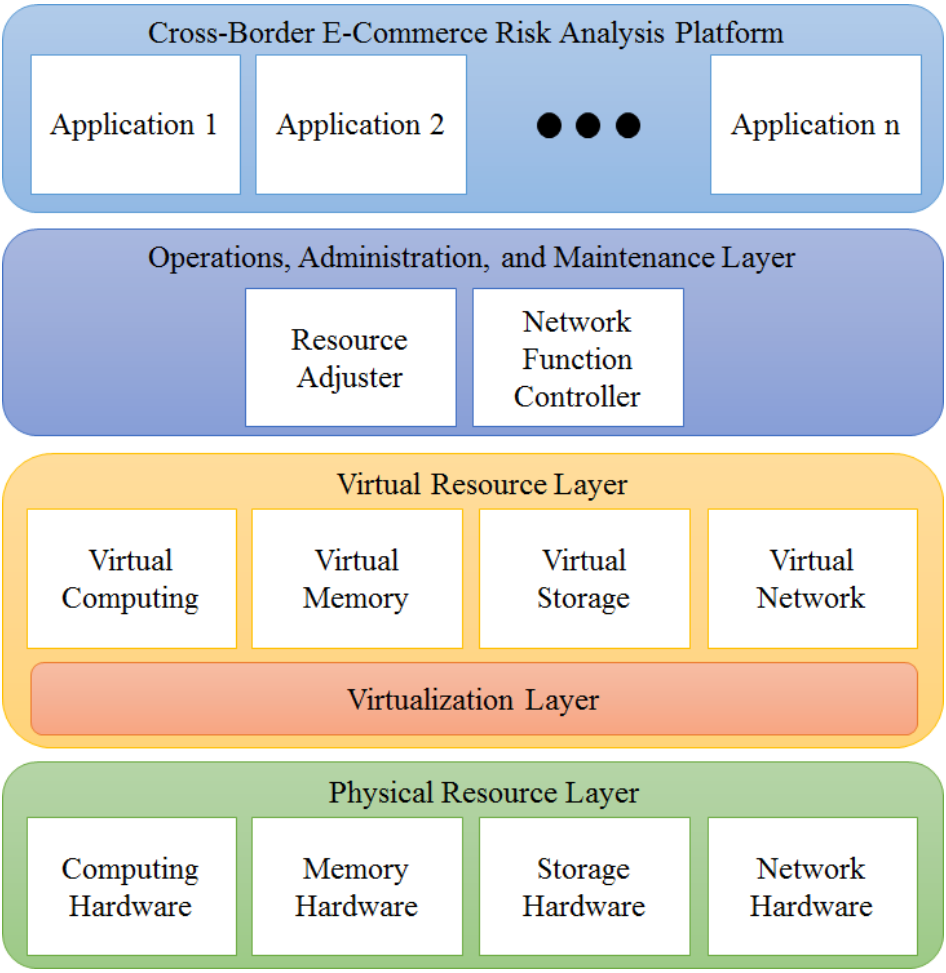


Figure 1. Operations, Administration, and Maintenance Platform Architecture.

The resource adjuster component manages the virtualized resource architecture, dynamically adjusting the resources by monitoring the resource use by each virtual machine. When too many users are using a particular virtual resource service, heavy loading occurs, and an excessive load on a single virtual machine causes low service quality and efficiency. When too many resources of a virtual machine are unused, light loading occurs, causing waste. Therefore, adjusting the configuration and monitoring the overall environment are important tasks. Figure 2 shows the sequence of tasks that are performed by the resource adjustment component.

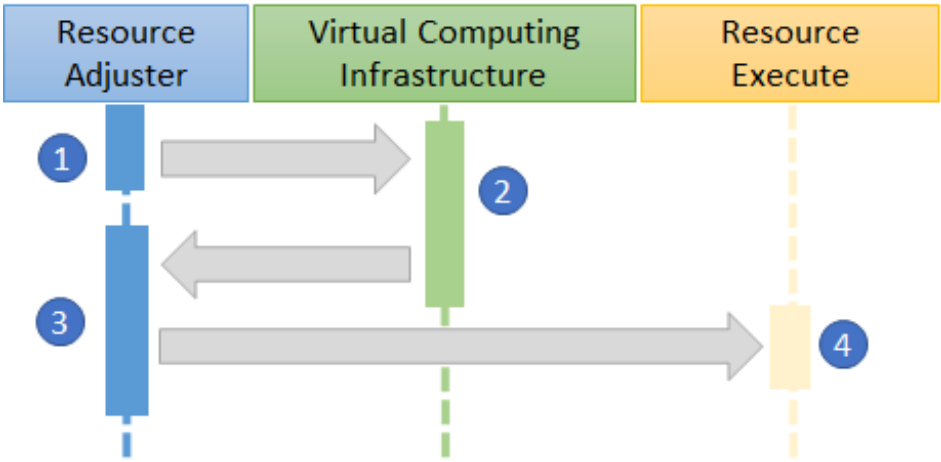


Figure 2. Time Sequence of Resource Adjustment Component.

When a virtual machine is lightly or heavily loaded, it triggers a resource reconfiguration. Smooth resource reconfiguration requires the calculation of the excess load in heavily loaded virtual machine, as well as other loads that can be accepted by the virtual machine with the same available resources. The above process re-allocates resources.

Step 1. The resource adjuster component requires a load condition for virtual machine.
Step 2. A virtual machine and the network function infrastructure collect load information and send it to the resource adjuster component.
Step 3. The resource adjuster component determines whether the virtual machine is heavily or lightly loaded.
Step 4. If the virtual machine or network function infrastructure is heavily or lightly loaded, then the resources are reconfigured.

Figure 3 shows the lower and upper bounds of thresholds for loads control. The lower and upper bounds of thresholds shows the usage of a virtual machine, and sets the boundaries on resource adjustment. When the usage exceeds the upper bound, the virtual machine is heavily loaded. When the usage is below the lower bound, the virtual machine is lightly loaded. In both cases, the resource adjuster is used to enable the system to perform various tasks.



Figure 3. Lower Bound and Upper Bound Threshold Setting.

2.2. Network Function Controller Component

Traditional network architecture cannot respond to the rapid growth of applications and users' needs for network services. Network virtualization provides a solution. NFV allows network functions to be quickly added, deleted or modified to support the rapid and arbitrary configuration of network functions. However, although network functions have been shifted from physical to virtual, the settings must still be manually configured. Therefore, this work combines SFC technology with the proposed network function controller to adjust dynamically service chain planning, consistent with future cross-border electric business risk analysis for various service requirements.

In this work, service chain technology is utilized to reduce the complexity of the configuration of setting, and the service function chain scheduling mechanism is used to adjust the service chain dynamically and flexibly, to provide service functions that meet users' requirements. Figure 4 show the sequence of and network function controller component.

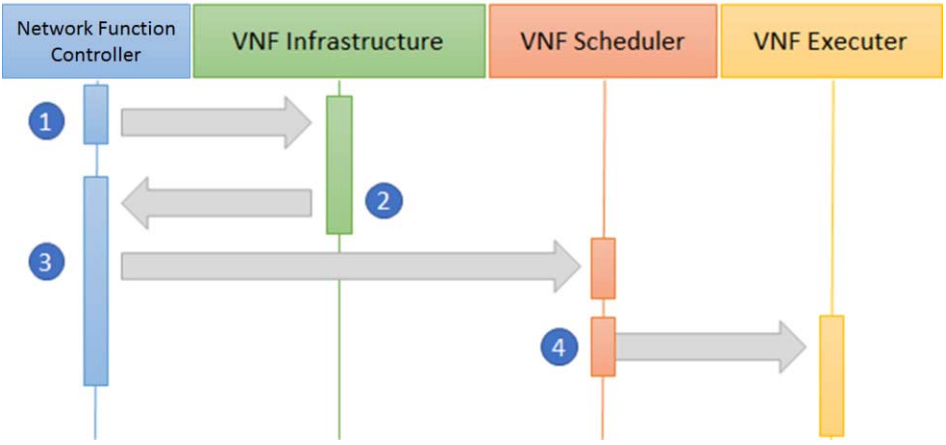


Figure 4. Time Sequence of Network Function Controller Component.

The network function controller establishes a connection between the service provider and the service requester, based on the type, level and price of a network function. The network function controller performs scheduling and execution as requested to satisfy the needs of the service provider and the service requester.

Step 1. The network function controller component requires a load condition to perform VNF.
Step 2. VNF collects load information and send it to the network function controller component.
Step 3. The network function controller component sends the information to the VNF scheduler for scheduling the network function service chain.
Step 4. The VNF scheduler sends the scheduling information to the VNF executer to arrange the service function chain.

3. Conclusion

In this work, a computer and NFV operations, administration, and maintenance platform is designed to monitor the computing and network environment, to adjust the number of virtual machines that perform particular network functions, to balance virtual resources of network functions, and to solve the problem of virtual machine overloaded and the network function service chain, improving the overall effectiveness of the system.

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Adaption of Logistical Distribution Networks with Complexity and Efficiency Considerations for Cross-Border E-Commerce in China

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Abstract. While China's economy is in deep reform and industrial transition, cross-border e-commerce industry in China has shown an annual growth rate of 30% in recent years, soaring to the top of global Cross-Border E-Commerce (CBEC) markets. However an efficient and flexible distribution network is required to fully reap the rewards of this growth, which has posed great challenges for CBEC retailers and carriers struggling to ease consumer shipment impatience. The aim of the study presented in this paper is to provide explicit explanationsof the emergence, development, opportunities, challenges and future of cross-border e-commerce in China both from the perspectives of China's legitimate authorities and e-commerce companies. The actions taken by China's authorities when facing the explosive emergence of cross-border e-commerce trade volume are the one of the key factors leading the development path of e-commerce in China. E-commerce companies are also devoted to the development of e-commerce trade seeking better ways to maintain competitive in the industry. An example of the logistical distribution network of one of China's e-commerce giants has been studied in this research. It is concluded that the logistical network is adaptive to the development trend of e-commerce in China. In future work, the performances of China's logistical distribution networks are to be evaluated from perspectives of network topology and functionality (trade-off between efficiency and cost) specified with CBEC consideration. A mathematical model is to be formulated as a Mixed-Integer Linear Programming (MILP) problem. Topological complexity of the mathematical model is studied based on the complex network theory. Trade-offs between delivery time (termed as "efficiency") and transportation costs of the model is also evaluated for it is the key factor of significance both for CBEC customers and retailers.

Keywords. Cross-Border E-Commerce, development, logistic distribution network

Introduction

With the shadow of 2008 global financial crisis being fading away, the global economy is still in slow structural adjustment and recovery, thriving to keep steady accelerating economic growth as prevailed in the old golden days. It seems that the recovery path is not easy to pass through. Those feelings might be experienced to varied contents by the developing economies such as China, Brazil and India and also by the advanced

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economies such as European countries, Japan and the U.S. China, after being presented as a sparkling rising star in the world economy with high-speed GDP growth for over two decades (about annual rate of 9.8%) [1], is now experiencing the lowest level of economic growth rate. China is currently swirled in the tangled interweave of three transitional cycles of global economy, energy and industrial evolutions catalyzed by technology innovation and ideological change from industrial civilization to ecologic civilization. "A new normality" of China's economy as put by Chinese Premier Keqiang Li in a speech in Davos in February 2015 states that the country had "entered the stage of the new normal, shifting from high speed to medium-to-high speed" [2]. Mr. Li implies that Chinese government and industry leaders are not quite worried about the lowered speed of economic growth but still inject strong confidence of promoting a more healthy and sustainable development of China's economy. It is assured by the Chinese government that the country authorities intend to gradually move forward the far-reaching structural reforms of economic growth from the old ways of three-decades of accelerated growth featured with investment-fueled and unsustainable debt to new strategies to encourage service sector growth, consumer spending and private entrepreneurship without a "hard landing [3]". A slew of strategies(such as "One-Belt-One-Road", "Internet Plus", "Made in China 2025"), policies, regulations and implementations [2,4,5] have been put forward, indicating the government's strong and solid determination to help China's economy to succeed through the transition period with pain though, but to embrace a bright future of sustainable development. Strategies include controlling the unbalanced supply-demand industries such as steel and glass production whilst promoting emerging industries such as advanced production, modern service, new energy and e-commerce [6,7].

The confidence and determination projected by the Chinese government can also be found in the majority of Chinese consumers. McKinsey, a famous global consulting firm concluded in their 2016 report "The modernization of Chinese Consumer" that Chinese consumers have maintained resilient confidence over the past few years as salaries have continued to rise and unemployment has stayed low [8]. McKinsey's findings are concluded from 10,000 in-person interviews with people aged 18 to 65, in 44 cities representing China's major regions and tiers. Findings in this report show that Chinese consumers are confident about their increasing salaries in the future and they are and will be continually willing to spend. It should be noted that Chinese consumers are becoming more discriminating on shopping with the enhancement of consumption knowledge and production choices [9]. They are more concerned about the authenticity, safety and quality of products. Also they are showing greater demand for shopping services and experiences. Chinese consumers are enriching their ways of traditional shopping at "brick and mortar stores" by embracing emerging ways of online shopping of "swipes and clicks" thanks to the Internet, e-commerce and mobile devices. In 2012 Chinese internet users have reached 560 million with a population of internet consumers of 230 million against 150 million of online consumers in the U.S at the same year [10]. Figure 1 presents two groups of populations of Internet consumers and Internet users in China and their relationship from 2012 to 2015. It can be seen from Figure 1 that the percentage of total internet users who shop online keeps growing in recent years. There is still enough space for the population of Chinese online consumers to grow since a large number of internet users remain active in Chinese rural areas and the number reaches 178 million until June 2014 [11].

China's middle class in terms of a wealth holding band of USD 10,000-100,000 has reached 109million according to [12] and takes up to 16% of the global wealth

middle class population and 10.7% of China's population. It is expected for the middle class in China to reach 520million and their share to reach 40.3% of global middle class segment by 2020. The net worth of China's middle class in 2015 amounted to 32% of country wealth [12]. The middle class is the major force in the consumption trends. In [10] it is stressed that the share of consumption of the lower middle class and upper middle class of China's total consumption will both present a 5% growth rate per year. The growth rate for upper middle class consumers is 17% per year. In 2020, China's middle class would make their share of consumption up to 70% of China's total consumption.

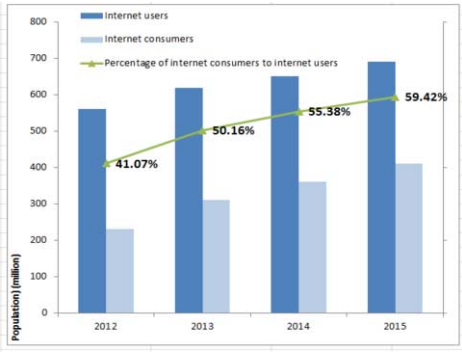


Figure 1. Populations of Internet consumers and users in China

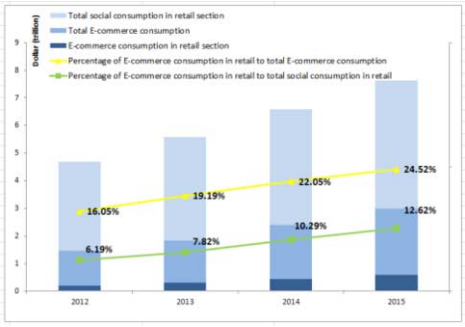


Figure 2. Transaction of e-commerce consumption in retail, in total and total social consumption in China from 2012 to 2015

The total on-line shopping GMV (gross merchandise volume) in China reaches $1.2 trillion in 2012 an increase of 66.1% from 2011[13]. Total volume of e-commerce transaction makes up 6.2% of total Chinese consumption in 2012 as compared to the percentage of 5.2% in the U.S.[13,14]. Figure 2 shows the relationship between e-commerce in the retail section, total e-commerce transaction and total social consumption from 2012 to 2015.

As depicted in Figure 2, the share of e-commerce in China's total retail has risen above 10% in 2014 and 2015- a remarkably higher percentage than in the U.S. and this will grow to 13.6% in 2016 [15]. In [15] it is highlighted that China has become the largest e-commerce market in the world. The Chinese online retail market is almost 40% larger than the U.S., and together these markets account for more than 55% of worldwide e-commerce.

1. Incubation and Development of Cross-border E-commerce in China

A series of fake and counterfeit baby formula, food and toy scandals exposed in 2008 [16] stirred up anger, dissatisfaction and disappointment among Chinese consumers, especially Chinese parents over China's domestic business brands and companies. Loss of loyalty and faith to certain domestic products, Chinese consumers started to build faith on products made in foreign companies or labeled with foreign brands. They have discovered they can go online to buy goods from foreign countries either directly from foreign websites or indirectly from companies run by Chinese merchants in foreign countries with less cost of money and time. Most imported goods are waived of import taxes since they are treated as personal-use goods by China's customs authorities [17]. The emergence of official cross-border e-commerce channels provides

Chinese consumers with authentic foreign products of more brands including more product categories at cheaper prices and to receive products in shorter periods of shipping time. These cross-border purchases by China's online shoppers grew over three-fold between 2013 and 2015, from $12billion to more than $40billion. Figure 3 shows the change of scale of China's cross-border e-commerce consumption and their share in China's e-commerce GMV (source data are combined from [18,19]). Both groups of GMV are collected in retail from the channels of B2C and C2C commercial models). Growth rates of cross-border e-commerce GMV from 2012 to 2015 reduce slightly from 31.3% to 29.3%[18]. If compared to the change of total amount of China's inbound and outbound commerce from 2012 to 2015 as 4.5%, 6.5%, 4.9% and -1.7% for outbound volumes and 1.0%, 5.9%, -0.6% and -13.2% for inbound volumes[18], the growth rates of cross-border e-commerce are quite eyes-catching. The share of cross-border e-commerce to the total annual turnover of China's import and export commerce has risen from 4% to 14.2% in 2008 to 2014[19]. It is reported that the inbound cross-border e-commerce shows a strong pick-up in 2015, to 17.8% from 4.2% in 2008. Penetration of e-commerce reached 11.7% of total import turnover in 2015, up from 8.6% in 2014[18].

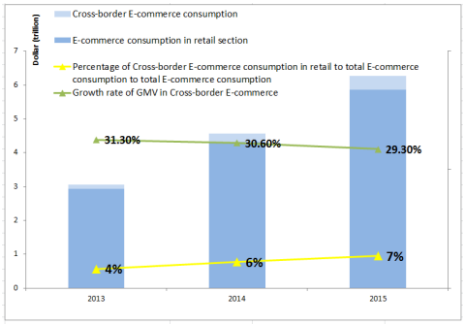


Figure 3. Transaction and growth rate of Cross-border e-commerce consumption and total e-commerce consumption in retail and their relations from 2013 to 2015, in China

Cross-border e-commerce especially in the inbound segment has shown robust growth over recent years as, in general, a reflection of combined factors of China's economic growth and industrial transition, wealth accumulation of the Chinese people especially the middle class, expanded willingness of spending of Chinese consumers, loss of made-in-China domestic-oriented products of Chinese consumers and their trust of strict production standards and regulatory controls in foreign countries and a bursting number of cross-border import sales channels in China. The rapid expansion of China's cross-border e-commerce has drawn attentions from brand owners, wholesalers, distributors, etc., nearly every part of the production supply-chain [15]. The exemplary industrial chains in China have formed including various stakeholders from the overseas products providers, companies offering trade platforms, logistics to payments methods as shown in Figure 4.

The boom of cross-border e-commerce in China has not only attracted freight flow and cash flow but also the attentions from Chinese authorities, especially from the customs and inspection organizations. It is always clear that the Chinese authorities would at some stage seek to better regulate cross-border e-commerce. The development of this cutting-edge business is in fact, dependent on the regulations and policies implemented by Chinese organizations say, the General Administration of Customs and the State Administration of Taxation.

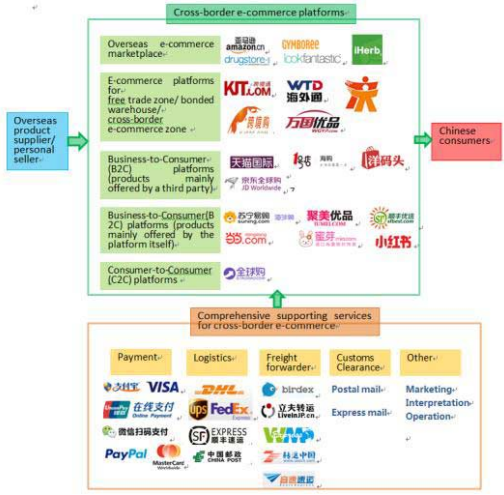


Figure 4. Industrial chain of cross-border e-commerce in China

As any company, Internet sellers need to design their product offering. In their case, this includes the choice of the offered delivery service, which is an important determinant of customer satisfaction.

2. Attitutes of Chinese Government towards Cross-border E-commerce

Before 2014 most importantly customs' rights and shopping experiences are impaired through both models of cross-border consumption to some extent. From China's supervision bodies' point of view, the existing grey custom clearance of most products labeled as 'personal items' may cause a huge amount of duty loss for China Customs.

To tackle the difficulties of supervision and tax loss, China's General Administration of Customs has lowered the duty-free allowance of Personal Luggage and Postal Tax to RMB 50 per package down from RMB 500 per package in September 2010 [20]. However it still remains great challenges for the customs organization facing the waves of growth for more and more piecewise cross-border packages.

2013 is seen by the business insiders as the 'beginning year' of cross-border e-commerce for China when five cities of Shanghai, Ningbo, Hangzhou, Chongqing and Zhengzhou were appointed as pilot cities of cross-border e-commerce service. Guangzhou became the sixth pilot city of cross-border e-commerce service soon and the seventh and eighth pilot cities are Shenzhen and Tianjin. The establishment of a batch of pilot cities of cross-border e-commerce in China reflects the solid determination of the Chinese government to lead the cross-border e-commerce into the sunny market of broad day light from the 'grey zone'. The general guidelines for the sunny market of cross-border e-commerce implemented by the Chinese government are 1) to guide commercial items formerly imported as personal-use articles through risky and grey customs clearance channels onto the road of legal levy of import customs duties and 2) to help the B2C outbound trade of cross-border e-commerce enjoy export subsidies.

In 2014 and 2015 the General Administration of Customs launches a series of announcements and circulars on modes of customs supervision on cross-border e-commerce inbound products and articles including the famous No. 56 and No.57 announcements in 2014 [21,22]. Since then a new approach of operating e-business for foreign merchants of bonded warehouse model has been legally accepted and regulated by China's Customs Administration besides the existing e-commerce model of direct shipping model. In March 2015, the first comprehensive cross-border e-commerce pilot zone was established in Hangzhou, home to the e-commerce giant Alibaba hosting the largest number of visitors and sales volume in China. In January 2016, a new batch of comprehensive cross-border e-commerce zones has been set up in 12 Chinese cities. These zones are designated exclusively for the development of cross-border e-commerce industry, featuring a slew of preferential tax policies and streamlined customs clearance procedures. Each of these zones has an online e-commerce platform operated by state-backed or licensed companies (e.g. Kuajingtong in the Shanghai Free Trade Zone as depicted in Figure 4).

From 2015, the administrative departments e.g. China Customs, China Inspection and Quarantine, State Administration of Taxation and State Administration of Foreign Exchange have launched opinions, announcements and notifications aiming to implement technical standards, business processes and information construction of cross-border e-commerce business in the comprehensive e-commerce zones.

Within these zones customs clearance procedures can be finished within 24 hours under the "365/7/24 customs clearance" scheme of China Customs. The General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China has designed a negative list management system for cross-border e-commerce in May 2015 and launched pilot policies exclusively for comprehensive zones aiming to promote portal development, simplify administrative operations and proceed risk inspection for product quality and safety. Shanghai Inspection and Quarantine Bureau in Shanghai Free Trade Zone has published a series of notifications and regulations to provide detailed operational provisions and rules for foreign and domestic companies and e-commerce platforms registered in the e-commerce zone on the principles of beforehand registration and declaration, digital bill confirmation and risk supervision and alert. Cooperation has been established between China Customs and CIQ to promote the practice of one-time declaration, one-time inspection and one-time release.

At the start of 2016 on a policy briefing conference the Ministry of Commerce of China has stressed that the main commercial model for cross-border e-commerce should be B2B subsided by B2C to help a sustainable development of China's foreign trade and an effective adjustment of China's economic structure. In April 2016, a new tax policy coupled with two "positive lists" concerning cross-section e-commerce retail sales was published jointly by China's authorities. The recent tax circular significantly changed the preferential tax policies that have been applied to cross-border e-commerce transactions. The changes were primarily adjustments to tax rates, introduction of a maximum RMB 2000 of single transfer in cross-border retail and an annual limit of RMB 20,000 per individual consumer.

The new tax policy and its attached positive lists mark the beginning of a long-term strategic development for the e-commerce industry in China. The low-tax advantages formerly enjoyed by this industry are disappearing and it is important for the e-commerce sales industry to remain attractive and competitive whilst complying with Chinese product quality standards.

3. Response and Expectation of Cross-border E-commerce Industry in China

The implementation of new tax policies and positive lists show good aims and correct interpretations of China's authorities for the current development trends of cross-border e-commerce in China. However it is hardly a happy moment or an easy time for merchants, companies and platforms conducting cross-border e-commerce. For these merchants and platform companies, the impact of individual consumer's single and annual transaction allowance and adjustment of tax rates is smaller than that of positive lists. E-commerce merchants and platforms have prepared to be involved in the price and tax-subsidies battles since the informal release of new tax policies in early March, aiming to attract consumers and maintain consumer market shares.

Chinese e-commerce giants such as Tmall global, JD.com etc. are facing the challenges of price subsidies and storage adjustment. Some are also making commercial transitions to direct shipping and overseas bonded warehouses or even high-end tourism businesses. Middle and small-sized e-commerce merchants are suffering from big reduction of sales volumes, lay-offs of staffs, shortage of product storages and cash flows. Merchants such as Jumei, Miya and Xiaohongshu conducted a closed-door conference, two weeks after the implementation of new policies, coming to conclusions that they are all experiencing a tough time that can be described as 'circular-break' and their difficulties should be informed to China's authorities. Some merchants claimed that in 20 days their products for sale would run out of storage.

After receiving negative feedbacks from e-commerce industries, China's authorities are making a few modifications to the newly implemented policies that positive-listed products in 10 China's pilot cross-border e-commerce zones are exempted from commodity inspection and registration before customs declaration for a transitional time period of one year with the tax policies remain unchanged. Cross-border e-commerce merchants and platforms can take advantages of this transitional time to adjust their business operation modes by enriching purchasing structure diversity, upgrading logistics services and promoting customers experiences etc. The transitional time could also be a vibrate integration development stage for cross-border e-commerce industry where opportunities and challenges coexist.

JD.com is one of China's largest comprehensive E-commerce retailers and self-run platforms and it possessed more than 50% of Chinese B2C E-commerce market since 2015. While maintaining the enormous market share of retail, its self-built logistics system has also drawn much attention and argument since its establishment in 2012. JD Express has made great effort in infrastructure investment, intelligent logistics techniques and human resources. Until 2016 seven RDCs (Regional distribution center), thirteen FDCs (Front distribution center) and a large number of DCs (Distribution center) have been operated spreading over China's mainland. The logistics network of JD Express is shown in Figure 5.

All the 7 RDCs, 13 FDCS and a small part of ACs of JD Express are included in the logistics network as shown in Figure 5 Logistics distribution is managed by JD Express as illustrated in Figure 5 here cargos are transported among RDCs, between RDCs and FDCs and between FDCs and ACs. The directions of cargo flow are also illustrated.

The logistics network is a multi-Hub-and-spoke one. It is a small world network in which two vertices are connected by a few links. For the example of AC in this network, it is connected to the nearest RDC hub by two links, one connecting this AC to its nearest FDC and second connecting the FDC to the nearest RDC. Benefits of this

multi-Hub-and-spoke model include a small number of routes required to connect all vertices in a network and complicated operations can be performed at each RDC hub and FDC sub-hub. Drawbacks of this type of the network include that it is required large efforts of infrastructure investment especially at hubs and sub-hubs. Inflexibility exists in the operation of the whole network since the change at the hub may have unexpected consequences throughout the network and may dampen the efficiency of operation.

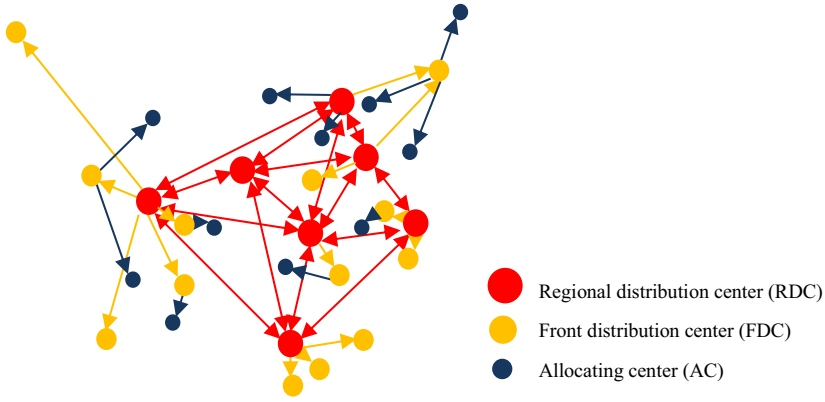


Figure 5. Logistics network of JD Express

A limited path percolation model (LPP) of a network concerns the stability of the network, i.e. under what conditions it becomes inefficient and cannot transmit flow within acceptable time period. The model is developed from the percolation theory. In this model, the critical percentage of links, p, needed to keep the vertices in a network connected is computed. A small value of p indicates longer length of paths. In some cases long paths for network users are inefficient and even unacceptable even the connectivity remains.

In this model, after removing a fraction $q = 1 - p$ of the network nodes, any two of these nodes, say i and j are considered connected only if the shortest path between them is shorter than a*ℓij (a ≥ 1), where ℓij is the shortest path before removal. The value of p is calculated for one type of complex networks by the author. Random removal and targeted removal to highly connected vertices are used in the simulations. The generated value range of p result to a small fraction of removed links to damage the connectivity of the network and its level of services to its users. In other words, events with small effort would lead to a great breakdown of the network. The combined utilization of small world analysis and the LPP model can help examine the trade-off between efficiency and cost of a logistics distribution hub-and-spoke network.

Except for JD Express, Amazon China, Federal Express, UPS have all successfully implemented hub-and-spoke distribution to achieve a competitive logistics advantage.

4. Conclusions and Discussions

4.1. Current status of China's cross-border e-commerce industries

Decades of rapid growth of China's economy results in the rising number of Chinese Internet users and middle class. Growing salaries, willingness to spend and

discrimination of purchased products for Chinese middle classes are three major factors that stimulate China's cross-border e-commerce industry. This industry is also encouraged by Chinese authorities aiming to create a more vibrate and competitive market for production and sale in China.

However for China's supervision organizations, the large amount of parcels is a challenge to be faced particularly for China's Ministry of Taxation and General Ministry of Customs. A slew of preferential policies and regulations have been implemented by the supervision bodies since the official establishment of cross-border e-commerce pilot cities and zones to promote the development of the cutting-edge e-commerce industry and to balance e-commerce trade with general trade and import with export trade at Chinese market.

The development of China's cross-border e-commerce industry, being sensitive to the implementation of supervision policies and regulations, has experienced distinctive stages of rapid growth and a recent slowed-down adjustment. For the e-commerce companies and platforms, the current adjustment of industry policies can be utilized as a good opportunity to reform their purchasing organizational structures and upgrade customer-oriented services for enhancing their competitiveness of international supply-chain and global trade.

4.2. Future expectations of China's cross-border e-commerce industries

In the long run the threat of cross-border e-commerce on the traditional import and export trade will remain with the benefits of quick flow of products and cash featured by cross-border e-commerce and advantages of foreign products in terms of quality, diversity and sales price.

As the second largest economy and the largest GMV in the world, China's economy is currently in deep structural reform and industry transition. The determination of Chinese government to open domestic market and be more engaged in global trade is injected in a series of national strategies such as the one-belt-one-road policy and establishment of free trade zones and pilot cross-border e-commerce zones. Except for the national strategic planning, it is reasonable for Chinese government to guild and boost the development of cross-border e-commerce as it has become a "new normality" for Chinese consumers purchasing foreign products.

A sustainable and healthy development for China's cross-border e-commerce industry would be achieved by the work of merchants, companies and platforms and the determination of the supervision authorities to guild and assist the industry but most importantly the establishment of an efficient negotiation mechanism between the industry and government authorities.

A hub-and-spoke distribution network maintains the balance between transport efficiency and cost. The main objective of E-commerce business in China should be to minimize transportation costs, having higher requirements to cargo handling cost and consolidation time in logistics hub and at the same time pay attention to complex route system design from demand point to logistics hubs.

The paper is limited to a contextual explanation of the research, future work will be done on the application of the Mixed-Integer Linear Programming (MILP) model on comparative examples of e-commerce companies. The topological complexity of mathematical models of logistical distribution networks is to be studies by use of complex network theory. Trade-offs between delivery time and transportation cost is to be evaluated.

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Key Technologies for Knowledge-Based Cross-Border E-Commerce Risk Assessment - Accurate Commodity Classification and Efficient Knowledge Acquisition

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Abstract. The potentially conflicting regulations of different nations add risks to cross-border e-commerce (CBEC), and the characteristic of small volume, multi-batch commodity transactions makes CBEC hard to be inspected by human experts. In this paper a knowledge-based CBEC risk assessment system is proposed and special attention is paid to the improvement of system functions including commodity classification and knowledge acquisition. While the former focuses on the accurate recognition of product types in order that right regulations can be applied to the product, the latter accomplishes the transformation from textual regulations into formatted, computer understandable rules with the least mistakes and redundancies. These two techniques collectively improves the usability of the knowledge-based CBEC risk assessment system to a practical level.

Keywords. Cross-broader e-commerce, risk assessment, commodity classification, knowledge acquisition

Introduction

Cross-border e-commerce (CBEC) is a fast developing business type in both China and all over the world. As the commodities imported through CBEC are of diverse kinds and often in multi-batch, small volume transactions, the supervision department of the government usually has no time to perform rigorous safety check for each of the imported commodities. This causes risks for people who are buying through CBEC. The risks associated with CBEC mainly include the potential harm done by the imported commodity to the buyers' body and property, as well as the harm to the importing country's environment, resources and safety. Although most countries have imposed safety regulations on their export commodities, contradictions between the regualtions of different countries exisit and thereby lead to the abovementioned risks. Currently the Chinese government is using a random manual check method to assess

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the risks of commodites imported through CBEC, which is a time-consuming approach and has led to delay of commodity delivery. To resolve this issue, a computerized, AI (artificial intelligence) enabled system needs to be developed to automate the risk assessment operation of CBEC and thus speed up the key step - customs clearance of CBEC.

In this paper, a knowledge-based CBEC commodity risk assessment system is introduced first, and then two operations affecting the accuracy and usability of the system the most are explained with details. The first operation is commodity classification, which is to determine which kind of official products an imported commodity belongs to. This is indispensable because only by knowing the official names of a commodity can we know which regulations to apply to assess the safety of the commodity. The second operation is knowledge acquisition, which is to transform the natrual language text in regulations into a computer-understandable form, such that the assessment of commodity risks can be automated.

1. Literature Review

Despite the abundant research on business risks, studies directly addressing the issue of CBEC risks are rare. Trzaskowski (2004) first recognized CBEC risks and proposed that it was necessary to manage the risks caused by the different laws of the countries involved in CBEC [1]. Other researchers have focused on the analysis of traditional e-commerce and supply chain risks. For e-commerce risks, Ngai and Wat (2005) classified e-commerce risks into three layers 51 types to establish the risk assessment model [2]. Wruck et al. (2016) studied the influence of small volume, multi-batch transaction environment on e-commerce risks and proposed a risk control method for e-commerce staff planning [3]. Ho et al. (2015) categorized supply chain risks into two types - micro risk and macro risk [4]. Micro risk includes demand risk, supply risk, manufacturing risk and infrastructure risk at enterprise level [4], which is often dealt with by mathematically modeling the risk and revenue and deriving an optimal solution from the model [5-6]. For example, Mohammaddust et al. (2017) developed two mixed integer nonlinear models for a four-tier supply chain to understand the strategies for managing the back-up emergency stocks [7]. Park and Kim (2016) modelled the risks in sourcing, production, distribution and transportation in an integrated way, and then used a simulation-based evolutionary algorithm to derive the optimal planning of global supply chains [8]. Macro risk refers to the risk caused by the environment, political policy, war and terrorism [4]. While policy risk refects the regulation perspective of CBEC risks, in previous works it is often treated as a given factor to be responsed to by an enterprise but not the target to be measured [9]. In general, most of the studies on business risks are addressing enterprise-level micro risks, which has little implication on CBEC risk assessment because risky CBEC importation harms not the enterprises but consumers and the environment. To protect consumers and the environment, the supervision department of the government needs to carefully check each of the commodities according to the country's safety regulations, and such a supervision action has become a knowledge-intensive task because of the great diversity of imported commodities and the complexity of safety regulations. As far as we know, despite the urgent need for supporting CBEC risk supervision with computerized knowledge reasoning and artificial intelligence, until now there has been

no research dealing with automation of CBEC commodity risk assessment using a knowledge-based method.

2. Knowledge-based CBEC risk assessment

2.1. Problem statement

CBEC commodities are being sold at different online stores, where the names of a same commodity can be different as the stores may want to add special information to advertise the commodity. This makes the identification of commodity types a difficult task for computer programs. On the other hand, the commodity types defined in official regulations are usually composed of terminologies which are different from the words people usually use to describe the commodity on the web. This makes the matching of a CBEC commodity's popular name to its official name more difficult. For example, the first two commodity names in the left hand side of Table 1 correspond to the same commodity, which is "Nutrilon period 1 infant milk powder". But in order to emphasize the selling point, the first seller adds "original binding", "free trade zone" and "direct mail" to the commodity name to show the logistic advantage of the commodity, while the second seller adds "native" and "purchasable period 2 period 3" to advertise other commodities in his store. Although the added noisy information can be easily stripped off by human, it is difficult for computer programs to do so. On the right hand side of Table 1 are the regulations potentially relevant for assessing the CBEC commodity risk. It can be seen that the popular commodity type name "infant milk powder" is nowhere to find in Chinese national standards, and the officially used terminology for this is "milk-based infant formula food".

The classification of CBEC commodities into product types officially defined in the national regulations is of great importance to the proposed risk assessment system, as only by this the rules in the regulations can be correctly applied to the target commodity. This is a challenging task as the noisy information exists in the names of commodities and the wording of commodities' popular names and official names can be significantly different. Another important task for the proposed system is to transform the textual rules in the national regulations into a computer understandable form which can be used by the inference engine. Such a transformation should keep as much original information as possible and at the same time avoid the contradictions and redundancies in the regulation text.

Table 1. CBEC commodities and national regulations.

CBEC commodities	Applicable national regulations
Nutricia period 1 newbom infants original binding free trade zone Netherlands imported milk powder period one Nutrilon 1 direct mail Nutrilon	GB 10765—2010 National food safety standard Infant formula Include: milk-based infant formula food
Native Netherlands Nutricia period 1 Nutrilon imported infant Nutricia milk powder period one 0-6 months purchasable period 2 period 3	GB 10767—2010 National food safety standard Older infants and young children formula

CBEC commodities	Applicable national regulations
[Combination] Gerber new product period 2 rice cereal combination (apple banana + wholewheat + peach + sweet potato) 227 g * 4	GB 10769—2010 National food safety standard Cereal-based complementary foods for infants and young children

2.2. System architecture

The overall process of knowledge-based CBEC commodity risk assessment is shown in Figure 1. There are totally 9 steps in the process. The operations performed in each step are listed below.

1. CBEC websites identification: To include the websites selling or commentating CBEC commodities into the risk assessment scope.
2. Web crawling: Using computer programs to access the CBEC websites and download the webpages describing the commodities being sold.
3. Commodity information extraction: To parse the downloaded webpages and extract commodity names, brands, producing areas, ingredients and other descriptive information.
4. Regulation collection: To include the regulations relevant for assessing the risks of CBEC commodities into the system scope.
5. Knowledge acquisition: To transform the textual rules in the regulations into a computer operable form which can be used by the inference engine.
6. Commodity classification: To classify the CBEC commodities into the kinds of products defined in the official regulations.
7. Rule base maintenance: To store the rules acquired from the regulations into the rule base and make sure the rule base is free of contradictions.
8. Rule inference: To infer the commodity risk types and factors using the rules in the rule base and the commodity information.
9. Risk assessment: To combine the risk factors and obtain the overall risk level of CBEC commodities.

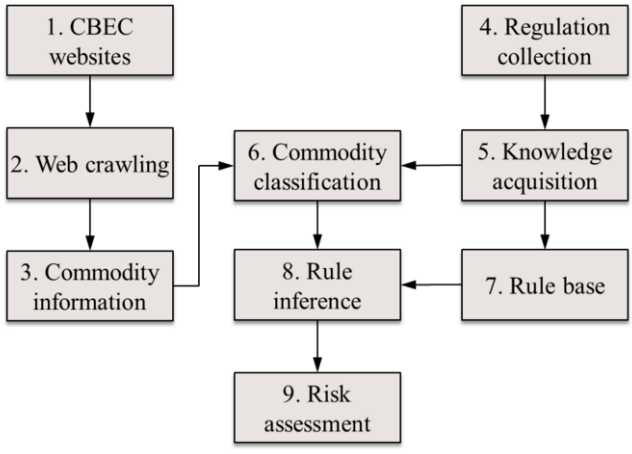


Figure 1. Process of knowledge-based CBEC commodity risk assessment.

3. CBEC commodity classification

3.1. Short text classification

The CBEC commodity names are very short text ranging from 10 to 30 Chinese characters. For this type of texts, it is difficult to use word frequency-based features to represent them and classify them [10]. For short text classification, Bobicev and Sokolova (2008) used the prediction by partial matching (PPM) method which consisted of training a language model for each class of texts and examining the cross-entropy of a previously unseen text regarding each text class model [11]. Sun (2012) proposed a simple, scalable, and non-parametric approach for short text classification. He first selected the most representative and topical-indicative words from a given short text as query words, and then searched for a small set of labeled short texts best matching the query words. The predicted category label was the majority vote of the search results [12]. Although these methods are effective, they require labeled texts for training, which are not available in our context.

3.2. Proposed Method

In our case of text classification, the class labels are the product types defined in the regulations. Each class is associated with an official name and a paragraph of definition. Since initially there are no commodities classified according to the regulations, supervised training cannot be performed. So in this paper we adopt a two-stage method to do unsupervised classification. The first stage is to extract keywords from the original names of CBEC commodities, which reflect the types and features of the commodities in terms of popular words. In the second stage, the extracted keywords are compared with the official class names as well as the class definitions, so as to determine which class a commodity most likely to belong to.

The first stage, namely the keyword extraction, will be accomplished using the TextRank method [13]. TextRank is a graph-based, unsupervised method for text ranking, and the text segments ranked high considering the importance score can be selected as the key words/phrases/sentences. In our context, let $G=(V,E)$ be a undirected graph with the set of vertices V denoting the Chinese words appearing in the commodity names, and the set of edges E being a subset of $V\times V$. For a given vertex V_i, let $Cn(V_i)$ be the set of vertices that connect to it, then the importance score of vertex V_i is defined as follows:

$$S(V_i) = (1-d) + d * \sum_{j \in Cn(V_i)} \frac{1}{|Cn(V_j)|} S(V_j) \tag{1}$$

where d is a damping factor that is uaually set to 0.85 [13]. Two vertices are connected if their corresponding words co-occur within a window of 2 words. The initial score associated with each vertex is set to 1, and the convergence threshold for the iterative computation of scores is set to 0.0001.

The second stage of commodity classification is performed by assessing the semantic relatedness between the extracted keywords and the official class definitions (including the class names). To measure the semantic relatedness between two words, one way is to use semantic dictionary such as the WordNet, and another way is to use

the statistical information about the words, for example, the pointwise mutual information (PMI) [14]:

$$PMI(w,w') = \log \frac{p(w,w')}{p(w)p(w')} \tag{2}$$

where $p(w)$ is the proportion of text pieces in the corpus that contain word w, and $p(w, w')$ is the proportion of text pieces containing both words w and w'. Due to the unavailability of a complete Chinese semantic dictionary, in this paper we use the *PMI* to measure the semantic relatedness between the commodity names and class definitions. To do this the following equation is used:

$$R(name,class) = \sum_{w \in name} S(w) * \max_{w' \in class} PMI(w,w') \tag{3}$$

where $S(w)$ is the importance score of word w. For each commodity name only the three most important keywords are kept for computing the relatedness score R.

4. CBEC risk knowledge acquisition

4.1. Knowledge representation

We use production rules to represent the knowledge for assessing CBEC commodity risks. This decision is made based on two considerations. Frist, the content of regulations is naturally written as rule like text, for example, the sentence "milk-based infant formula food cannot contain fructose" can be transformed into production rule "If x is milk-based infant formula food and x contains fructose > 0mg/kJ; Then x has fructose risk". Second, there are many commercial and open source rule engines capable of inferring with the production rules. In this paper we use the Drools software package to carry out rule inference, so the rules are represented according to Drools's requirements.

4.2. Knowledge acquisition interface

Although the production rules are easy to read by human, it is not easy for non-computer experts to write Drools rules directly. To deal with this problem we develop a visualized knowledge acquisition interface with which people can write computer readable rules by simply typing or selecting concepts represented in natural language vocabulary.

4.3. Knowledge consistency check

To avoid introducing contradictive rules often caused by typing errors or inconsistent source information, we take two measures to maintain the consistent state of the knowledge base. The first is to use only two types of consequences for the production rules, which are the "has * feature" consequences and the "has risk" consequence. As there are no negatives included in the feature expression, and the feature expressions

are not reasoned with antonyms, the instances of the above consequences will never contradict each other. The second measure is to check the mathematical part of any rules that have the same expression except the mathematical portion. For example, the rule "If x is milk-based infant formula food and x contains fructose > 0mg/kJ; Then x has fructose risk" contradicts with the rule "If x is milk-based infant formula food and x contains fructose > 5mg/kJ; Then x has fructose risk", which can be identified by recognizing the difference between ">0mg/kJ" and ">5mg/kJ". As most rules acquired from the national regulations take on the form like in the above example, this check method appears to be effective in application.

5. Case study

To evaluate the proposed methods, we implement them in the environment of a real commodity risk assessment system. The commodity names previously collected by the system are used as the corpus for computing $S(V_i)$ and PMI. From the total 86435 commodity names, we choose 400 food names and 400 electrical appliance names to test the classification performance in terms of precision and recall. The comparative method is the manual feature selection method originally adopted by the risk assessment system.

Table 2. Precision and recall of commodity classification

Method	Precision		Recall	
	Food	Electrical appliances	Food	Electrical appliances
Manual feature selection	71.2%	82.3%	76.5%	90.2%
Proposed method	63.6%	73.9%	66.1	77.8%

From Table 2 we can see that manual commodity classification has higher precision and recall scores than the proposed method which is an automatic one. This is easy to understand since the manually selected commodity features reflect the experience and insights of human experts. For example, the "period" feature is a very informative feature for the commodity type "infant and young children formula food". While human experts can directly relate "period 1" with "infant formula food" to ensure an accurate classification, the automatic method has to learn such relatedness by counting the co-occurrence of the two phrases, which is not as reliable as human experience. Nevertheless, the proposed method has achieved similar performance with manual method but uses much shorter time. When there are too many regulations and commodity names to compare, such as in the case of CBEC, automatic commodity classification becomes the only solution. In the future, by using more advanced machine learning techniques and drawing upon the accumulated correct classification result as training samples, the accuracy of automatic commodity classification will continue to improve and eventually reach the human level.

6. Conclusion

In this paper we studied two important aspects of the knowledge-based CBEC risk assessment, namely the commodity classification and knowledge acquisition. By

extracting keywords from the commodity names and comparing them with the national regulations, the diversely named CBEC commodities are classified regarding their official types and therefore can be assessed using the regulation content. The knowledge acquisition phase accomplishes the transformation of regulation content into machine readable rules, which enables the use of rule-based reasoning to infer the risk types and level of CBEC commodities. The proposed methods are integrated into a working CBEC risk assessment system and experiments with real data show that the proposed methods can improve the automation and intelligence level of CBEC risk assessment.

Acknowledgement

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Domain Risks Management in Software Products Lines Projects

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Abstract. The domain model represents the knowledge for the planning of a project, for the definition of requirements and the construction of the logical model of a solution, in the field of software or in any other. The development of products lines requires to dispose earlier more complete domain knowledge than that for the development of individual software products. Indeed, it is necessary to consider just at the beginning the domain variability and components reuse in an ample family of products, as well as, the initial investments for this change of development paradigm. The three project risk categories more recognized in the PERIL data base (Project Experienced Risks Information Library): *Scope*, *schedule* and *resources* are aspects whose management in the products lines approach require more rapid and comprehensive treatment of the domain knowledge. In order to attend this high exigency and risks in managing of domain knowledge, this research proposes a defect-based risks model combined with a set of generic radical and moderate solutions, applicable to any project phase or to the whole project. The proposed solution covers from risks identification to the formulation of preventive, corrective and mitigation controls. The not consideration of some load cases in a structural analysis in a civil engineering project illustrates the application these different types of controls.

Keywords. Domain Risks, Defect-Based Risk Model, Products Lines Risks, Products Lines Domain Risks

Introduction

In software development projects it is recognized that more than 50% of defects and costs in the lifecycle of software products comes from insufficiencies in elicited requirements. Our research in Software Product Lines pays special attention to the definition and analysis phases of software project, the earliest life-cycle phases of software products.

In the definition phase of any project, two central aspects are considered: From one hand, the essential knowledge that will be managed by the solution to be constructed in this project. From another hand, the identification of agents interested in any lifecycle phase of the solution. An agent is an object responsible for an Intervention (action or interaction). The agents their actions and interactions, the means and circumstances of their interventions constitute the context where the domain knowledge acquire meaning and value. The essential knowledge managed by the solution enables the actions and

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interactions of interested agents using that knowledge for satisfying their individual or collective objectives. A domain model represents interrelated conceptual knowledge associated to tangible and intangible objects identified in the real world. Software systems are solutions whose functions treat the domain knowledge required by interested agents.

In software engineering, the knowledge associated to interrelated products, services, and objects is represented in the domain model used in methodologies for the development of Information and knowledge systems. *Domain*, is the real or imaginary field on which system and their interested agents, from different contexts, intervene aiming to satisfy specific objectives. An agent is an object responsible for individual actions or interactions

In traditional software systems development, domain models may be classified in a general way in two categories: information representation-based models and data processing-oriented models. Data processing Models, developed by Constantine [1] and Ross [2], correspond to classical approaches, which use the Data Flow Diagram (DFD) as their system conceptual model. Requirements elicitation is based on low abstraction levels of the DFD, combining domain and context concepts.

In the category of representation-based models appears two sub-categories: Hierarchical Information Structures and Graphs of Information Structures. The last one contains Entity-Relationship Diagrams, developed by Chen [3], classes graphs treated - among others- by Shlaer and Mellor [4], Booch [5]; and Frames created by Minsky [6]. The Hierarchical Information Structures gathers Domain Ontologies, the Structure of Domain Services and Objects (SDSO), Features Models and Goals and Characteristics Model. The last two are domain models oriented to Products Lines development. Features model, created in Carnegie Melon University, [7], is a simple and expressive model widely used for considering big sets of interrelated and high variability, in the Product Lines development. This approach involves earlier and wider management of the domain knowledge, than the traditional methods for individual software development.

This high exigency in the domain modelling requires higher initial investments in the definition phase of the project and in the risks management.

A crucial aspect in project development is the risk management. Some projects risks management methods are related to the project life cycle described in the body of Knowledge for the project management PMBOK [8]. Many methods have been elaborated for affront risks in Software Product Lines projects [9-13]. In general these methods are circumscribed to defined risks categories and factors and they are no flexible for including other categories and factors belonging to processes of any lifecycle phase. Some methods are inspired or validated in the database PERIL, the acronym in English for Project Experienced Risks Information Library. Similarly, some classifications have emerged from risks documented in the referenced database. For example, one of these methods [14], reproduces the three projects risks categories consider in PERIL: risks in determining project scope, risks associated with resource management, and risks associated to the project schedule. Each of these categories have assigned factors, which have been validated in PERIL. For example, the risk category *scope* considers two factors: *changes* and *defects*. The factor *changes* of the scope may be required, for different reasons, and *defects* may have occurred in determining the scope. Both factors, *Changes* and *Defects*, and other project risk categories and factors considered in other methods are covered by our model.

In our research, we introduce an adaptable defect-based risk model applicable in the lifecycle phases. The proposed defect-based risk uses cause-effect diagrams and generic radical and moderate agents' interventions on one object, related to its evolution, [15], in order to complete the risk analysis and formulate preventive, corrective and mitigation controls.

The Sections of this article have the following contents: After Introduction, Section 1 presents the Products Lines lifecycle. The proposed Defect-Based Risk Method for Product Lines projects is described in Section 2. The formulation of problems and Solutions is the subject of Section 3. Conclusion and Future Work appear in Section 4.

1. Product Lines Lifecycle

A simplified view of SPL lifecycle, in Figure 1, contains four modules: Domain Modelling, Assets Modelling, Products Configuration, and Products Assembling.

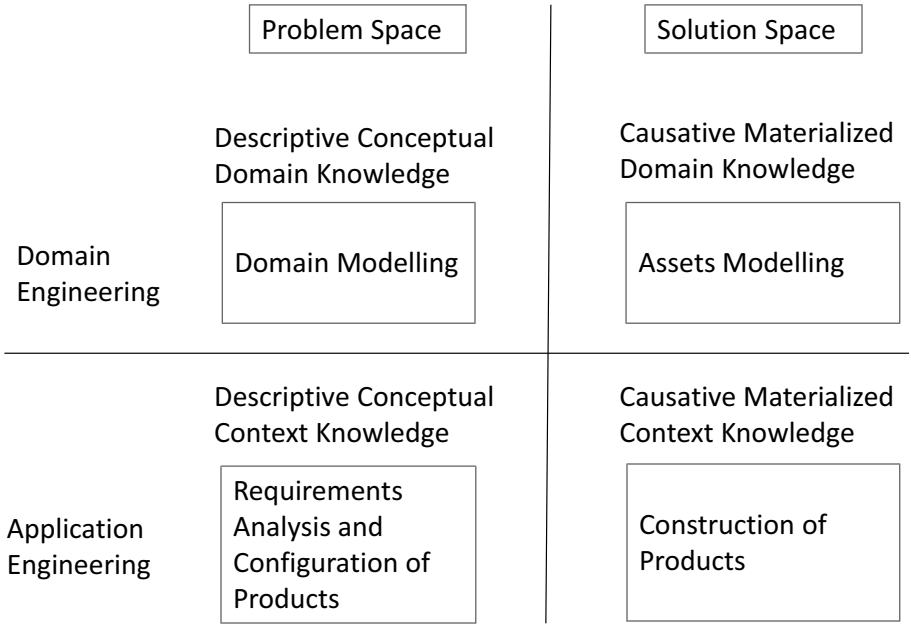


Figure 1. Simplified Lifecycle of Products Lines

Two levels are recognized in SPL development: Domain Engineering and Application Engineering, in Figure 1. The first one considers the Domain Modelling and Assets Modelling. The second one covers, in turn, two phases: Requirements Analysis and Configuration of Products, and Construction of Products. In a vertical view, Domain Modelling, Requirements Analysis and Configuration of Products belong to the Problem Space. Whilst, the Solution Space encloses the Assets Modelling and the Construction of Products.

Next Section introduces a short overview of risk methods applicable in SPL.

2. Defect-Based Risk Management Method for Products Lines

The project risk management searches to contribute to the achievement of organizational and project objectives. Many existing risk management methods are applicable to whole projects and to any phase of the project life cycle. This characteristic enables the extension of those general risk management methods to software Products Lines.

Kendrick [14] follows the PERIL data base classification, which group project risks into three categories: *risks in determining project scope*, *risks associated with resource management*, and *risks associated to the project schedule*. The category projects *Scope* represents the third part of data reported in the data base, but this category causes the half of the impacts on the completion date of projects. The amount of projects and the diversity of risks categories collected in PERIL data base constitute a robust platform for the validation of our risk management method, proposed in this article. *Scope* category considers two factors: *changes* and *defects*. The factor *changes of the scope* may be required, by different reasons in the project life cycle, while *defects* may have occurred in determining the *scope*.

The risk category *project schedule* considers the following factors: *dependence on legal, regulatory and technical aspects*; *dependence on other projects*, *underestimation of the complexity* and *specialization of the project*; *imprecise estimates of durations*, *failures in analysis and definition of processes of the life cycle*, *delayed decision-making*, *delays due to the non-availability of information* and *the unavailability of materials and technical resources*. The category *management of resources* takes into account three factors: *people*, *supplies from suppliers*, and *financial resources*. In turn, the most influential factors in relation to the factor *people* correspond to: *effective participation in the tasks of the project*, *permanent or temporary disengagement of the project*, *inactivity due to bottlenecks*. The factor *Supplies* takes into account the factor delays related to *hiring and deliveries*.

The above categories and factors represent types of risks in projects and are applicable in one or all phases of a software products line project.

Our proposal refers the products lines projects risks to particular categories of defects in each phase of the life cycle. The first phase, named definition phase is characterized by the domain model, which is in this article represented by a Features Model. For this one, in Table 1, appear four defects categories applicable to the first phase: *defects in features*, *defects in relationships*, *defects in restrictions*, and *defects in the model*. For each category four subcategories are considered. The category *Defects in Features* contains the subcategories *denomination*, *decomposition*, *essence*, and *representation*. *Defects in Relationships* has the subcategories *identity*, *function*, *cardinality*, and *origin and destination*. For *Defects in Restrictions* the subcategories are: *consistence*, *operation meaning* and *pertinence*. The subcategories, *representation*, *correction*, *expression*, and *concision* belong to the risk category *Defects in the Model*.

Table 1. Defect-Based Risk Categories for a Domain Feature Model.

DEFECTS-BASED RISKS IN A DOMAIN MODEL REPRESENTED AS A FEATURES MODEL			
DEFECTS IN THE FEATURES	DEFECTS IN THE RELATIONSHIPS	DEFECTS IN THE RESTRICTIONS	DEFECTS IN THE MODEL
DENOMINATION	IDENTITY	CONSISTENCE	REPRESENTATION
DESCOMPOSITION	FUNCTION	OPERATION	CORRRECTION
ESSENCE	CARDINALITY	MEANING	EXPRESSION
REPRESENTATION	ORIGIN AND DESTINATION	PERTINENCE	CONCISION

The three defects categories considered in PERIL data base *scope*, the *schedule* and the *resources* are applicable in each projects life cycle phase. For the whole project, beginning from scratch these project categories are defined in the analysis phase, after the definition phase, of the product (solution). In products lines projects the risk associated to those categories are technically defined in the definition phase, given the early and high exigency of products lines projects for managing the domain knowledge. One result of the definition phase is the domain model, in this case the feature model.

In the Products Line approach, the definition of the project *scope* need*s* be early and rigorously defined due to a higher exigence of *expressiveness* and *correctness* of the domain model. The definition of *scop*e in products lines projects is determined by the *essence* and *decomposition* of the domain features, Table 1. This two risk subcategories support the Relationships subcategories *function* and *cardinality*, which determine *resources*, the second PERIL risk category. The nature *operative* and the *meaningfulness* of restrictions determine the *schedule* category of PERIL. *Operation* and *Mining* belonging to the risks category restrictions are supported by *essence* and *decomposition* of the risks category features, and the subcategories *function* and *cardinality* of the category relationships. *Essence* and *decomposition* of the domain features, *function* and *cardinality* of relationships, and *operation* and *Mining* of restrictions contribute to the *expressiveness* and *correctness* of the features model, in Table 1.

A cause-effect model applicable to each risk subcategory of the risk model, in Table1, supplements the proposed defect-based risks model. The cause-effect model for the risk subcategory *essence* is represented in Figure 1, which starts with a problem (Effect) *Absence of the essence of features*, referred to the essence of a *feature* represented in the feature model. Reflexing on causes of the problem *Absence of the essence of feature*, four big causes are identified: *Incorrect definition of the essence concept*, *Incorrect management of the essence of features*, *Incorrect Identification of the essence of feature*s and *Loss of essence of features*. Reflexing on each one of these big causes, considered as problems may in turn lead to discovering their causes. These ones considered as problems let find, in turn, their causes, and so successively. Thus, ten problems subordinated to the four initial identified problems appear in Figure 1. Reflexing in this way more problems could be identified. Problems are materialized risks. A risks is the probability of occurrence of problem. Preventive, corrective, and mitigation control face the problems.

The identified problems, in Figure 1, related to the risk category essence, are:

1-Incorrect definition of the essence concept

1.1 Misunderstanding of the essence concept, and its applications

1.2 Lacking of knowledge about essence

2-*Incorrect management of the essence of features*
2.1 Inexactness or ambiguity of the essence of a feature
2.2 Absence of essence of features at the start of a Project
2.3 Feature introduced late to the project
2.4 Incompatibility of the essence of feature
3-*Incorrect Identification of the essence of features*
3.1 Permanent or temporary misunderstanding of the essence of features
3.2 Incomplete identification of the essence of features at the start of a Project
4-*Loss of the essence of features*
4.1 Changes in the consideration of the essence of features
4.2 Evolution or mutation of the essence of features in the project life cycle

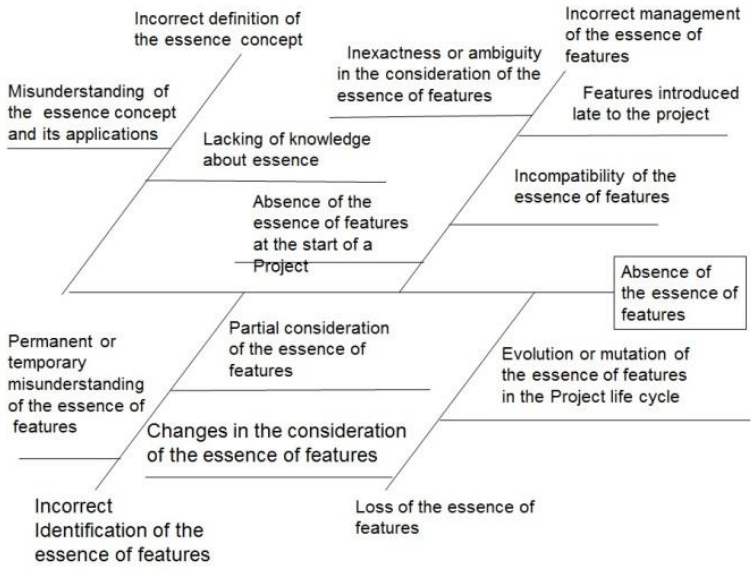


Figure 1. Problems related to essentiality of features.

These problems are, in turn, a rich set of reflexing factors aiming at identifying the maximum of risk possibilities in software products. The materialization of a risk is a problem.

In this work the focus is on the feature model (domain model), but for the other life cycle phases, risks categories based on the defects of the particular elements of each phase, are defined. In the same way like in the feature model, in all life cycle phases, problems are the materializations of risks. The application of radical and moderate solutions controls those problems, as it will be explained in Section 3.

For explaining the covering of the proposed risks model are considered the risk factors changes and defects, included in the scope category of PERIL database. There, the three following aspects determine the changes factor:
1-Requirements that evolve and mutate as a project runs.
2-Specifications or activities added late to the project.
3-Inputs or other needs of the project not anticipated at the start of a project.

Our method covers the problematic aspects experienced in projects development with different risks management methods, documented in PERIL database. For

example, the three mentioned aspects, related to the factor *changes*, receive directly influence from elements of the features model (domain model), in particular from the *features*. In fact, the problems depicted in Figure 1, *Incomplete identification of the essence of features at the start of a Project* subordinated to the problem *Incorrect Identification of the essence of feature*, subordinated, in turn, to the main problem *Absence of the essence of features* determine in a high measure these aspects.

For example, in a structural analysis in a civil engineering products line project, we treat the main problem *Absence of the essence of features*, in Figure 2, and in particular, the sub-ordinate problem *Incorrect Identification of the essence of features*, and more explicitly *Incomplete identification of the essence of features at the start of a Project*. This problem meets the third aspect *Inputs or other needs of the project not anticipated at the start of a project*. This aspect corresponds to the just before mentioned factor *change,* in the risks category *project scope* included in the PERIL database.

Thus, problems and subordinated problems considered in our method and the corresponding category, factor and aspects, in PERIL, cover the risk and derivate problem *Some Analysis of particular models (load cases), are not considered in the features models*. *Analysis of Particular models* is subordinated to *Structural analysis model* in Figure 2. *Load cases* are a feature related to the feature *Analysis of Particular Models*, with a mandatory relationship. These subjects were introduced in [16].

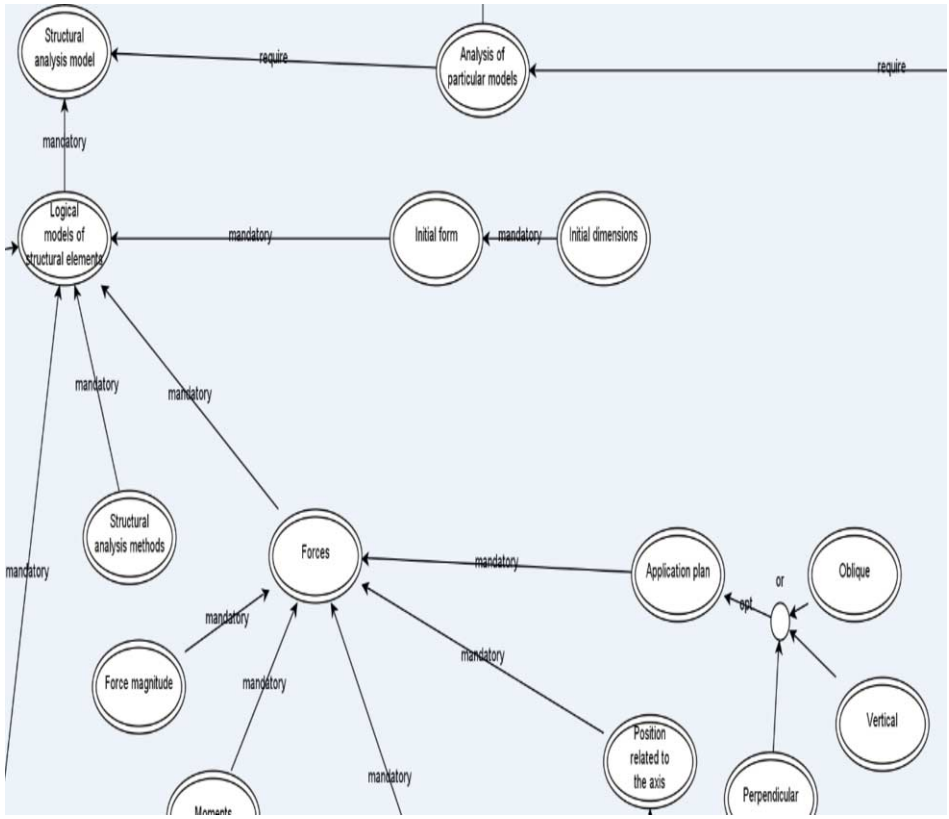


Figure 2. Extract of Structural analysis Model.

The influence of the other domain problems referred to relationships, restrictions, and the feature model are considered in our research, but they are not included here for sake of space. In fact, our work includes, in the four aspect-based risks categories depicted in Table 1, all aspects of the factors considered in the risks categories of the PERL data base. The dominant participation of the element *feature* is enough for illustrating the covering of the proposed risk model.

Next Section introduces the problems and solutions including the formulation and application of preventive, corrective and mitigation controls.

3. Formulation of Problems and Solutions

Problems identified in cause-effect diagrams, as in Figure 1, for risk categories listed in Table1may be solved with radical or moderate agents' interventions depicted in Table 2. In this work, we are considering only the definition phase, but in a similar way, we have been established defect categories for the other life cycle phases. The radical and moderate solutions, applicable in every phase, correspond to corrections identified in the evolution of an object (solution). The three radical solutions are *Aggregation*, *Substitution*, and *Elimination*; and the eight moderate solutions: *Reparation*, *Adaptation*, *Strengthening*, *Maintenance*, *Modification*, *Correction*, *Updating*, and *Recovering*.

In this way, a diversity of Risks and problems appear in the reflexion on the defects-based risk categories of the Table 1 and then, disaggregating them using the cause-effect diagrams. Radical and moderate solutions, in Table 2, may be applied in order to solve these problems. The proposed solutions are valid for problems surged from any element in any life cycle phase. These solutions correspond to agents' interventions considered in the evolution of an object [17][18].

Table 2. Radical and Moderate solutions.

RADICAL AGENTS' INTERVENTIONS ON THE OBJECT (RADICAL SOLUTIONS)	MODERATE AGENTS' INTERVENTIONS ON THE OBJECT(MODERATE SOLUTIONS)
AGGREGATION	REPARATION
SUBSTITUTION	ADAPTATION
ELIMINATION	STRENGTHENING
	MAINTAINANCE (REVISION, CONSERVATION-ADJUSTMENT, PROVISION, SUPPORT, ATTENTION)
	MODIFICATION
	CORRECTION
	UPDATING
	RECOVERING

Figure 3 illustrates the formulation of preventive, corrective and mitigation measures for facing the enounced problem *Some load cases are not considered in the features model*. The negative impact *Delay on the completion date of projects*, caused by this problem is controlled by the adopted measures.

The application of controls in order to the problem some load cases are not considered in the features model is illustrated using the radical measure *Aggregation*. In this example we adopt *preventive*, *corrective* and *mitigation controls* thinking at the aggregation of one or several elements in order to prevent correct or mitigate the negative impact on the *project scope*.

Domain Modelling for a Produt Line of Civil Structures Services			
Feature n: Services of Analysis of Particular Models Problem: Some load cases are not consider in the features models. Load cases is related to the Feature n with a mandatory relationship Impact: Delay on the completion date of projects			
Categories of Radical Change: Aggregation	**Solutions**		
	Preventive Controls	**Corrective Controls**	**Mitigation Control**
Agregation of one or several elements in order to prevent, correct, or mitigate the negative impacts on the *Project Scope*	Introduce specilized software for checking the testing plan as a basic technical resource. Contract a technical reviwer for the structural analysis	Add in the analysis phase experienced human resources looking for reuse the analysis of load cases of other projects Add human resources in the design phase in order to compensate the time lost in the strucutral analysys	Provide more detalied structural plans and graphical documentation offer additional technical support for the construction process

Figure 3. Problems and controls.

4. Conclusion and Future Work

The objects and their associated knowledge, involved in the construction of the solution related to risks management throughout the projects phases, belong to the domain model of that solution. This representative and expressive domain model constitutes the base for establishing the *project scope*.

In software products lines, the domain model, in this case the features model, introduces essential knowledge for the requirements identification and products configuration earlier than in the development of individual software products. This advance of knowledge is due to the consideration of features variability and commonality; influencing in this way, more directly on the determination of the *project schedule* and r*esources* categories, considered in the PERIL database.

The proposed risks model focus on defects categories for each project phase. The present work referees the explanation and application of the proposed risks model to the four elements of the domain model: features, relationships, restrictions, and the whole model.

Ongoing works extend the defect-based risk model to a process-centred risks model considering the quality features associated to defects in the project life cycle phases. Other works may combine the defect-based risks model with generic problems and risks controls, related to the life cycle phases. A comparative analysis of these risks method and the validation against PERIL database risks categories is an important contribution to the project risk management.

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Part 3

Product Innovation and Marketing Management

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Transdisciplinary Engineering: A Paradigm Shift
C. Chen et al. (Eds.)

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An Exploratory User Study on a New Social Networking Communication Application

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Abstract. This paper presents the results of an exploratory study designed to evaluate Deja, a new mobile application that combined communication and social networking functions. The underlying question of this study is sought to understand how young users, accustomed to using this app, to communicate with friends and conduct other social networking activities. The app was empirically tested by a group of selected participants in Singapore. Multiple ways to collect consumer data were conducted including think aloud, observation, usability tasks, customer satisfaction survey as well as customer behavioral survey. An analysis of the problems experienced by the users was discussed. The results also provided the basis to suggest specific improvements to the application. Beyond the enhancement of the user experience design, the results of this study have significant theoretical and practical implications for enterprise to study young user behavior toward new mobile applications, especially communication and social networking applications.

Keywords. Mobile applications, user behavior, new product design, user experience

Introduction

Use of smart phone is becoming increasingly popular in Singapore [1]. As the penetration of mobile phones in societies increases, there is a large growth in the use of mobile phones [2-3]. Applications, which combined the social networking function of Social Networking Service (SNS) application and the communication function of (Instant Messaging(IM) application, become a new trend in mobile application industry [4-6]. New launch mobile apps such as Line, WeChat gained extremely popular in Southeast Asia countries, especially, Thailand and Japan [7-8]. Among them, young users are a dominated segment in using these apps. According to a latest report, young users (aged from 18-24) are the most active group in using SNS applications [9].

The underlying question of this study is sought to understand how young users (aged between 18 and 24), accustomed to using this app, to communicate with friends and conduct other social networking activities. This study has two objectives. First, this study attempts to find the actual young user behavior in using mobile apps. This may help companies better understanding young users' behaviors, and provide supplementary information about young users' characteristics when doing customer

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segmentation and targeting. Second, we examine the effectiveness and outcomes of different roles of both structured and unstructured methods in young user study for product enhancement. To achieve this goal, this study conducted an exploratory user study to evaluate the usability and user experience of this Deja App. An analysis of the problems experienced by the users provided the basis to suggest specific improvements to the application. Beyond the enhancement of the product design, this study also investigated the theoretical and practical implications on young user behavior toward new mobile applications, especially communication and social networking applications.

The rest of the paper is organized as follows. The next section is the research methodology. Section 3 discusses the results and findings as well as their implications for research and practice. The last section concludes the paper and identifies its limitations for future research.

1. Research Methodology

1.1. Participant selection

Empirical data for this study was collected via a combined user study with different methods including usability testing, thinking aloud method, observation, and customer survey. Participants aged from 18 years to 24 years old were invited to gather data. These participants were smart phone users with more than 1 years' experience in using similar social communication app. Participants were asked to conduct the different method to a new developed social networking app. The whole process for each participant was recorded and observed by investigators in long distance at the same time. A voucher of S$50 was given to the participant at the end of the user study.

1.2. Combination methods on user study

A combination of open, semi-open and close methods was conducted for this user study. Participants were put in a high fidelity simulated experiment environment, investigators and user experience experts were only allowed to observe user behavior from long distance. During the open playing around session, participants were not allowed to be interrupted. And they were just put in a comfortable environment to explore freely with the apps. Participants were observed and asked to thinking aloud during this session, a follow-up usability testing was conducted later to collect information more specifically. Before the end of the user study, a questionnaire survey was required to fill in with basic information. Data were analyzed independently by investigators not involved in data collection. Analysis involved identification of action points with comparison of number and type of results identified with each of the four data collection techniques.

The structural usability testing was conducted with fixed tasks prepared earlier. It aimed to check the product design from user experience and human factors perspective. Success, failure rate and time duration was calculated for each task.

When the customer survey was conducted, users were also asked about their usage behavior and attitude towards the app. Investigators also raised questions based on the observation. These questions were changed case-by-case depends on the specific user behaviors. All these questions are marketing related and help companies to make

marketing strategies for this segment. Examples of questions raised during this session are shown in Table 1.

Table 1. Examples of interview questions.

No.	Examples of Interview Questions
1.	"How do you like the design of the smileys?"
2.	"Why do you ignore the "stories" cell under social?"
3.	"Why do you try to swipe when viewing the photos?"
4.	"Why do you skip the user guide?"
5.	"How do you find the entrance to customize your smileys?"
6.	"How do you think the 'clear chat history'?"

2. Results & Discussions

2.1. Data analysis

Data was analyzed from investigators and user experience experts in this study. Results of user behavior from Singapore young mobile user (Table 2), selected high quality inputs for product enhancement (Table 3) and problem shooting (Table 4) were identified and put into action points.

Table 2. Results from Singapore young mobile user behavior.

No.	Description
1.	User tutorial and guide is intrusive to young users.
2.	Singapore young mobile users prefer to separate communication and social networking in different applications.
3.	Singapore young mobile users tend to be impacted significantly by peers to discover new things.
4.	Singapore young mobile users don't accept very cute and stylish design.
5.	Singapore young mobile users show high loyalty to an IM and SNS applications.
6.	Singapore young mobile users tend to express themselves in a more brave way.
7.	Singapore young mobile users prefer social media marketing channels instead of traditional channels such as TV Ads, Radio and direct sales.
8.	Singapore young mobile users prefer the way of viral marketing and word-of-month from peers.

Table 3. Enhancement points.

No.	Action Points	Methods
1.	Show overflow menu for all devices	Think Aloud
2.	Improve Android notification settings, e.g., customized notification forms & tunes	Interview
3.	Add "A-Z" bar in name list	Think Aloud
4.	Remove automated user guide	Think Aloud
5.	Remove compulsory button to proceed	Observations

No.	Action Points	Methods
6.	Design more nice looking smileys	Interview
7.	Make entrance for group chat and broadcast visible	Usability Testing
8.	Send multiple photos in chat	Think Aloud
9.	Swipe to view more photos/videos	Observations
10.	Remember recent smileys and smileys	Think Aloud
11.	Smart recommend latest photos taken	Interview

Table 4. Problems identified by users.

No.	Action Points	Methods
1.	Video sending: shouldn't change oriented direction to vertical	Usability Testing
2.	Send location in chat is crushed	Usability Testing
3.	Couldn't add friends in chats tab	Usability Testing
4.	When add a friend to group chat, reminder of "Your friend didn't support." but still succeed to join this friend	Usability Testing
5.	Receive a new message, click to view and find it is still there after viewing	Observation
6.	Read status is not showing	Observation
7.	Video message has "noise"	Usability Testing
8.	Change gender icon didn't change the colors	Observation

2.2. Discussions

These results suggested that a combination of data collection method may help to collect a rich data. Although similar user study is done to collect mobile user data for smart phone applications, we could still see some differences. For example, compared to traditional way of structured task analysis and structural satisfaction survey, think aloud could get better results on potential enhancements as 45.5% of the enhancements are from think aloud. However, usability testing, which is a semi-structural user study method could help us to identify problems which is easily ignored by Quality Assurance (QA) or testers inside the company. And overall, observations are an effective way for both enhancements and problem shooting as it contributed 26.3% of action points in total. Interview session could be a good supplementary for users to recall the missed needs during other sessions with the facilitating and leading from investigators.

Also, many interesting finding are obtained from this user study regarding young user behavior. As several studies have examined the relative importance of tutorials in app design, many empirical studies have provide some evidence that the link between a better design tutorial and the effectiveness in using the apps from ordinary users. This is because the tutorial information could help those users who lack of expertise of using the product to be more confident and properly tutorial or to guide a necessity from classical usability theory by Nielsen (provide clues to users time to time when using the products). In mobile app design disciplines, users' perceptions of a product are to some degree relying on the tutorial page and introduction to this product. Thus, good tutorial

and guide could help users to have better experience when using the app. However, from the results, we could find that young people hate all kinds of tutorials; they are motivated to play around and find information by their own.

Meanwhile, traditional user experience theory also emphasis on the simplicity and efficiency of using product for ordinary users. For most of young users, the social networking has two major functions: communication and social networking. It is assumed that users could fulfill the need for both purpose from one app, the satisfaction could be much higher. While from the user study results, young users in Singapore wants to separate these two purpose and they find it is much simpler for them to manage two different apps at the same time which is quite out of the expectation from investigators and marketing folks.

Another interesting finding is that young mobile users are affected a lot by friends and they are motivated to be in a group. Most of them admitted that they discover or use a new app from friend's recommendation instead of discovering the new app by their own. Meanwhile, they want to express in a brave way that they are willing to try different styles using expected design combinations in the app. Besides, they are asking multiple smileys to better express their personality. It has implications for application designers to make the design

And the most influential media to them is word of mouth and they prefer online media instead of TV ads or traditional press. Young mobile users use Facebook and Google to search and word of mouth from peers, which are the main source for them to accept a new product.

3. Conclusions

The goal of this study is to identify user behavior of young users in Singapore for Social networking and communication app by developing an integrated user study. Our findings suggest that Singapore young users show certain characteristics that matched classic human factors theory regarding user behavior and marketing studies among this young group of customers. However, as this special segment of users also shows certain behaviors violate the classic theory and conclusions. In addition, the usage of social networking and communication on smart phone are different from usage of other apps. Smart phone i.e., iPhone and android plays a major role in determining users behavior toward the emerging apps. And the bond between apps and those young users are stronger than expected.

While our findings make a significant contribution to understand young users' behavior in using social networking and communication apps, there are limitations of this study that should be considered when designing future studies on related topics. Individual differences among participants are not factored into the research model. Second, future studies may consider to enlarge the sample size, for example, to obtain participants from online resource. For this study, all the participants are from Singapore while the usage of this communication and social networking app is worldwide. Future studies on related topics may extend our findings by addressing the limitations.

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The Impact of Online Lottery Promotion on User Acquisition and Engagement

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Abstract. Online lottery promotion during holidays has become an important approach for online communities to attract new users and activate current members. The objective of this study is to empirically examine the influence of an online lottery promotional campaign on user acquisition and user engagement from both short-term and long-term perspectives. The aquired data recorded individual users' daily activities on the mobile application before, during and after the lottery promotional campaign, as well as users' participation in the lottery draw and the awards received. This study found that the online promotion attracted more users to register, activated the registered users during the lottery promotion and the users who won non-virtual prize (monetary prize) will be more active in commenting after the promotion. While in the long run all the users' posting activities slightly decreased after the promotion, the lottery promotional campaign is effective in attracting and activating users in short term period.

Keywords. Online lottery promotion, user acquisition and engagement, logistic regression model.

Introduction

As the development of mobile technology and convenience of Internet services, online promotion has gained increasing popular in the past decade, especially during the events of holiday. Companies held varied promotion campaigns, like lucky draw and online fun quiz. The main purpose of such online promotion is to attract more new users and excite the older users. Consumers who participate in these campaigns could not only strive for monetary benefits but also fulfill their entertainment purpose.

In China, there is a national tradition that the elder would give their blessing to children through monetary motivation (i.e., cash) during Chinese New Year holidays. The cash is usually put into a small red paper bag, called "Red Envelope", and passed from the elder to children to represent luck and fortune. In recent years, the "Red Envelope Battle" among Internet giants such as Tencent, Alibaba, Baidu, and Sina Weibo has gained such spotlights. During the Chinese New Year holidays, hundreds of millions of smartphone users participated in these campaigns

Despite of its popularity, there is much debate on the effectiveness of such online lottery events. One of the major concerns is that new customers attracted solely by the promotional event may not be valuable to the companies, as these customers' engagement may quickly diminish after the promotion. Therefore, this study is to

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empirically examine the influence of an online lottery promotional campaign on user acquisition and user engagement from both short-term and long-term perspectives.

A two-week online lottery promotion campaign had been launched in a popular user-generated content (UGC) mobile application in China with millions of active users during 2016 Chinese New Year holiday. This study obtained user engagement data for a random sample of 23350 users. The users were divided into two different groups based on registration period. One group was formed by 16602 new users who signed up during the promotional campaign, and the other group was formed by 6748 old users who signed up before the promotional campaign.

The rest of the paper is organized as follows. Section 1 reviews and developed the main hypothesis. Section 2 introduces the research context of the online community and the field study. Section 3 analysis the data and presents the empirical model, and the estimation results. Section 4 concludes.

1. Literature review and hypothesis

1.1. Online user engagement

Encouraging user engagement in community activities is the key to the success of online communities [1]. Therefore, motivating participation and building thriving communities are frequently cited central challenges for any online community providers [2]. Two types of online community engagement has been defined in previous study: active members, who post and comment the majority of the content, and passive members, who only browse and take advantage of the benefits offered without contributing to community activities. Both types of activity are needed and reflect the members' level of engagement to the community [3].

1.2. Online promotion

Online promotion is extensively used in the online communities to attract new customers and to activate existing customers [4]. As Smith [5] suggests, UGC within online communities enjoys economy of scale and the impact of UGC increases with the number of community members who can assess it.

In studies on the effect of rewarding and incentives on user engagement, both immaterial and material incentives have been identified as the effective rewards [6, 7, 8]. The idea of using monetary rewards to boost review contribution is grounded in well-known economic and psychological theories. Garnefeld et al. [9] conducted a lab study with members of a German online community and found that a hypothetical monetary reward increased their intention to contribute in the short run, but not in the long run (within three weeks). Undoubtedly, a monetary reward have a positive effect on user engagement. While Henning-Thurau et al. [10] finds that rewards drive review contributions. The online lottery provide various prize, thus it can attract more users to acquire and more active.

1.3. Hypothesis

This logic leads to the following hypothesis:

- H1: The online lottery promotion can attract more new users to participate.
- H2: New users are more active than the old members during the promotion.
- H3: The users who win monetary prize will be more active than users who just win non-monetary prize after the promotion.
- H4: New users' participation activity will go down after the campaign.

2. Methods

2.1. Data collection

This online promotion event is carried out on QiuShiBaiKe, one of the most popular UGC platform in China. Established in 2005, QiuShiBaiKe has over 20 million registered users, with an accumulation of more than 100 million posters and 1 billion user comments since its creation. User engaged with Qiushibaike through different ways. Each registered users of QiuShiBaiKe have their own unique ID and only successful registered users are able to commenting on the post.

QiuShiBaiKe launched a two-week long online lottery promotion campaign during the 2016 Chinese New Year holiday season. Hundreds of millions of smartphone users participated in the online lottery promotion event, which were held by this online platform during Chinese New Year.

The data records individual users' daily activities on the mobile app before, during and after the promotion, as well as users' participation in the lottery draw and the award received. The daily activities include registered date, lottery participation content (the frequency of draw and winning), commenting and posting. The online lottery was from 2/1/2016 to 2/14/2016. A random sample of new users and existing users for a three month period from 1/1 /2016 to 3/31/2016 has been obtained.

2.2. Model building

In order to observe the effect of the promotion on both new users and the existing users, a binary logistic regression model is applied to describe the users' acquisition and engagement behavior in this study.

2.2.1. Model on new users

New users registered between 1/1/2016 and 2/14/2016, and the data of their daily commenting and posting activities starting from 1/1/2016 (or their registration day) to 3/31/2016 were tracked in this study. The logistic regression model for new user is as follows (Table 1).

Table 1. The time period of new users.

	Before	**Promotion**	**After**
Regular Registration	Baseline	Baseline + Promotion	Baseline + After
Promotion Registration	N/A	Baseline + Promotion + RegType	Baseline + After+ RegType+ RegType x After

A binary logistic regression model on new users was proposed in Equation (1).

$$Wit = \alpha + \beta 2Promt + \beta 3Af\,t + \beta 4RegTypej + \beta 5RegTypej*Aft + \beta 6ln(Tenureit) + \beta 7LCPit + \beta 8LCCit + \beta 9Lotteryit + \beta 10Prizeit + \beta 11LOT*Aft + \beta 12PZi*Aft + \beta 13LOTi*Aft*RegTypei + \beta 14PZi*Aft*RegTypej + \varepsilon it \quad (1)$$

1. RegType = 1 if the user was acquired during the lottery campaign; 0 otherwise
2. Promotion = 1 if the time was during the lottery campaign period; 0 otherwise
3. After = 1 if the time was after the lottery campaign period; 0 otherwise
4. Lottery = 1 if the user participant in lottery campaign last week
5. Prize = 1 if the user won a non-virtual prize last week
6. Lot = 1 if the user participant in lottery campaign
7. PZ = 1 if the user won a non-virtual prize during the campaign

2.2.2. Model on existing users

The existing users registered more than half a year ago before the lottery campaign and have been recently active in the community, and the data on of their daily commenting and posting activities starting from 1/1/2016 (or their registration day) to 5/2/2016 were tracked.

Table 2. The time period of existing users.

	Before	**Promotion**	**After**
Existing User	Baseline	Baseline + Promotion	Baseline + After

A binary logistic regression model on existing users was shown in Equation (2).

$$Wit = \alpha + \beta 2Promt + \beta 3Aft + \beta 4ln(Tenureit) + \beta 5LCPit + \beta 6LCCit + B7Lotteryit + \beta 8Prizeit + \beta 9LOT*Aft + \beta 10PZi*Aft + \varepsilon it \quad (2)$$

1. Promotion = 1 if the time was during the lottery campaign period; 0 otherwise
2. After = 1 if the time was after the lottery campaign period; 0 otherwise
3. Lottery = 1 if the user participant in lottery campaign last week;
4. Prize = 1 if the user won a non-virtual prize last week;
5. Lot = 1 if the user participant in lottery campaign;
6. PZ = 1 if the user won a non-virtual prize during the campaign;

After the models were established, all activities data mentioned above were recorded in order to analyses the lottery effect on users.

3. Results & discussions

3.1. Descriptive analysis

This study obtained daily user engagement data for a random sample of 16,602 new users and 6,733 existing users. A descriptive analysis is done on the users' daily activities. The temporal trend of their daily posting and commenting activities have been plotted in Figure1 and 2. As seen, there is a significant upward trend after the

lottery promotion in both daily posting and commenting, which may be due to the increased engagement or enthusiasm after the participation of the lottery campaign.

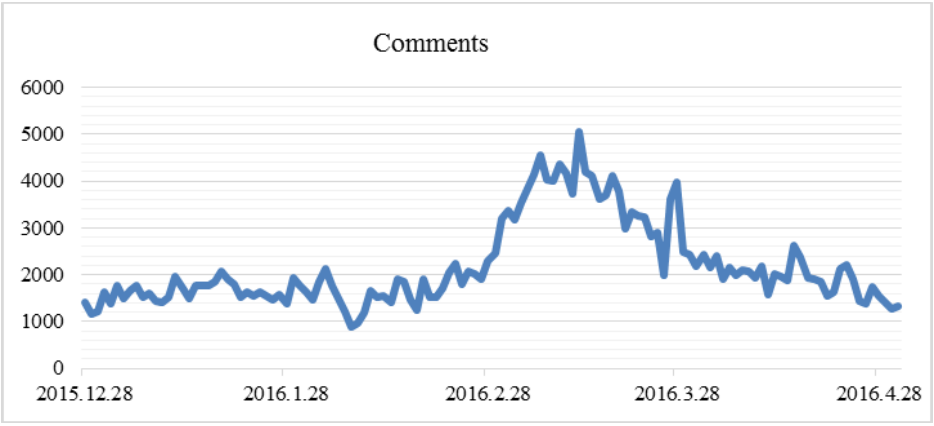


Figure 1. The temporal trend of their daily commenting.

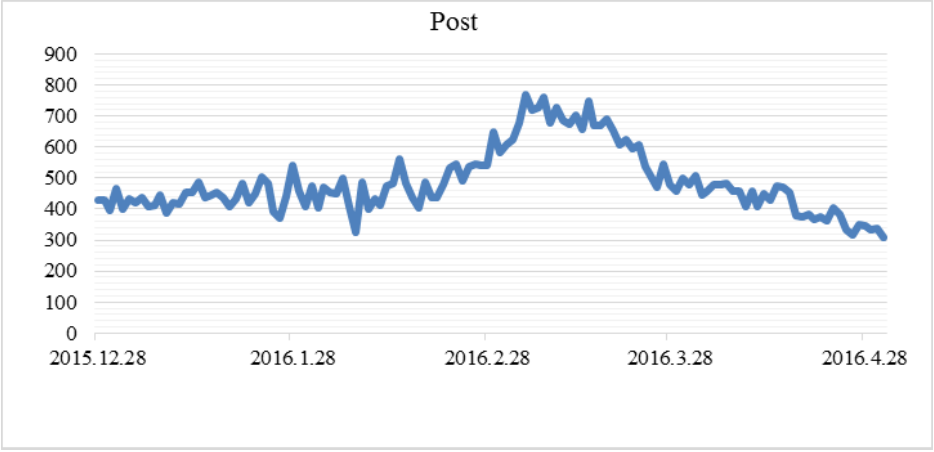


Figure 2. The temporal trend of their daily posting.

Based on the preliminary analysis of new users, the follow patterns have been observed:

- For each user group (i.e., the users who registered on the same date), normally the experiment have before > during > after for all daily activity variables.
- If check the same before > during > after curve across user groups who registered on different dates, observe an increasing pattern: the more recently registered the more active the user is.

These two patterns suggest the existence of a tenure effect or fatigue effect, which should be accounted for in the model. Users who registered during lottery campaign have a higher participation rate in lottery campaign. To model this formally, the user daily level comment and post have been as dependent variables, the before/during/after lottery dummies, the weekday/weekend/holiday dummies, the tenure effect(the days since from the join),maybe fatigue effect (i.e., cumulative lagged activities) as independent variables. To study what factors explain the likelihood a new user

submitted a post or a comment during a week, the experiment also take some other variables into consideration. For example if the user participated in lottery and won a non-virtual prize last week, he will be more active or less active.

3.2. Results from logistic regression

Based on the results from logistic regression, a series of interesting results could be observed in Table 3 and Table 4.

For new users, the users registered during the lottery promotion are more active; but their posting activities significantly went down after the campaign. Lottery participation last week increases the commenting probability next week but decreases the posting probability next week. Winning a non-virtual prize during the campaign significantly increases the commenting and posting probability for new users who registered before the promotion event.

For existing users, during and after the campaign, the average level of activities decreases. Lottery participation last week increases the commenting and posting probability next week. Winning a non-virtual prize last week increases the commenting likelihood next week. Lottery participation increases the posting likelihood after the campaign but decreases the posting likelihood after the campaign. Winning a non-virtual prize during the campaign decreases the posting probability after the campaign.

Table 3. Result of commenting and posting behaviors for new users.

Variables	Commenting		Posting	
	Parameter Estimate	**Significance**	**Parameter Estimate**	**Significance**
RegType	0.584	< 0.001	0.484	< 0.001
Promt	-0.093	0.443	-0.016	0.862
Aft	0.062	0.750	0.224	0.159
RegType×Aft	-0.227	0.282	-0.361	0.862
Lottery	0.091	< 0.001	-0.529	< 0.001
Prize	2.640	0.339	0.121	0.904
LOT×Aft	-0.185	0.378	-0.067	0.707
LOT×Aft×RegType	-0.719	0.506	-0.088	0.679
PZ×Aft	6.182	< 0.001	4.740	< 0.001
PZ×After×RegType	-6.544	< 0.001	0.785	< 0.001
LCC	0.091	< 0.001	0.015	0.005
LCP	0.355	< 0.001	0.785	< 0.001
Ln(Tenure)	-1.186	< 0.001	-1.332	< 0.001
Intercept	-5.461	0.056	-2.674	0.023

Table 4. Result of commenting and posting behaviors for existing users.

Variables	Commenting		Posting	
	Parameter Estimate	Significance	Parameter Estimate	Significance
Promt	-0.106	< 0.001	-0.190	< 0.001
Aft	0.073	< 0.001	0.384	< 0.001
Lottery	0.210	< 0.001	-0.460	< 0.001
Prize	0.327	0.001	0.016	0.890
LOT×Aft	0.171	< 0.001	-0.116	< 0.001
PZ×Aft	< 0.001	0.993	-0.192	< 0.001
LCC	0.030	< 0.001	< 0.001	0.008
LCP	0.009	< 0.001	0.139	< 0.001
Ln(Tenure)	-0.038	0.006	-1.332	< 0.001
Intercept	-1.364	< 0.001	-1.372	< 0.001

4. Conclusions

This study is to examine the effect of online lottery promotion on new users and existing users. The binary logistic regression has been used to explore the factors that can explain the likelihood a new submitted a post or a comment during a week.

Based on the experiment results, this study found that the online promotion actually attract more users to register and the users registered during the lottery promotion is more active. However, their posting activities significantly went down after the campaign. Although the result is not accord with expectation, but some facts can also be explained. During the Chinese New Year holiday, people are busy with make preparations for the festival and visit relatives and friends. Thus, the time they send on the community decrease. After the holidays, they have more time to commenting and posting the experiences about the holidays.

Although this study has made some progress in theory, and have guiding significance for practice, there are still some limitations which should be pointed out. First, the time of online lottery promotion is only two weeks and future research can examine the effectiveness of a longer period. Second, future research can also take more variables such as user characteristics into consideration to make the study more complete.

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A Novel Framework to Achieve Innovative Product Design and Recommendation for Multi-Functional Tablets: A TRIZ Perspective

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Abstract. Recently, the boundaries between smartphones, tablets and ultrabooks are becoming much more blurred than before. To sustain in a fiercely competitive environment, global brand companies start to design multi-functional products to satisfy diverse consumer requirements. For instance, Asus and Lenovo design Padfones (a smartphone inside) and Yoga Pro3 (a micro-projector inside) to enhance visualization of smartphones and tablets, respectively. Meanwhile, Acer, Sony, and Fuji develop varieties of tablets like Padbooks (pad + keyboard) and Padnotes (pad + stylus pen) to enhance keyboard interface. In this study, a TRIZ (theory of inventive problem solving) based framework is presented to analyze these innovative ideas and indicate how innovative solutions tackle the trade-offs between the improving features and the worsening features. Thereafter, rough set theory (RST) is applied to elicit the causalities between user preferences for ergonomic features and demographic variables. Finally, product recommendation w.r.t. the niche segments can be accordingly achieved..

Keywords. TRIZ, rough set, innovative design, recommender system

Introduction

Today, smartphones, tablets, and ultrabooks are facing almost saturating and seriously declining product sales. It reveals that the conventional products in consumer electronics may not effectively capture dynamically changing customer desires because of limited capabilities and poor generalization. For convenience, the key features to characterize the conventional products are briefly described below [1][2][3]. Obviously, ultrabooks excel other alternatives in terms of “system performance”, “screen visualization” and “keyboard interface” while smartphones perform the best in dimensions of “wireless communication” and “portability”. In contrast, tablets tend to demonstrate a more balanced result in terms of the above-mentioned evaluation criteria. To satisfy diverse user groups, seeking a systematic way to design innovative alternatives is of importance to help firms survive in the area of consumer electronics. In the past, manufacturers provided products with high quality, low cost, and at most, courteous after-sale service to satisfy market majorities. Nowadays, for the purpose of

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target marketing, they need to offer customized products or services to fit diverse requirements of the ad-hoc segments [4][5]. In reality, dynamically changing customer desires coupled with rapid technology advances concurrently guide the trends of new product development. Theoretically, it is perfect to configure a product that is superior to competitors' alternatives at all of the dimensions, such as aesthetic attributes, functional capabilities, and ergonomic features. However, due to intrinsic design constraints, the fact that improving features accompanied with worsening features often results in a compromised solution in practice. To overcome the aforementioned difficulties, a TRIZ (theory of inventive problem solving) based framework is presented in this study to design innovative varieties of tablets. In particular, several critical issues are addressed and highlighted as follows:

- How to handle the trade-offs between improving features (i.e. loss of information and ease of operation) and worsening features (i.e. weight, area, and length) in product design?
- How to construct a rule-based decision support system to connect users' demographic variables with their diverse preferences?
- How to incorporate user preferences into the process of product recommendation for acquiring the distinct niche segments?

The rest of this paper is structured as follows. Section 1 briefly reviews the concepts of product innovation and product recommendation. Section 2 introduces the proposed framework. An industrial case study is illustrated in Section 3. Conclusions and future studies are drawn in Section 4.

1. Overview of product innovation and product recommendation

Thus, in developing attractive varieties of tablets, the objective of this study is to present a TRIZ based framework to help brand companies solve two critical problems: (1) innovative product design with consideration of the trade-offs between improving features and worsening characteristics and (2) user-driven product recommendation to acquire diverse requirements of ad-hoc segments.

1.1. Production innovation

TRIZ (theory of inventive problem solving) has been widely applied to the top three areas, such as technical problem solving, product and technology innovation, and technology strategy [6]. A Soviet inventor named Genrich Altshuller, who analyzed over 400,000 patents, developed the TRIZ. It is composed of a contradiction matrix, 39 engineering parameters, and 40 innovative principles. Specifically, TRIZ includes a practical methodology, tool sets, a knowledge base, and model-based technology for generating new ideas to break through conventionally compromised solutions. The entire process of implementing the concept of TRIZ can be summarized as follows: (1) abstraction- converting specific problems into general problems, (2) mapping- finding typical solutions for solving general problems, and (3) concretizing- projecting typical solutions into specific solutions that can be tailored to specific domain problems. In brief, TRIZ presents a systematic framework for analyzing challenging problems where innovation is needed to provide a range of tools for finding innovative solutions. Today,

TRIZ has been widely applied to different problems, including product development [7][8], process improvement [9], service innovation [10][11], and eco-innovative design [12]. Furthermore, some of the aforementioned studies have integrated QFD (quality function deployment) with TRIZ to analyze the interrelationships between customer requirements and engineering characteristics and the conflicts among them [13][14]. Obviously, TRIZ has become a powerful tool for generating inventive principles to solve the trade-offs between an improving feature and a worsening feature.

1.2. Product recommendation

Generally personal recommender systems can be classified into two main categories [15]: content based and collaborative filtering Content based filtering uses textual documents to search for items with contents which are the most similar to users' interests. In contrast, given a database of other users' preferences, collaborative filtering predicts respondents' preferences, which are typically expressed in terms of numerical evaluation scores [16]. Recently, powerful data mining techniques greatly assist companies in constructing personalized recommender systems [17][18]. These methods predict items of interest to one user according to the recommendations of other people who also use the recommender system. For example, a respondent is often asked to give ratings of popular movies or TV programs. Then, the system matches respondents to their close (nearest) neighbors who have already rated these items similarly to achieve recommendation. Despite recommenders' typical benefits, such as increasing the cross-selling probability, consolidating customer loyalties, and attracting prospect customers, usually require a big number of historical purchase database or transaction records to predict customers' future desires and buying intentions [3]. In other words, most conventional schemes conduct product recommendation in a supervised manner. Hence, they are incapable of handling a scenario in which users' buying profiles or interest ratings are insufficient or unavailable [3]. When a new product is initially launched into the market, it is not only difficult but also infeasible to gather sufficient training samples for constructing recommender systems. Various data-mining techniques are used in constructing recommender systems [19] [20].

2. Proposed methodologies

As mentioned before, this study proposes a TRIZ based framework to incorporate user preferences and performance ratings into the process of product design and recommendation. The proposed framework is described as follows: (1) A contradiction matrix originated from the TRIZ is used to seek innovative solutions for tackling the conflicts between improving features and worsening features, (2) RST (rough set theory) is employed to capture user preferences for ergonomic features (i.e. screen size, screen type, keyboard interface, and body color) of multi-functional tablets, (3) Managerial insights are generated to help companies construct a recommender system for acquiring the ad-hoc user groups. Rough set theory (RST) is regarded as a knowledge discovery system because it is powerful in performing feature selection, dimension reduction, decision rule generation and pattern extraction. Suppose an information system is represented by $IS = (U, C, D)$, where U is the universe of finite objects, C and D denote conditional and decision variables, respectively. The

terminologies of RST include lower approximation ($\underline{BX}$), upper approximation ($\overline{BX}$), indiscernibility, positive region ($POS_C(D)$), dependency ($\gamma(C,D)$), significance ($\sigma_{(C,D)}(a)$), core, and reduct. They are defined as:

$$\underline{BX} = \left\{ x_i \in U \middle| [x_i]_{ind(B)} \subset X \right\} \tag{1}$$

$$\overline{BX} = \left\{ x_i \in U \middle| [x_i]_{ind(B)} \cap X \neq 0 \right\} \tag{2}$$

$$POS_C(D) = \bigcup_{X \in U/D} \underline{CX} \tag{3}$$

$$\gamma(C,D) = \frac{|POS_C(D)|}{|U|} \tag{4}$$

$$\sigma_{(C,D)}(a) = \frac{\gamma(C,D) - \gamma(C - \{a\}, D)}{\gamma(C,D)} \tag{5}$$

$$CORE(C) = \cap REDUCT(C) = \bigcap_i B_i \tag{6}$$

$$\gamma(B_i, D) = \frac{|POS_{B_i}(D)|}{|U|} = \gamma(C,D) \tag{7}$$

Basically, the set of lower/upper approximations contain the elements undoubtedly/possibly belonging to the associated set. The positive region of the partition U/D with respect to C, $POS_C(D)$, is the set of all elements of U that can be uniquely classified to the blocks of the partition U/D by using U/C. Hence, the degree of D depending on C can be either full dependency ($\gamma = 1$) or partial dependency ($0 \leq \gamma < 1$). The conditional variables that have positive significances are recognized as the "core" features and they are mathematically equivalent to the intersection of all possible reducts. Notice that the "core" features are not sufficient to complete the entire decision (classification) process. Only the "reduct" (B_i) can achieve the whole process since it preserves full dependency (like using all of the conditional variables). Specifically, both coverage (defined by $(if \cap then) / then$) and strength (defined by $(if \cap then) / if$) are adopted to measure the effectiveness of decision rules. Here, the "Intersection" means the concurrences of the "Antecedent" and the "Consequent".

$$Strength = \frac{\#\{antecedent \cap consequent\}}{\#\{antecedent\}} \tag{8}$$

$$Coverage = \frac{\#\{antecedent \cap consequent\}}{\#\{consequent\}} \tag{9}$$

3. An example for designing and assessing varieties of tablets

A global Taiwanese brand company attempts to accomplish product portfolio management by developing multi-functional tablets, such as padfones (pad + smartphone), padbooks (pad + keyboard) and padnotes (pad + stylus pen). For convenience, Figure 1 and Figure 2 demonstrate several varieties of tablets which were designed to accommodate different scenarios. To enhance reliability and validity of this survey, the questionnaires were sent to diverse user groups (268 respondents). For convenience, their demographic profiles are shown in Table 1. Actually, they act as domain experts to carry out marketing assessments on multi-functional tablets.

3.1. Applying TRIZ to generate creative ideas for designing multi-functional tablets

Let's look at the details of the contradiction matrix in Table 2, three improving features (i.e. #6- area of a stationary object, #24- loss of information and #33- ease of operation) and three worsening features (i.e. #2- weight of a stationary object, #4- length of a stationary object and #6- area of a stationary object) are selected. After consulting industrial domain experts, several potential solutions are extracted, including principle 1 (segmentation), principle 5 (combining), principle 7 (nesting), principle 15 (dynamicity), and principle 30 (flexible shells or thin films). For clarity, let us quickly overview representative industrial cases to validate the-above mentioned principles (see Figure 1 and Figure 2 again). For instance, Asus's transformer series and Acer's Switch 10 are Padbooks (characterized by separable keyboards) which adopt principle 1 (segmentation). Meanwhile, Asus's Padfone series are the result of principle 7 (nesting). In addition, for enhancing smartphone's or tablet's visualization while keeping portability, principle 5 (combining) and principle 30 (flexible shells or thin films) are adopted to generate Lenovo's Pro3 and folio. Furthermore, principle 15 (dynamicity) is used to explain Fuji's rotatable design and Sony's sliding design in padnotes. Although padnotes are not comparable to Padbooks or Padfones in terms of portability, they provide powerful system performances and friendly user interface to accommodate diverse requirements of different groups.

3.2. Conducting RST to incorporate user preferences into the process of product recommendation

Again, RST is conducted to 268 invited respondents to capture user preferences for ergonomic features, namely, screen type, screen size, keyboard interface, and body color (see Table 3). Despite statistical Chi-square test can be applied to test the interrelationship between demographic variables (i.e. age, gender, and user categories) and user preferences, however, it does not demonstrate the causalities among the aforementioned variables. Thus, RST is adopted in this study to reveal the hidden causation and achieve the goal of product recommendation. As indicated in Table 4, six significant decision rules are derived by RST. In order to justify the validity of decision rules, two metrics like "coverage" and "strength" are measured. To simplify the analysis, the thresholds of the strength and coverage are set by 0.2 and 0.6, respectively. Obviously, distinct user categories possess different requirements for EFs. For example, educators prefer a tough screen with a pen, to support their instruction in class. In contrast, gamers favor a big-sized screen and a separable interface for convenience. Similarly, business users also need a stylus pen, a big-sized screen and a separable

interface for reporting their information. Finally, home users merely require a medium-sized screen and a sliding interface to support video or movie watching while they do not concern the stylus at all. Very interestingly, "age" does not present any specific pattern but "gender" reveals useful information. Male users prefer a big-sized screen and gray body color while female users prefer a medium-sized screen and white body color. Very surprisingly, a small-sized screen is not favored by all of the surveyed participants because of the popularity of a "big-sized" smartphone (bigger than 5.5 inch).

Table 1. The demographic profiles of the surveyed respondents (268 samples).

Demographics	Descriptions (in percentages)
Age	Below 30 (40%), between 30 and 50 (45%), Above 50 (15%)
Gender	Male (60%), Female (40%)
User group	Gaming users (25%), business users (28%), educators (26%), home users (21%)

Table 2. TRIZ's innovative principles for designing varieties of tablets.

		Worsening feature	
Improving feature	f6. Area of a stationary object	f2. Weight of a stationary object → P2, P14, P18, P30	f4. Length of a stationary object → P7, 9, 26, 39
	f24. Loss of Information	f2. Weight of a stationary object → P5, P10, P35	f6. Area of a stationary object → P16, P30
	f33. Ease of operation	f2. Weight of a stationary object → P1, P6, P13, P25	f6. Area of a stationary object → P15, P16, P18, P39

Table 3. Ergonomic features (EFs).

	Specifications (levels)	Descriptions
Ergonomic features (multi-levels)	E1 Screen type (2)	Touch with a pen (E11), Touch without a pen (E12)
	E2 Screen size (3)	7-8.4 inch (E21), 8.5-10.1 inch (E22), 10.2-12.2 inch (E23)
	E3 Keyboard interface (3)	Separable (E31), Slider (E32), Rotatable (E33)
	E4 Body color (3)	Black (E41), Gray (E42), White (E43)

Table 4. Conducting rough set theory to seek the attractive portfolios of EFs

Rule	Antecedent	Consequent	Strength	Converge
R1	(Screen type=E11) and (Screen size= E23) and (Keyboard interface= E33)	Educator	24.3%	77.9%
R2	(Screen size= E23) and (Keyboard interface= E31)	Gamer	22.6%	61.3%
R3	(Screen type=E11) and (Screen size= E23) and (Keyboard interface= E31)	Business	26.8%	65.7%

R4	(Screen type=E11) and (Screen size= E22) and (Keyboard interface= E32)	Home	27.7%	71%
R5	(Screen size=E23) and (Body color= E42)	Male	32.1%	81.4%
R6	(Screen type=E11) and (Screen size= E22) and (Body color= E43)	Female	29.7%	74.8%



Asus's Padfone (smartphone inside)



Lenovo's yoga Pro3 (micro-projector inside)



Lenovo's yoga Folio (folding screen)

Figure 1. Various design of multi-functional tablets.



Acer's Switch 10 (separable interface)



Fuji's Lifebook T936 (rotatable interface)



Sony's VAIO Duo13(sliding interface)

Figure 2. Various design of keyboard interface.

4. Conclusions

The emergence of TRIZ has stimulated a creative way of rethinking and redesigning new concepts for tackling multi-functional product design. In general, TRIZ provides a systematic framework to help product planners or industrial practitioners find innovative solutions (potential design concepts). Meanwhile, TRIZ also offers a good way to avoid human psychological inertia and break the conventional mindset. In this study, two improving features (#6- area of a stationary object, #24- loss of information and #33- ease of operation) and three worsening features (#2- weight of a stationary object, #4- length of a stationary object and #6- area of a stationary object) are considered for designing multi-functional tablets. With the aid of TRIZ's contradiction matrix, several potential solutions are suggested, including segmentation (principle 1) for designing Padbooks, combining (principle 5) for designing a tablet integrated with a

micro-projector, nesting (principle 7) for designing Padfones, dynamicity (principle 15) for designing sliding or rotatable Padnotes, and flexible shells or thin films (principle 30) for designing folding or bending tablets. Industrial examples include Acer's Switch 10 (principle 1), Lenovo's Yoga Pro3 (principle 5), Asus's padfone (principle 7), Fuji's Lifebook or Sony's VAIO Duo 13 (principle 15) and Lenovo's Folio (principle 30). In summary, this paper presents a user-driven framework to help firms generate decision rules to accomplish product design and recommendation. In future studies, user-rating based social-media mining and co-creation based concurrent design deserves to be further explored to conduct advanced product recommendation.

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New Kid on Copycat Block: Why Do Consumers Choose Shanzhai vs. Counterfeit?

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Abstract. In addition to authentic brands and counterfeits, a new product category has surfaced, providing a wider spectrum of choices for consumers. Known as 'Shanzhai,' these products closely mimic authentic products/brands while copying key elements and adding innovative features. Given the added complexity in consumer choice, the present study attempts to understand the characteristics of consumers choosing counterfeit vs. Shanzhai products, based on their values, attitudes and demographics. Findings indicate substantial differences in consumer segments. Specifically, (i) Shanzhai buyers weigh functional values more than counterfeit buyers, while (ii) counterfeit buyers weigh status consumption, social conformity, and materialism values higher, implying they seek recognition from peers; yet they experience less clear self-identity than Shanzhai buyers. Our study sheds light on whether different values affect consumers' choices of counterfeit vs. Shanzhai products and offer important implications for brand managers.

Keywords. Shanzhai products, counterfeits, consumer values, demand drivers

1. Introduction

For years, brand marketers have engaged in the fight against counterfeiting of their products. Despite these efforts, sales of fake products are thriving, even rising, as counterfeiters have increasingly shifted to online distribution to reach a worldwide audience [1]. Too tempting are the benefits of the fake versions: the prestige of owning a branded product without paying a high price is a major attraction [2].

In recent years, however, a phenomenon called Shanzhai has entered the copycat landscape, particularly in Asian countries such as China, Korea, India, etc. [3]. Shanzhai refers to a "bandit stronghold outside government control" [4, p.2]. Shanzhai products are products that imitate market leaders' offerings, and may provide innovative functional improvements. Shanzhai products are different from counterfeit as to the degree of similarity to the authentic brand and the additional benefits they provide. Shanzhai sales grow as quickly as counterfeiting products. Among the most highlighted examples are Shanzhai versions of the Apple iPhone, such as HiPhone, the

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Mini IPhone, or the iPhone Air. Many of these phones are copies of the original, but with improvements that are extremely popular with local customers, such as a slimmer appearance, slots for two SIM cards to exploit mobile operators' pay scales, electro shock panic functions, etc. The Financial Times in 2010 estimated that Shanzhai phones accounted for about 20% of the global 2G mobile market. Shanzhai mobile phones accounted for 30% of the total mobile phone market in China [3]. Starting with Shanzhai cellphone manufacturing, Shanzhai products have appeared in other product categories, including luxury apparel, luxury fashion accessories, global fast food operations, fast moving consumer goods, and cultural events. Shanzhai manufacturers collaborate with a global network of distributors to sell their products not only in emerging markets (i.e., India, Russia, and African countries), but also in developed economies. For example, according to China's Xinhua News Agency, on June 19, 2015, the Italian police shut down 410 online shops selling fake and Shanzhai luxury products in 11 cities from Milan to Palermo, Sicily. In 2014, Italian police seized fake (i.e., counterfeits and Shanzhai) luxury products worth approximately $3 billion, or 5% of the Italian luxury market.

While the demand for counterfeit products has been the focus of substantive research (for a literature review see Cesareo, [5]), Shanzhai has not attracted much scholarly attention, particularly in the area of consumer behavior, with some exceptions (e.g. [6]). While counterfeit products and Shanzhai products share some commonalities such as high similarity and inexpensive prices, they differ in the degree of similarity to the authentic brand and the unique set of additional benefits they offer. It is of interest to both scholars and marketers to understand how consumers differentiate Shanzhai from counterfeits as well as what motivates consumers to buy Shanzhai rather than counterfeits when both are priced the same. Consequently, understanding what consumer motivations drive demand (i.e. the order) for Shanzhai products is of interest.

The present study aims to offer the following contributions to extant knowledge. First, we introduce the phenomenon of Shanzhai products to the field of consumer choice behavior research, by defining and differentiating it from authentic brands and counterfeits. Second, we aim to shed light on the drivers of Shanzhai product purchase, and how this differs from factors leading to the purchase of counterfeits. In doing so, we develop a greater understanding of the difference between Shanzhai products and counterfeits. Finally, we define consumer segments based on their likelihood of choosing Shanzhai over counterfeit products. Our findings allow for a greater understanding of consumers' tendency to choose one product over the other (Shanzhai vs. counterfeit), therefore assisting brand managers who are attempting to avoid the threat of unauthentic variants.

2. Theoretical framework

2.1. Description of Shanzhai

Literally, in Chinese the term Shanzhai describes "a mountain village controlled by a Robin Hood kind of figure, which implies a rebellion against officials and stands for the general public" [7, p.54]. "Shanzhai" originated from the Chinese characters "山寨" to imply the meaning of not an authentic version, but an inferior imitation. The focus of the present study is Shanzhai products -- imitations of well-known brands with

enhanced features that are desired by many consumers [8]. For example, Chubb [3, p.267] quotes a highly ranked businessperson who notes two meanings in defining Shanzhai "One is copying and the other is creativity."

Among the first industry sectors to develop Shanzhai products was mobile phone. In the 2000s, many Chinese mobile phone producers -- often privately owned small and medium-sized enterprises (SMEs) -- started out as counterfeiters by copying the design and brand names of well-established global brands. Increasingly, they started to develop these counterfeits further and introduced innovative aspects into their products such as built-in TV receivers, UV lights, loudspeakers etc. Their previous experience in counterfeit production allowed for low production costs for Shanzhai products, thus offering customers attractive prices (compared to authentic global mobile phone brands) and interesting additional features. Shanzhai products are no longer poor-quality. For example, Shanzhai brands, once they are established, can even compete against the leading brands [9]. Xiaomi, a Chinese mobile phone brand that imitates the popular mobile phone brand Apple (and was thus called "Apple of the East") was worth around $4 billion in 2013. Its CEO, Mr. Jun Lei, was Forbes Asia's 2014 Businessman of The Year [10].

While Shanzhai products are typically said to appeal to low income consumers for their attractive price/performance offering, they attract higher income buyers as well [3][7]. Currently, Shanzhai products appear in other product categories in addition to technological devices. For example, Adivon, a Chinese sports brand that imitates the leading global player Adidas, reached profit of $15 million in 2012 [11].

In summary, unlike counterfeits, Shanzhai products imitate the authentic brand through obvious similarities. Additionally, consumers are often aware of the difference between Shanzhai and the authentic version. Lastly, Shanzhai products may offer additional product benefits.

2.2. Differentiating Shanzhai from Counterfeits

Cordell, Wongtada, and Kieschnick (1996) define counterfeiting as "any unauthorized manufacturing of goods whose special characteristics are protected as intellectual property rights (trademarks, patents and copyrights) [2,p. 41]." Counterfeits therefore exist, because owning branded products is desired by many consumers. To be profitable, counterfeits need to resemble the authentic product as much as possible. Traditionally, counterfeits did not completely live up to the quality promise of the authentic version; their price/performance ratio still was quite appealing to consumers [12]. However, the quality gap between authentic brands and their counterfeits has been narrowing in recent years due to advanced production technologies [13].

When comparing Shanzhai and counterfeit products, counterfeits try to resemble, at least visually, the authentic product as much as possible. Being nearly indistinguishable from the authentic brand allows the consumer to enjoy the prestige of a branded product without paying for it [2]. Unlike counterfeits, Shanzhai products try not to perfectly mimic, though still resemble, the authentic product through obvious similarities. Shanzhai products usually do not try to mask their origin, and consumers are typically aware of the difference between the Shanzhai and authentic products. Since their early days, similar to counterfeits, Shanzhai products have improved substantially in terms of quality and quite often offer an innovative edge compared to (global) authentic products [6][14].

In summary, unlike Shanzhai products, counterfeits are:

- A copy of the authentic version of a brand name product;
- Nearly visually similar to the authentic brand; and
- Function almost identically to the authentic version.

2.3. A Conceptual Model of the Determinants of Counterfeit and Shanzhai Choice

Given the differences between counterfeit and Shanzhai products, it is of interest to understand the drivers of purchase for the two categories of products. We draw from the model to capture consumers' value perception toward brands and counterfeits advanced by Wiedmann, Hennigs, and Klarmann [13]. We developed a variation of their conceptualization which is illustrated in Figure 1. The model suggests that functional, financial, social, and individual values drive purchase intention of authentic, counterfeit and (in our context) also Shanzhai products. Next, we describe the different value dimensions and formulate hypotheses regarding consumer purchase intention of counterfeit vs. Shanzhai products.

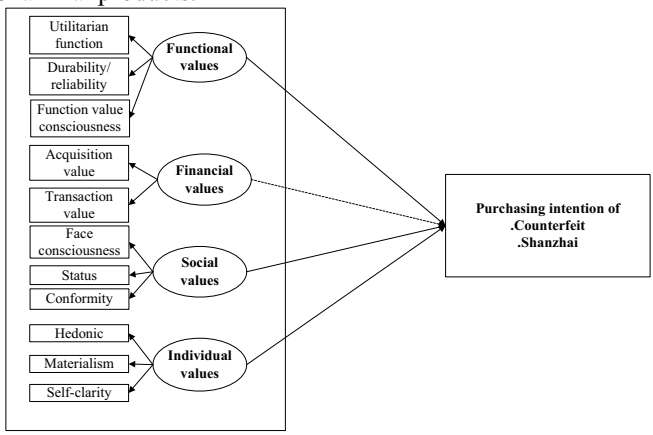


Figure 1. The conceptual model.

2.3.1.Functional Values

Functional values refer to a product's basic utilities and benefits such as product quality, usability, reliability and durability [13]. Both counterfeit and Shanzhai products can provide such functional values to satisfy consumers' utility needs. However, the motivation for purchase of the two types of products may differ. To capture the product's functional values, we consider utilitarian benefits, product quality/durability/reliability, and functional value consciousness represents the influence of the products' functional values on the purchase motivations for either counterfeit or Shanzhai products. We hypothesize:

H_{1a}: The more consumers' attitudes are utilitarian function value-oriented, the more likely they will be to choose Shanzhai over counterfeit products.

H_{1b}: The more consumers value product quality, durability and reliability, the more likely they will be to choose Shanzhai over counterfeit products.

H_{1c}: The more consumers are functional value conscious, the more likely they will be to choose Shanzhai over counterfeit products.

2.3.2. Social Values

Apart from functional values, products also possess social values such as conveying social status and acceptance within a social group [15]. Counterfeits may appear to be the authentic product, leading others to believe the consumer possesses the desired, highly-valued brand. Shanzhai products, however, are typically distinguishable from the authentic version. We consider face consciousness, status seeking, and social conformity to capture the impact of social values on purchase motivation of counterfeit and Shanzhai products. We hypothesize:

H_{2a}: The more consumers are face-conscious, the more likely they will be to choose counterfeit over Shanzhai products.

H_{2b}: The more consumers value status, the more likely they will be to choose counterfeit over Shanzhai products.

H_{2c}: The greater the consumers concern for social conformity, the more likely they will be to choose counterfeit over Shanzhai products.

2.3.3.Individual Values

Products are also associated with ego-focused, individual values, such as conveying personal information, obtaining pleasure, and portraying one's self-identities [13]. In this paper, we use hedonic value, materialism, and self-clarity to capture the impact of individual values on purchase motivation of counterfeit and Shanzhai products. We hypothesize:

H_{3a}: The more consumers seek hedonic value in a product, the more likely they will be to choose counterfeit over Shanzhai products.

H_{3b}: The more consumers are materialistic, the more likely they will be to choose counterfeit over Shanzhai products.

H_{3c}: The weaker the consumers' self-concept, the more likely they will be to choose counterfeit over Shanzhai products.

2.3.4. Financial Values

Financial value reflects the cost of the product to the consumer [16]. Acceptable product quality for a reasonable price is the key factor that drives consumers to purchase both counterfeit and Shanzhai products. In the present study, we use product acquisition value and transaction value to capture the impact of product financial values on the purchase motivations for counterfeit and Shanzhai products. Acquisition value is defined as "the perceived net gains associated with the products or services acquired" [17, p.48]. Transaction value is defined as "the perception of psychological satisfaction or pleasure obtained from taking advantage of the financial terms of the price deal" [17, p.48]. In our framework, we propose that the price advantage of both counterfeit and Shanzhai products can provide consumers value (an acceptable alternative to the authentic product at a fair price). We control for financial values equally across counterfeit and Shanzhai products.

3. Methodology

3.1. Research design and procedure

We conducted an experiment in which we manipulated a Shanzhai product's functional benefits (low vs. high) as a between-participants factor in China. A total of 374 Chinese university students participated in the experiment. Demographic characteristics of the respondents were as follows: (a) 52% were male and 48% were female, (b) the median age was 23-26 years old, and (c) the median monthly family income was above $2250 USD.

We asked the respondents to choose between counterfeit vs. Shanzhai sunglasses. Although cell phones, athletic shoes, smart watches, and the other fashion accessories were also considered, we chose to use sunglasses as the target product in our experiment because it embodies functional, individual, social and financial values. We ultimately selected Dior brand sunglasses as the stimuli since it is a gender neutral and moderate value product. Additionally, it provides all four types of values and is well-known in the local market.

The study first asked the participants to read: (1) an explanation of the purpose of the study, and (2) the definition of counterfeit and Shanzhai products, and (3) a request that the participant carefully read the hypothetical situation and imagine that this situation actually happened to them. Next, participants read scenarios showing the pictures of two pairs of sunglasses: 1) counterfeit Dior sunglasses were described as "This pair of sunglasses look like the original Dior in all respects, yet the price is only one tenth of the authentic Dior sunglasses", and 2) Shanzhai Dior sunglasses (i.e., Tior Brand) which look similar, but not identical, to the Dior sunglasses; Shanzhai Tior sunglasses are also one-tenth the price of the authentic Dior sunglasses.

Manipulation. We manipulated Shanzhai Dior sunglasses functional benefits at two levels: low functional benefits versus high functional benefits. The low function group's description of Shanzhai sunglasses states "Tior sunglasses come with a cleaning kit, including a piece of cleaning tissue and a small bottle of eyeglass cleaning detergent that can clean sunglasses quickly and they stay clean for longer." The high function group's description states "Tior lenses filter out the light rays which are harmful to eyes, thus protecting eyes effectively." We controlled the price across counterfeit and Shanzhai sunglasses being equal. After reading the scenarios, the participants were asked to choose one pair of sunglasses, as well as assess product functional, financial, social, and individual values.

Control variables. The *control variables* include (i) gender, (ii) attitude toward the Dior brand (i.e., Please indicate your general evaluation toward Dior brand; 1= very negative and 7 = very positive), (iii) importance of Dior sunglasses (i.e., Please indicate to what extent the authentic Dior sunglasses are important to your daily life 1= very unimportant and 7 = very important), (iv) the purchase likelihood of the authentic brand (i.e., Please indicate to what extent you would buy the authentic Dior sunglasses 1= very unlikely, 7= very likely), (v) attitude toward Shanzhai (i.e., Shanzhai products offer good value for money), (vi) attitude towards counterfeit products, and lastly (vii) financial acquisition value and transaction value.

3.2. Measures

Multiple item scales were created to measure each construct. The items were adopted from past counterfeit and consumer values research and were adapted to fit the context of this study. All items were measured using a seven-point Likert-type scale. Items were anchored with "strongly agree/strongly disagree"

4. Conclusions and implications

Product imitation is a cross-cultural, cross-industry phenomenon which can be found in many countries, including China, Brazil, India and Korea. It is particularly common in emerging economies as imitation (i.e. Shanzhai) is often an efficient and effective strategy that late movers in less developed economies adopt to catch up with competitors in developed economies. Shanzhai imitators in less developed economies pursued a late mover advantage, imitating original technology developed in the United States, Germany, and the Scandinavian countries. Shanzhai imitators are often skillful in improving features of the authentic product while adapting to local needs. As Shanzhai imitators raised capital and gained recognition from their early Shanzhai products, some later built their own global brands (i.e., Xiaomi Phone). Therefore, Shanzhai products can be seen as an alternative source of innovation and local adaptation. Consumers in emerging markets enthusiastically embrace Shanzhai innovation. Original brand manufacturers can learn from Shanzhai manufacturer's innovation and local adaptation to improve their product functions.

In this paper, we attempt to understand how consumers' value drivers differ between buyers of counterfeit vs. Shanzhai products. Recognizing the emergence of Shanzhai products in international markets, our contributions address the three research questions initially raised. These are (1) introducing the phenomenon of Shanzhai to the consumer behavior literature, by defining it and comparing it to well-known concepts such as brands and counterfeit products; (2) to shed light on the drivers of Shanzhai purchase and how they differ from factors inducing the purchase of counterfeits, and (3) to describe consumer segments based on their likelihood to choose Shanzhai over counterfeit products.

The present study makes several contributions to consumer research. First, we highlight an emerging phenomenon, Shanzhai, and contrast it to counterfeit buying behavior. While both originate from the demand for popular brands, they represent two different product concepts with different appeals. Therefore, it is vital to acknowledge that a "new kid has appeared on the copycat block", which demands attention. This contribution is not trivial as Shanzhai providers can grow quickly to become global brands while "under the radar" since original brand manufacturers often ignore the competitive threats from these Shanzhai imitators.

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The Effect of Different Internet Slang Styles on Brand Personality and Ad Persuasion

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Abstract. Internet slang, the product of computer-mediated communication, is being widely used in advertising in China. However, Chinese advertisers are still exploring appropriate methods to integrate this slang into their ads for positive effects. To this end, we conducted two experiential studies. The results reflected that different perceived styles of internet slang enhance the five dimensions of brand personality as discussed in this publication. Furthermore, the congruence between internet slang style and brand personality can lead to positive effects on consumers' attitude toward the brand and the ad itself. The findings of this research can help advertisers use the most suitable internet slang for building the desired brand personality and achieving the most positive outcomes.

Keywords. Internet Slang Style, Brand Personality, Ad Persuasion

Introduction

Internet slang is the product of computer-mediated communication [1]. In China, the prevalence of cyber culture has generated a significant amount of popular internet slang. People, especially the younger generation, use internet slang in their daily lives as an entertaining way to express themselves. Internet slang is also widely used in advertising in China. For example, McDonald used the internet slang "么么哒" (Muah, a mimetic word for kissing) to promote its "Ice-Cream Day". As internet slang has become a new trend, advertisers in China are trying to utilise this practice and are exploring a useful way to integrate internet slang into their advertisements to achieve more powerful effects on attitude toward the ad and the brand. A potential factor affecting the effectiveness of internet slang can be its style. Prior research by Gong [2] has identified seven styles of internet slang used in China: Overtness, Stylishness, Emotivity, Harshness, Candor, Amiability and Liberty. However, research on the impact of internet slang style in advertising, to-our-knowledge, is non-existent. This research seeks to fill this gap and further understanding of the effect of internet slang styles in advertising, by exploring how different styles influence both brand personality and advertising persuasion.

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1. Theoretical framework and hypothesis developments

1.1. The persuasive advantages of internet slang

Internet slang (a.k.a., internet language, cyber-slang) refers to "a variety of slang languages used by people in different communities in the cyber space" ([3] p. 232). People, especially the youth, invent internet slang by using acronyms (e.g., LOL: laugh out loud, [1]) or time-saving abbreviations (e.g., 4u: for you). Some internet slang comes from the news, movies, TV programs or online videos. For example, a recently popular online video, "cash me ousside, howbow dah" (catch me outside, how about that), originated from the mouth of a misguided girl in an American TV show and went viral due to her strong accent and rebellious attitude. In China, popular internet slang spreads via social media. It becomes a useful tool with which media and companies can build a closer relationship with the audience [3]. Cognitive neuroscientists have found that internet slang induced a delayed and extended N400 effect [4]. In this case, internet slang may be considered as a creative thinking process that is similar to that of verbal creativity such as metaphorical speaking [4]. Many studies have proven that proper message framing can increase persuasion (e.g., [5]). According to the similar-attraction theory, people tend to be attracted by people/things similar to them [3]. For internet users, internet slang is funny, trendy and expressive. Using internet slang can be seen as a behavior of in-group members. Thus, internet users may have positive attitudes toward ads with relevant internet slang. The research by Li and Mao [3] suggests that, by adopting a communication style aligning with the internet slang usage pattern of the user, a virtual advisory system can be perceived to be more credible, fun, engaging, informative and transparent.

1.2. Internet slang styles and brand personality

Internet slang styles (ISS) refer to the different traits of expressing an individual's thoughts on the Internet. Seven styles of internet slang are identified by Gong [2] based on the grounded theory: Overtness, Stylishness, Emotivity, Harshness, Candor, Amiability, and Liberty. Each style contains distinctive features. For example, the internet slang "么么哒" (Muah) is considered to be trendy and "Stylish", while "矮穷矬" (to say somebody is a poor and ugly shorty) is "Harsh" and mean. Just as language styles can influence consumers' attitudes [6], different internet language styles may also have different effects on advertising persuasion and perceived brand personality. Brand personality (BP) consists of five dimensions [7], that is, Excitement, Sophistication, Competence, Ruggedness, and Sincerity. Prior research shows that many factors (e.g., advertising campaigns, communication styles) influence a brand's perceived personality [8]. For instance, message framing has an impact on brand personality. Brands using metaphorical ads are perceived to be more Sophisticated and Exciting, but less Sincere and Competent than those using non-metaphorical ads [9]. Similarly, a particular style of internet slang may work well in conjunction with a particular dimension of brand personality. For example, brands using Stylish internet slang may be perceived to be more trendy, charming, and delicate, which may enhance individuals' perceptions of the brand as being Sophisticated. Analogously, internet slang perceived as Overt may deepen the consumers' view of the brand dimension of Excitement; the perceived Candor of internet slang strengthens the dimension of

Sincerity; the perceived Emotivity of internet slang makes the brand more Competent and the perceived Harshness of internet slang reinforces the impression that the brand is Rugged. As such, we assume the perceived style of internet slang enhances the corresponding dimension of brand personality:

h1: The perceived Candor of internet slang enhances the Sincerity of a brand.
h2: The perceived Stylishness of internet slang enhances the Sophistication of a brand.
h3: The perceived Overtness of internet slang enhances the Excitement of a brand.
h4: The perceived Emotivity of internet slang enhances the Competence of a brand.
h5: The perceived Harshness of internet slang enhances the Ruggedness of a brand.

As a complementary style of internet slang may enhance the corresponding dimension of brand personality, an incongruent style of internet slang may damage the original brand personality, which induces negative effects. Schema-based expectancy theories can explain this process. A schema (i.e., "a learned, internalized pattern of thought-feeling that mediate both the interpretation of on-going experience and the reconstruction of memories", [10]: 3) is organized through one's experience [11]. One's schemas influence his/her perceptual cognitive activities by generating the expectancies. For instance, individuals tend to use their existing schemas to process the congruency of new information [11]. When high Candor internet slang is used by a brand whose dominant brand personality is Sincerity, individuals will compare the nature of this internet slang with the existing brand attribute. The congruence between the new information (the internet slang style) and the existing information (the brand personality) results in a success of receiving the affect linked to the schema ([11] [12]), which produces positive attitude toward the ad (Aad) and the brand (Ab) [13]. As such, we propose the following hypotheses:

h6: *For brands whose brand personality is Sincerity, ads with high Candor internet slang lead to higher Aad and Ab than other styles of internet slang.*
h7: *For brands whose brand personality is Sophistication, ads with the high Stylishness internet slang lead to higher Aad and Ab than other styles of internet slang.*
h8: *For brands whose brand personality is Excitement, ads with high Overtness internet slang lead to higher Aad and Ab than other styles of internet slang.*
h9: *For brands whose brand personality is Competence, ads with high Emotivity internet slang lead to higher Aad and Ab than other styles of internet slang.*
h10: *For brands whose brand personality is Ruggedness, ads with high Harshness internet slang lead to higher Aad and Ab than other styles of internet slang.*

2. First study

2.1. pilot study

A pilot study was conducted to select the proper internet slang to represent the seven styles. A pool contained 920 pieces of internet slang that were collected from the search engine, relevant websites, news and the Baidu Library. Based on the popularity, the appropriateness for advertising, and the style of the internet slang, we screened out unsuitable ones and only kept 28 pieces for the next step. Twenty-eight pieces of slang

were pre-tested among 42 respondents. At last, we chose seven pieces based on their scores. Each piece of slang represented a particular style (see Table 1).

Table 1. The score of internet slang on the perceived level of each style.

Internet slang	Stylishness	Harshness	Candor	Amiability	Overtness	Overtness	Liberty
么么哒 Luv ya/Muah	**3.53**	1.57	2.63	2.46	2.61	3.02	2.26
买买买 Buy it! Buy it!	2.47	**3.57**	2.87	2.53	2.24	2.79	2.63
哥吃的不是面，是寂寞 What I eat is not the noodle but sorrow.	2.24	1.78	**3.65**	2.36	2.55	2.43	2.33
主要看气质 Focus on my aura.	2.84	1.48	2.43	**3.67**	2.04	2.84	2.82
有钱就是这么任性 I am willful because I am rich.	2.24	1.78	1.67	2.31	**3.42**	3.27	2.33
重要的事情说三遍 Important things are to be repeated for 3 times.	2.55	1.86	2.22	2.46	2.24	**3.04**	2.51
给力 brilliant /awesome	2.34	2.14	2.35	1.89	2.14	2.02	**3.76**

2.2. Methodology

Design and stimuli: Seven pieces of internet slang were used in ads for a high involvement product (i.e., a camera) and a low involvement one (i.e., a bottle of mineral water) from fictitious brands. Respondents were randomly exposed to one of fourteen ads (7 styles x 2 types of product) which had been designed using Photoshop. Each ad contained the product, the brand name, and the internet slang. **Participants and procedure:** We targeted young consumers as they are the main users of internet slang. Therefore, we handed out the questionnaire in Shenzhen University and Guangdong University of Technology for one week. Respondents were asked first to read the ad and then answer the question. Afterward, they were thanked and given a cash reward of 5 Yuan. In total 700 respondents completed the questionnaire (female: 293, 42%). Nearly 77% of the respondents were aged 23 to 30. Among the respondents, 85.4 per cent were a student. **Measures:** The perceived style of internet slang was measured as an independent variable by means of 32 items from the study of Gong [2]. Participants showed to which degree they felt the style of the internet slang was "straightforward", "concise", "arrogant", "exquisite", "lively", etc. on 5-point Likert scales, with 1 = *completely disagree* and 5 = *completely agree*. Brand personality was measured using the Brand Dimensions Scale (BDS, [7]), a 5-point Likert scale containing 15 items.

2.3. Results

Reliability and factor structure: The reliability was tested by calculating the Cronbach α. The α of each dimension of perceived style of internet slang was as follows: Stylishness (α = .91); Harshness (α = .81); Candor (α = .68); Amiability (α = .86), Overtness (α = .88); Emotivity (α = .90); Liberty (α = .81). As the α of the Candor dimension was below .70, two low loading items (self-mockery and rebellious) were dropped. The α of each dimension of brand personality was listed as follows: Sincerity (α = .71); Excitement (α = .87); Competence (α = .85); Sophistication (α = .87); Ruggedness (α = .83).

Next, we conducted an exploratory factor analysis (EFA) with a varimax rotation to closely explore more closely the internal structure of the measure of the perceived internet slang style and the measure of brand personality. Based on the observed eigenvalues, a seven-factor solution was extracted for the perceived internet slang style,

accounting for 68.3% of the total variance. For brand personality, a five-factor solution was extracted, accounting for 72.8% of the total variance. The Kaiser-Meyer-Olkin measures of sampling adequacy were .818 (ISS) and .864 (BP). For both scales, Bartlett's tests for sphericity were both significant at the $p < .001$ level.

Table 2. Results of Exploratory Factor Analysis.

Factor 1		Factor 2		Factor 3		Factor 4		Factor 5		Factor 6		Factor 7	
Emotivity1	**.85**	Overtness3	**.84**	Stylishness3	**.85**	Amiability1	**.82**	Candor5	**.86**	Harshness2	**.92**	Liberty2	**.91**
Emotivity4	**.84**	Overtness5	**.84**	Stylishness6	**.84**	Amiability 3	**.88**	Candor1	**.85**	Harshness1	**.92**	Liberty1	**.91**
Emotivity6	**.82**	Overtness6	**.80**	Stylishness1	**.82**	Amiability 2	**.87**	Candor4	**.81**				
Emotivity2	**.82**	Overtness1	**.80**	Stylishness2	**.81**								
Emotivity5	**.81**	Overtness2	**.78**	Stylishness5	**.79**								
Emotivity3	**.81**	Overtness4	**.64**										
Emotivity7		Overtness7											
Eigenvalue/ % Of variance accounted for following rotation													
4.40/ 15.16		**4.11/ 14.16**		**3.41/ 11.74**		**2.37/ 8.17**		**2.13/ 7.34**		**1.71/ 5.91**		**1.70/ 5.33**	

Table 2 showed items from the scale of internet slang style that loaded positively with loadings higher than .60. The factors extracted were consistent with the study of Gong [2]. Only Emotivity7 and Overtness7 had a loading smaller than .60 for the respective factor. For the measure of brand personality, five factors extracted were in line with the study of Aaker [7]. Only the item Sincerity2 had a loading smaller than .60. To assess the psychometric characteristics of our measures, a confirmatory factor analysis (CFA) was also performed. The results indicated adequate fit. A $\chi 2$ value was obtained ($\chi 2/df = 2.476$). Other fit indices were: CFI = 0.92; GFI = 0.90; RMSEA = 0.054; IFI = 0.92. All factor loadings were significant. Both the EFA and CFA confirmed the internal structure of the two measures.

Hypothesis testing: In line with the pilot test, seven pieces of internet slang scored differently in different dimensions. To examine the relationship between perceived internet slang style and different dimensions of brand personality, SPSS 20 was used to perform related analyses. Simple linear regression analyses were performed to predict a dimension of brand personality based on each perceived internet slang style.

Table 3. Correlations, **: $p < .01$, *: $p < .05$.

IV / DV	Overtness	Stylishness	Emotivity	Candor	Amiability	Harshness	Liberty
Excitement	.960**	.020	-.377	.140	-.105	-.123	.164
Sophistication	-.106	.944**	.077**	.497**	-.038	.025	-.132
Competence	-.069	.103**	.955**	-.133	-.217	-.082	-.193
Ruggedness	-.057	.110	-.055	.091	-.046	.924**	-.379
Sincerity	-.178	-.064*	-.147	.956**	-.167	.131	-.158

We also added all the perceived styles of internet slang in a model to predict the specific dimension of brand personality. The results were similar to the previous step. We found the maximum variance inflation factors (VIF) were below 10, which meant multicollinearity was not problematic. The results showed that a particular perceived style of internet slang enhanced the corresponding dimension of brand personality (see Table 3): the perceived Overtness of the slang had a significant effect on perception of Excitement in the brand's personality; the perceived Stylishness of internet slang had a positive effect on the dimension of Sophistication; the perceived Emotivity enhanced the Competence dimension; the Harshness elicited a positive effect on the Ruggedness dimension of the brand; the perceived style of Candor was associated positively with the Sincerity dimension of brand personality.

3. Second study

3.1. Methodology

Design and stimuli: The second study consisted of 5 experiments. In each experiment, we tested the effect of seven styles of internet slang for ads with a real brand which already possessed a distinctive type of brand personality. In each experiment, there were seven groups (a treatment group containing a particular internet slang style and six control groups including the other six styles). **Participants and procedure:** For each experiment, we recruited 350 respondents from the same universities. After the respondents finished the survey, they were thanked and given a cash reward of 5 Yuan. **Measures:** Besides the perceived style of internet slang and brand personality, we also measured the attitude toward the ad (Aad) and attitude toward the brand (Ab). Aad and Ab were measured using a five-point Likert-type scales from the research of Campbell and Keller [14] and Friedman [15]. We measured respondents' knowledge about internet slang to control the potential influence of different levels of pre-existing knowledge. Follow-up tests showed there was no significant difference in the knowledge between different experiments and different groups. Additionally, the reliability and validity of the measure were checked by calculating the Cronbach alpha and by conducting EFA and CFA. The results suggested that the measures used in the five experiments all had acceptable reliability and validity (details are available upon request from the authors).

3.2. Experiment 1

In the first experiment, we selected the Chinese brand "Nongfu Spring" whose dominant brand personality was expected to be Sincerity. Ads contained the product (a bottle of mineral water) and one of the seven pieces of internet slang used in the first study. In total 350 respondents (female: 153) completed the questionnaire. The demographics of the respondents was similar to the first study. We first checked the manipulations. In accordance with our expectation, compared to other dimensions of brand personality, the Sincerity dimension had the highest score for Nongfu Spring ($M_{sincerity} = 3.6 > M_{sophistication} = 2.86$, $t = 9.8$, $p < .01$; $M_{sincerity} > M_{excitement} = 2.91$, $t = 10.1$, $p < .01$; $M_{sincerity} > M_{compentence} = 2.71$, $t = 12.4$, $p < .01$; $M_{sincerity} > M_{ruggedness} = 2.48$, $t = 17.7$, $p < .01$). In addition, the internet slang "what I drink is not water but sorrow" scored highest in the perceived style of Candor ($M = 3.17$, $F = 14.15$, $p < .01$). Thus, the manipulations were all successful. Furthermore, respondents exhibited more positive attitude toward the ad containing high Candor internet slang than the other ads which contained other styles ($M_{Candor} = 3.18 > M_{stylishness} = 1.99$, $t = 8.5$, $p < .01$; $M_{Candor} > M_{harshness} = 2.05$, $t = 7.9$, $p < .01$; $M_{Candor} > M_{Overtness} = 2.21$, $t = 7.0$, $p < .01$; $M_{Candor} > M_{Amiability} = 2.23$, $t = 6.9$, $p < .01$; $M_{Candor} > M_{Emotivity} = 2.14$, $t = 7.1$, $p < .01$; $M_{Candor} > M_{Liberty} = 1.95$, $t = 8.7$, $p < .01$). Compared to the ads containing other internet slang styles, the ad containing high Candor internet slang significantly enhanced respondents' attitude toward the brand.

3.3. Experiment 2-5

The luxury brand Dior was selected for the second experiment. We assumed that Sophistication would be the most prominent brand personality of Dior. For the

experimental materials, we replaced the brand name "Nongfu Spring" and the product (a bottle of mineral water) with the brand name "Dior" and another product (i.e., a bottle of perfume) while keeping other elements constant. We recruited 300 respondents (female: 158) from the same universities. The manipulation checks showed that Sophistication was the dominant brand personality of Dior ($M_{sophistication}$ = 3.79). The score was higher than any of the other four dimensions at a significance level of .01. Consistent with the previous findings, the internet slang "Luv ya/Muah" had the highest score in the perceived Stylish style (M = 3.33, F =16.71, p < .01). Respondents who were exposed to an ad with the Stylish internet slang style, showed higher Aad and Ab than respondents exposed to ads with any other internet slang styles (p < .01).

The third brand we tested was Coca-Cola whose main brand personality was expected to be Excitement. The product shown in the ad was also changed to a bottle of Cola. Data from 300 respondents (female:160) suggested that Excitement was regarded as the main brand personality of Coca-Cola ($M_{excitement}$ = 3.62, p < .01 for all pairwise tests). The internet slang "I am wilful because I am rich" had the highest score in the perceived Overtness internet slang style (M = 3.17, F = 3.68, p <.05). Respondents displayed more positive Aad and Ab for the ad with the Overtness internet slang style (i.e., I am wilful because I am rich) than ads containing any other styles (p < .01).

In the fourth experiment, together with the internet slang, the popular mobile phone designed by Apple was used in the stimuli. Three hundred participants (female: 161) answered the survey. As was expected, the data showed that Competence was the key brand personality of Apple (M = 3.72) and the internet slang "important things are to be repeated for three times" got the highest score in the perceived Emotivity internet slang style (M = 3.12, F = 10, p = .03). Respondents' attitude toward the ad and brand were significantly higher when exposed to the ad with Emotivity internet slang than any other styles of internet slang (p < .01).

The international brand NIKE was chosen in the fifth experiment to represent brands that were adventurous and Rugged. A pair of sport shoes was displayed, and the internet slang was placed next to the shoes. Three hundred completed questionnaire were collected (female: 143). The results showed the principle personality of NIKE was Ruggedness ($M_{ruggedness}$ = 3.54). Compared to other dimensions of personality, Ruggedness had the highest score (p < .01 for all pairwise tests). The internet slang "buy! buy! buy!" had the highest score in the perceived Harsh internet slang style (M = 3.13, F = 14.5, p <.001). Similarly to the prior experiments, respondents held more positive attitude toward the ad and the brand for the ad with the Harsh internet slang style (i.e., buy! buy! buy!) than ads containing any other styles (p < .01).

4. Conclusion, implications, limitations, and future research

By observing the correlation between different internet slang styles and the respective dimensions of brand personality, the first study suggests that certain styles of internet slang can enhance the corresponding dimensions of brand personality. For example, the perceived degree of Candor in internet slang is associated positively with the Sincerity dimension of brand personality, while the perceived Stylishness of internet slang has a positive effect on the dimension of Sophistication. In the second study, we apply the findings from the first study to existing brands. The results show that congruence between internet slang style and brand personality induces positive attitudes. For

example, for Dior, whose brand personality is Sophistication, using the Stylish form of internet slang leads to higher Aad and Ab than the other six available slang styles.

The language used in advertising influences the advertising effects [16]. The findings serve the purpose of contributing to the literature on use of language in advertising by exploring niche internet language. This research is also meaningful for the building of schema-based expectancy theories as it confirms that congruence between communication style and brand personality can lead to positive effects. As internet slang has been increasingly used in advertising, marketing managers can make use of this slang to build up a brand with the desired personality. Using a proper style of internet slang can increase consumers' brand attitude, while a style that is incongruent with the brand personality may induce negative perceptions of the brand.

This research has several limitations which may offer suggestions for further research. First, the scale measuring the style of internet slang was developed in 2014. Compared to the Brand Dimension Scale, this scale is less mature and additional research and tests are needed. The second issue pertains to the data. The participants are limited to the young consumers in two cities in China. To increase the generalizability of the findings, future studies may recruit respondents from different regions in China.

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How Does Brand Community Identity Affect Brand Loyalty and Brand Recommendation?

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Abstract. Once consumers identified a brand community, will they be loyal to the brand or recommend it to others? To answer the question, our study investigated the relationship between brand community identity and consumer behaviors (brand loyalty and brand recommendation); also, we examined the mediation role of brand identity. Results showed that brand identity can fully mediate the relationship between brand community identity and brand loyalty. However, as for the impact of brand community identity on brand recommendation, it can only play a partial mediation role. Specifically, when consumers identified with a brand, they are certainly loyal to it instead of recommending it to others. These conclusions complement brand community theory and provide significant guidance to corporate marketing activities when building brand community.

Keywords. Brand community identity, brand identity, brand loyalty, brand recommendation.

Introduction

Brand communities offer a fresh, effective, and viral approach to building brands in the unresponsive marketing environment [1]. With the development of market economy, marketers have become more interested in learning about, organizing and facilitating brand community [2]. From the perspective of consumer-brand relationships, previous studies indicated that brand satisfaction and brand trust are important antecedents of brand loyalty [3], and brand loyalty is an important antecedent of brand recommendation. The proposal of brand community provided a new idea for cultivating brand loyalty. Brand trust or brand satisfaction describes the relationship between the brand and consumers; while brand community is concerned with relationships among consumers [4].

Existing studies found that community identity and participation can lead to brand identity and consumer's purchase behavior [5]. That is to say, by cultivating brand community, companies can obtain consumer brand loyalty and brand recommendation [6]. However, how members with brand community identity develop brand loyalty and recommend the brand? Does brand community identity lead to brand loyalty and brand recommendation directly? Answers to these questions will help companies to promote consumer brand loyalty and brand recommendation through brand community.

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Prior research has analyzed this topic from different perspectives. Based on social practice theory, Schau, Muñiz, and Arnould (2009) found that brand community participation could influence brand loyalty and brand recommendation through brand identity, respectively [7]. However, from social identity and social impact perspective, other scholars have proposed that virtual brand community identity does not always affect brand commitment positively; instead, it may affect brand loyalty negatively [8].That is to say, the impact of brand community identity on consumer behavior (such as brand loyalty and recommendation) is also affected by other factors. In this study, we introduced brand identity as a mediator to study the relationship between brand community identity and brand loyalty and recommendation.

1. Hypotheses Development

1.1. Social identity theory

Social identity theory believes that group identification is the basis of group behavior. Tajfel (1972) defined social identity as "the individual's knowledge that he belongs to certain social groups together with some emotional and value significance to him of this group membership" [9]. It believes that 3 steps existing in social identity development: social categorization, social comparison and positive distinctiveness. Because social identity is self-evaluative and derives its value from the evaluative properties of the ingroup, social comparisons between groups are focused on establishing positive distinctiveness for one's own group. Intergroup relations involve a process of competition for positive identity in which groups and their members strive to protect or enhance positive distinctiveness and positive social identity. The specific way this occurs is governed by people's subjective understanding of the psychological permeability of group boundaries and the stability and legitimacy of status relations between groups.

1.2. Brand Community Identity and Brand Loyalty

Brand community identity is the application of social identity theory to brand research. It reflects the extent to which people see themselves as members of the brand community and their sense of belonging to the brand community [1]. Once people see themselves as members of a brand community, they will offer emotional and moral support for the long-term development of the community [10]. Some studies have suggested that social identity with an organization includes two aspects: cognitive and affective identity [11]. The cognitive factors of brand community identity are mainly related to the categorization theory; people see themselves as members of the group and stress similarity with other members of the community and dissimilarity with members of other communities [1]. Affective factors of brand community identity are based on the relationship theory and stress the affective commitment of members to the community [12] and intimate relationships among members of the community [2].

Brand community can promote consumer brand commitment and brand loyalty because repeated brand purchase and usage are important symbol of brand community members [1]. McAlexander, Kim, and Roberts (2003) proposed that brand community has a positive impact on brand commitment from the perspective of brand community integration [13]. Additionally, studies from the perspective of consumer participation

showed that brand community has a positive impact on brand loyalty [14]. Accordingly, we proposed the following hypothesis:

H1: Brand community identity has a positive impact on brand loyalty.

1.3. Brand Community Identity and Brand Identity

Lastovicka and Gardner (1979) defined brand identity as a declaration of personal brand choice and an emotionally or psychologically attachment towards a brand [15]. Sven and Sue (2010) further suggested that brand identity is the extent of the common characteristics between the perceived consumer personality and the conveyed brand personality [16]. Brand community identity and brand identity are essentially similar terms and both come from consumer self-image and brand community or brand image. Bagozzi and Dholakia (2006) proposed that brand community identity has a positive impact on brand identity [5], while Algesheimer, Dholakia, and Herrmann (2005) proposed the opposite view through additional studies [1]. Therefore, a two-way relationship exists between community identity and brand identity. Given the research objective, this paper focuses on the impact of brand community on brand. Brand community identity helps members define their self-image through community membership. Members will be grateful when they are appreciated by society because of their special membership. Therefore, members who are proud of their brand community membership will also be proud to become brand advocators. Accordingly, we proposed the following hypothesis:

H2: Brand community identity has a positive impact on brand identity.

1.4. Brand Community Identity and Brand Recommendation

Community engagement results from the overlaps that members perceive between their own unique self-identity and their group-based identity [1]. It is viewed as an expression of personal value [11]. When acquiring brand community identity, members will share experiences, information and brand value, and even recommend the brand to others [6]. Therefore, community engagement has a positive impact on brand recommendation [14]. Additionally, brand community is formed around a particular brand [4] and is composed of brand enthusiasts. Once community members have developed a community identify, they will strive to maintain this positive social identity. At the same time, to achieve self-affirmation, they will take the initiative to recommend this brand to others. Accordingly, we proposed the following hypothesis:

H3: Brand community identity has a positive impact on brand recommendation.

1.5. Brand Identity and Brand Loyalty

Studies have shown that consumers usually maintain self-identity and define their relationships with others through the consumption of product or brand [17]. Consumers tend to purchase the brands that are consistent with self-image and personality [18]. When consumers perceived that a brand can reflect their personality, improve their self-image and social status, long-term relationship might develop [16]. Thus, when consumers have developed a strong brand identity, their satisfaction with the self-definition conferred by the brand will promote brand loyalty. Accordingly, we proposed the following hypothesis:

H4a: Brand identity has a positive impact on brand loyalty.

H4b: Brand identity mediates the positive influence of brand community identity on brand loyalty.

1.6. Brand Identity and Brand Recommendation

Brand identity reflects the extent of common characteristics between the self-perceived personality and the personality conveyed by the brand [16]. Brand recommendation is one of the best indicators of brand association. When consumers associate a brand with a highly affective experience, they are more likely to recommend the brand to others [19]. Consumers recommended a brand to others not only indicates their belief about the brand, but also the intimate association between the brand and their reputation. Consumers will recommend the brand to others when brands are conducive to self-expression. Therefore, we proposed the following hypothesis:

H5a: Brand identity has a positive impact on brand recommendation.

H5b: Brand identity mediates the positive influence of brand community identity on brand recommendation.

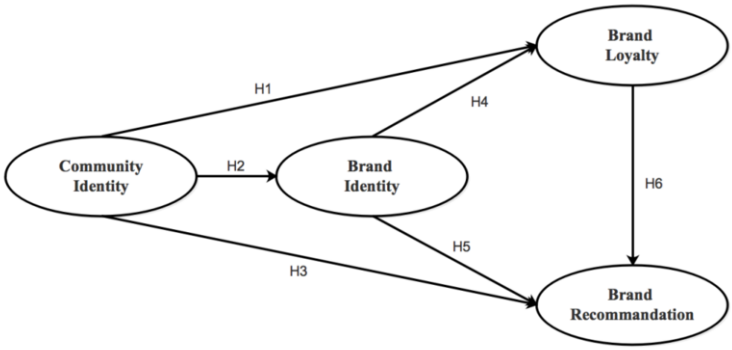


Figure 1. The conceptual model.

1.7. Brand Loyalty and Brand Recommendation

Brand recommendation is the result of brand loyalty. Consumers with brand loyalty will actively provide feedback to the company and recommend the brand to their friends. In a brand community, members who are loyal to the brand and the community are usually very concerned about the long-term development of the community and the brand. They not only exchange brand information in the community, but also actively recommend the brand to others and generate positive publicity for the brand. Accordingly, we proposed the following hypothesis:

H6: Brand loyalty has a positive impact on brand recommendation.

Based on the above literature review and rationale, the research model of this study is shown in Figure 1.

2. Methods

2.1. Sample

The automotive community is more suitable for empirical research due to the members' higher participation [1]. Currently, China has a large number of domestic automobile brand communities (such as Chery and BYD), which have become the sources of data in this study. We collect data from Sojump (www.sojump.com), which is a popular online survey platform in China. Compared with Dichehui (a BYD automobile brand community), it is easy to collect member's e-mail addresses from Xinqijun (a Chery automobile brand community) forum. We published the URL link to the questionnaire on the Dichehui Forum and also sent the URL link via e-mail to more than 5000 members of the Xinqijun community. A total of 820 enthusiastic members visited the online questionnaire, totally, we got 394 valid questionnaires. The demographic informations like gender, age, education and income (RMB) are collected. Among them, 97% were male and only 3% were female, this is possble due to the community we chose are car communities. And for age, most of the people are between 31-40; more than 97% are junior college and higher and their income is evenly distributed between 2000-15000.

2.2. Measures

Scales from prior research were adapted or combined to measure all the constructs included in the conceptual model. According to Rungson Chomeya (2010), the Likert's scale 6points tend to give the discrimination andreliability values which are higher than the Likert'sscale 5 points. If we wanted to emphasize thediscrimination and reliability high, therefore theyshould use the Likert's scale 6 points, also, if want to reduce the deviation to be the least orreduce the risks which might be happened from thedeviation of personal decision making, it should choose the Likert's scale 6 points.So, all of the measurement scales were 6-point Likert scales[20]. Brand community identity refers to a scenario in which community members define themselves as a part of the brand community; it was measured by 6 items [1, 21]. For brand identity, we referenced Mael and Ashforth (1992) and Kim, Han, and Park (2001) and selected 5 items [21, 22]. Brand loyalty refers to consumer desire to maintain a relationship with the brand, which was measured by 3 items [23, 24]. Items selected from Zeithaml (1988) were used to measure brand recommendation [25].

2.3. Method of data analysis

In this paper, the partial least squares (PLS) was used to test the hypotheses. PLS is a useful multivariate causal modeling tool that can be used to analyze the relationships between several dependent and independent latent constructs [26]. That is, PLS considers the relationships among all variables at the same time but does not require multivariate normality. Thus, SmartPLS 2.0 was used to test the hypotheses.

3. Results

3.1. Measurement model

In this study, Cronbach's α and confirmatory factor analysis were used to test the internal consistency. The results indicate that all 17 items have relatively significant standardized factor loadings (SFL> 0.606). As expected, four factors were extracted and the Cronbach's α were all above 0.830 (α> 0.70), which indicates the high internal consistency of the items [27]. The composite reliabilities (CR) of all of the constructs exceed 0.900 (CR> 0.70), suggesting that the measurement items have adequate reliability.

Average variance extracted (AVE) and the coefficient of combination reliability were used to test convergent and discriminate validity. The overall model fit indices are fairly satisfactory. All of the AVEs (>0.729) were greater than 0.50, and the square root of each construct's AVE exceeds the coefficients of the relationships between the measure and other constructs [28]. Therefore, the items possess adequate convergent and discriminate validity.

3.2. Tests of hypotheses

In order to test the mediation effects, this study uses two models. In model 1, we introduced 3 variables (brand community identity, brand loyalty and brand recommendation) to test the total effects. Brand identity is added in Model 2 to test the mediation effects.

The results from the model 1 analysis supports H1 by showing that brand community identity impacts brand loyalty significantly (β = 0.284, t = 6.663> 1.96), supports H3 by showing that brand community identity impacts brand recommendation significantly (β =0.208, t = 4.832> 1.96) and supports H6 by showing that brand loyalty impacts brand recommendation significantly (β = 0.535, t = 13.234> 1.96).

In model 2, we first calculated the path coefficient from brand community identity to brand identity (β = 0.444, t = 11.564> 1.96) according to the mediating effect test method from Baron and Kenny [28]; which supports H2a. Next, we calculated the path coefficient from brand identity to brand loyalty (β = 0.586, t = 12.187> 1.96); which supports H4a. After the introduction of brand identity as a mediator, the impact of brand community identity on brand loyalty becomes non-significant (β = 0.023, t = 0.744 <1.96), suggesting that brand identity played a full mediating role in the relationship between brand community identity and brand loyalty, which supports H4b.

Similarly, once brand identity is included in Model 2, the relationships between brand community identity and brand identity (β = 0.444, t = 11.564> 1.96) and between brand identity and brand recommendation (β = 0.250, t = 4.321> 1.96) are significant, which support H2a and H5a, respectively. After the introduction of brand identity as a mediator, the impact of brand community identity on brand recommendation decreases substantially (Model 1: β = 0.208, t = 4.832, p< 0.001; Model 2: β = 0.132, t = 2.705, p< 0.05).Therefore, brand identity plays a partial mediating role in the relationship between brand community identity and brand recommendation, which supports supporting H5b.

4. Discussion

What is the intermediary mechanism from brand community identity to brand behavior and willingness? In this study, we combined with social identity theory and social psychological theory to introduce brand identity as a mediator. The empirical results reveal that brand identity plays a full mediating role between brand community identity and brand loyalty, but a partial mediating role between brand community identity and brand recommendation.

4.1. Theoretical implications

Many studies have indicated that brand community identity has positive impact on brand behavior and consumer willingness [6, 8, 14], but relatively few studies have addressed the intermediary mechanism. In this study, we investigate the intermediary mechanism between brand community identity and brand behavior and between brand community identity and brand willingness.

First, brand identity plays a full mediating role between brand community identity and brand loyalty. According to organizational commitment theory, consumers' commitment to a brand community may be based on different psychological bonds, such as need, affect, and/or obligation. When consumers are committed to a brand community based on need or obligation, they will not loyal to the brand. Only when members identify a brand, do they become committed or loyal to the brand.

Second, brand identity plays a partial mediating role between brand community identity and brand recommendation. Sociological studies have noted that there are two types of emotion among Chinese people: "real emotion" and "assumed emotion"; the former is heartfelt, real, and spontaneous, while the latter is what is expected due to obligation and norms. We believe that there are also two pathways of "real" and "assumed" when community members recommend the brand to others. On the one hand, some brand community members may develop feelings of attachment to and identification with a community and thus may feel a sense of belonging. Their participation and interactions with other members help to strengthen their brand experience and value, leading to brand identity, and then recommend the brand to others [6]. This is the "real" part of brand recommendation. On the other hand, brand community is formed around a particular brand [4], and once community members have developed a community identity, they will strive to maintain this positive social identity through social categorization and social comparison, even in the absence of strong feelings towards the brand (brand identity).

4.2. Managerial implications

Previous studies have found that participate in a brand community may cultivate consumer brand loyalty. Therefore, it is important to know how brand communities influence brands. The results of this study have several managerial implications. First, to effectively manage the relationship between brand community and brands, companies must cultivate consumer brand community identity. Companies should establish a brand community or help consumers to organize a brand community. Assisting community members is a valuable investment for companies. Next, consumers with brand community identity will not develop brand loyalty until they have developed brand identity. Therefore, it is important for companies to input brand

information such as brand usage experience, brand reward information and new product distribution into the brand community. Additionally, companies can design logos and slogans for the community that are similar to the brand in order to enhance brand identity among the community members. Furthermore, brand community identity has a direct or indirect impact on brand recommendation, which provides a new idea for companies.

4.3. Limitations and further research

Although this paper has provided some ideas regarding the impact of brand community on brand behavior and willingness, there are also shortcomings. First of all, to collect the data, we posted notices of the questionnaire on online forums and sent emails to thousands of members. To our surprise, almost all of the data (97%) were from male participants. This might be because current drivers are mostly male. Therefore, future research may take into account other categories. Second, according to Algesheimer, Dholakia, and Herrmann [1], the relationships between brand communities and brands may be bidirectional. But we were only concerned about the impact of brand community on brand behavior and willingness. Further researchers should use longitudinal studies to capture the dynamics of brand communities and their relationship to brands.

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Requirements Engineering in the New Product Development Process: Bibliometric and Systemic Analysis

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Abstract. In the recent decades, the challenges related to global competition, the reduction of product lifecycle, the increase of technological changes and the level of customer demand have been intensified. In this scenario, the New Product Development Process (NPD) is noticed as a critical factor to maintain the competitiveness in organizations. The New Product Development Process (NDP) is noticed as a critical factor to maintain the competitiveness in organizations. The Requirements Engineering (RE) approach plays a vital role within the New Product Development Process (NDP) lifecycle, once the product performance and its acceptability on the market depend on how RE is integrated into the product development. In this way, this article aims to identify the proposed solutions and trends regarding Requirements Engineering, through a literature review based on studies produced in the last five years. Hence, the existing gaps in the literature about this theme will be presented and analyzed. In order to achieve these objectives, the present study was based on ProKnow-C process (Knowledge Development Process - Constructivist). In the first step, the bibliographic portfolio was obtained, represented by 38 articles aligned with the research theme. Moreover, the bibliometric analysis was performed to identify the relevance of journals and congresses about the topic of research, the authors that stand out in the research area, the year of publication of the articles, as well as the keywords found in the portfolio. Thereafter, a systemic analysis was accomplished in order to analyze the content of the articles from the bibliographic portfolio and to identify the main research problems, objectives and proposed resources. Finally, the main research opportunities were recognized and presented.
Keywords. Requirements Engineering (RE), Requirements, New Product Development, Bibliometric Analysis, Systemic Analysis

Introduction

The costumers' needs conversion and other factors into well-defined requirements is called clarification. This transformation of customer needs into specifications can be ambiguous, therefore the requirements must be specified and documented, describing all the parameters, constraints and product properties. Requirements specification allows the developer to create a product design and it forms the basis of the relationship between developer company and customer. In addition to that, this specification can be reviewed at any time during the NPD [1].

Thus, source [2] defines RE as the process by which the requirements of the products or systems are defined, by discovering the needs of stakeholders, understanding the context in which requirements are proposed, modeling, negotiating, validating, recording and managing these requirements.

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The use of requirements that are not well defined and structured may cause an increase in product development time or even non-acceptance by customers, generating extra costs and delay in placing the product on the market [3]. In this way, this article aims to identify the proposed solutions and trends regarding RE, through a literature review based on studies made in the last five years. Hence, the existing gaps in the literature about this theme will be presented and analyzed. In order to achieve these objectives the present study, based on *ProKnow-C* process, is represented by 38 articles aligned with the research theme.

Section 2 presents the methodological aspects of the research, followed by the presentation of the sequence of activities to realize the selection of the bibliographic portfolio in section 3, as well as the bibliometric analysis and the systemic analysis in sections 4 and 5, respectively. Section 6 presents the final considerations.

1. Methodological aspects

This section aims to provide a methodological support for this study, presenting the steps used to select the articles that compose the bibliographic portfolio and that will be used in the bibliometric analysis, thus enabling understand how the objectives are achieved.

It was chosen to adopt *Knowledge Development Process-Constructivist* (*Proknow-C*) as a methodological procedure in this research. This instrument was developed to assist researchers in the recognition of relevant content, since there is an extensive availability of information at the present time [4]. *ProKnow-C* consists of the following steps: selection of the bibliographic portfolio, followed by bibliometric analysis, systemic analysis of the portfolio and, finally, definition of the research question and objective respectively [5][6]. In the first step, definition of the bibliographic portfolio, the research axes and the keywords are defined, as well as the databases, and then the searches are carried out. After this search, the bibliometric analysis stage begins, which defines the authors, articles, journals and the most relevant keywords to the subject of research. The third step, systemic analysis, consists of the articles' interpretation of the bibliographic portfolio.

In this paper, we will cover only the first three steps of *ProKnow-C*, since we intend to present the state of the art and the research opportunities based on the systemic analysis step. To achieve this result, the *EndNote* and *Microsoft Excel* softwares were employed. *EndNote* supports bibliography management, while the data tabulation was performed in *Excel*.

2. Bibliographic portfolio selection

In this section the steps for selecting the bibliographic portfolio are presented, which aimed to gather publications with relevant content and scientific recognition that are aligned with the research theme.

A. Preliminar article database selection

This phase is composed by the following activities:

1) Definition of research axes and keywords:

The axes were defined as: *(i)* Requirements Engineering; *(ii)* New Product Development Process. These axes were defined according to the purpose of the study, i.e. to identify RE trends in NPD.

Afterwards, keywords were defined for each search axis. The choice of these words was based on the previous reading of some articles aligned to the research. Because the searches were more comprehensive when done in English, keywords were defined only in English. In addition, in some words the "*" operator was used to allow their variations to be found.

Thus, searches were carried out with the following combination: (*"requirement* engineering" OR "requirement* identification" OR "requirement* management" OR "requirement* analysis" OR "requirement* standardization" OR "requirement* specification" OR "requirement* validation" OR "formaliz* requirement*" OR "requirement* model*") AND ("NPD" OR "new product development" OR "product development" OR "product development process" OR "product requirement*").*

2) Selection of database:

The databases were defined according to their alignment relative to the research area, as well as their availability in the CAPES (Coordination of Improvement of Higher Education Personnel) periodicals portal. Thus, the bases chosen were: ProQuest, Engineering Village (COMPENDEX), Scopus, Web of Science, Wiley, Emerald, Springer, Science Direct, EBSCO e IEEE.

3) Definition of limiting search filters:

Only papers from congresses and journals published in the last five years (2011 to 2016) were considered.

4) Test keyword adherence:

The keywords adherence was accomplished by reading the titles of the papers. Three articles that were aligned to the research theme were selected and were verified that the keywords were aligned with those defined previously. In this way, the search continued using the keywords presented above.

5) Criation of the preliminar article database:

Searches, according to the above definitions, were done between October 24 and 29 2016 and resulted in 844 references.

B. Filtering Articles

As an initial activity in this step of filtering the base of papers, all duplicate references were removed, which accounted for about 7% of the preliminar articles base, resulting in 787 articles. Were also detected, despite the pre-selection performed directly in the bases, the presence of 3 references from previous years to those considered in this study, as well as the presence of other types of references and documents from other areas that were not of interest (medicine, biology, etc.), leaving 619 references.

Thereafter, the individual analysis of each article was started. First, each of the 619 titles in the portfolio was read, analyzing which were or were not aligned with the objectives and axes of the research. The papers that were not aligned were excluded, leaving 99 papers for the following analyzes.

Through Google Scholar [7], the citations number for each article were verified on October 30, 2016. The references were tabulated, sorted in descending order in

number of citations, identifying which articles were the most cited. The criteria for selecting articles for the next stage of the analysis was that it should be cited at least once. With this, 61 articles were chosen.

Then, with the 61 articles with the highest scientific recognition, the paper went to the stage of reading and evaluating its abstracts to select the papers that in fact were aligned with the research. Thus, 38 publications remained.

3. Bibliometric analysis of bibliographic portfolio

Bibliometric analysis allows evaluating and interpreting the bibliographic portfolio [10]. In this way, it is possible to identify the relevance of journals and congresses about the topic of research, the authors that stand out most in the research area, the year of articles publication, as well as analyze the keywords found in the portfolio.

During the analysis of publications, it can be seen that most of the publications were written by different authors. With the exception of authors A. Knauss, D. Damian, D. Hauksdottir, E. Knauss, NH Mortensen, PE Nielsen, R. Feldt, S. Choie T. Gorschek who have two articles in the bibliographic portfolio, the other 118 authors wrote only one article each. When analyzing the year of article publication, it can be observed that the year of 2014 had the most publications on the subject.

Continuing the analysis, keywords found in the portfolio articles were verified. The similar terms were clustered together, resulting in 82 words. It is possible to realize that 67 words appeared only once in articles. The words *engineering requirements* and *product development* appeared 10 and 5 times respectively. Therefore, the words defined at the beginning of this research were in line with the results found. It can be verified that the journal Requirements Engineering is the most representative in the portfolio, followed respectively by Computers in Industry and Research in Engineering Design.

4. Systemic analysis

The systemic analysis stage focused on analyze the articles content on the bibliographic portfolio according to established criteria. In this study, to conduct systemic analysis, each of the selected articles was read aiming to identify the following aspects: *(i)* objective, *(ii)* methodology, *(iii)* main results, *(iv)* future recommendations, *(v)* research opportunities pointed out by the authors and *(vi)* research opportunities identified from critical analysis. To organize this information extracted in this stage, an Excel spreadsheet was prepared and data were tabulated to facilitate the overall analysis after the readings. The solutions proposed by each study and the research opportunities were identified and presented below.

A. Key research issues presented

Customer requirements*:* The difficulty of incorporating customer needs into product development is exposed [8][9], as this incorporation is one of the critical factors for the success of all products on the market. For [8] one of the problems is the

lack of integration between product development tools, customer needs and engineering requirements in the development of product families. The imprecision and uncertainty in customer requirements (CR) is addressed [10], which also highlighted the need of CRs prioritization. Another problem presented is the need for customer requirements to be better integrated into the product lifecycle management [11].

Specification, formalization, categorization and prioritization of requirements: The absence of specification, formalization, categorization, and prioritization of requirements are extensively discussed in studies of [1][12]. Thus, increase time and costs of product development with the lack of clear and unambiguous requirements [2] and some associated problems such as the lack of a structured workflow for the creation and specification of requirements [1][19] are presented. In study [18] the difficulty in identifying the criteria, methods and techniques used in the practice by the companies for the prioritization of requirements is perceived. The lack of a requirements model also leads to difficulties in product development cooperation, as presented by source [17], beyond currently requirements categorization models being used only in defining the product or system boundaries in development [16]. In turn, the difficulty generated by the lack of standardization for structuring requirements can be observed in the work of [17], [12], [13]. According to source [20], problems with requirements specification are probably the main reason for project failure, late delivery and unsatisfactory product performance.

Knowledge transfer: The efficient and effective knowledge transfer during the engineering requirements process is crucial to the success of product development. However, this transfer is a challenge since the requirements are often not tangible and the knowledge about them is, most of the time, unspoken [21]. In this sense, the main difficulties in the product development have been the lack of knowledge of the whole life cycle by developers, the lack of clarity in the request of the clients and the poor communication [22]. All projects require some information exchange inside and outside organizations, especially in the early stages of the product life cycle. However, often the loss of information fidelity for issues related to the lack of formalization of this exchange occurs [23].

The objectives and resources used to address and solve these problems as follows.

B. Proposed objectives and resources

Improving requirements reliability: Source [10] develops an improved Kano model that takes into account both the discontinuity problem and uncertainty of customer requirements, proposing a new tool for decision support in product development. Also, in this sense, Source [16] propose a model capable of categorizing requirements that influence design, such as constraints and non-functional requirements, to assertively establish the correct requirements, determining the minimum necessary requirements to meet the needs of stakeholders.

Methodological processes to drive requirements: Many of the objectives and development methods presented are focused on software development. Source [1] considers that the creation of methods in companies or in specific projects is fundamental to have a process to follow in the implementation of the idea or the product. In this way, a method is created for the evaluation of engineering requirements in technology companies information [3].

Requirements modeling: Source [21] presents a requirements modeling method to conduct the formal expression of the requirement, proposing a framework model and its optimization algorithm. Using this model, the problem of semantic consistency between client and designer is solved. Source [22] applied the SysML language to show the importance of modeling requirements in the development of complex products in order to mitigate cooperation difficulties in product development, providing transparency, communicability and coherence.

Requirements reuse: With regard to the requirements reuse search, source [24] propose a new structure for specifying requirements, so that they can be reused. For this, they identify the structural characteristics necessary for the reuse of the requirements, suggesting a structure that fulfills these criteria.

Identifying knowledge stream: In order to overcome the challenges linked with knowledge transfer practices without a requirements engineering process, source [25] collect several data, in interviews and in the literature, combine an extensive theoretical review and empirical analysis findings to develop the means to overcome the challenges and propose suggestions to improve the process of knowledge transfer to RE process.

Evaluating PDP activities related to requirements: In qualitative analysis, the work [24] aims to describe and analyze the role of requirements manager of new product development projects through interviews and document analysis. In the same way, Source [25] aims to analyze the effects of cultural aspects in improving RS processes and to understand the interaction between technical and cultural perspectives. It is noteworthy that most of these modifications are related to the incomplete capture of requirements at the early stage of product development.

C. Research Opportunities:

Through the problems and solutions presented, some research opportunities could be identified:

- ***Requirements standardization and formalization:*** the representation and communication of stakeholder requirements in a format that requirements engineers can easily incorporate into their formalized requirements documents is one of the identified gaps. In addition, another gap concerns the transformation of stakeholder requirements into tangible project requirements that can be easily implemented by development teams [9].
- ***Knowledge management:*** although there are several studies indicating the best technique or method for the management of requirements, is necessary to focus on improving the knowledge and understanding of all those involved in the requirements management process [18]. In this way, managing the interaction of stakeholders across boundaries and between teams, as well as managing the domain and technical knowledge during requirements deployment at all organizational levels, are some of the challenges identified [23].
- ***Optimization of interaction between stakeholders:*** there is also an research opportunity in the development of methods and support tools to optimize the engineering requirements, in order to make possible a real interaction of stakeholders in the NPD, connecting the process to the right people early to establish requirements [25].

- ***Requirements reuse:*** requirements reuse has been recognized as a capable source of increasing the efficiency and quality of product development processes [20]. It is recommended a practical application with requirements reuse approaches that combine different levels of fit and results, on how different implementations affect the process performance result [26].
- ***Conducting studies in other areas of application:*** analyzing the application of all studies, it is clear that the topic of requirements engineering is still closely linked to its area of origin (systems / software engineering). It is suggested to deepen the knowledge on the subject, as well as to study the research opportunities presented above in other areas of engineering development.

5. Conclusion

This article presents a structured review of the literature on the topic of requirements engineering, which plays a vital role within the product development process life cycle, identifying the state of the art and research opportunities on the subject, through the ProKnow-C.

In the systemic analysis, the reading of all papers was conducted in order to identify the main research problems addressed, the proposed objectives and resources, and future research opportunities. The research opportunities encountered were: *(i)* standardization and formalization of requirements; *(ii)* knowledge management; *(iii)* optimization of stakeholder interaction; and *(iv)* reuse of requirements.

During the course of this work some difficulties were encountered. The first one was related to the searches in the databases, since each base has a unique way to carry out the research. In addition, exporting references was also a difficulty, as some bases required it to be done manually, exporting one by one. Also, the methodological procedure adopted in this study requires that the researcher record each step performed, which makes the process laborious.

It is recommended in the future to carry out all the steps again, including the analysis of the references of the papers that constitute the bibliographic portfolio which, in favor of brevity, has been adapted in this study. Besides that, ensuring the analysis not only of the most recent articles but also of the articles that give rise to the concepts on the subject.

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Ownership, Institutional Environment and Institutional Capital: Evidence from China

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Abstract. To demonstrate organizational response to institutional voids, the concept of institutional capital is introduced for purposes of capturing the firm's innate and acquired competences which help the firm utilize institutional opportunities, reduce institutional constraints, and hence gain legitimacy. We identify three components of institutional capital, namely political influence, industrial power and organizational cognition. In most studies of *ownership* and firm performance, researchers have assumed that different forms of ownership have direct or indirect effects on firm strategy or performance. This research aims at exploring the difference of institutional capital for firms of different ownership types. Empirical tests based on a sample of two hundred firms located in China finds that different ownership types of firms do have different levels of political influence, industrial power and organizational cognition. State-owned enterprises have the highest level of political influence, while foreign enterprises have advantages in industrial power, such as higher ability of standardization, superior network position, and better organizational cognition. Discussion and managerial implications are provided following the data analysis results.

Keywords. Institutional capital, institutional environment, ownership type, political influence, industrial power, organizational cognition

Introduction

As institutional theory suggests, organizations may imitate others' activities because they face social pressures to comply with dominant norms, because they have limited ability to make decisions in uncertain environments, and/or because they are affected by prevalent professional knowledge [1]. By adopting the activity of the majority, organizations obtain legitimacy as the social environment views their practices to be rational and efficient [2, 3]. However, although prior research provides some strategies for gaining legitimacy, few studies conclude through what competences firms gain and maintain their legitimacy.

To answer the question "How do firms respond to their institutional environment?", the concept of institutional capital is introduced to capture the specific conditions within an organization's innate and acquired competences which help the firm utilize institutional opportunities, reduce institutional constraints, and hence gain legitimacy. Based on institutional theory, we develop and provide a construct demonstrating dimensions and influential factors of the institutional capital. This research also examines the differences of institutional capital in firms of different ownership types.

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Contingencies of institutional capital and the relationships among uncertainties, competences and outcomes are context-specific. China possesses its own requirements of social acceptance, i.e., legitimacy. From a regulatory standpoint, the heavy influence of government and a long tradition of tie utilization make it important to gain political influence. Further, China has a long tradition of using ties or engaging in networks to coordinate transactions, which cause some to refer to ties as the 'lifeblood' of business conduct in Chinese society [4]. Several studies have already validated the notion that the frequency or level of using managerial networking exerts a positive impact on the performance of Chinese firms [4, 5]. Therefore, China serves as a rich context for exploring the concept and antecedents of institutional capital. In addition, as emerging markets in China become more heterogeneous, most industries in China are undergoing structural transformation, which provides complex industrial dynamics that significantly affect firm behavior and outcome [6]. In conclusion, the research objectives of this thesis are focused on firms in the Chinese market since China provides an interesting and dynamic setting to conduct a study about institutional capital and ownership.

1. Institutional environment and institutional capital

The greater and greater importance of legitimacy in the competence of organizations suggests that their competitive success largely feeds on institutional capital. Ghiselli, Campbell [7] introduce the concept of institutional capital and defines it as "the firm's capability to support value-enhancing assets and competences" through the "effective management of the firm's resource decision context". Bresser and Millonig [8] state institutional capital as the specific conditions in an organization's internal and external institutional context that allow the formation of competitive advantage. In this research, *institutional capital* is defined as the firm's innate and acquired competences which help the firm utilize institutional opportunities, reduce institutional constraints, and hence gain legitimacy. So a firm's institutional capital focuses on a firms' capability to survive and succeed in a certain institutional environment.

Previous research find that an organization's institutional capital increases active management of its institutional context facilitating the acquisition, creation, and improvement of superior resources, i.e., legitimacy, supporting the competitive advantage of organizations [9]. Hence, the strategies for managing the institutional context so as to create or sustain institutional capital are vital to the success of a firm.

The concept of institutional capital is explored in a different research field, and scholars refer institutional capital to different content in different research context. For example, aiming at exploring the relationship between institutional capital and sustainable development, Platje [10] presents four elements of institutional capital: public domain, institutional strength, good governance, and institutional equilibrium. In exploring the institutional determinants of export performance in high-tech industries, Schneider, Schulze-Bentrop [11] describe institutional capital as the formal and informal institutions of an economy, which, in conjunction with other resources, influence company performance. They interpret strong export performance in high-tech as institutional capital conducive to the competitive advantage of single firms. Handelman, Cunningham [12] use the institutional capital (cultural, social, and economic) afforded to marketers given the dynamics of the organizational field as one of the important factors in understanding of stakeholder marketing. In the research of

local development, institutional capital was identified with the public and private institutions present in a given territory, including the number of public and private organizations that exist in the locality and the structural attributes of these institutions [13]. In studies of information and capital acquisition, institutional capital is mentioned as capital provided by government or private agencies [14] and the acquisition of institutional capital is associated positively with their familiarity with the particular source of capital, as well as with technical assistance from major agencies.

Although these institutional capital-related studies have been done, clear definition and construct of institutional capital are still needed. Particularly from the foregoing body of literature, we find that the definition of institutional capital is largely disjointed, segmented and even unrelated. The dimensions or factors constituting institutional capital are also quite blurred. None of the prior research has comprehensively explored how firms can survive and succeed in a certain institutional environment. We still need further research which can help marketers determine how to best assess their institutional context and how to use that information to design strategies to acquire institutional capital [12].

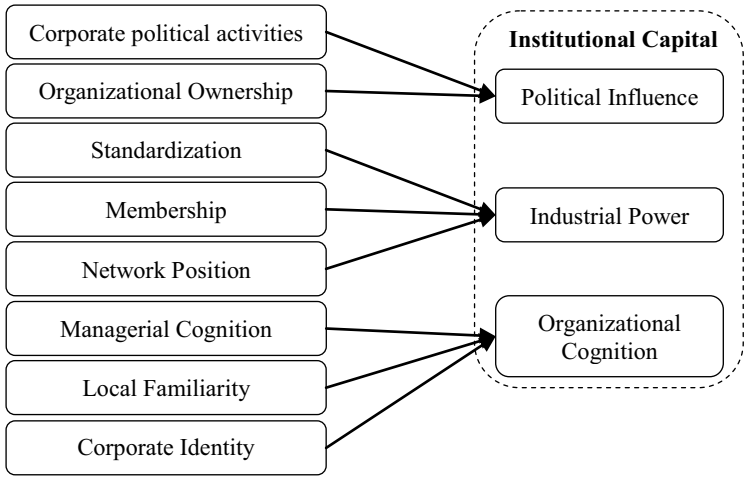


Figure 1. Dimension and Antecedents of Institutional Capital.

2. Ownership and institutional capital

In most studies of *ownership* and firm performance, researchers have assumed that different forms of ownership have direct or indirect effects on firm strategy or performance. In the context of developed markets, many studies are built on the premise that greater stock ownership by managers (insiders) aligns managerial interests with those of the other owners (outside stockholders), thus enhancing firm performance [15-17]. Rather than examining with the insider/outsider contradiction, this research will focus on the differences between ownership groups such as state vs. private ownership, local vs. foreign ownership.

In China, government has different policies for different ownership types: state-owned, private, foreign-owned, joint venture. For example, stated owned companies

are created on the basis of strong ties with government, and hence obtain better access to scarce resources. The leaders of firms with government ownership generally do not have to worry about political access as much as the leaders of privately controlled firms do, because the governmental firms already enjoy preferential treatment in terms of inputs and access to product and capital markets [18]. Neiheisel [19] found that state owned firms have more secure property, greater contractual rights, and closer ties with government. As a result, they enjoy significant advantages and exhibit faster growth.

On the other hand, firms without government ownership have less secure property and contractual rights and are thus in greater need of assuring political access by establishing good government relations through other means, such as corporate philanthropy [20]. In China, uncertainty about private ownership's legal status and possible new policy devaluing their ownership remains a major worry of private company owners. Moreover, access to critical factors and capital resources, such as debt financing, is least favorable for privately controlled firms. Compared to state owned companies, privately controlled enterprises have less institutional trust capital, which should normally be established by an enterprise's track record and reputation. However, because of the Chinese market's infancy and the need to contend with popular distrust, private enterprises have to seek government for institutional trust to convince people and secure loans. To overcome these disadvantages, privately controlled firms may have incentives to engage in charitable activities as a means of creating goodwill with potential regulators and government officials [19].

The third kind of organizational ownership deserving our attention is foreign-invested enterprises. Well established in the international business literature are the challenges that foreign entrants face when adapting their systems to country-specific economic, legal, political, institutional and cultural differences of a host country [21]. To adapt business systems to those used in China and enhance legitimacy, foreign firms make a great effort, such as building ties, in surviving in the Chinese market [22]. However, except for these challenges, foreign companies do have some policy or legal advantages. Huang [23] shows that there is a dualist legal regime in China in that different bodies of laws and regulations apply to foreign-invested enterprises (FIEs) from those that apply to domestic firms. In general, the legal and regulatory treatments of FIEs are superior to those that pertain to domestic firms, especially domestic private firms.

Although state-owned, private and foreign firms have different advantages and disadvantages in the Chinese market, they also have differences from the perspective of political influence. In summary, state-owned enterprises have the most superior legal treatment and inherent advantage; hence, they possess the greatest political influence. They are followed by foreign invested enterprises, which enjoy superior legal treatment compared to domestic private firms, but face challenges of a different institutional environment. Private firms have the least inherent advantage from a regulatory aspect, and usually make greater efforts in other aspects, like corporate philanthropy [20] and political activities, to gain political influence.

Proposition: Organizational ownership affects a firm's political influence in such way that, generally, state-owned enterprises possess the greatest political influence, followed by foreign invested enterprises, while private firms possess inherent political influence.

3. Methods

3.1. Data collection method and sample description

Data used in this study were collected through questionnaire survey. Questionnaire were collected mainly in three ways. The first way was through a market research company in mainland China, who sent the questionnaire through email directly to managers of manufacturers randomly selected from a list of all manufacturing firms belonging to the four-digit Chinese Industrial Classification (CIC) system. The second part of the participants involved the managers of enterprises which had been created by venture capital in Guangdong. These participants were contacted through the Association of Promotion for Venture Capital in Guangdong. The last part of the sample was connected through personal relations. The non-random sampling method limits generalization of the results to a certain degree. But, given the difficulty of primary data collection in China, it is not realistic to survey in a fully random way.

All potential participants were managers who were initially contacted via e-mail, and the electronic versions of the questionnaires were attached to these e-mails. These contacts were invited to participate in this survey; they were also asked to forward e-mails to others who might be interested in participating. All participantes were required to complete the questionnaire independently and email the completed questionnaire to me. Totally, I sent out about 400 questionnaires and received 261 from the managers. Excluding improper or incomplete questionnaires, 198 questionnaires were finally obtained and used for analysis.

Of the final samples, the company with the longest history was founded in the year 1849, and six young companies were founded only one year ago. The majority of the companies (24.4%) had a firm history of 6 to 10 years. In terms of company size, the firms had 6 to 100, 000 employees and many of them (18.8%) have 50 employees or less. As to the organizational ownership style, 54.4% of the final samples were private companies, 23.8% were state-owned companies, 3.9% were joint ventures and 10.2% were foreign-owned enterprises. 19.3% of the companies possessed a market share of 5% to 9.99%, another 19.3% enjoyed a market share of 20% to 29.99% and 17.8% of the companies had a market share of 10% to 19.99%.

3.2. Measures

The development procedure for the institutional capital scale is following scientifc procedures including literature review, in-depth interviews, pilot study, expert evaluation. The finalized scale includes 30 items in three aspects. Ten items are used to measure firms' political influence, i.e., corporate political activities and organizational ownership. The sample items for political influence include "Our company has lobbied government officials, industry association officers or officers of the judicial system for the company's development", "Our company's shareholder background (state-owned, private or foreign, etc.) can get some preferential policies for company". Ten items are used to measure firms' industrial power, i.e., standards, membership and network position. The sample items of industrial power include "Our company's product or service is considered to be the industry standard", "When compared with others in the industry, our company holds more industry information", and "Our company enjoys a good reputation in the network of peers and partners". The last ten items are used to

evaluate a firm's organizational cognition, i.e., managerial cognition, local familiarity and organizational identity. The sample items for organizational cognition include "The managers of our company have the ability to discover market opportunities", "Our company is familiar with local consumers of current market", and "Our company's corporate image meets social expectations". All items used the seven-point Likert-type scales with anchors of 1, "strongly disagree" to 7, "strongly agree". The Cronbach's alpha of three aspects of institutional capital, political influence, industrial power and organizational cognition, were .90, .95, and .92, respectively. The Cronbach's alpha of institutional capital was .94.

4. Results and implications

The ANOVA results reveal some interesting findings about institutional capitals of firms with different ownership types. Different ownership types of firms do have different levels of corporate political activities. State-owned enterprises have the highest level of corporate political activities, followed by foreign-owned and joint venture. Private enterprises have the lowest level of corporate political activities. Specifically, firms of different ownership types have significantly different co-optation behavior and government relationships, but have no significant difference in terms of lobbying.

Of the eight factors of institutional capital, firms of different ownership types have significant differences in five of the eight factors. The means of these five factors with different ownership types are shown in figures 2 to 6. Three exceptions include membership, managerial cognition and local familiarity. State-owned, private, and foreign firms have no obvious difference in the ability of setting membership rules, managerial cognition (multi-angle analysis, competitor analysis, and market opportunities identification), and their familiarity with local markets.

For the two factors in political influence, corporate political activities and ownership type advantage, state-owned enterprises have the highest level and private enterprises have the lowest political influence. Joint venture, foreign-owned and other firms are in the middle. This result is supportive of our proposition that proposing stated-owned enterprises have the highest political influence.

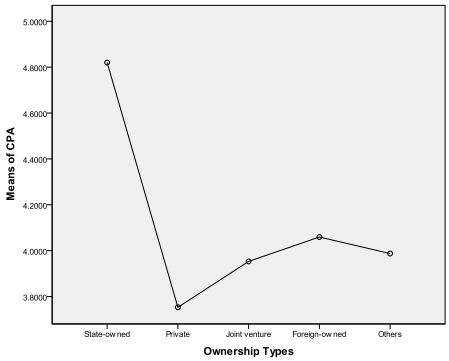


Figure 2. Means of CPA of Different Ownership Types.

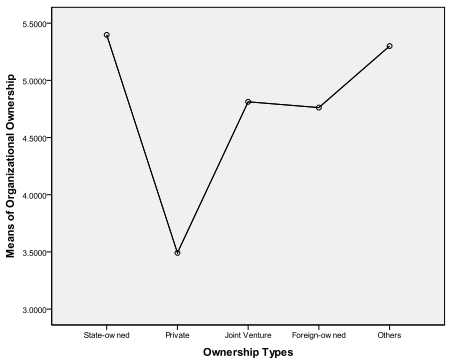


Figure 3. Means of Organizational Ownership Advantage of Different Ownership Types.

However, state-owned enterprises do not have higher level institutional capitals in their normative and cultural-cognitive aspects. Foreign-owned enterprises have the highest level of standardization, the ability of setting industry standards, followed by joint venture and state-owned, and private firms have the lowest standardization ability. This order (foreign-owned > joint venture > state-owned > private) is also shown in the aspects of network position and organizational identity.

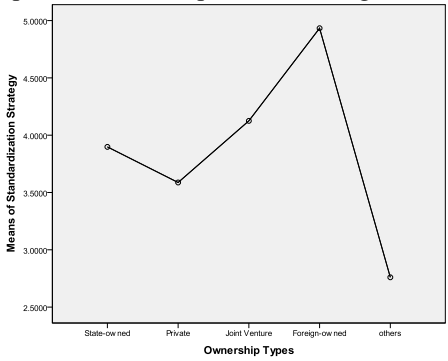


Figure 4. Means of Standardization of Different Ownership Types.

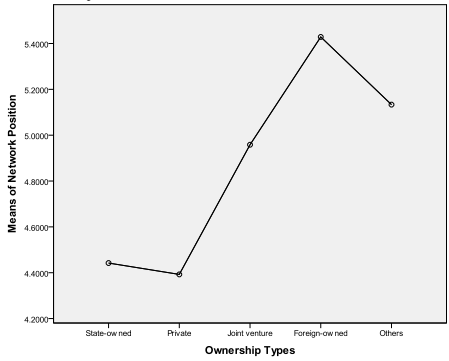


Figure 5. Means of Network Position of Different Ownership Types.

Combining factors of institutional capital together, foreign-owned enterprises hold higher institutional capital than stated-owned enterprises. Private enterprises hold the lowest institutional capital. In fact, state-owned enterprises have an absolute advantage only in political influence. However, for industrial power and organizational cognition, foreign companies derive most of their institutional capital by means of their ability to set standards, their superior network position, and their well-accepted organizational identity.

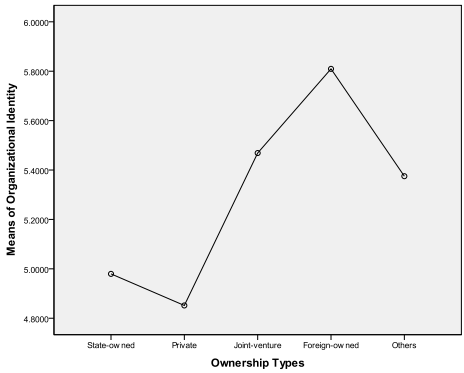


Figure 6. Means of Organizational Identity of Different Ownership Types.

Acknowledgement

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Part 4

Human Factors in Design

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Transdisciplinary Engineering: A Paradigm Shift
C. Chen et al. (Eds.)

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Usability Investigation on the Localization of Text CAPTCHAs: Take Chinese Characters as a Case Study

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Abstract. Text CAPTCHA has been an effective means to protect online systems from malicious attacks. However, nearly all the Text CAPTCHA designs are based on English characters, which may not be the most user-friendly option for non-English speakers. Therefore, there is an increasing interest in designing local-language CAPTCHAs, which are expected to be more usable for native speakers. However, systematic studies on the usability of localized CAPTCHAs are rare, and a general procedure for the design of usable localized CAPTCHA is still unavailable. Here, we comprehensively explored the design of CAPTCHAs based on Chinese characters from a usability perspective: a usability comparison of CAPTCHAs based on Chinese and English characters, then the evaluation of intrinsic design factors of Chinese CAPTCHAs. It's found that Chinese CAPTCHAs can be equally usable comparing with alphanumeric ones. Meanwhile, guidelines for designing user-friendly Chinese CAPTCHAs are also presented. Those design practices are further summarized as a general procedure which is expected to be applicable for the design of CAPTCHAs based on other languages.

Keywords. Text CAPTCHA, Usability, Human Factors, Cross-culture Design

Introduction

CAPTCHA (Completely Automated Public Turing test to tell Computers and Humans Apart) has always been an effective means to defend automatic scripts and protect online systems from spam and abuse [1]. CAPTCHAs today are mainly based on Image, Sound or Text [2]. For Image CAPTCHAs, a set of images are presented and the user is instructed to click on particular image(s) to solve them [3]. A sound-based CAPTCHA usually requires users to solve audio-recognition tasks. Text CAPTCHAs usually include several alphanumeric characters (a-z, A-Z, 0-9) that are distorted and added with background noises [4], human users are required to correctly input those characters [5]. Given that this paper focuses on Text CAPTCHA, the word CAPTCHA mentioned afterwards represents only the text one unless otherwise specified.

With the increased distortion of texts and backgrounds, CAPTCHAs are more efficient to defend automatic scripts [4] but also at the cost of degraded usability. Therefore, many studies have been conducted to investigate the usability of CAPTCHAs. For example, Chellapilla [6] presented the limits of distortions that are acceptable for users; Elie Bursztein [7] investigated the effects of visual features, anti-

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segmentation and anti-recognition features on the usability of CAPTCHAs. Belk [8] revealed that participant's cognitive styles also affect the usability of CAPTCHAs, etc. In addition to those usability studies, there is also an increasing importance to design localized CAPTCHAs due to the large number of non-English Internet users. Localized CAPTCHAs could have several advantages: (i) Familiar for local users: it is intuitively more comfortable with native languages; (ii) More durable with design factors: for local languages that are complex in form, it may not be easily confused with security features such as distortion; (iii) More candidate characters and better security: there are 26 letters and 10 numbers for alphanumeric CAPTCHAs, however, take Chinese characters for example, it can provide thousands of different candidate characters. For instance, Shirali-Shahreza [9] designed CAPTCHAs that employed Persian/Arabic characters with improved security and usability. Yang [10] explored the application of Korean characters in CAPTCHAs and revealed that the Korean CAPTCHAs could be easily understood by native Korean speakers while difficult to be defeated by OCR (Optical Characters Recognition) programs. Banday [11] investigated the usability of CAPTCHAs based on Urdu, one of the regional languages in India. The results indicated that, for native speakers of Urdu who had little familiarity with English, they solved Urdu CAPTCHAs significantly faster and more accurately than those based on English. There is also an emerging interest in developing new algorithms for Chinese CAPTCHAs. Wang [12] proposed double-layer Chinese CAPTCHAs against OCR. Several other methods for generating Chinese CAPTCHAs are also reported [13-15].

However, previous studies are mostly focused on new means of generating localized CAPTCHAs while lack systematical investigations on the usability of such CAPTCHAs. Particularly, the general procedure for designing localized CAPTCHAs is still unavailable yet. In this study, taking the usability investigation of Chinese CAPTCHAs as a case study, we compared the usability of CAPTCHAs based on English and Chinese (Experiment I), and explored the intrinsic design factors that may affect the usability of Chinese CAPTCHAs (Experiment II). Such comprehensive practices on Chinese CAPTCHAs were further generalized as a standard procedure, which is expected to be applicable for the localization of CAPTCHAs based on any other regional language.

1. Methods

The three key dimensions of usability [16] were used to evaluate the usability of testing CAPTCHAs: effectiveness, efficiency and satisfaction. The effectiveness and efficiency were measured by the correction rate and average solving time for each type of CAPTCHA, respectively. The satisfaction was obtained through online questionnaires and face-to-face interviews. The satisfaction questionnaire, which used a 5-point Likert scale (1=strongly disagree, 5=strongly agree), focused on the following three aspects: Q1. It is visually comfortable; Q2. It's easy and efficient to recognize and input; Q3. It's appropriate for wide application. Testing CAPTCHAs were generated through the revision of Securimage [17], a widely-used open source code. Except for the characters in each CAPTCHA, all other design factors were kept the same, such as the font size, interfering lines, etc. Furthermore, the average number of keystrokes [18] required for the input of English and Chinese CAPTCHAs were kept the same under current experimental setting, i.e. 8 keystrokes. The keystroke number of Chinese characters were based on the predominant input method in China--Pinyin [19] input

method. Therefore, it maintained a similar workload to input different CAPTCHA types and provided a similar condition to evaluate the efficiency of different designs.

1.1. Experiment Design

1.1.1. Experiment I: usability comparison between English and Chinese CAPTCHAs.

See in Figure 1, four kinds of CAPTCHAs were deployed to compare the usability of English and Chinese CAPTCHAs: Random English Characters (REC), Frequent English Words (FEW), Random Chinese Characters (RCC) and Frequent Chinese Words (FCW). Each REC CAPTCHA included 8 English letters and each FEC CAPTCHA included a single English word that is consisted of 8 letters. The RCC CAPTCHA is the counterpart of REC CAPTCHA and it randomly included 3 or 4 individual Chinese characters. The FCW CAPTCHA is the counterpart of FEW CAPTCHA and it included a single Chinese word that is composed of 4 individual Chinese characters. Testing characters or words were those frequently used in daily life.

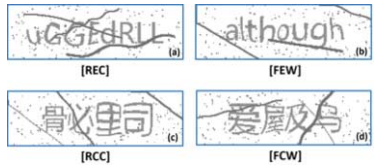


Figure 1. Illustration of CAPTCHA designs in the usability comparison of English and Chinese in current study: (a) Random English Characters (REC); (b) Frequent English Word (FEW); (c) Random Chinese Characters (RCC); (d) Frequent Chinese Word (FCW).

1.1.2. Experiment II: Evaluation of intrinsic usability factors of Chinese CAPTCHAs

Experiment II focused on some unique design factors of Chinese characters, which included different font families, characters that are similar in form or pronunciation, characters of different usage frequencies, etc. The four fonts studied were (a) Yahei, (b) Songti, (c) Heiti and (d) Caoshu, see in Figure 2. The first three fonts are widely used on the Internet and have better readability comparing with the last one, Caoshu. Among all those fonts, the boldness of characters is the main difference. In addition to the fonts, Figure 3 (a) and (b) show two other design factors: CAPTCHAs based on less frequently-used characters and characters with similar appearance, respectively. Generally, the Pinyin of a Chinese character includes two parts: initial consonant and vowel. However, the pronunciation of several pairs of initial consonants, “z” and “zh” for example, are similar, which may mislead the input of characters that contain those initial consonants. It is the same case for vowels. Therefore, the last two factors focused on the influence of easily-confused Pinyin: Figure 3 (c) and (d) are examples of CAPTCHAs that employed characters with similar initial consonants (z/zh, c/ch, s/sh, r/l, l/n, f/h) and similar vowels (an/ang, en/eng, in/ing), respectively.

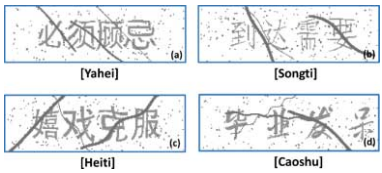


Figure 2. Illustration of Chinese CAPTCHA designs based on four different fonts: (a) Yahei, (b) Songti, (c) Heiti and (d) Caoshu.

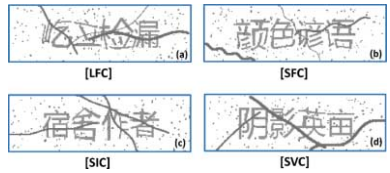


Figure 3. Example of CAPTCHAs based on (a) less-frequent characters [LFC], (b) similar-form characters [SFC], (c) characters with similar initial consonants [SIC], and (d) characters with similar vowels [SVC].

1.2. Participants

Thirty participants (13 males, 17 females; aged from 18 to 25, M=21.6, SD=1.3), who were native speakers of Chinese with English as a familiar second language, were recruited for Experiment I. They were students at Shanghai Jiao Tong University from different majors. All the participants had passed the College English Test Band 6, a language proficiency test held by the Ministry of Education of China. Therefore, they were familiar with all the testing English words. Another 30 native speakers of Chinese (14 males, 16 females; aged from 18 to 25, M=21.4, SD=2.17) were recruited for Experiment II. They were also students from different majors at Shanghai Jiao Tong University. All participants for both experiments were experienced computer users who spent at least 2 hours per week on word processing. Furthermore, Pinyin was their daily-used input method for Chinese characters and they all had encountered English and Chinese CAPTCHAs during their previous online activities. Also, none of the participants had trouble reading on the screen.

1.3. Apparatus

The two experiments were both conducted in a controlled lab environment. All participants were instructed to solve CAPTCHAs on a same setup, which included a computer with 20-inch liquid crystal display, a set of regular QWERTY keyboard and mouse as the input devices. Microsoft Pinyin was used for the typing of Chinese characters. All CAPTCHAs were generated on a remote server and downloaded in the form of webpages to the local browser, which was Google Chrome in this study.

1.4. Procedure and tasks

The experiments were carried out in three stages—preparation, testing, and interview. During the preparation stage, the apparatuses were reset and each participant was informed of the experiment tasks. After that, the participant was instructed to get familiar with the experiment apparatuses by solving five CAPTCHAs. During the test session, the participant was left alone in the lab and different types of CAPTCHAs were presented one by one through the web interface, 12 pieces for each type. After the submission of each CAPTCHA, a record would be generated on the remote server, indexing the solving time, the input values and whether the CAPTCHA was solved correctly. The webpage also refreshed automatically after submission and the participant was directed to solve the next CAPTCHA till the end of the task cycle. After solving all the CAPTCHAs, an online questionnaire was presented for the participant to fill. The questionnaire contained pictures of each type of CAPTCHA to help participants better rate testing CAPTCHAs. After that, each participant was also asked to share his/her subjective opinion about the testing CAPTCHAs. Finally, he/she was paid to appreciate the cooperation.

2. Results and Discussion

2.1 Usability Comparison between English and Chinese CAPTCHAs

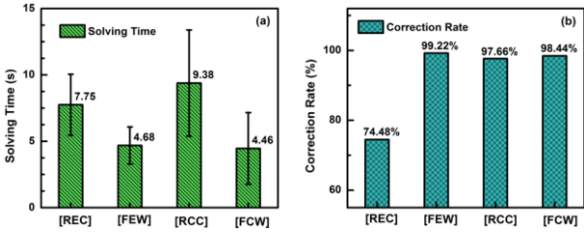


Figure 4. (a) Average Solving Time and (b) Correction Rate for four kinds of CAPTCHA design: Random English Characters (REC), Frequent English Words (FEW), Random Chinese Characters (RCC), Frequent Chinese Words (FCW).

The average solving time and correction rate for all four kinds of CAPTCHA design, which based on Random English Characters (REC), Frequent English Words (FEW), Random Chinese Characters (RCC), or Frequent Chinese Words (FCW), are illustrated in Figure 4. The solving time of FEW (M=4.68s, SD=1.4s) is essentially the same as that of the FCW (M=4.46s, SD=2.7s). This is because all participants were familiar with both the English and Chinese words tested in this study. CAPTCHAs based on RCC (M=9.38s, SD=4s) have the longest solving time, followed by REC (M=7.75s, SD=2.3s). Meanwhile, the solving time of both RCC and REC are longer than that of FEC and FCC. Because, for both languages, it took a longer time for participants to recognize and type individually each random character. The similar solving time for FEC and FCC further shows it took basically the same efforts for participants to response to their native language and a familiar second language. Also, CAPTCHAs based on frequently-used English and Chinese words have better efficiency than those employing random characters, while there is no significant difference in the solving time of frequent English and Chinese words.

The effectiveness of those four CAPTCHA designs are represented by the percentage of CAPTCHAs that were correctly solved, see in Figure 4 (b). The accuracy for FEW (99.22%), RCC (97.66%) and FCW (98.44%) are similar and significantly higher than REC (74.68%). The high correction rates for the first three kinds of CAPTCHAs demonstrate there was no difficulty for participants to correctly recognize CAPTCHAs of both languages. As to the low correction rate of REC CAPTCHAs, a majority of those incorrect inputs were caused by similar letters, such as “I” and “L”. When we removed the results from CAPTCHAs that contained confusing letters, the accuracy of REC was improved from 74.48% to 85.31%. However, such an accuracy is still lower than the other three CAPTCHA designs. This is further attributed to the random lines, background noises and distortions, while FEW CAPTCHAs maintained a high correction rate of 99.22%, indicating FEW design was less sensitive to the security features such as random lines than REC. The satisfaction questionnaires are summarized in Table 1. The results indicate that FEW and FCW were the most preferred CAPTCHAs, while REC and RCC were negatively rated. The face-to-face interview further revealed that, more than 97.3% of the participants believed it was easy to recognize FEW and FCW CAPTCHAs with just a single glance. On the contrary, for CAPTCHAs based on random characters, it took more efforts to recognize each character individually.

Table 1. Satisfaction of CAPTCHAs based on Random English Characters (REC), Frequent English Words (FEW), Random Chinese Characters (RCC), Frequent Chinese Words (FCW).

	Yahei		Songti		Heiti		Caoshu	
	AVG	SD	AVG	SD	AVG	SD	AVG	SD
Q1. It's visually comfortable	3.03	1.13	4.13	0.78	2.87	1.17	4.13	0.78
Q2. It's easy and efficient to recognize and input	2.93	1.20	4.60	0.50	2.53	1.22	4.40	0.72
Q3. It's appropriate for wide application	2.63	1.13	4.50	0.86	2.07	1.23	4.20	0.87

2.2 Intrinsic design factors that may affect the usability of Chinese CAPTCHAs

Experiment I indicated that, for native speakers, the usability of Chinese CAPTCHAs can be the same as those English ones in terms of efficiency, effectiveness, and satisfaction. Therefore, we further explored the design factors that may affect the usability of Chinese CAPTCHAs. However, we mainly focused on some intrinsic factors rather than external factors such as background noises, strikethrough lines, etc., which had been extensively studied in previous publications, like [4, 7].

The solving time and correction rate for the four different fonts, Yahei, Songti, Heiti and Caoshu, are introduced in Figure 5. The solving time of Yahei (M=6.97s, SD=3.01s), Songti, (M=6.11s, SD=2.11s), and Heiti (M=6.46s, SD=3.04s) are similar while shorter than that of Caoshu (M=8.74s, SD=4.69s). The correction rate of Yahei (97.40%), Songti (96.75), and Heiti (98.05%) are also similar while higher than that of Caoshu (93.5%). Those results reveal that the efficiency and effectiveness are the same for the first three fonts and better than that of Caoshu. Because the most prominent difference among the first three fonts is the boldness of characters, the results indicate the usability of Chinese CAPTCHA is insensitive to the thickness of characters. Participants' relatively poorer performance with Caoshu can be explained by the lower readability of Caoshu.

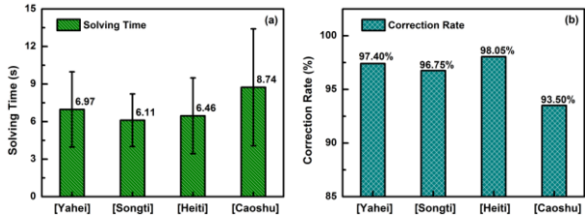


Figure 5. (a) Solving time and (b) correction rate of CAPTCHAs based on four different fonts: Yahei, Songti, Heiti and Caoshu.

The solving time and correction rate of four other factors are shown in Figure 6. For CAPTCHAs employed low-frequency characters (LFC), the solving time (M=10.19s, SD=7.77s) and correction rate (91.61%) are longer and lower comparing with that of the reference group, Yahei in Figure 5, respectively. This reveals that, CAPTCHAs based on unfrequently-used characters have lower usability in terms of efficiency and effectiveness. For CAPTCHAs based on similar-form characters (SFC), there were at least two similar characters. The solving time (M=6.69s, SD=2.57s) and

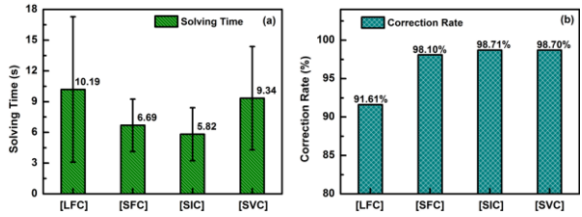


Figure 6. Solving time and correction rate of Chinese CAPTCHAs based on (a) low frequency characters [LFC], (b) similar form characters [SFC], (c) similar initial consonant characters [SIC] and (d) similar vowel characters [SVC].

correction rate (98.10%) of SFC have no much difference with that of Yahei in Figure 5, the reference group. This means even if the candidate Chinese characters look similar, no notable confusion or difficulty would be imposed on the solving efforts. The last two factors focused on the characters that contain easily-confused Pinyin. For CAPTCHAs containing similar initial consonant characters [SIC], the solving time (M=5.82s, SD=2.60s) and accuracy (98.71%) are similar with that of the reference group of Yahei in Figure 5. However, for CAPTCHAs containing similar-vowel characters [SVC], the solving time (M=9.34s, SD=5.05s) is slightly longer than the reference group of Yahei in Figure 5. This implies participants had been confused to some extent and it took longer time to figure out the correct vowels. However, the accuracy remains high (98.70%), because participants were familiar with the appearances of the characters and could recognize the characters correctly.

As to the satisfaction, see in Table 2, among all the four fonts, participants were highly satisfied with Yahei, Songti and Heiti. The font Caoshu, which is relatively harder to recognize, was not preferred. In addition, CAPTCHAs that contained less frequently-used or similar-form characters also turned out to be less favored. Although participants reported characters with similar pronunciations were visually comfortable, they believed that CAPTCHAs based on those characters were less efficient. This is probably because that it takes extra efforts to distinguish similar pronunciations.

Table 2. Satisfaction of Chinese CAPTCHAs based on four different fonts (Yahei, Songti, Heiti and Caoshu), low frequency characters [LFC], similar form characters [SFC], similar initial consonant characters [SIC] and similar vowel characters [SVC].

	Yahei		**Songti**		**Heiti**		**Caoshu**	
	AVG	SD	AVG	SD	AVG	SD	AV	SD
Q1. It's visually comfortable	4.43	0.86	4.10	0.99	4.40	0.81	2.60	0.93
Q2. It's easy and efficient to recognize and input	4.43	0.90	4.23	0.97	4.47	0.90	2.83	1.23
Q3. It's appropriate for wide application	4.10	0.82	4.10	0.92	4.40	0.86	2.43	0.86
	LFC		**CFS**		**SIC**		**SVC**	
	AVG	SD	AVG	SD	AVG	SD	AV	SD
Q1. It's visually comfortable	3.53	1.14	3.97	1.03	4.20	1.00	4.17	0.95
Q2. It's easy and efficient to recognize and input	2.93	0.91	4.06	0.94	3.90	0.99	3.53	1.04
Q3. It's appropriate for wide application	2.77	0.97	3.90	0.84	3.87	0.94	3.5	1.00

2.3 Procedure for the localization of Text CAPTCHAs

The localization study of Chinese CAPTCHAs presented here is expected to be capable of generalizing to many other languages, such as Arabic, Japanese, Korean, etc. Figure 7 shows the general procedure we proposed for the localization of CAPTCHAs, which consists of three consecutive steps: (i) Comparing the usability of CAPTCHAs based on English and local language; (ii) Evaluating the design factors that may affect the usability of localized CAPTCHAs; (iii) Refining CAPTCHA designs according to security analysis and medium-scale user test. Step I is to determine if CAPTCHAs based on local language is comparable or better than English ones. The first thing is to analyze the cognitive processes of inputting local language and English. According to the analysis, a design matrix is generated to help prepare English and local CAPTCHAs within a similar frame (fonts, noises, workload, etc.) for the comparison of usability. Thereafter, native speakers of local language who are also familiar with English are recruited to perform the usability tests. For speakers who are unfamiliar with English, their performance on English CAPTCHA is expected to be lower than those who know English, as is the case for Urdu [11]. As a consequence, if the usability

tests indicate that participants perform equally or better with local language CAPTCHAs, it is worthy to localize CAPTCHAs based on that local language. Otherwise, it is suggested to use English CAPTCHAs.

If CAPTCHAs based on local language provide equal or better usability than English ones, then move to the next step: evaluating the design factors that may affect the usability of localized CAPTCHAs, including intrinsic factors and general factors. The intrinsic factors are defined as those uniquely related with a particular language, for example, similarity of characters in form or pronunciation, typical font families, etc. All other design factors are classified as general factors, such as background noises, distortion, etc. For the full process of CAPTCHA localization, it is recommended to evaluate both the intrinsic and general factors. During the last step, security evaluation and medium-scale user test are suggested to further polish the design of localized CAPTCHAs, followed by the actual deployment.

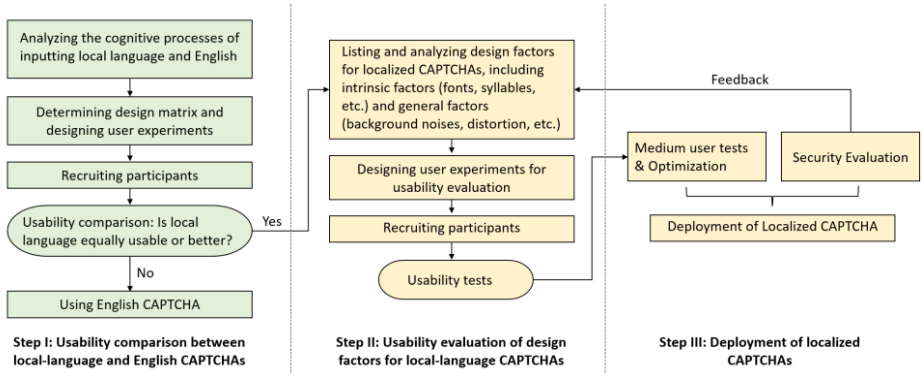


Figure 7. Procedure for the localization of text CAPTCHAs.

Limitations of this study

The current study mainly focused on the usability while the security of localized CAPTCHAs was not discussed. Another limitation is the scale of the usability test. Large-scale evaluations are expected to provide more specific results, such as how people of different ages may perform. Also, the CAPTCHAs studied here were not deployed in real-life situations.

3. Conclusion

In this study, we compared the usability of CAPTCHAs based on Chinese and English, evaluated the intrinsic design factors that may affect the usability of Chinese CAPTCHAs, and finally proposed a procedure that is applicable for the design of user-friendly CAPTCHAs based on other languages. The usability comparison experiments indicated that CAPTCHAs based on the two languages can be almost equally usable within the same design factors such as background noise level and typing workload. Comparing with CAPTCHAs that employ random English or Chinese characters, those based on frequently-used English or Chinese words provide the best usability. Further analyses on intrinsic design factors of Chinese CAPTCHAs revealed the usability of those CAPTCHAs is less sensitive to the daily-used fonts. Meanwhile, although the

characters that are similar in form don't affect the usability, characters that are similar in pronunciation may bring confusions to users. Basing on the comprehensive evaluation on the localization of Chinese CAPTCHAs, a generalized procedure for the localization practice of other languages is proposed, which includes three steps: usability comparison between English and local-language CAPTCHAs, evaluating design factors that may affect the usability of local-language CAPTCHAs, medium-scale deployment for feedback and final deployment of localized CAPTCHAs. This study may shine a light for designing usable CAPTCHAs that employ local languages.

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A Reference Model to Analyse User Experience in Integrated Product-Process Design

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Abstract. The analysis of human factors is assuming an increasing importance in product and process design and the lack of common references for their assessment in industrial practices had driven to define a reference model to analyse the so-called User eXperience (UX) to support human-centred product-process design. Indeed, the recent advances in ubiquitous computing, wearable technologies and low-cost connected devices offer a huge amount of new tools for UX monitoring, but the main open issue is selecting the most proper devices for the specific application area and properly interpreting the collected information content in respect with the industrial design goals. The research investigates how to analyse the human behaviours of "users" (i.e., workers) by a reference model to assess the perceived experience and a set of proper technologies for UX investigation for industrial scopes. In particular, the model has been defined for the automotive sector. The paper defines a set of evaluation metrics and a structured protocol analysis to objectify and measure the UX with the final aim to support the requirements definition in product-process design. The model has been defined to fit different cases: vehicle drivers at work, workers in the manufacturing line, and service operators.

Keywords. User eXperience, Human Factors, integrated product-process design, protocol analysis, digital mock-ups.

Introduction

The Fourth Industrial Revolution is starting to transform the modern companies, but also the way people interact with products and processes due to the change in product smartness as well as the work environments [1] through 2025 and beyond. This technological trend pushes towards the evolution of design, manufacture, operation, and service of products and production systems [2]. Most researches focused on the description of the technological solutions from different points of view (i.e., smart products and connectivity issues, smart machines, IoT applications for industry, cyber-physical systems, embedded technologies to enable product-related services, methods of data acquisition and elaboration, as well as software interface) [3]. Advanced digital and industrial technologies will help people to interact with products and machines, to work better and more efficiently, and return to or be incorporated into the modern manufacturing workforce. Meanwhile, technical developments and interaction

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technologies among components, machines and people will make the production systems more lean, integrated, agile, traceable, and adaptable [4]. As a consequence, manufacturing enterprises, and in particular "smart factories", will need to consider the socio-technical aspects and to include the assessment of the human interaction into their evaluation. Therefore, the socio-technical transformation towards the smart factory will need new design reference models according to this new "human-centric" perspective focused on the assessment of the so-called User eXperience (UX) [5].
The present research investigates how to analyse the perceived human experience by a reference model for the UX analysis and a technological set-up suitable for industrial scopes.

1. The reference model for UX analysis

1.1. Importance of UX analysis in industrial contexts

Human factors have been recognized as a fundamental aspect in industrial engineering, so that ergonomics is always more often considered in industrial products and systems design. The analysis of human factors is focused on the analysis of the effectiveness and the efficiency with which activities and tasks are carried out, related to both physical and cognitive workload [6]. As far as industrial operations, in different contexts it has been demonstrated that human factors highly affect the global efficiency of industrial processes [7-8]. Indeed, low attention to human factors brings to unnatural positions and dangerous actions executed by workers during their jobs, with consequent lower performances, higher production time, greater absence from work, and a general increase of Musculoskeletal Disorders (MSDs) with a consequence impact on national economies, in Europe as well as in other countries [9].

The term User eXperience (UX) indicates the compendium of reactions and feelings as the combination of physical efforts and stresses with the subjective perceptions (e.g., predispositions, expectations, needs, motivation, mood), which affect human factors and are generated during the interaction between humans and an external system, like a product, a machine or an environment [10]. Such experience depends on the characteristics of the designed system (i.e., complexity, purpose, usability, functionality, etc.), the context of use, and the human factors.

In the industrial context, traditional approaches for the analysis of the human factors are based on the assessment of ergonomic and cognitive performances by observing the users or operators at work and collecting data about their actions, mainly by interviews and video-recorded analysis. In industry, analyses are traditionally focused on posture assessment of physical exposures according to objective methods, such as rapid upper limb assessment (RULA), rapid entire body assessment (REBA), Ovako working posture analysis system (OWAS), or workplace ergonomic risk assessment (WERA) and others [11], while psychophysiological methods, based on monitoring of the human biometrical data like electromyography (EMG), electro-dermal measures, electroencephalography (EEG) or heart rate are not used in industrial contexts. More recently, higher attention to cognitive ergonomics is paid, also thanks to the ISO regulations [12]. Although numerous studies demonstrated the importance of the physical and cognitive stress and their interference, as well as their effects on the human response (with the concept of "strain") [13-14], their analysis in product-process design is still limited. Main researches about cognitive aspects focused

traditionally on product design and human-product interaction [15], but they do not explore the new potentialities of smart factories. Indeed, the new enabling technologies offered by IoT and smart systems can support the development of human-product-process symbiosis systems based on real-time data sharing and deep collaboration between the humans and the surrounding environment. This could create a new framework for UX analysis for workers, based on synergistic interactions between humans and machines with the combination of digital and physical worlds. Only recently a structured protocols to assess UX about integrated product-services have been recently proposed an interesting approach [16], but without any integration within smart factory environments.

1.2. The UX analysis reference model for product-process design

The research approach is based on the Norman's model of perception. According to such model, when any human being interacts with an object, a machine or a system, two kind of responses are generally generated: behavioural and cognitive, and information and meanings flow from the user/worker to the product/system in different ways. Such responses automatically occur when a task is accomplished, independently from its type and nature, depending on objective constraints (e.g., posture, duration, task nature, loads, environmental conditions) and subjective conditions (e.g., skills, cultural background, abilities, age, gender). Indeed, anytime a human being performs an action, his/her body and his/her brain generate behaviours and cognitive feedbacks, which respectively affect his/her physical and cognitive workload contributing to the ergonomic performance as well as the cognitive stress. This process characterizes both product interaction and interaction with machines, interfaces and complex systems as generally happens in workplaces. Furthermore, workplaces response is more delicate since it is usually characterized by strong time compression, long execution of tasks, repetitive actions, merged with stressful conditions.

The reference model defined starts from the analysis of the UX generation process and is synthetized in Figure 1. The UX is generated by the exploration of the product-process-system entities, that can be real or virtual, and the stimuli perceived by the "user" by the sensorial and motor channels. As a result, the perceived UX is due to the combination of the physical postures assumed, the executed actions, the mental workload, the subjective impressions, and the perceived usability. According to the Norman's model, three levels of response are generated: behavioural, cognitive and affective. The behavioural response generates the physical workload that is determined by operational comfort, related to physical stress and muscular fatigue, and sematic understanding related to the task comprehension. The cognitive response can be divided into descriptive, associative and intuitive, and refers to the mental stress as combination of numerous causes (e.g., feedback of actions, association, mental mapping, usability, coherence of stimulation, work overload and pressure). Finally, the affective response is linked to the emotional and sensorial perception (e.g., environmental stressors, psychological stressors, life stress, fatigue and sleep disruption). The theoretical bases of such model refer to several models elaborated in literature about human factors analysis and cognitive psychology [17]. The UX analysis is possible thanks to the monitoring of the human response thought different devices, wearable and environmental, able to provide a real-time assessment of the user / worker experience. Two main issues have to be faced at this point: the data collection and the interpretation of the collected data. As far as data collection, a proper UX

monitoring set-up has to be chosen according to the product-process nature, the most significant human factors to control, and the company objectives. About data interpretation, a proper protocol analysis has to be defined in order to relate the measured data with a set of assessment metrics. Also in this case, the protocol has to be specific for the company and the scopes of the investigation, but it can be independent from the specific task, the specific worker and the occurring external conditions. The reference model considers also a set of metrics that allows to measure the UX and to relate those metrics with a set of monitoring tools, properly selected according to the investigated area: posture, occlusion, mental load, interaction, and emotions. Their measurement is detailed in the following protocol.

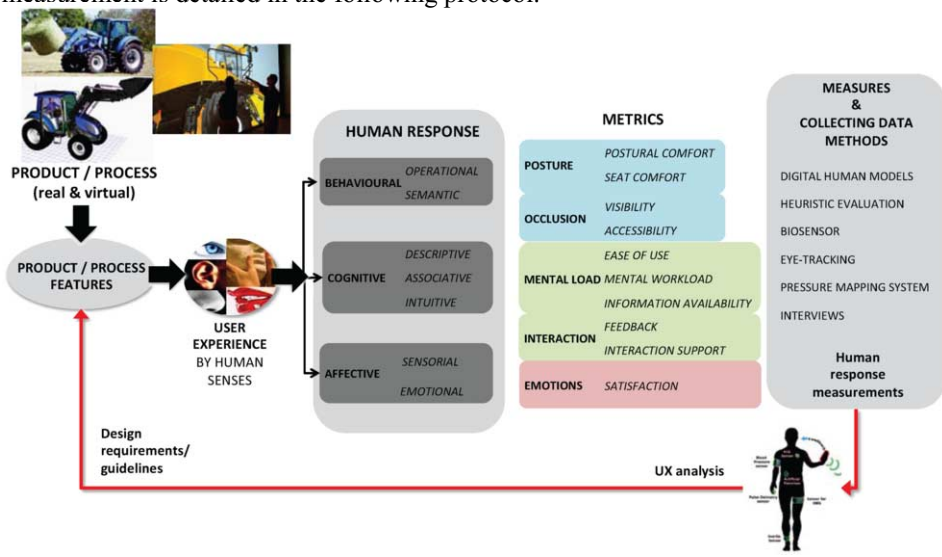


Figure 1. The proposed reference model for UX analysis

Posture assessment is carried out by two assessment metrics:

- *Postural comfort*: it measures the level of comfort perceived by the user as a consequence of the positions assumed and the task executed. It is assessed by analysing human body measures on digital or physical manikins;
- *Seat comfort*: it is applied when tasks require to be seated and measures the comfort perceived by the user as a consequence of the seated positions assumed and the task executed. It is assessed by proper objective methods;

Occlusion assessment is carried out by two assessment metrics:

- *Visibility*: it evaluates how the working space is clearly visible to the user and It is calculated by considering the amplitude of the view cone and analysing the number of obstructions;
- *Accessibility*: it measures whether and how devices and objects involved in task execution are easily accessible from the user, considering the specific body part that should use or manipulate them;

Mental load assessment is carried out by three assessment metrics:

- *Ease of use*: it expresses the effort required to perform a specified task. According to human-machine interaction theories, ease of use is improved by absence of ambiguity, action-driven suggestions offered by the design itself, and limited number of steps required for task execution;

- *Mental workload*: it measures the cognitive stress that the user perceived during task execution. It can be inferred considering fatigue and distraction signals (e.g. gazing, scratching the head, looking around) and monotony signals (i.e. yawning, gaping, decrease of attention and responsiveness);
- *Information availability*: it considers if the information and data necessary to the user for task execution are easily available when needed;

Interaction assessment is carried out by three assessment metrics:

- *Feedback*: it considers if the environment (product-process-system) offers feedback to the user actions (i.e., visual, acoustic, haptic) to make the user aware about the occurring events;
- *Interaction support*: it measures the ability of the system to drive the user actions according to the right operational sequence, which is usually related to properties such as logical constraints and natural mapping. It is measured by considering the ration between the worker's time for task completion in relation to the experts' time, and considering the number of affordances;

Emotions assessment is carried out by three assessment metrics:

- *Satisfaction*: it indicates the sense of satisfaction and the subjective aesthetic impression perceived during task execution.

2. The experimental set-up

2.1. The protocol analysis for UX

A protocol analysis is formalized to measure the UX through a set of evaluation metrics in order to support requirements definition in product-process design. The protocol is described in Table 1. It details, for each evaluation metrics as presented in the model in the previous paragraph, the adopted measures and the different methods used for collecting data, both traditional (e.g., heuristic evaluation and direct interview) and technological (i.e., digital simulations, eye-tracker, biometrical parameters measurements).

Table 1. The UX analysis protocol

Analysis	Metrics	Measures	Collecting data methods	Assessment rules
Posture	Postural comfort	Joint Angles (deg): - Hip, knee, ankle, back, shoulder, elbow - Head flexion & rotation - Stooping - Max upper arm flexion & elevation Distance from objects (cm) Weight of objects (kg)	- Postural analysis (DHM*) - Heuristic evaluation (1-10) according to SAE scale - Interview (1-5) - Biosensors** - Energy expenditure	*General:* NIOSH 91 UNI EN 1005 Dreyfuss / OWAS Garg equations RULA *Specific:* ISO 4254 ISO/TR 3778 SAE J1814 (cabin) SAE J817 (service)
	Seat comfort	Seat dimensions (cm) Seat shape (surface) Vibration (Hz) Pressure maps (N/mm^2)	- Seat dimensions - Pressure sensors	*General:* ISO 3411 ISO 23205 Dreyfuss *Specific:* ISO 4253 SAE J899 SAE J1163

Analysis	Metrics	Measures	Collecting data methods	Assessment rules
Occlusion	Visibility	View cones (deg.)	- View cone (DHM) - Reach zone (DHM) - Heuristic evaluation (1-10) - Interview (1-5) - Eye-tracking - Biosensors*	*General:* 79/1073/EEC UNI EN 547 ISO 4252 ISO 4254 *Specific:* ISO 5721 SAE J817 (service)
	Accessibility	Distance between the user and reached zones (cm) Steps dimensions (cm) Door dimensions (cm)		
Mental load	Easy of use	Requests of support (no.) Errors (no.) Movements' sequence (no.)	- Eye-tracking - Heuristic evaluation (1-10) - Interview (1-5) - Biosensors* [1]e.g., gazing, scratching the head, looking around [2] e.g. yawning, gaping, decrease of attention and responsiveness	*General:* UNI EN ISO 9241 UNI EN ISO 10075 UNI EN 894 ISO 3767 ISO7000
	Mental workload	Fatigue / distraction signals[1](no.) Monotony signals[2]((no.)		
	Information availability	Time spent to complete the task in relation to expert users (s)		
Interaction	Feedback	Time for task completion in relation to expert users (s)	- Eye-tracking - Heuristic evaluation (1-10) - Interview (1-5) - Biosensors* - Pressure sensors	*General:* UNI EN 894 *Specific:* SAE J817 (service) Bio-measures correlation
	Interaction support	Errors frequency (no.) Affordances (no.)		
Emotions	Satisfaction	Subjective impression (no.)	- Interview (1-5) - Biosensors*	*General:* UNI EN ISO 10075 *Specific:* SAE J817 (service) Bio-measures correlation

** DHM = Digital Human Modelling tools*
*** The considered parameters are: hearth rate, respiratory rate, real posture data, activity rate, and temperature*

Indeed, new technology to monitor the UX has been introduced to bring the gap created by traditional techniques and/or to combine the results obtained by difference sources in order to have more robust results. The last column contains the assessment rule adopted in the study. Even though the reference model is general and could be applied to different context of application, the protocol has been more specifically defined for the automotive sector. It can be adapted to agricultural vehicles, race vehicle, construction vehicles, special vehicles, or urban cars, according to the specific rules considered as reference standards.

2.2. The experimental set-up

The protocol can be put into practice thanks to a proper technological set-up that include the simulation and analysis tools identified in the experimental protocol. For the present study, the following tools has been adopted:
- Siemens Tecnomatix Jack for digital modelling of the environment and simulation via digital human models;
- VICON motion tracking system, made up of 8 infrared cameras and ad-hoc rigid bodies made up by rapid prototyping;
- Tobii Glasses 2 as eye-tracking device;
- Aditech Bioharness 3 as biosensor;

- Xsensor X3 wireless mattress system as pressure sensor.

2.3. The industrial case studies

The protocol has been applied to a set of industrial case studies in the automotive sector, in particular in the agricultural vehicles. In more details, the industrial cases focused on analysing the UX to support tractors' integrated product-process design on three different areas: product design of the cabin, product design of the technical spaces for maintenance inspections), and the design of the manufacturing line, in particular assembly phases. As a consequence, three types of workers as "users" are monitored: vehicle drivers at work, assembly workers in the manufacturing line, and service operators. Examples of UX analysis on the industrial cases are presented in Figure 2.

Experimental sessions were carried out on real environments, where users were monitored by the above-mentioned technologies and video recorded. On the basis of available 3D CAD models, motion capture tracking and video recording, the tasks were simulated also in digital environment to carry out further assessment on digital mock-ups. Data from real and virtual simulations can be properly combined and correlated.

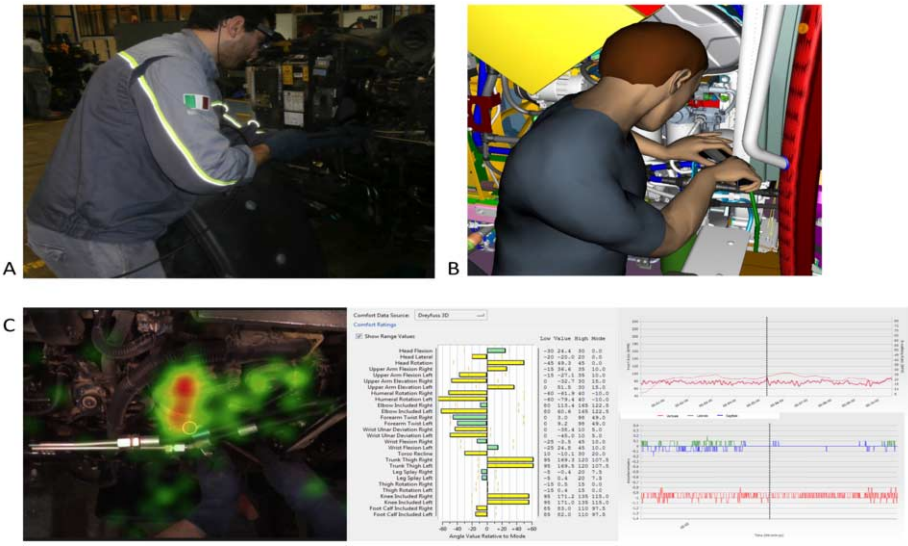


Figure 2. Case study about service operator: real user observation (A), digitalisation (B), and correlation with user monitoring parameters from eye-tracking and biometric data (C)

3. Conclusions

The paper presents a reference model for UX analysis for the automotive sector, consisting of a protocol analysis and an experimental set up. The set-up merges traditional monitoring techniques with digital modelling tools and biometric measuring devices (i.e., eye-tracker, biometrical parameters monitoring, pressure maps). The model has been applied to a set of industrial case studies on agricultural vehicles, focusing on vehicle driving, serviceability, and assembly tasks in the assembly line. It demonstrates the model applicability in industrial context and its validity to include human assessment into the design process. Future works will be focused on the

correlation of the collecting data to provide structured guidelines for integrated product-process design.

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A Study on Senior People's Driving Behaviors Aiming at Low-Speed Motor Vehicle's Design

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Abstract. Interdisciplinary research methods bring about more opportunities for designers to understand the users and predict some problems that hard to clarify by traditional methods. This study takes the elder-friendly low-speed vehicles design as an example, discussing the rationality of some quantitative methods introduced from other fields. By means of protocol analysis (PA), low-speed vehicles that are suited for elder drivers are checked out. After calculating and T-testing the results, two kinds of driving styles are sorted out for the experiment. The collected data include the subjects' heart-rate, finger moving times and operations' finishing time. By means of multiple linear regression and logistic regression, senior people's driving behavioral model is built to clarify their physical and mental characteristics. According to the results, a prototype design is proposed. The set of feasible methods used in the research process is sorted out for solving other similar issues targeting relative product design.

Keywords. Industrial design, design research methods, low-speed vehicles, senior people, driving behaviors, multiple regression equation.

Introduction

Contemporarily, more and more design researches make use of quantitative study. Such kind of methods can be an excellent design research paradigm, especially for special users. Available researches showed that senior people hold a longer reaction time and always take a low-speed driving [1]. Elder drivers may feel hard to adapt a high speed. Based on statistic results, this study takes the most popular elder-friendly vehicles, electric scooters and motor wheelchairs, as an entry point and experimental instruments. By experiments and data analysis, the study tries to clarify the rationality of low-speed vehicles' driving style. Based on the results, a design prototype of elder-friendly low-speed vehicle is proposed.

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1. Reviews of motor vehicles design suited for senior people

1.1. Characteristics of senior drivers

In China, since the Ministry of public security relaxed the driving license applicants' age limit to 70 in 2003, a large number of senior people are able to travel by driving and enjoy it. Driving behavior demands the behavioral agent have a high level of activities of daily living (ADL) and cognitive abilities, which can be seen as a challenge for senior people. Some Chinese researchers discover that there is a significant difference in behavioral reaction time between the elderly and the youth (including the middle-aged) in China. With the increasement of age, senior people's perception time, decision time and moving time are all prolonged [2].

With the increasement of age, limb moving abilities decline conspicuously. Compared with lower limbs, upper limbs' muscle fibers decease more in quantity and shrink in a higher level. Thus senior people's limb movement disorders first appear in leg movement [3]. Some common diseases in the elderly, such as arthrophlogosis and rheumatosis, also make senior people's lower limbs decline in function and capacity. Aging of lower limbs' function imposes a huge impact on senior drivers' lower limbs' operation, and proposes a special request for the function and layout of the motor vehicle's operators. Such declination hampers hands-feet operation and makes it hard to coordinate. Reasonable driving style plays an important role in remedying the declination of senior people's limb movement abilities.

1.2. Motor vehicles suited for senior people

There are various driving styles that can be chosen by senior people. In order to make an effective comparison, it is necessary to grasp the market and users' preference. We analyzed a data of A Research for Urban Senior People's Travelling Behavioral Pattern, which is collected by the industrial design department, Tsinghua University in 2013 (Sample quantity=323). One of the important data is to study The Vehicles Used in Travelling. It is discovered that besides the people travelling by bus and on foot, 16.8% of the subjects choose mini cars, 26.9% of them choose electric scooters and 11.7% choose motorized wheelchairs [4]. Percentages of the three choices are much higher than the other travelling styles such as by bike, by motorbike or by self-balancing vehicle. In this way it can be assured that senior people have a high level of acceptance for the three driving styles, which can represent a higher research value.

By means of protocol analysis (PA), we analyzes the users' trust propensity for the three driving styles. The formula to calculate users' propensity is [5]:

$$Q = \alpha \cdot E = \alpha \cdot \frac{1}{N} \sum_{i=1}^{m} \left(n_i a_i \right) \tag{1}$$

There are 4 grades of users' opinions to a driving style. For each propensity (positive or negative), n_i means the number of occurrences of adjectives that present certain grade. a_i means the weight value of a grade (1-4). N= Σ _(i=1)^m(n_i) 〗 calculates the total times of certain propensity's adjectives of all the 4 grades. From this E can be obtained, which means the weighted means of users' certain propensity for a

driving style. The total number of people who evaluated certain driving style divided by the total number of subjects of the whole test is the probability level α. Results of 30 subjects in the protocol analysis is listed as Table 1. By calculating means of positive and negative evaluation and T-testing the results, we try to judge whether the results have a generalizability.

Table 1. Results of Users' Protocol Analysis.

	Positive Evaluation	Negative Evaluation	t	Sig.
Automobile	0.24	1.69	5.004	0.004
Electric scooter	1.65	0.61	4.367	0.027
Motor wheelchair	1.43	0.43	6.812	0.031

Therefore, research for senior people's motor vehicles' design should focus on electric scooters and motorized wheelchairs. Basically, a driving style includes 5 operations, which are Starting, Accelerating, Left-turning, Right-turning and Braking. Based on the movements to achieve the 5 operations, the operational feasibility of the two driving styles are analyzed.

2. Experiment design and data collection

2.1. Subjects and experiment design

In terms of the two kinds of low-speed motor vehicles' driving operations, researchers make a real-time collection of drivers' data of operational behaviors, vehicles' running status and traffic condition images. Based on previous analysis and theories, the research takes Reasonable Driving Styles Suited for Senior Drivers as a breakthrough point. The experiment is done in daytime. The aim is to compare the two kinds of vehicles (Figure 1) and clarify the advantages and disadvantages of the two driving styles. With a certain speed (20km/h) and in a certain distance (600m), real-time data of drivers' operational behaviors, time to finish certain movement, swing times of the vehicle bodies and traffic condition images are collected to analyze these driving indexes' change characteristics. By means of the analysis, regression model to reflect driving behavioral variations will be built and the two driving styles are compared.



Figure 1. The two experimental vehicles.

A key point that need to be paid attention to is that the experiment focuses on operational behaviors rather than certain vehicle's design. Thus the volume of the vehicle, transmission styles and influences of existing application environment on driving performance will not be put into the researched variables.

2.2. Experimental instruments and data collection

The whole experimental system is divided into 3 modules, which are operational behaviors collection module (GoPro Hero cameras), vehicles' running situation collection module (Casio EXILIM digital cameras) and outside environment collection module (vehicle data recorder).

Researches of sports psychology demonstrate that human's reaction time is related to movements accuracy [6]. From the point of driving behaviors, reaction time means the time interval from when perception organs receive signals to that when the body reacts [1]. But collecting reaction time of driving operations will meet some problems. Conceptually, reaction time is the time that drivers spend to do a series of reactions including identification, judgment, taking actions and making the actions achieve the expected target after perceiving a signal [1]. But people's abilities to identify and select external information are influenced by many factors such as road situation, environment and driving proficiency. So there is a high randomness in the abilities' variation. Besides, from the point of driving, the time to make the actions happen is connected to the vehicle's characteristic, such as the vehicles' volume and transmission style, and not completely controlled by the driver. So the reaction time is less meaningful for this research. Therefore, researchers choose to collect the operation finishing time that can reflect the human-vehicle relationship, rather than the whole time of accepting signals, identification, judgment before the operations happen and the time that movements achieve the expected target after the operations happen.

3. Arrangement and analysis of the data

3.1. Data analysis

To analyze the driving operations of the two experimental vehicles, the first step is T-testing the variation of the driving operational data. The 30 subjects drive both of the two vehicles in the process of the experiment and so the researchers can obtain two groups of data. The analyzed variables include the driving operation finishing time and vehicles' swing times. For the variables with a significant difference between the two groups, researchers compared the two groups' mean values of the variable to clarify the more reasonable one. Results are listed as Table 2:

Table 2. Results of driving operation time analysis on the two driving styles.

	Electric Scooter		Motorized weelchair		Sig.	t
	Mean value	Standard deviation	Mean value	Standard deviation		
Braking (X1***)	1.79	1.035	0.82	0.472	0.000	-23.633
Left-turning (X2***)	2.16	1.647	1.31	0.841	0.005	-7.852
Right-turning (X3***)	2.18	1.318	1.74	1.915	0.048	-5.687
Accelerating (X4)	1.28	0.894	1.18	0.338	0.756	-1.342
Drawing back(X5***)	2.09	0.537	2.36	1.008	0.001	13.438
Swing times(X6***)	6.72	1.289	18.75	2.108	0.000	28.375

Table 2 shows that only the accelerating operations finishing time (X4) is not significantly different between the two groups. The other variables all present a significant difference ($p < 0.01$) between the two groups, which demonstrate the change of driving styles has a significant influence on drivers' operations.

3.2. Analysis of vehicles' stability

Researchers take the swing times of the vehicles in the experiment process as the evaluation index to reflect the driver's performance. Fewer swing times show a higher level of maneuverability. More swing times show that the driver is unable to fit in with the driving mission, which is very dangerous for the mission.

According to the hypothesis, researchers take the swing times as the dependent variable and take the 5 operation finishing time as independent variables to build a linear regression model. The model reflects how much each operation of the motorized wheelchair influence the vehicle's swing times. Results are listed as Table 3:

Table 3. Linear regression analysis of motor wheelchairs' driving operation.

Model	B	Std. Error	t	Sig.	Collinearity Statistcs	
					Tolerance	VIF
(Constant)	21.328	0.896	42.63	0.000		
Braking (X1)	0.452	0.431	4.32	0.041	0.459	2.18
Left-turning (X2)	0.498	0.264	3.89	0.008	0.413	2.42
Right-turning (X3)	0.527	0.258	3.81	0.011	0.398	2.51
Accelerating (X4)	-0.108	0.146	-1.14	0.430	0.529	1.89
Drawing back (X5)	0.324	0.357	0.81	0.417	0.508	1.97

X1 to X3 all significantly influence the swing times ($p < 0.05$) while X4 and X5 are both insignificant variables ($p > 0.05$). The result shows that braking and turning operations influence the vehicle's stability significantly. The change of the 5 driving

operations' finishing time can interpret approximately 73% of the vehicle's swing times change (R^2=0.7298). The model's goodness of fit is satisfactory.

3.3. Lane-keeping ability

Driving operations influence not only the vehicle's stability, but also influence the level of drivers' lane-keeping ability. The lane-keeping ability is also an index to evaluate the driving performance. A reasonable driving style should be better maneuverable for the users and bring about a higher level of keeping the lane. In this step of the research, senior drivers' lane-keeping ability is studied by means of logistic regression.

Tsuyoshi Moriyama and Takashi Yonekawa researched drivers' operations to avoid obstacles in the process of changing lanes [7]. The research showed that there are two kinds of operations under this situation, one of which is controlling directions purely and the other is combining the operation of controlling directions with that of braking together. Any kind of lane-changing mission includes the accelerating operation, which is the first operation in the driving process. Thus it is needed to bring the three operations as independent variables into the analysis of lane-keeping ability. The operations' finishing time can reflect the interactivity between the driver and the vehicle. From the point of driving operations, the logistic equation can be built as:

$$\log\left(\frac{p}{1-p}\right) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 \tag{2}$$

P refers to the probability that certain subject cannot keep the lane, while (1-P) means the probability that the subject keeps the lane. After fitting, results are listed as Table 4:

Table 4. Logistic regression analysis of motor wheelchairs' lane keeping level.

Model	β	S.E.	Wald	Sig.
Braking (X1)	-0.396	0.531	1.628	0.189
Left-turning (X2)	-0.798	0.483	6.957	0.011
Right-turning (X3)	-0.543	0.462	10.322	0.004
Accelerating (X4)	-1.463	0.751	5.148	0.027
Constant	8.952	1.696	16.871	0.000

From the results it can be known that for motor wheelchairs, the 4 independent variables all have a negative influence on logit P. Among them, braking finishing time is not significant and acceleration finishing time (X4) has a larger influence ($|\beta_4| > 1$). This illustrates that the change of acceleration finishing time can make the probability that senior people cannot keep the lane change more. This result may be caused by the natural mapping style of motor wheelchair's operation. It means when the driver accelerates, direction of the operation lever movement is the direction that the vehicle moves towards. Because of the negative influence, the longer the finishing time is, the probability that senior people can keep the lane is higher. On the contrary, the shorter the finishing time is, the probability that senior people cannot keep the lane

is higher. Lane-keeping is an accurate operation, so it should not be simply explained by theories of driving-information processing model. Sometimes a long period of time unlikely make some problems caused by psychological resource allocation. Oppositely, a longer finishing time can bring about a higher level of lane-keeping performance. This is consistent with the theory of motion accuracy [8].

3.4. Heart-rate variation

In the study of vehicle's stability, it is found that a shorter operational time is positively related to fewer swing times. But for lane-keeping ability, a longer operational time can always result in a better performance. This may be caused by the specialty of driving operations which are more precise than common operations. Table 2 shows that the driving style of electric scooters presents a longer operational time. In order to clarify whether this style is feasible, we analyzed the subjects' heart-rate when they suddenly braked and compared the data with mean heart-rate of the four driving situations which are straight line driving, large radius turning driving, S-road driving and reversing (Figure 2).

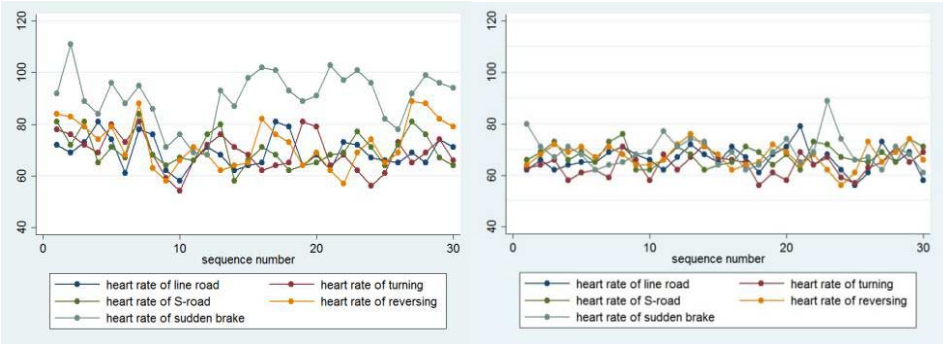


Figure 2. HR of sudden brake and mean HRs of four driving situations on scooter (left) and motor wheelchair (right).

It can be seen that in the process of driving the scooter, there is a large variation in most of the subjects' heart-rate. 5 subjects' HR is above 100. While when they drive the motor wheelchair, the fluctuation is weak. The HR is concentrated between 50 to 80. Senior people's HR is often lower than younger groups'. And an HR value above 100 means that the driver is very nervous at that time. This may be caused by many factors. A rational driving style should relief senior people's tension mood. From this point of view, it can be said that the driving operations of motor wheelchairs are more suitable for elder drivers.

4. Proposals of a rational driving style

4.1. Discussion and problem description

The driving style of motor wheelchairs is more appropriate for the elder drivers. But there is a problem existed in this style. We can know from Table 2 that the swing times of motor wheelchairs are significantly more than electric scooters. It shows that the elder drivers hardly control the motor wheelchair so well that the vehicle often swings.

For one thing, this may be caused by the vehicle's mechanism. For another, it can be known from Table 4 that driving operations significantly influence the vehicle's swing times. Therefore, the driving operational problem must be one of the factors that caused the situation of the overmany swing times. By means of observing and counting, it can be found that because of the operational stick is so short and small that drivers need to use two hands to hold the stick to avoid driving errors. In the process of driving, fingers are used to achieve two operations which are grasping and pushing. Thus the stick is easy to slip out from the drivers' hands. Besides, the left hand always moves unconsciously, which may also hinder the operation.

4.2. Prototype and design proposal

Based on the results, a prototype is proposed. It adopts motor wheelchairs' driving style which controls the driving directions by pushing a stick, and brakes by relinquishing the fingers. But considering the swing problem existed on traditional motor wheelchairs, the prototype's operational stick is enlarged to a size as big as electric scooters' steering column and the interactive parts are two handle bars. A traditional steering stick is still on it to assist the driving missions. By means of holding the handle bars, both of the driver's two arms are used to control the steering stick (Figure 3). This prototype maintains motor wheelchairs' driving style so that the driver can have a better operational performance as well as reducing the possibility of incorrect operations caused by a small and short stick. Meanwhile, by such a style, senior people without driving experiences can easily learn to drive it. And it liberates senior people's lower limbs, which is corresponding with senior people's limb movement characteristics.

The prototype has a longer wheelbase and turns by the deflection of front wheels, just as the electric scooters' swerving wheels. This mechanical structure is propitious to make the vehicle body keep balance better and not swing excessively. With the coordination of motor wheelchair's driving style, such a structure can bring about a better driving experience.



Figure 3. A design proposal.

5. Assessment

In order to assess the design proposal, researchers evaluate the three driving styles of the proposal (style A), the electric scooter (style B) and the motor wheelchair (style C) by Analytic Hierarchy Process (AHP). An AHP model (Figure 4) is set up to seek out the optimal choice for senior people.

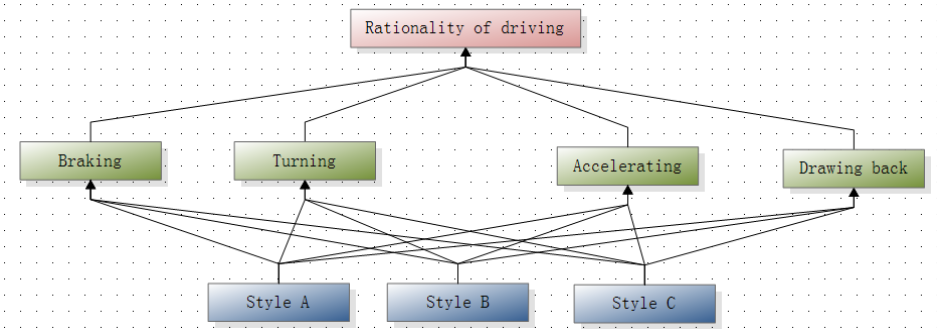


Figure 4. AHP model of 3 driving styles.

Using the software yaahp 10.3, total order weight values of every rater's judgment matrix are generated. C.I. Values of all the raters' judgment matrices are less than 0.1, passing the consistency test. After dealing with the 30 raters' total order weight, the group-decision results are listed as Table 5:

Table 5. Results of AHP Analysis.

	Braking	Turning	Accelerating	Drawing Back	Weight of Total Order (W_i)	Total Order Sorting
	0.4982	0.1874	0.0748	0.2396		
Prototype	0.4789	0.4051	0.2193	0.4786	0.4762	1
Scooter	0.4137	0.5236	0.1286	0.3128	0.3821	2
Wheelchair	0.2036	0.1383	0.5947	0.2737	0.1417	3

From the results, it can be seen that senior people have the best recognition to the driving style of the design proposal (W=0.4762). While among the various driving operations, braking functions best to the vehicle's accessibility and usability (W=0.4982). And the proposal's braking and drawing back operations get the most positive feedback from the elder drivers, better than the operations of the other driving styles.

6. Conclusion

Based on the operations' finishing time and mental workload, this study set up models for elder drivers' driving ability on low-speed vehicles. In future researches, designers can use the methods discussed in this study to do rigorous experiments and consummate the designs step by step. Methods of design research are developing with each passing day. An increasing number of methods of other disciplines are introduced into design research field to solve various problems. The paper takes elder-oriented

motor vehicles design as an example to discuss a set of methods to deal with data. From sorting out researching subjects, collecting data to setting up models and assessing design proposals, these methods solved a lot of problems that is hard to settle by traditional design research methods. Quantitative methods have been widely used in predicting problems and making decisions. But how to apply them in concrete themes still needs design practitioners to introspect constantly.

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Human Factors Evaluation in Maritime Virtual Simulators Using Mobile EEG-Based Neuroimaging

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Abstract. Neuro-ergonomics using mobile electroencephalogram (EEG)-based neuroimaging is a new area of Brain-Computer Interaction (BCI) applications. We propose and develop an EEG-based system to monitor and analyze human factors measurements in maritime simulators. The EEG is used as a tool to monitor and record the brain states of subjects during human factors study experiments. In traditional human factors studies, the data of mental workload, stress, and emotion are obtained through questionnaires that are administered upon completion of some task/tasks or the whole experiment. However, this method only offers the evaluation of overall feelings of subjects during the task performance in the simulators. Real-time EEG-based human factors evaluation in maritime virtual simulator allows researchers to analyze the changes of subjects' brain states during the performance of various navigational tasks under different environmental and collaborative scenarios. Machine learning techniques are applied to the EEG data to recognize levels of mental workload, stress and emotions. By utilizing the proposed EEG-based system, true understanding of subjects working pattern can be obtained. Based on the analyses of the objective real-time data together with the subjective feedback from the subjects, we are able to reliably evaluate human factors during experiments in simulator. We describe real-time algorithms of emotion recognition, mental workload, and stress recognition from EEG and its integration in the cadets/captains stress assessment systems. We design a simulator-based experiment to record EEG signals of cadets, from which we recognize the changes of their emotions, mental workload, and stress levels during the task performance. We recorded EEG of 12 participants using Emotiv device in maritime simulator. The participants went through four exercises (around 30 minutes per exercise) with 20-minutes break in between. The exercises were with increasing difficulty levels and shuffled to be given to the participants. Videos were taken to analyze the behavioral data of the participants and used to label EEG data. Emotion, workload and stress levels are calculated from EEG recording with the time resolution 1 sec. From the preliminary case study it can be seen that there is a correlation between the EEG-based emotion recognition results (in terms of timing and magnitude) and the events that were happening in the simulator.

Keywords. EEG, human factors, neuroergonomics, maritime simulator, mental workload, stress, emotion

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Introduction

In recent years, the rapid advancement in technology allowed greater improvement in the shipping industry in terms of vessel structural design, safety systems, comfort and also navigational systems. The ships and vessels today are created with many different kinds of technologies implanted to increase the overall performance, efficiency and safety [1]. Unfortunately, despite such efforts and evolution in the industry, maritime casualty rate still remains high and almost 80% of the shipping incidents cited human factors as the main cause [2]. As a result, scientists and researchers start to realize the need for deeper understanding in the field of human errors. Existing studies of the human factors mainly involved statistical analysis and breakdown of casual factors occurring at different parts of a chain of failures that gave rise to the final disastrous outcome. Recent research efforts attempted the inclusion of bio-signal measurements in the human factors study. For example, electroencephalogram (EEG), which has a high time resolution, revealed better accuracies in monitoring human effects such as stress and emotional levels [3].

In our research, we applied machine learning on EEG data to monitor brain states such as emotion, workload, and stress levels of the maritime trainees during an experiment in the maritime simulator. In the experiment, the trainees had four 30-min exercises with different difficulty levels. With the help of videos recorded in the simulator, we are able to label the demanding events of the exercises in the EEG data. In this paper, we present a case study on the emotional changes of one trainee during the exercise.

The paper is structured as follows. In Section 1, we give related work including the review on methods used in human factors study and EEG-based technique in human factors study. In Section 2, the EEG-based brain states recognition algorithms are introduced. In Section 3, the experiment is described. Section 4 presents the results of preliminary case study, and Section 5 concludes the paper.

1. Related work

Maritime industry is regarded to be a people industry and thus a significant percentage of accidents are attributed to human errors. It is reported that human errors contribute up to 89-96% of collisions and 75% of fires and explosions [4]. With an intention to support accident prevention and improve maritime safety by adequate training to the crew, human factors are identified and investigated [5]. Council has summarized the various human factors such as stress, workload and fatigue that could implicitly affect individual and team performance of maritime professionals [6]. Traditional approaches use standard questionnaires such as NASA Task Load Index (TLX) and Situation Present Awareness Method (SPAM) to study the direct influence of workload on personnel. TLX is a standard tool developed by NASA to estimate the perceived workload using a multi-dimensional rating scale by studying the variations in subjective workload between each type of tasks [7]. The relationship between situation awareness, workload and performance was studied in a cognitively oriented air traffic management simulator using SPAM technique [8]. A theory of situation awareness (SA) has been presented in relation to decision making ability in complex dynamic systems. The SA model was proposed based on a hierarchical arrangement of factors that influence decision making like workload, stress and memory [9]. However,

reliance on questionnaires did not prove to be effective as they are just the perceived information by the participants and does not guarantee to be the actual mind state. Cook et al. had found that the participants were reluctant in declaring themselves to be stressed even though the pilotage was stressful [10].

Recently, research on psychophysiological measurements has become the top priority to study human factors [11-14]. An attempt to evaluate and improve the training process in a ship navigation simulator which used the registered eye movements to determine the decision making ability of the crew in an unexpected and sudden situation causing a collision [13]. A similar study on evaluation of flight training effectiveness was carried out in an actual and simulated aircraft to determine physical and mental workload by monitoring heart rate and its variability during basic flight tasks [11]. The application of Galvanic Skin Response as a cognitive load indicator was studied using a simulated traffic control management task [14]. Apart from simulator based human factors study, numerous research studies have been conducted in normal environment. Research has been conducted to study the relationship between pupil response and cognitive load levels using an eye tracking application for enhancement of training and adaptive learning. The gaze data from the eye tracker had not only be used to indicate cognitive workload but also to user attention and distraction for designing training materials [12].

Among various psychophysiological measurements used in human factors assessment, Koester et.al. shows that EEG gives more valid and reliable results than other subjective methodologies in maritime crew domain [15]. In this paper, we focus on various brain states such as emotion, workload, and stress. The states are monitored using EEG signals.

2. EEG-based brain state recognition

In our previous work [16], we presented an integrated brain states monitoring system called CogniMeters. This system can visualize the real-time brain states such as emotion, workload, and stress in the form of meters. The algorithms used for brain states recognition in this system are briefly described below. We apply the algorithm to identify the brain states in this paper.

2.1. EEG-based emotion recognition

A subject-dependent emotion recognition algorithm is proposed in our previous work [17]. Compared with subject-independent algorithm, subject-dependent one can obtain a higher accuracy but an individual calibration is needed for each subject. To obtain calibration data, sound clips from IADS [18] are selected as stimuli and played to the subjects. The EEG data are recorded at the same time.

In the feature extraction step, the Higuchi fractal dimension [19] and statistical features [20] are extracted from the raw EEG data. Then a Support Vector Machine (SVM) is trained using the calibration data which can be applied in recognition phase. In [17] , we showed that the accuracy of the proposed algorithm can be up to 69.53% for the recognition of 8 emotions, 84.41% for the recognition of 3 emotions, and 90.35% for the recognition of 2 emotions.

In this study, three emotions defined on valence dimension such as negative, neutral, and positive, are recognized.

2.2. EEG-based workload recognition

An EEG-based workload recognition algorithm was proposed and validated in our previous work [21]. Same as emotion recognition algorithm, FD and statistical features are extracted and SVM is the classifier. For 2 levels of mental workload, we showed an accuracy of 90.39% and 4 levels as 80.09% [21].

In this study, we focus on four levels of mental workload recognition. As the algorithm is subject-dependent, to train the SVM classifier, Stroop color test is used as the stimulus to elicit different levels of workload. For the elicitation of the lowest level of workload, the subjects need to do nothing but relax. For low workload, the subjects are required to do the test by choosing the correct answer that matches the ink color of the given word. Here the meaning of the word and the ink color are congruent. For moderate workload, the subjects need to select the choices that match the ink color. However, the meaning of the word and the ink color are incongruent. For high workload, the test is incongruent plus a response time limitation of 1 second. The EEG data are recorded when the subjects are exposed to the stimuli. Then FD and statistical features are extracted and used as the training data for the SVM classifier. For both emotion and workload recognition, SVM with polynomial kernel is used. The value of *gamma* for polynomial kernel was set to 1, *coef* was set to 1, order *d* was set to 5, and the *cost* was set to 1.

2.3. EEG-based stress recognition

To obtain the levels of stress, we decided to combine the recognized emotion and workload results. As emotion recognition focuses on 3 states including positive, neutral, and negative, we assign numerical numbers to represent different emotions. Namely 0 denotes positive, 1 denotes neutral, and 2 denotes negative. For workload, same idea is applied. 0-3 is assigned to increasing workload levels. The details of the protocol to get stress level from emotion and workload are listed in Table 1.

Table 1. The protocol to get stress level from the combination of emotion and workload.

Brain States		
Emotion	**Workload**	**Stress**
0	0	0
1	0	0
2	0	0.5
0	1	1
1	1	1
2	1	1.5
0	2	2
1	2	2
2	2	2.5
0	3	3
1	3	3
2	3	3.5

3. Experiment

Over the course of 2 consecutive days, the experiment was conducted on 12 subjects who are cadet trainees from Maritime Institute @ Singapore Polytechnic. Each trainee was required to complete 4 bridge simulation exercises, with each exercise lasting about 30 minutes. By varying factors such as traffic condition, weather visibility, and occurrence of systematic alarms, these 4 exercises are designed to be of different difficulty levels.

Prior to each exercise, the trainees were briefed by an instructor. Although information such as type of vessel, initial location and final destination were given, there were no specific routes of advancement or specific instructions given to the trainees. Thereafter, each trainee was given the necessary navigational equipment such as parallel rulers and map, and the trainee proceed to their respective simulation room for preparation. Before the actual commencement of the simulation exercise, the trainees were allowed time to plan their route of advancement and to fill in a personal background questionnaire regarding their biography and sea service experience. Additionally, trainees had to go through a series of calibration tests where emotion and workload EEG data were collected to train the SVM classifiers. The Emotiv [22] device with 14 channels were used in the experiment to collect EEG data. During the exercise, the trainee performed their duties with the EEG device attached. EEG data and video footage of each exercise in the simulation room were recorded for synchronization and analysis purposes.

Upon completion of each exercise, the trainees were required to complete 2 sets of questionnaires which include Self-Assessment Manikin (SAM) to rate their emotion and workload/stress rating experienced over whole task.

4. Results and discussion

After collecting the data, we did a preliminary case study on one trainees' data. We manually synchronize the timestamps of the demanding events, which happened during the experiment, from the video to EEG results. The changes of emotion defined on valence dimension for different situations are plotted in Figure 1 to 5.

At the beginning of this exercise, the task was just navigation with minimal traffic and the mean value of emotion level over 12 min and 26 second is 1.31, which is close to neutral emotion level as label 1 is assigned to neutral state.

From 12:26 to 12:43, the trainee tried to stabilize the direction and sail between 2 vessels. The mean value of emotion level over this period is 1.33, which is slightly increased comparing with the beginning of the exercise. The detailed emotion changes are plotted in Figure 1. In the figure, the x axis denotes the time points and y axis shows different emotion level, namely 0 for positive, 1 for neutral, and 2 for negative. The solid curve represents the emotion levels at certain time point, the dash line is the linear trend of the intermittent emotional states. In Figure 1, the trend shows that the emotional state was gradually changed from neutral to negative during this period.

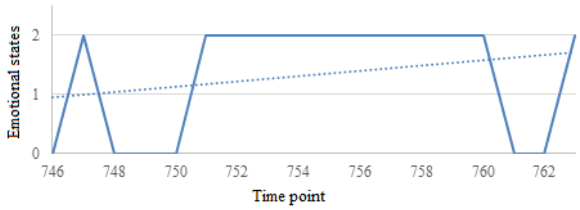


Figure 1. The emotional changes from 12:26 to 12:43

From 13:23 to 15:23, alarms and a lot commands were given to the trainee to adjust bearings. It was the toughest navigation of the entire exercise. As a reflection of the situation, the mean emotion level value increases to 1.60. This is closer to negative state and much higher than all the other period of the exercise. From Figure 2, we can see that the emotion states maintain at value 2 at most of the time, indicating negative emotion was detected.

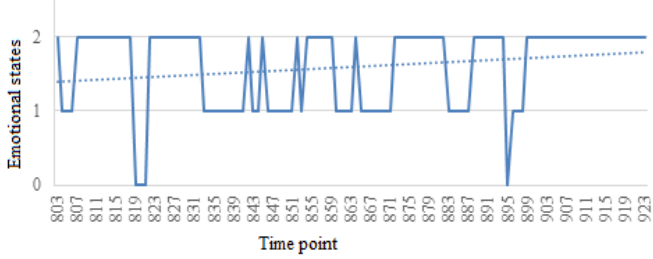


Figure 2. The emotional changes from 13:23 to 15:23

Figure 3 illustrates the emotional change from 14:00 to 14:20. It shows that the emotion values reduced from the 14:00 to 14:10 as only two spikes of negative emotion was observed. However from 14:10, the trainee had to steer away more from another vessel, thus negative emotion started to appear more frequently and it stayed for a while. The average emotion over these twenty seconds is 1.43, which is closer to neutral than the previous event in Figure 2.

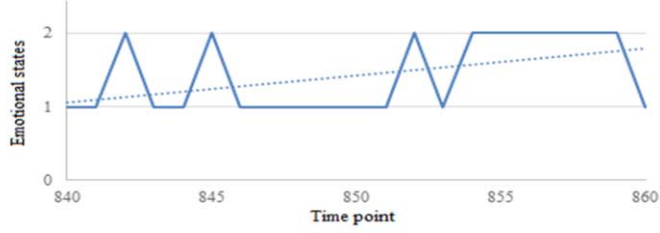


Figure 3. The emotional changes from 14:00 to 14:20

From 16:48 to 19:58, the trainee was overtaking the vessel and finally passed it from its starboard side. The emotion in most of the time is negative as shown in Figure 4. The average emotion value is 1.54, which is closer to negative emotion. However, an interesting phenomenon is that the trend line shows a deceasing pattern which may be due to the completion of passing the vessel nearby at the end.

From 19:58 to the end, the trainee was cruising to final destination with minimal traffic thus the mean emotion level value decrease to 1.38 which is very close to neutral state. From the curve (Figure 5), it can be seen that there are more neutral states detected.

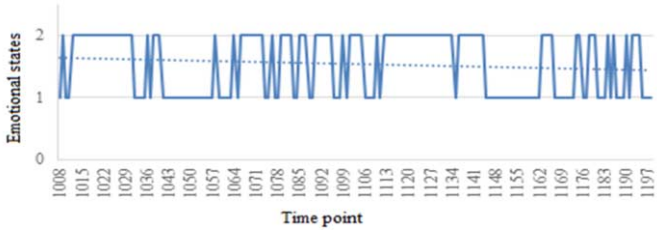


Figure 4. The emotional changes from 16:48 to 19:58

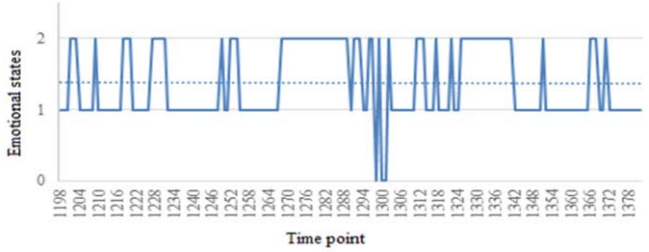


Figure 5. The emotional changes from19:58 to the end of exercise

Although in this section we present the results of only one subject, it gives positive support to the use of EEG technique in maritime human factors study.

5. Conclusion

In this paper, we introduce the EEG-based brain states recognition algorithms which can continuously identify the ongoing states such as emotion, workload, and stress. An experiment was carried out to collect the EEG data when the maritime trainees were performing different exercises in the simulator. We present an initial case study to investigate the emotional response to demanding events during the exercise. The results show that EEG-based recognition can accurately reflect the demanding events. Different from the traditional human factors study like use of surveys or interviews, the proposed EEG-based method allow researchers capture the detailed changes of emotion, stress, and mental workload levels in maritime simulator, and in future during maritime simulator-based assessments. Thus, human factors can be studied in maritime virtual simulators using EEG-based mobile neuroimaging tools to analyze the causes of human errors and failures in different scenarios. In the next step, we will analyze more data together with workload and stress levels identified, and link the brain states with the performance of the trainee.

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Research on Attractive Factors of Electric Motorcycle Design

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Abstract. Abstract goes herElectric motorcycle has become the most popular vehicle for people to travel in the short distance due to its convenience and the environmentally friendly design. With the development of the renewable energy techniques, the electric motorcycle was designed to obtain more flexibility compared to the traditional generation. Considering the situation where the product just appeared and also has fewer restrictions in design, all the designers are now sharing a common struggle about how to meet users' expectation. Kansei Engineering focuses on investigating how people respond to products in emotion and incorporating emotional reaction in product design. Therefore, Kansei Engineering serves as a very effective approach to address the emotional need of users from products.This study is to find out what interests the users in the electric motorcycle by survey. Specifically, the users will be asked to select the most attractive electric motorcycle among all the pictures to locate which part in motorcycle is able to catch their eyes and also give several Kansei words to describe it. Each Kansei word for each product will be scaled according to Liszt table. Then, with collected data, Quantification Theory Type I (QTT-I) will be applied to explore the association between design style and attractiveness. This paper is aimed at providing a design style methodology that is suitable for the brand new product with high degrees of freedom through Kansei Engineeringe.

Keywords. Electric motorcycle, Kansei Engineering, Quantification Theory Type I (QTT-I), Product design.

Introduction

The electric-powered motorcycle is widely welcomed by the consumers as a type of green vehicles. Based on the collected data, the production and inventory of electric motorcycle in China have kept annually increased in recent years and have also reached the first position in the world [1]. Apart from the booming domestic market, the immense potential of the electric motorcycle can also be found in the worldly market. Given that more and more attention has been paid to the environmental issues especially in the developed country, the electric motorcycle with nearly no pollution is facing the golden opportunity to make the stunning development. To satisfy the demand of the market, some corporate giants in the field of motorcycle like Yamaha and Honda have already launched the new product of electric motorcycles to open up the international markets. In America, the demand for electric motors has also increased every year. However, the American consumers have their different

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understanding of this product. Some of them treat riding the electric motorcycles as a sort of entertainment and exercise, while the others also use them for the short journey. As the global center of the manufacturing, China has become the hugest market of electric motorcycles production and distribution due to the distinct advantages of prize and quality. On the other hand, the domestic electric motorcycles factories excessively concentrate on the producing work but relatively neglect the designing part with the barely independent design team. Therefore, the lack of designing capacity leads to they can simply imitate the appearance of the lightweight motorcycles produced by international brands without independent and scientific design [2].

Thus, under the premise of the current technology, the style of electric-powered motorcycle still needs to study around the user preferences [3]. It is the key to design research for the designers to clearly get the form factors of the automobile modeling which improved user satisfaction. Except for the source of transportation, the electric motorcycles also represent the sentimental demand of beauty for the consumers. Thus, it is essential for the designers to make the satisfied design according to the personalized needs figured out from the comprehensive market research. From this perspective, the Kansei engineering should be an effective method which is able to help the designers to understand the consumers' sentimental demand more objectively. The principle and method of using the Kansei Engineering, which can effectively discover and evaluate the vehicle form of attractiveness, and accurately capture the user perceptual image, so as to provide a positive reference for the modeling designer [4-10]. This report is mainly aimed at establishing a research method of designing the outlook of electric motorcycles with the help of Kansei engineering, so that the designers can obtain the more accurate understanding of consumers' preference related to the appearance of electric motors.

1. Method

The pattern of the experiment in this study is indicated in the following contents.

1. Collect the Kansei words and sample pictures related to the appearance of the electric motorcycles and select the typical products and Kansei words through the conclusion of questionnaire survey.
2. According to the analysis of the appearance, pick up the main features and conduct the experiment of Kansei evaluation associated with the table of semantic differential.
3. Conclude the collected data from the experiment of Kansei evaluation and apply the least square method to conduct the quantitative and qualitative analysis to attain the partial correlation coefficient [11].
4. Summarize the reflection relationship between Kansei images and design elements and figure out the design method related to the appearance of electric motorcycle based on the Kansei evaluation.

1.1. Selecting the representative samples

During the investigating and survey, 30 samples which are suitable for the research are picked out from relevant magazines, manufacturer's catalog, websites and forums.

After the considerate group discussion, the ultimate 17 samples are finally decided as indicated in the following pictures (see Figure 1).



Figure 1. The samples of electric motorcycle.

1.2. Sifting and deciding the Kansei words

The appearance of the motorcycle is one of the significant factors for the consumers when they select the electric motorcycles and the subjective feeling will also be created by them for the overall appearance. The main tasks for this stage are to collect, sift and analyze the words which can describe this subjective feeling so that it can provide enough data for the further research. Through the various ways like online survey and brainstorm, over 100 Kansei words in total are collected. Then, the words with opposite meaning are matched together and 30 pairs of the Kansei words are finally obtained. Furthermore, the questionnaire including these 30 pairs of the words is created to sift out the representative Kansei words. To guarantee the accuracy of the investigating, the respondents are required to have the basic knowledge of the electric motorcycles. Finally, 26 students majoring in industrial design are decided as the respondents and each of them is demanded to pick out 10 pairs of Kansei words which are able to describe the characteristics of the appearance of the electric motorcycles. As a consequence, 3 most selected pairs are fashionable vs. retro, flexible vs. steady as well as strong vs. soft.

1.3. Analysis of significant elements of appearances

Given that the appearance of the electric motorcycles is an integral design, it is exceedingly difficult for the designers to make the targeted design. Therefore, to pick out the key point of designing the appearance design must be divided into several parts to conduct the different analysis. 18 respondents are requested to observe the representative samples selected by themselves one by one and point out 3 parts which are most attractive to them. From the compilation of the views held by the respondents, 3 most attractive parts are picked out as the significant attractive items (see Table 1).

Table 1. The choice times of every attractive items.

attractive items	choice times
Headlight	17
Front face	15
Tailstock	15
Headstock	14
Front mudguard	10
The turn light	8
Rearview mirror	5
Cushion	3
Baseboard	3

According to the selected three appearance parts, they are further divided into couples of “design elements”. Therefore, 3 main attractive items and 12 design elements are concluded to attain a classification table (see Table 2).

Table 2. The classification table. Maked A1-A4,B1-B4,C1-C4 for every design elements.

A: headlight	B: front face	C: Tail-stock
A1: Circular arc	B1: square	C1: square
A2: separated in V shape	B2: straight line with sharp angle	C2: lifted tail with sharp angle
A3: circular curve on the head	B3: steam line shape	C3: lifted tail without sharp angle
A4: eye shape on the head	B4: shape of plump curve	C4:plump shape paralleling with the ground

1.4. The experiment conduction of the Kansei evaluation

Combining the 3 pairs of Kansei words sifted from the early stages with the 17 types of electric vehicle samples, the table of semantic difference can be established, which classifies the 3 pairs of Kansei words into 7 levels and scores for: 7,6,5,4,3,2,1.Each sample corresponds to one table of semantic difference to make the questionnaire. The experiment of Kansei evaluation is conducted by the questionnaire which concludes 17 types of electric motorcycles(see Table 3).

During the process of the survey, the respondents make their subjective evaluations to the appearance of these 9 types of electric motorcycles from level 1 to 7. Based on the data from this Kansei evaluation, the average scores of these 17 types of samples related to each pair of Kansei words can be calculated (see Table 4). Due to the restriction of the article length, the example "strong vs. soft" is listed below.

Table 3. The questionnaire of Kansei evaluation.

Fashionable	7	6	5	4	3	2	1	**Retro**
Flexible	7	6	5	4	3	2	1	**Steady**
Strong	7	6	5	4	3	2	1	**Soft**

1.5. Data analysis

To conduct the further analysis of how deeply each appearance element can affect the Kansei attempting of the consumers, the Quantification Theory I is applied to calculate the corresponding average grades of Kansei words to each design element as well as the correlation coefficient between each of the appearance features and Kansei words [12,13]].

At first, it is necessary to establish the "01" matrix (The matched sample is labeled as 1 while the unmatched is labeled as 0) based on the situation of each sample to indicate the average grades related to Kansei evaluation of the sample "strong" (see Table 4).Then the solution of this mathematic model is with the help of Matlab and the category scores of the catalogs can be shown below (see Table 5).

Table 4. The "01" matrix and the average scores of the samples.

No.	average scores	**A1**	**A2**	**A3**	**A4**	**B1**	**B2**	**B3**	**B4**	**C1**	**C2**	**C3**	**C4**
1	1.88	1	0	0	0	0	0	0	1	0	0	0	1
2	1.79	0	0	1	0	0	0	0	1	0	0	0	1
3	2.02	1	0	0	0	0	0	1	0	0	0	0	1
...	...	...	...	...	...	...	...	...	...	...	...	...	...
17	2.45	1	0	0	0	0	0	0	1	1	0	0	0

Table 5. The QTT-I results of "strong vs. soft" .

attractive items	**design elements**	**CS**[a]	**PCC**[b]
Headlight	A1: Circular arc	-0.544	0.381
	A2: Separated in V shape	0.306	
	A3: The circular curve on the head	-0.899	

Front face	A4:The eye shape of the head	-0.211	0.686
	B1:Square	-0.552	
	B2:Straight line shape with sharp angle	1.053	
	B3: Steam line shape	0.771	
	B4: Plump curve	-1.354	
Tail-stock	C1: Square	-0.754	0.589
	C2: Lifted tail with sharp angle	0.949	
	C3:Lifted tail without sharp angle	-0.003	
	C4: Plump shape	-0.754	

Note: [a] Category scores, [b]Partial correlation coefficients.

The table indicates the "CS" and "PCC" of the pair of Kansei words "Strong vs. Soft" obtained from the Quantification Theory I. By the same method, the quantitative analysis can also be conducted for the other two pairs of Kansei words.

The numbers in the column of "CS"and "PCC" displays the relationship between each design element and the importance of the Kansei words in expression, that is, the higher the grades are, the more significant effect this design element can make on the Kansei expression.

2. Results and conclusion

Based on the calculated results of quantitative analysis related to the Kansei words "Strong vs. Soft", the quantitative process of Kansei attempting can be analyzed. In terms of the analysis of "Grades of design elements", the score of "Straight line shape with sharp angle for the front face" is 1.053, which is the highest mark among the design elements. It indicates that if the straight line shape with sharp angle could be applied in the design of front face, the appearance of the motorcycle would approach to the Kansei word "Strong". On the other side, "The shape of plump curve" for the design of front face obtains the lowest score, which is minus 1.354. That is, this kind of design for the front face most approaches to the Kansei word "Soft". According to the calculated partial correlation coefficient, this coefficient for the front face is 0.686 which is the largest one. Therefore, the design of front face should be the most important factor in the expression of the Kansei words "Strong vs. Soft". While the second important one is the design of tail stock with 0.598 and the third one is the outline of the headlight. Then it can be figured out that if the design target tends to be "Strong", the straight line shape with sharp angle for the front face should be the most suitable. As to the other parts of the motorcycle, "V" model for headlight and lifted tail with sharp angle are both beneficial to attain the meaning of "Strong".

This research is concentrated on the appearance design of the light weight electric motorcycle through the experiment on the basis of kansei engineering to obtain the analysis result of how attractive each of the appearance features can be to people and how strong the relationship is among consumers' sentimental demand. Benefited from this research, the following similar design project related to the new product of the electric motorcycles can acquire more reliable theoretical support. From the quantitative calculation of the Kansei words, the more scientific technique is able to be applied by the designer to satisfy more sentimental demand of the consumers.

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Litigation Visualization Through Transdisciplinary Design

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Abstract: Law is the rules of the society. The judgments are based on understanding the rules and legally-valid information as well as corroborating advice. Recently, the questioning of the impartiality of the judges has caused people's mistrust of judicial system. There are many ways to visualize the litigation process such as data visualization and language analysis. Clarifying the meaning and function of these terms in a socio-political system can be a helpful start towards unraveling the notion of transparency. Legislative transparency remains an issue with many interesting aspects yet to be explored. In this study, the graphic and simple ways are utilized to express the verdict so that people with no legal backgrounds have more opportunity to understand the arguments. By conjoin legal professional and designer, court decisions were analyzed and represented as graph to visualize the facts, laws and logical reasoning. User and task analysis is a process of learning about user by reviewing them in action. We observed and talked with users to acquire the opinions as follows. Visualization of litigation process through flow chart, diagram, color and shape help people to understand its meaning; users need to have a consistent meaning of colors, symbol and shapes to reduce possible confusion. It indicated that for exploration and to comprehend its legal relation visualization rules for legal items are required in further study.

Keywords: Litigation, administrative law, visualization

Introduction

Litigation is a highly structured process of dispute resolution to provide a means to authoritatively adjudicate a dispute between parties based on a set of formalized procedures [1]. While parties argue their case against each other through the usage of discovery and courtroom procedures, each party assembles its argument supported by findings and facts.

The first stage involves the investigation and filing of the complaint. During this stage, the attorney investigates the factual basis of the claim and legal theories of liability. The second stage is discovery; it allows both the plaintiff and defendants to send written questions to the opposing party. In the third pre-trial motions stage, parties issues narrowed to establish the procedures to be used at trial. In the fourth stage, both parties present their case to a judge and listen to the instructions of law given by the judge [1].

What people concerns are whether the desired decision can be obtained, and

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whether the decision will be enforceable? General litigation concerns from the public include: who wins and who loses, the reason, and whether the results meet the society expectation? The definition of expectation is problematic:

1. The general public assessed only limited information mostly through news. Sometimes the reporters are biased, or focus only on certain issues. The general public also has limited legal knowledge. Powerful, well-legal resourced parties have a tendency to determine justice according to their interests.
2. The outcome of the trail is written in legal terms, which are difficult to understand by people. People have no time and ability to understand it, so that the communication between the court and public are not well connected.
3. The complexity of facts, law and procedures made a plaintiff confused on preparing and obtaining expected decision. When procedures are incorrect, or when factual evidences are insufficient to be verified, plaintiff's request may not be acknowledged during the legal procedure. The plaintiff may feel disappointed and give unfair accusation on the legal system.

Public interest litigation (PIL) is also known as "social action litigation". Litigation commenced in the pursuit of the public interest, either by a public-spirited individual or by the court acting. It is not in pursuit of individual remedies by or for a specific person, but often for the protection or advancement of group rights, most useful in the pursuit of social, economic and environmental rights. Law is social auditor and this audit function can be put into action when someone with real public interest ignites the jurisdiction. Public interest litigation can be a panacea for administrative ills in public administration - involves judicial review of government policies and actions.

Administrative law encompasses laws and legal principles governing the administration and regulation of government agencies [2]. Administrative agencies are created to protect a public interest rather than to vindicate private rights. Taiwan follows the civil law system and the principle of "nulla poena sine lege" (no penalty without a law). When trying to make a decision, the Courts look to what the Constitution states first and then to codes, statutes, and ordinances.

Taiwan has a three-tiered court system made up of the Supreme Court, the High Courts, and the District Courts. High Courts have several tribunals for civil and criminal trials made up of a presiding judge and two other judges. District courts are usually presided over by one judge. Court decisions become binding precedent when they are final judgments entered by the Supreme Court [3].

1. Legislation as TE

Trans-disciplinary Engineering (TE) emphasizes the need for different disciplines to collaborate across intra- and inter-knowledge borders. Such collaboration already exists in engineering renovation, product and service design. Not only engineering disciplines are involved in collaboration, but also marketing, production, maintenance, service, sales, legal and financial entities [4]. It takes many years to take the necessary steps to master the many challenges that accompany TE [5]. There are also many trade-offs to be made, such as legislation of the different countries, differences in cultures and working habits [6].

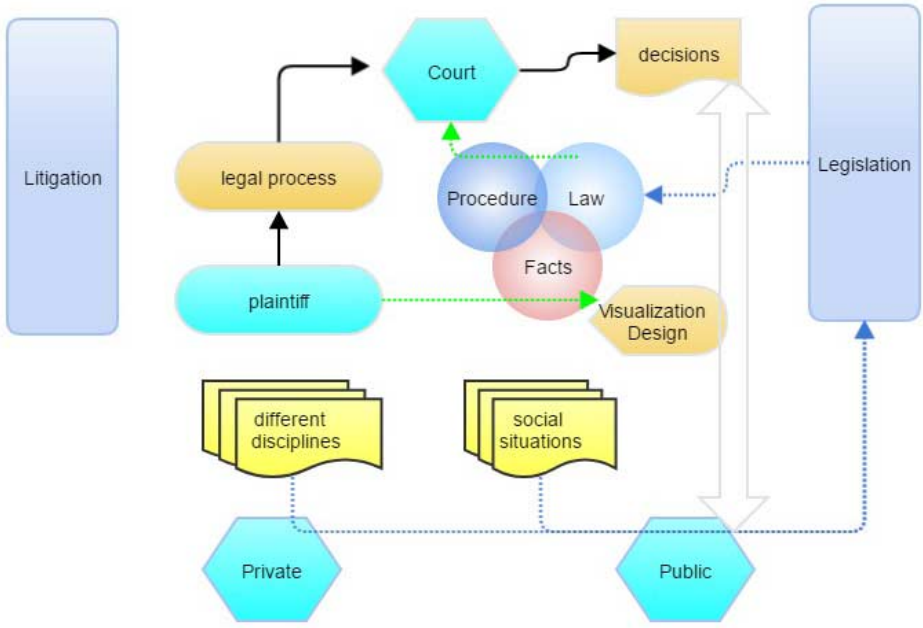


Figure 1. Integrated legal process.

We can make the analogy between the legal process and the product TE process. The society is changing fast, the technology and business also update quickly. Behind the changing society, there are values changing and new requirement arises. For instance, owing to understanding the human health, the industrial pollutions become critical issues for our society. A private legal event about local water pollution may hold the attention by public domain. While the court make decisions based on previous legislation, it may deviate from the current mainstream public opinion. To achieve integrated dynamic legal process, more active legislation are required through communication with different disciplines and society (Figure 1). Quick information and opinions feedback are needed for enabling and supporting such positive self-adaptive loop. Such systems require intra- and inter-society collaboration and exchange of facts, knowledge in the form that most people can understand.

"Judge without extra word" means decision (the verdict) can communicate with the people by itself. But the verdict is usually long and arduous; people can not understand it, hence the communication channels are blocked. Traditional passive communication way is no longer effective and causing misunderstandings among the public. Visual design can reduce communication barriers; promote the understanding between the parties, lawyers and judges. To achieve integration, positive feedback loops are needed by the current legal system. The Figure 1 also emphasizes that the communication is a key element of legislation and litigation process.

2. Visualization through Transdisciplinary Design

Visualization through design does have great impact of product acceptance; i-Phone is a successful example. User friendly design can reach customers whom have never been

reached before [7]. User interface engineering is the design of user interfaces for machines and software, such as computers, home appliances, mobile devices, and other electronic devices, with the focus on maximizing usability and the user experience [8]. The goal of user interface design is to make the user's interaction as simple and efficient as possible. Graphic design is utilized to support its usability, influencing how the user performs certain interactions [9]. Those design principle can transfer to improve the communication of legal system too. Some examples are discussed as the follow.

Visually representing a legislative text and its amendments might possibly reveal important aspects. In recent design camp of the Law Factory project [10], two designer groups independently combined data for law-making processes with an array of visualization methods, in order to bring forward different points of view of the same phenomenon. The ability of in-depth exploration is facilitated by providing further background information in order to help end users navigate, comprehend and interpret the visualization.

Using data visualization, language analysis, and machine learning, the Stanford Law grads created Ravel, aiming to reinvent legal research and deeper understanding of their field in the process [11]. Early users have reported that Ravel cut their overall research time by up to two thirds. It lets you see how cases evolved over time, and potentially lets you see outliers that could be useful in crafting an argument.

"Legislative transparency for non-lawyers" was discussed recently. Clarifying the meaning and function of these terms in a socio-political system can be a helpful start towards unraveling the notion of transparency. Citizen engagement requires constant commitment and strives through a variety of tools and actions. Legislative transparency remains an issue with many interesting aspects yet to be explored. The transition from the natural language of people into everyday life jargon of professional people is an important issue. C.W. Kessel imparts intensive and reflected law knowledge to children and young people and tries to arise the curiosity for the logic and concepts of law [12]. The structures of legal elements (Figure 2) are demonstrated as a mechanism which helps people understand its relationship between the legal elements [13].

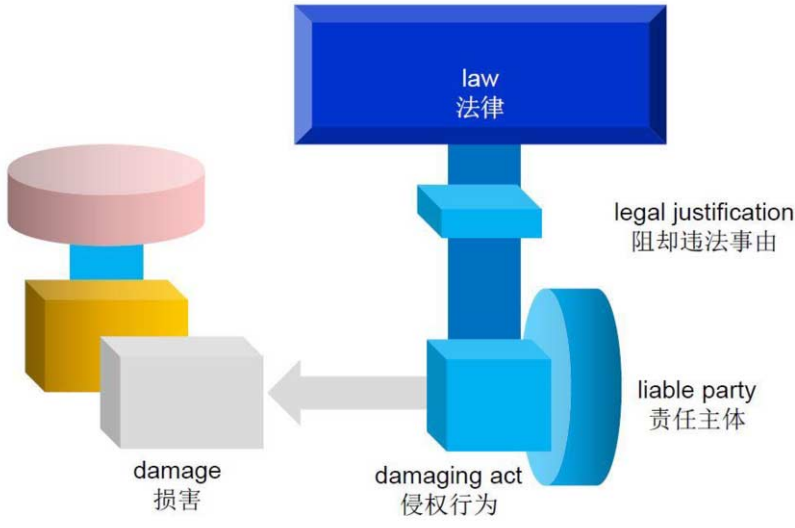


Figure 2. Mechanism of legal elements [13].

David maps out the potential benefits of visualization tools [14]. It can provide faster, more meaningful search results. A strong visualization element represents a compelling value proposition. Data visualization allows for relationships between legal data to be highlighted in a way more readily discernable to the human eye. Visualization can transform the process of understanding the meaning of results turned up in legal research. Relevant cases through relationship mappings let people quickly understand the links between cases.

3. Litigation visualization of cases in Taiwan

Taiwan Administrative Litigation Act, taking effect on July 1, 2000, consisted of 308 articles. It abolished the second administrative appeal that had been mandatory prior to suing a government agency in an administrative court for expanded protection of rights.

The case on appeal will check whether the case complies with procedural requirements. An appeal to Supreme Court may only be filed on the ground that the judgment is contrary to laws and ordinances. Each panel, comprised of a Presiding Justice and four Associate Justices, decides cases by majority. Joint Conference of the Justices is held periodically, based on the circumstances; it is usually held 1 to 3 months apart [15]. When the topic has been thoroughly discussed, a poll will be conducted by the attendee, and the result be published. It is a statutory mechanism that functions as the en banc court to maintain the uniformity of legal opinions. Four cases of Joint Conference of the Justices were analyzed in next section.

3.1. Joint Conference 2016-10-1: Violation of drug

Article 24 of the Pharmaceutical Law states: "drug advertisements referred to in this Law refer to the use of communication methods to promote medical performance for the purpose of attracting sales." Advertising is a collective concept of attracting sales one or more times. Repeated violations of the law should therefore be assessed as one offence, and only after the authorities ruling, will new offence be counted as next offence. The plaintiff advertised "far-infrared therapy instrument" in the same period 76 times. The behavior should be considered one violation of Article 65 of the Administrative Law, rather than a number of activities.

Visualization design (Figure 3) indicated with:

1. There are 2 lines (law and fact) that can be reference to each other.
2. Article 24 of the Pharmaceutical Law use a document symbol.
3. Logic reasoning represented by bar with one circular end.
4. Solid line: consequence, dotted line: possible implication.
5. Hexagonal box represented related facts.

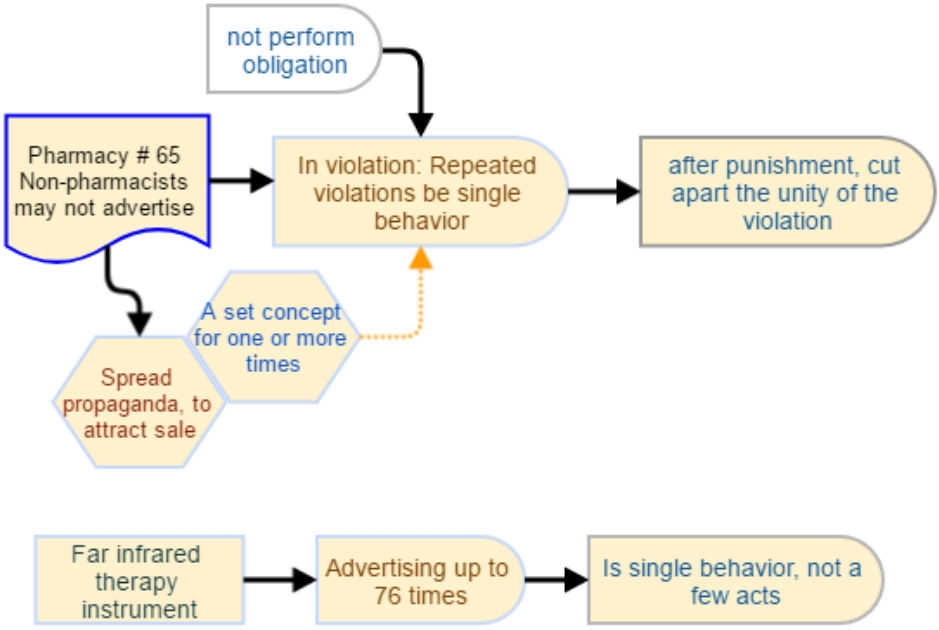


Figure 3. Repeated violations of the law.

3.2. Joint Conference 2016-07-1/ Refund the wrong tax

After tax payment, if taxpayers found any mistakes, they need to report it. If the wrong calculation resulted in paying more tax, one can apply for tax rebate. The reporting process and tax levy authority's verification must be done during specific time, but for more complex cases, mistakes may often be discovered after that period. The period is 5 years from the date of payment. However errors due to tax levy authority's calculation, authority must refund within 2 years. Even if the authority error was discovered after 5 years' time, it was ruled that the case will not be bound to the 5 years limitation.

Visualization of litigation (see Figure 4) indicated with:

1. Claim the tax rebate period is divided into different sector.
2. Wong fact or law caused by government agencies follow different path.
3. Special consideration on government agencies aware and corrected error.
4. The permitted time period for tax rebate application depends on type of claim rebate.

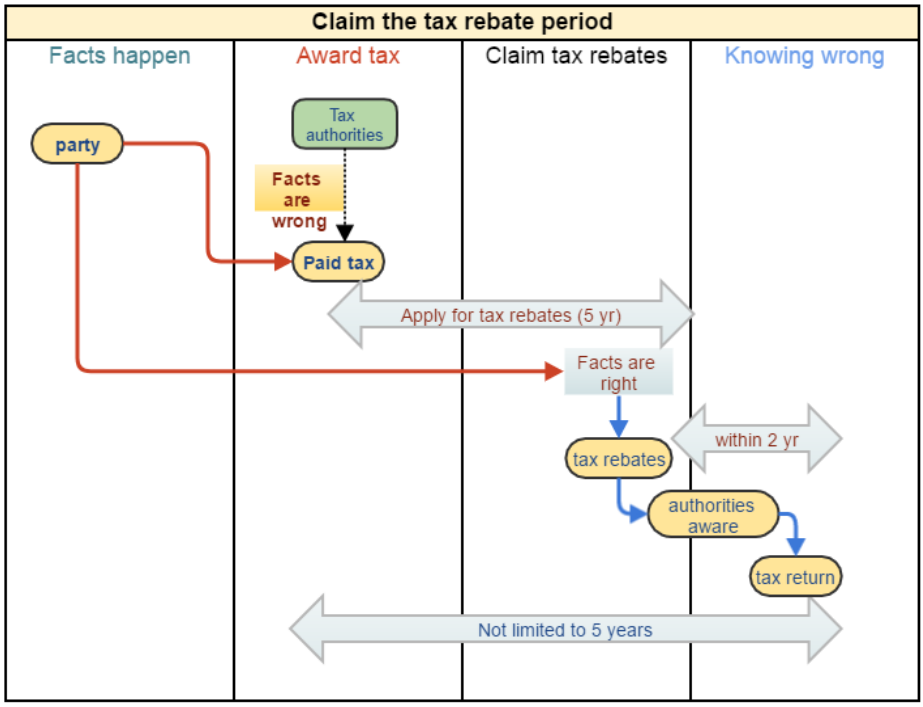


Figure 4. Case on apply tax rebate.

3.3. Joint Conference 2016-04-2/ Impose a duty of disposition

When one was ruled a fine due to tax paying process, but passed away during administrative dispute process, should the heir faced with the enforcement of such fine based on the earlier rulings? Article 50-2 of the Tax Collection Law: If the victim is dissatisfied, it shall be handled in accordance with the administrative relief procedure. Before the end of the administrative relief procedure, shall not be enforced in accordance with the provisions of Article 39. After ruling takes effect, unless stated otherwise in law, the ruling can be forcefully executed. In accordance with the provisions of Article 50-2 of the Tax Collection Law, it shall be exempted from the compulsory enforcement of the administrative proceedings. This law provides suspension of execution, and by no means it is not enforceable.

Visualization (Figure 5) of litigation indicated with:

1. Tax succession event was characterized by four phase.
2. The plaintiff's action display on each time frame.
3. The inherit process happened after the tax enforced due to the tax fine.
4. Article #50-2 reference applied regulation.

3.4. Complex cases with the land

Liberty Times A28 reported that "the lawsuit lost, the school will tear down". In order to avoid misleading of the public, the Taichung Administrative Court specifically

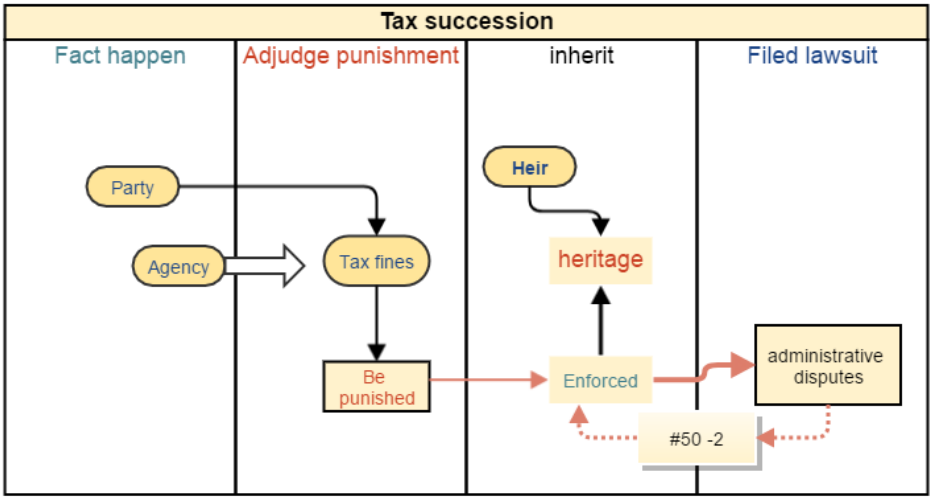


Figure 5. Case of tax succession event.

stated to the general public [16]. The county government's urban planning provided the new school building project; need to utilize the original location of Changhua County (total 24 pieces of land). The Government approved the land acquisition in 1989 and the approval period had been extended to 2001. Owing to the county government did not start to use the land to construct the school before approval period, the original land owners apply to the county government for the returning their land. Consequently, they filed suit in administrative court. The litigation process, facts and the result of the trials are summarized in Figure 6.

The Changhua County had completed the school construction at the moment, based on public interest and benefits the court dismiss the plaintiff's request. Ministry of Internal Affairs should compensate the plaintiff to recover their damage with money (recalculate the price of the land in 2001 and the accumulative interest since 2005). Owing to the complicity of litigation process, legal relation and the sequence of court judgments, the visual chart was divided in four parts;

1. Facts: major events and the party are arranged according time relative sequence.
2. Process: the sentences that obtained are placed as timeline.
3. Main decisions: the major concerns and its basement were connected with dotted line.
4. Declarations: the announcement to public and the evidence that support it.

Complex cases with the land involved time, different parties, law and public concern. Experimenting with visualization design is to categorize different states, and order them according to time. Then the relationships between different elements are explored, and main relationships between categories are plotted, so ordinary people can understand the ruling based on the corresponding facts and arguments. By presenting these it is hoped that misunderstandings are minimized.

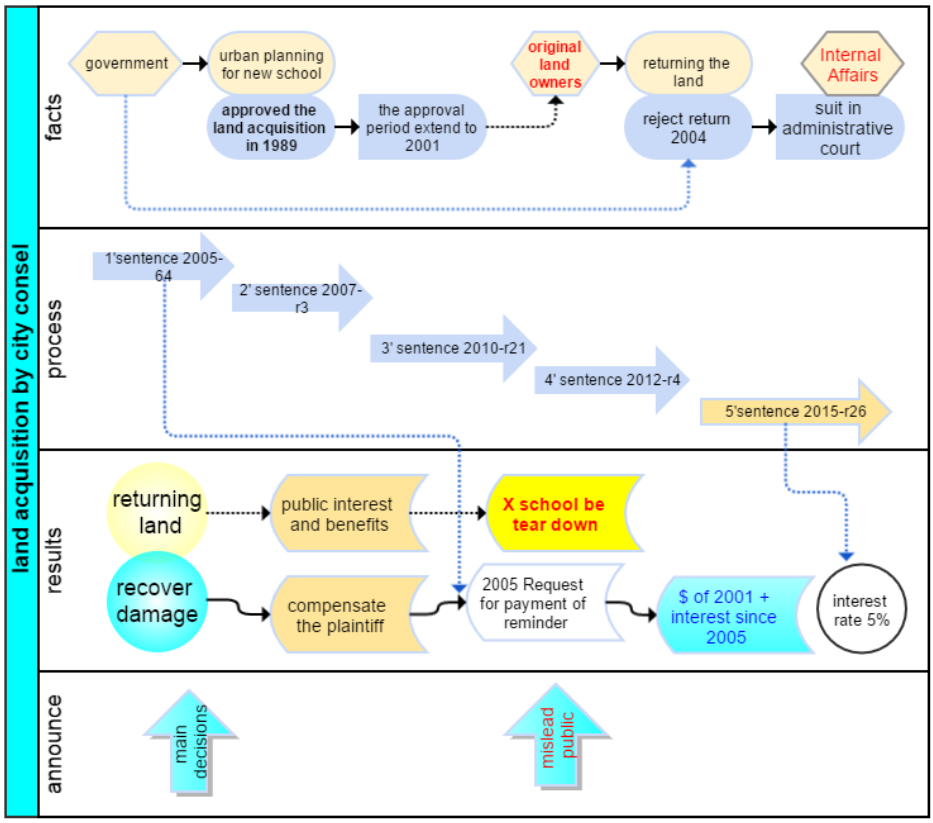


Figure 6. Case of land acquisition event.

4. Acquire public opinions

User and task analysis is a process of learning about the users by reviewing them in action for more understanding in the context. Three visualization cases of Joint Conference and one administrative court case were presented to ordinary people as testers using transdisciplinary design. Testers were divided into two groups. One group reads the text as is, and another group sees the graph first then read the text. After observation, users' opinions were acquired as follows:

1. Seeing the graph first reduces reading time and difficulties. If the graph represents actual logic and relationships, it would construct a more solid mental model in the reader's mind, helping one to understand more fluidly.
2. Visualization of litigation process through flow chart, diagram, color and shape help people to understand.
3. Different colors and shapes increase the attractiveness, but also bring questions. Colors and shapes relative to its meaning; user needs to have a consistent meaning to reduce the confusions.
4. In order to reach an objective understanding of individual cases and allow users to deduce similar reasoning based on prior experience, it is necessary to separate the major concepts and a consistent pattern before presenting.

5. Colors are not chosen based on the aesthetic sense, but by the emphasis or the internal characteristics of facts, processes or judgments. An understanding of local culture and habits is needed in order to choose suitable design elements and presentation styles.

The judge of that specialty was also invited to see the graph, and guess which case the graph was representing. The fact that the case can be recognized successfully also indicates that visual design's effectiveness.

5. Conclusion

We can make the analogy between the legal process and product TE process. The modern society is changing fast, the technology and business also update quickly. To achieve integrated dynamic legal process, more active litigation and legislation are required through communication with different disciplines and society. Quick feedback from people and party is needed for enabling and supporting the positive self-adaptive loop. Such systems require intra- and inter-society collaboration and enable exchange of facts, knowledge in the form that ordinary people can understand.

Interface design principle can be applied to improve communication of the current litigation process. Three cases of Joint Conference of the Justices and one Administrative Court decision were plotted through flow chart and timing diagram. User observation and analysis were conducted to acquire the user's opinion. Visualization of litigation process through flow chart, diagram, color and shape help people's understanding. For visualization to improve, consistent meaning of visual cues is needed to reduce confusion. The design should avoid meaningless decorations, aims to improve cognitions and also understand the meaning of each element in respect to local culture and society. When background visualization rules are established and well understood by the general public in future, one has the ability to conduct in-depth exploration and to comprehend legal relations more easily.

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Research on Improvement of Human Interface Design for AXIOM Digital Micro Machining

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Abstract. Local machine tools usually utilize a common compatible module within the control unit which is often bought from other company. Digital micro milling machine (AXIOM Auto Route) was evaluated in this study to point out the interface problems. Usability study methodology and experimental performance evaluation were carried out by observe participant's performing on specific common tasks in the laboratory. The results show that the handheld common control module uses a mixed approach on the graphical user interface, making each button to handle multiple activities. The multi-functional buttons made the control operations complex and it's difficult to memorize and to discover the relevancy. The flowchart, the screens and icon were designed with App interface approach to improve the shortcomings of the existing interface. Based on the experiments conducted, the operation procedure and the learning efficiency are enhanced, which can be applied on interface design on other control units.

Keywords. Micro-controller, usability evaluation, App interface

Introduction

Human Machine Interface usually means hardware controlling interface used for communication between human and industrial machineries. This research mainly uses digital micro milling machine to explore issues between the user and the control interface. In addition to the software interface, by examine current user interface for operational analysis, supplemented by graphical icon recognition, it is possible to re-define the control sequence, the "input" and "output" format and operation of the timeliness. Usability is the performance and satisfaction when using the product : it indicates the features characteristics include learning, efficiency, memory, error rate and satisfaction [1]. Usability can be broadly defined as the capacity of a system to allow users to carry out their tasks safely, effectively, efficiently, and enjoyably. Trans-disciplinary Engineering (TE) emphasizes the need for different disciplines to collaborate across intra- and inter-knowledge borders [2]. There are also many trade-offs to be made in design process, such as engineering, industrial design, aesthetic, usability and working habits.

Figure 1 indicate the multi-disciplinary relationship in design, engineers takes required functionality and control unit to construct a system. During this the manufacturing process and cost requirements are considered. Industrial design often

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dealt with outer appearance design, sometimes resulting in poor usability. After usability problems discovered, usually the main structure is settled so only minor adjustments can be made. Lacking of early communication and overall considerations result in design proposal with more pitfalls. Industrial and interface designers need to communicate with each other early, enhance the applicability of design and reduce obstacles. When interface designer needs different support at hardware and software levels, engineers can adjust the controlling methods and redefine interfacing modules. The co-ordination of the two can raise level for innovation design.

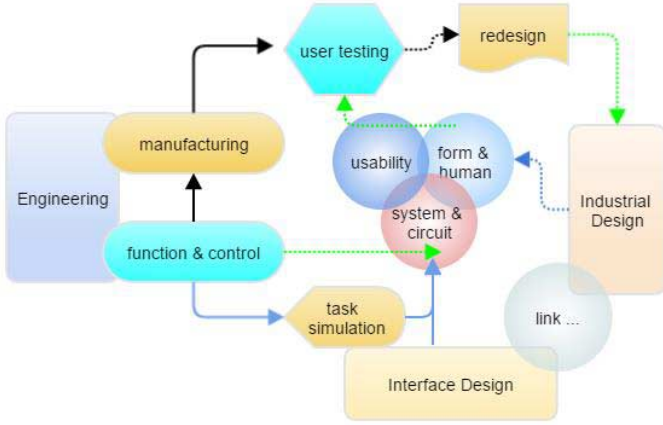


Figure 1. Multi-disciplinary of interface design.

The App interfacing need overcome the communication problems with control signal. Bluetooth interface has to encode the control signals, and decode the signal at receiver end and then pass to the machining system. Control signaling hardware and communication requires early coordination due to interface requirement and system integration.

1. Research methods

In this study, first we examine usability of desktop digital micro milling machine's whole hardware operation procedure, and list the issues of common operations. Weighting is set on different prospects and solutions are offered, covering the required functionality and limitation. Finally we use design methodology to increase the product's usability and lower the learning curve, to fulfill the eagerness for increased value in industries.

The performance evaluation methods in the usability evaluation experiments are used to analyze and improve the operation of digital micro-controller. The reproducible procedures enable data collection and statistic analysis. Before the experiment, we study the AXIOM Auto Route basic operating instructions and processing procedures, summed up the typical task to observe in experiment. The icon and placement of micro-machine tool handheld manipulator is shown in Figure 2.

The controller utilizes g-code to communicate with the Router with one-touch and combined key commands. The operation within typical tasks included:

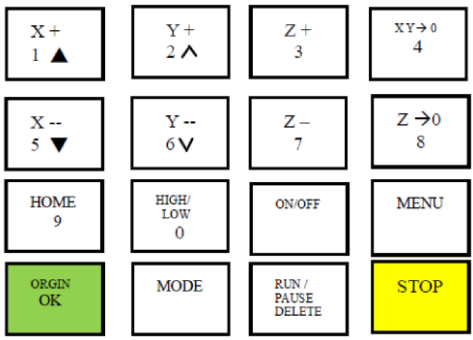


Figure 2. Keyboard placement of handheld manipulator.

- Task 1: Power on
  (1) Return the tool spindle to the origin, press "HOME9" to reset the spindle. Press "ORGIN OK" button, the tool will back to the machine origin.
  (2) First verify the total width of the machine, press "X + 1 ▲", "X - 5 ▼", "HIGH / LOW 0" and then "Y - 6" key.
  (3) Press the "XY → 04" key to reset the X axis and Y axis, next, making Z axis correction.
- Task 2: Configure origin (base) point
- Task 3: File selection
  (1) Insert the USB flash drive, press the "RUN / PAUSE DELETE" key, and then press the "ORGIN OK" key to select the machining file using "X + 1 ▲" and "X - 5 ▼" keys.
  (2) To select the disk file, press the "ORGIN OK" button, then use "X + 1 ▲", "X - 5 ▼" up / down keys to select the processing file.
  (3) Press and hold the "ORGIN OK" key, and the machine starts to run.
- Task 4: Adjust the processing speed during working
  (1) Pressing the "Y - 6" key will cause the machine to operate at a slower speed.
  (2) Press "Y + 2" key, the machine running speed becomes faster.
- Task 5: Interrupt and resume processing
  (1) "X - 5 ▼" up / down keys to select the "Save break point" option. After pressing the "ORGIN OK" button, the system will be interrupted.
  (2) Press "RUN / PAUSE DELETE" and "X + 1 ▲" to select the break point and press "ORGIN OK" key to continue the machining program.
- Task 6: Power off

In this study, we found that icon identifiably is not clear. With its complex operating procedures, users often can not smoothly operate unless after proper education and training. Both the flow chart and good icon reconcilability help to meet the user goal. The usability evaluation experiments were arranged, site is located within the Industrial Technology Research Institute (ITRI) [3] of the perceptual observation laboratory. Cameras were set up to record the participant activities from different angles (Figure 3). During experiment, participant was separated from others to avoid interference. The participant performed the six typical tasks according to the instructions and prompts on screen and reviewed the experimental situation through one-by-one interviews [4, 5]. The bottlenecks were recorded.



Figure 3. Laboratory's set up of the camera screen.

2. Results

After viewing the operation in the film, we select and set typical task measuring points to record the operation time. The summary of the typical task were measured (Table 1) by the time spent, total time and the most time-consuming bottleneck of each participant.

Table 1. Typical task operating time consolidation table.

Participant	Standard Task						Total time	bottleneck
	1	2	3	4	5	6		
A	15	114	105	7	180	130	434	Breakpoint Reply
B	4	282	30	15	129	7	467	Z axis zero / breakpoint recovery
C	10	129	182	24	303	6	654	Origin setting / breakpoint return
D	7	36	27	7	281	4	362	Breakpoint reply
E	4	142	54	8	79	4	295	Z axis to zero
F (familiar user)	9	44	49	17	32	6	157	None
Average	8.2	124.5	74.5	13	167.3	26.2	394.8	

On the whole, task 1 and 6 only involve on / off operation. In task 4, the processing speed is adjusted during operation. Although the key figure is complicated, the increment and decrement can be identified from the icon. Tasks are performed after training and practice, so the three have no operation troubles. Task 3 (read processing files) and task 5 (interrupt and restore) are not easily identified, the misunderstandings lead to the failure during operate which indicate the bottleneck of the operation. After the operating of the experimental situation, and 1-1 interviews, the machine encountered following bottlenecks:

1. The setting of the base position: the keyboard makes it difficult to see which key to press first, and to know the length and width of the machine to calculate the midpoint of the X-axis and Y-axis. Z-axis zero is more complex, one must use the correction block alignment firstly, due to the need to use the composite key, it is not easy to remember its operation.
2. Interrupt program and then return to work: the operator is the most time-consuming and most error-prone steps, because the need to use two irrelevant composite key.
3. Operation step is not convenient; users need to be trained before they can get started. Receive comments include: provide drop-down menu for different functions; add instructions guide so that the machine can be promoted more easily.
4. The first operation of the machine will be intangible, need to be trained after the operation. There is no way to clearly determine the function of the key only by the symbols and numbers on the button. There are no correlations between the composite key and is bad for memorization.

3. Interface improvement design

The experimental data and the interview data had summarized the interface problem. When operating the machine, certain steps need to be followed. For example, choose type, reset the settings, choose setting, halt and adjust machining path, etc. When users are not clear about these steps, and when controller offers too many options but displays no current and next stage, users can often miss a step and cause errors. Operation commands requires pressing many buttons in order and someone unfamiliar often has to pause halfway. Designers need to understand the function and acquired proper image icon to guide the operation [6].

In improvement design, we operate via mobile phone app and redefine the operation flow (Figure 4), and use the paper prototype software (POP) to construct the task simulation environment. The reasons being:

1. Mobile phone interface is familiar with the general public. It has build-in capability to connect to online cloud database, update when required and provide directions.
2. Build-in sensors can sense on-site environment to provide information about adjustments.
3. Control options will be directed by the current and next steps, to avoid errors caused by missing steps. Related buttons can be displayed in certain order to reduce memorization burden placed on the users.

Mobile app interface though has its pros, still need to overcome the requirement of communicating the control signals. Bluetooth interface can communicate in short distance. The control signaling hardware and communication require changing, so co-operation with system engineer is needed in the early stage. As indicated in Figure 4, the improvement design of the flow chart include,

1. Vertical axis represents main steps; horizontal axis represents side options. Solid line represents required procedure, and dotted line represents possible auxiliary procedures.

2. Due to users often neglects choosing the machine type, QR reader is added.
3. Positioning defaults to machine's center position. User can change the base position or use current cutter position as base. Positioning is complete once selected.
4. Machining file can be selected from in memory, reset mode or USB.
5. Processing speed to be adjusted during the process, or it can be halted and resumed.

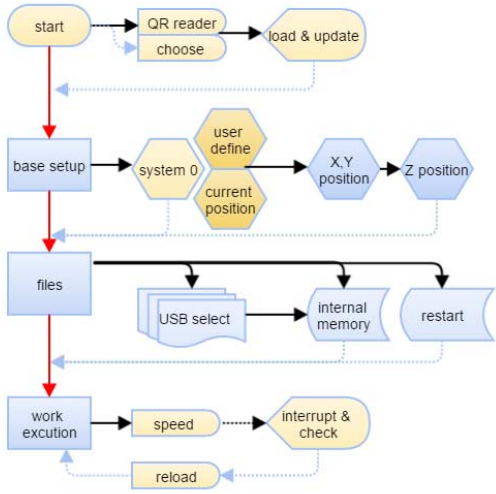


Figure 4. Improvement design of the flow chart.



Figure 5. APP user interface simulation scenarios.

Figure 5 shows detail screens of the improvement design. Before entering the main screen, user will be shown the whereabouts of machine power switch and QR code. The recognized machine type will then be displayed on to top of main screen. Touch interface can be convenient, but it is also easy to trigger by mistake, so the main screen and all other screens will only show related operation buttons. In the main screen there is the buttons for positioning and file selection, and the return shutdown button and help icon. Buttons are placed apart from each other to avoid touching by mistake.

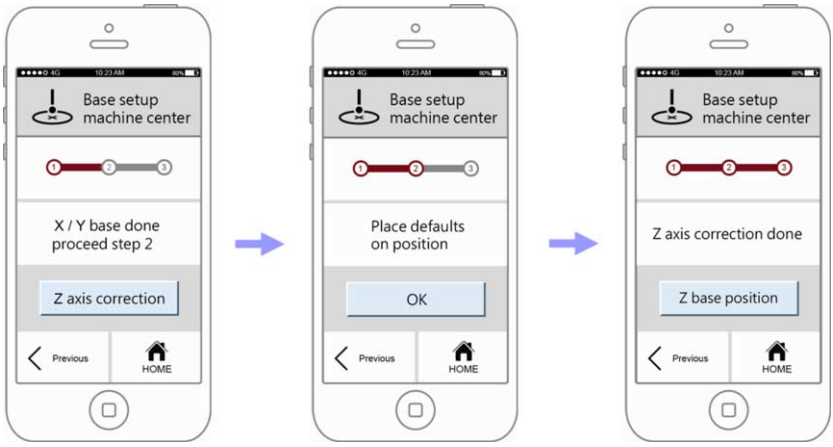


Figure 6. Screen of the origin point setting.

Figure 6 shows screen for the base position setting, base position utilized a touch sensor to feedback contact point. Icon design takes the idea of the vertical probe and its cross point directly below it. Positioning defaults to machine's center position, user can change the base position by entering the coordinates. When user has moved the cutter to be in contact with the material, they can set the current cutter position as the base. After selection, the XY horizontal plane is first set, and uses the position block to adjust the Z-axis height. Since these have to be followed in order, the screen displays a horizontal progress bar with the step number 1, 2 and 3.

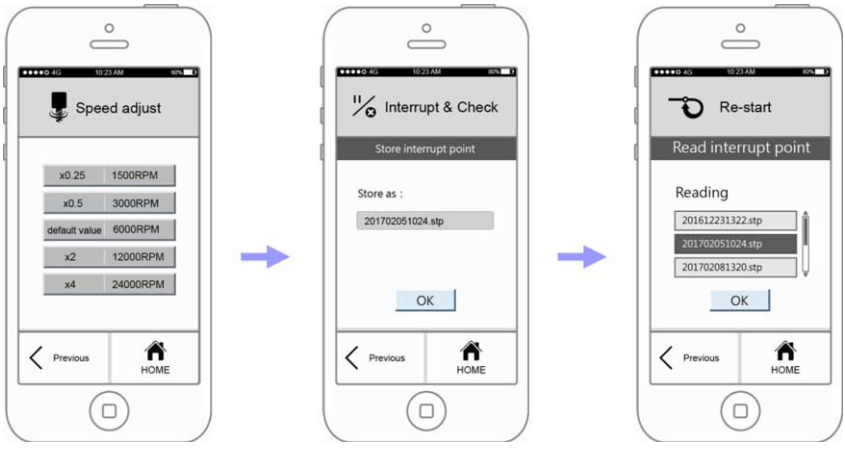


Figure 7. Screen for adjusting speed, halting and resuming.

Machining file can be loaded from in-memory, reset mode or USB drive with a drop-down file selection menu to avoid input error. After this procedure is done, we entered the "Start Execution". During processing, the speed can be adjusted, or it can be halted and resumed. Due to material's hardness, processing speed can be changed. When material is not longer held stably, or if defects start to appear, the process can be halted and processing routes can be adjusted, so the material won't come to waste. When users do not have a clear picture of the procedures in their heads, they tend to overlook the option, and cannot correctly return, resulting in process being halted. The

modified icons for resuming / adjust processing speed use the image of a returning arrow / rotating axis (Figure 7).

App improvement design was evaluated through the task simulation environment. The summary of the typical work items are shown in Table 2.

Table 2. Typical work items operating time in sec. (App).

Participant	Standard Task						Total time	bottleneck
	1	2	3	4	5	6		
G	23	48	19	6	42	10	148	Z axis zero
H	16	20	14	5	16	14	85	None
I	16	27	9	16	6	9	83	None
J	18	35	13	12	25	13	116	Z axis to zero
K	18	26	12	20	23	9	108	None
L	28	30	13	4	22	5	102	None
Average	19.8	31	13.3	10.5	22.3	10	106.9	

Before the experiment, the subjects only spend 5 minutes to learn app operation. During the test, instructor did not prompt, each subject can easily finish the typical task through the guidance of APP information. Participants spend more time during starting setup, all the rest of the typical task spend much less time than the previous handheld operator. Consequently, the average time spent with APP operation is much shorter than that of the manipulator.

4. Conclusions

Through the user observation and retroactive record, one button performs variety of functions, images and text mixing, and sometimes with other keys combination cause misunderstands. The app operation using mobile phone was proposed. The flowchart, the screens and icon were designed to improve the shortcomings of the existing interface. The instruction is organized by simple and easy-to-understand icons. The menu which guides the operator step by step can reduced the pressure of remember, even new customer can quickly get start. The usability assessment verified the effectiveness of the proposed design.

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The Use of Intuitive Thinking in Product Design Semantics: From Chinese Characters to Product Design

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Abstract. Intuitive thinking is a creative way of thinking that abstracts people's life experiences and talents into expressive symbols or forms, enabling people to have an immediate knowledge of something before thinking and studying it logically. In product design, if designers can use the intuitive thinking in design activities, making products associated with the user's experience, then it will greatly reduce the user's learning difficulties, resulting in a more pleasant experience. Chinese characters is a rational product with intuitive thinking that created in ancient China. It not only has a high degree of simplicity and abstraction, but also reflects people's lives with a strong cognitive. From the pictographic in very beginning, people have created varied Chinese characters by six basic formations, which is an outstanding example of intuitive thinking. The creation of Chinese characters provides practical guidance and reference for the modern creation. This paper analyzed the corresponding relationship between the "Six Categories of Chinese Characters" and the modern design technique, and we also analyzed the common function of intuitive thinking in the creation of words and products with designing cases. At last we organized the Intuitive Thinking Schema. By using the Intuitive Thinking Schema, designers can associate the user experience with product design semantics, which can provide users with a more intuitive product experience and provide a reference for later design practice.

Keywords. intuitive thinking, product design semantics, Chinese Characters

Introduction

With the development of the science and technology, the product functions are further optimized. However, the conflict between growing complexity of products and the limited information processing capability of human beings is more evident. Thus, how to enhance the users' cognitive ability through the improvement of product models and to lead them to respond to those products' utilization rapidly and naturally should be taken into consideration. The "intuition" connecting the users and the products will become a crucial focus of product design in future.

Intuitive thinking is a significant part of innovation. Nowadays, the consumer market more tends to be emotional and personalized, and the consumers value not only the product quality, but also the pleasant spiritual experience [1]. Different from the functional and rational one, intuitive thinking provides better user experience with

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decreased learning difficulty and makes users react to the products in a very short time. As a typical high-context country, China has developed the intuitive thinking habit in its long history. Nowadays, Chinese Design is attracting increasing attentions from all over the world, so the analysis on the Chinese intuitive thinking could bring more references for the cross-cultural design research.

1.Intuitive Thinking and Human Development

Intuition is one of the human virtues that leads us to explore the general developing trend of events, leads us distinguish the relationships between current and previous experiences, leads us to summarize, and leads us to deduce the general laws in common objects. In our long evolving history, intuitive thinking has been always playing an important role to guide human beings to summarize rules and further make innovation [2].

In primitive creating period, intuitive thinking inspired by some supernatural phenomena enlightened human beings to conduct creating activities on purpose. Our ancestors respected nature, so they materialized some unaccountable phenomena with intuitive thinking and imagined them based on the realities. The creating activities in this period do not have obvious intuitive features and systematical aesthetic concept has not arisen. Therefore, those activities tend to be imitations or abstracts of natural objects.

In handicrafts period, creating concept involved aesthetic intuitive thinking and practical rational thinking. People further summarized the natural laws, as well as learning and inheriting experience. During this period, our languages greatly developed and aesthetic appreciation achieved a higher standard. Meanwhile, human beings started to create objects without the limitations of nature. Thus new intuitive experience formed. The imitations of nature gradually became highly abstract symbols.

After the Industry Revolution, the society stepped into the period of modernism. Handicrafts were rapidly substituted by automatic manufactures. Limited by the pursuit of efficiency, decorative intuitive thinking was overweighed by rational thinking, so finally creating activities at that time were unprecedented rough and indifferent. Decorative patterns were not on the product anymore and people had to devote more time to learn those new products with lots of repeating practices, which naturally brought users a sense of fear and abhorrence [3].

Extreme functional ration inspired people to reconsider about intuitive thinking. With the increasing criticism of modernism, many designers undertook to look for the new design directions from ourselves once again who emphasized the importance of human emotion and cognition and involved them into the designs, which formed a design ideological trend centered by users. In this period, the creating activities were much more connected with the emotional designs and the relationship between products and users was even closer.

With the advent of Industry 4.0, informatization and automatization are newly combined. Meanwhile, the dematerialization trend of products is more evident and the boundary between virtual and real world is more ambiguous. The manufacture development breaks the efficiency increasement away from the only pursuit and a large-scale of tailored products emerge. For new products with more complex functions, people are more likely to handle them with exiting cognitive habits. To put the users'

needs directly into consideration and to integrate design with intuitive cognition habit become the practical design methodology in this period.

Objectively speaking, thinking from intuition to abstract reflects the general rule for human to understand the natural world. To a degree, intuitive thinking greatly influences our lifestyles, such as concept of "time". Strict time concept rules human behaviors (Figure 1, 2). Accurate as it is when calculated by number and clock, compared with natural and intuitive one, separated time concept ignores existence of mental time and totally breaks the intuitive link between time and events [4].



Figure 1. Clepsydra.



Figure 2. Sandglass.

The theoretical meaning of research on intuitive thinking is the analysis of foundation for human unconscious behaviors. At the same time, it enriches exiting design theories and further explores a new research direction.

2.Intuitive thinking in Chinese characters

The creation of Chinese characters illustrates the way how Chineses understand the world and connect with it. It could be regarded as a national systematical intelligence project throughout Chinese cultural and ideological history, in which our way of thinking is involved and from which our Chinese design thinking is derived. Chinese characters reflect the human understandings of objects through graphs and symbols, as well as the mental activities. As the only exiting ideogram in the world, thinking pattern behind Chinese characters still has effect on the direction of Chinese cultural development, including literature, art and other different fields. The research on the design concept of Chinese characters is a significant aspect of cross-cultural design communication between west and east.

The traditional form of Chinese characters is named as "Six Categories of Chinese Characters" and it is still used in modern society, including pictographic, self-explanatory, ideographic, pictophonetic, transformed and borrowed characters. As a typical expression of Chinese ideology, the process of creating characters had showed apparent tend of intuitive thinking.

2.1. Pictographic Characters

From the origins of human civilizations, pictographic characters were commonly adopted by our ancestors. Through the imitation and extract of natural phenomena, they demonstrated the rules of movement in nature with simple lines, which was the most direct reflection of intuitive thinking. In Chinese characters, sun ("日") and moon ("月") are precisely the imitation of sun and moon in the real world. Although there are many restrictions, pictographic characters, with the closest connection to nature and most intuition attributes, are the foundation of other characters' types.

2.2. Self-explanatory Characters

Based on the pictographic characters, Chinese ancestors created some characters that could not been described by pictographic method by abstracting some parts in the character, thus they had the symbolized features, such as up ("上") and down ("下"). In fact, self-explanatory characters are not independent of previous ones, instead changing some parts in each character. They are further improvement of pictographic characters and also embrace the distinct intuitive features.

2.3. Ideographic Characters

When single pictographic character failed to explain the nature of object, Chinese ancestors creatively combined several characters together, which could express more complicated meanings, for example, crowd ("众" - three people) and believe ("信"- human and saying). Despite more complex in shape, ideographic characters more emphasis the connections among different parts, thus they reflect the overall understandings of objective events.

2.4. Pictophonetic Characters

Based on the previous categories, a new type composed of half semantic and half phonetic features was created. Pictophonetic characters, as the biggest one among six categories, greatly enriched the structure of this system. Those characters combined our vision and audition, such as "江-Jiang" and "河-He" (both mean river), which strongly evoked our intuitive feelings.

2.5. Transformed Characters

Different from the creating categories, transformed characters are more related to the character utilization. In Chinese, some characters share the same part in shape and similar meaning in semantics, like "考" and "老" (both mean "old"). Those transformed characters illustrate our human understandings for the connections and relations among objects and events, and they are in line with intuitive features as well.

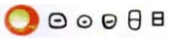
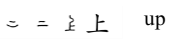
2.6. Borrowed Characters

Borrowed characters indicate those ones that do not exist before, but created by borrowing the shape from other characters which have similar meaning as them, for example, "令" and "长". The category of borrowed characters was developed based on the premise of fully comprehension over cognitive habits of other categories. Thus, it involves human experience and highly demonstrates our intuition.

It deserves to be mentioned that "Six Categories of Chinese Characters" is the objective summary of creating Chinese character methodologies that bring us a comprehensive overview of ancient ideology [5]. The idea of intuitive design in

Chinese characters provides designers more inspirations and references of intuitive design in modern society (Table 1).

Table 1. Six Categories of Chinese Characters.

Category	Example	Formation
Pictographic Characters	日 (sun)	 sun
	月 (moon)	 moon
Self-explanatory Characters	上 (up)	 up
	下 (down)	 down
Ideographic Characters	众 (crowd)	人(human) + 人(human) + 人(human) → a lot of people → 众(crowd)
	信 (believe)	人(human) + 言(saying) → some one keep his words → 信(believe)
Pictophonetic Characters	江 (river)	 (water) + 工-gang → 江-jiang(river)
	河 (river)	+ 可-ke → 河-he(river)
Transformed Characters	考 (old)	 These two characters share the same part in shape, and both mean “old”
	老 (old)	
Borrowed Characters	令 (chief)	令(order)→ The one who gives the order → 令(chief)
	长 (leader)	长(long) → The one who stands in front → 长(leader)

3.From Chinese Characters to product design

Most of information we need is stored in the outside world and the combination of information from our memory and from the outside influences our behaviors.[6] From ancient times, Chinese believe that objects have their own emotions and feelings. The idea of regarding the objects as the bridges to communication makes the highly integration of Chinese creating objects and creating character. Intuitive thinking is a matching process that leads us to look for the most optimized combination between previous experience and the status quo. Intuitive thinking should also align with natural laws we have acquired and further put human behavior modes and cognitive habits into design considerations. There is an evident coherence between “Six Categories of Creating Characters” and modern design [7]. The synthesis of two sides could form a practical product intuitive design process.

3.1. Pictographic and Bionic Design

Similar with pictographic characters, bionic design also borrows the ideas from natural phenomena and further abstract and summarize them for product shapes and

interactive designs, which echoes with users' memories by matching this natural cognition and brings them better user experience. Egg Chair, designed by Arne Jacobsen, precisely adopt this idea (Figure 3). The shape of egg evokes the sense of comfort and relax from users' intuition and then the product spiritual experience is improved accordingly.



Figure 3. Egg Chair. Arne Jacobsen.1958.

3.2. Self-explanatory and Symbolic Application

The proper symbols added in the design to guide the users could greatly decrease the misoperation possibilities. Delicate-designed buttons on the product could instruct users how to operate it for the next steps. Those instructions attached to the products themselves could bring users more pleasant experiences. Meanwhile, the difficulty to learn about this product is declined.

3.3. Pictophonetic and Synesthesia Design

Synesthesia is inspired by pictophonetic characters in product design. In the process of product design, some parts of auditory and olfactory features could be transformed into visible product semantics to achieve better user experience. whistling bird teakettle, designed by Michael Graves, illustrates this practice vividly(Figure 4). When water is boiling, the signal is designed as bird singing. It brings more joy to users and incredibly shortens the waiting period in mind [8].

3.4. Ideographic and Modeling Design

Ideographic characters provide some new ideas for product design. When the singular product shape could not individually satisfy users' intuitive feelings, the methodology of combination is adopted, in which some separated parts constitute the overall shape. This deconstructive way greatly enriches the product modelling language. Meanwhile, users could achieve sense of joy when experiencing different combinations.

3.5. Transform and Product Family

In product development, modelling language in existing product could be transformed to new ones in the same family then a series of product is formed, which

share some similarities with transformed characters. In this way, connections among products are built and users could have a more direct understanding of them.



Figure 4. Bird Teakettle. Michael Graves.1985.

3.6. Borrow and Substitution Design

In design of new product, creatively borrowing the usage or shape from other similar products and further substituting to the new product could decrease the difficulty for users to understand them and make users much closer to the products. Naoto Fukasawa borrowed the idea from the way that people pull a string to switch on the lamps to CD Player in MUJI(Figure 5). Therefore, the CD Player with which people are not so familiar before could be easily learned to use afterwards [9].



Figure 5. CD Player. Naoto Fukasawa.2004.

Among these six formations, Pictographic and Self-explanatory are singular methods, Pictophonetic and Ideographic are conjunctive methods, transform and borrow are methods of how to use. From the map of the methodologies between Chinese characters creating and product design, we could summarize the intuitive design as several steps and draw intuitive design schema (Figure 6).

Conclusion

Products, integrated art and technology, reflect our human empathy. Product exterior shows the function and structure and its' design language would directly influence

users' understanding of instruction and further real utilization. Adopted Intuitive design, designers could simplify the product shape, summarize the design language and finally transmit to users. In this way, those products could be more easily accepted by contemporary customers. A good product should involve both highly simplified shape and comprehensive design language. At the same time, product itself should build a connection with culture and technology – usage instruction, so that users could catch the meaning expressed by designers as soon as facing the product. Precisely, modern lifestyle at the high speed calls for the efficiency in quick understanding and operating products. "Six Categories of Creating Characters" reflects Chinese comprehension for the rules in objective world and demonstrates Chinese intuitive thinking. Through the summary of the intuitive thinking in character creation, intuitive design flowchart is generated, which brings new ideas for product intuitive design. This intuitive design not only could expand current product design theoretical system, but also provides an opportunity for more people to make acquaintance with oriental creating wisdom, and further supports the enactment of intercultural design policies.

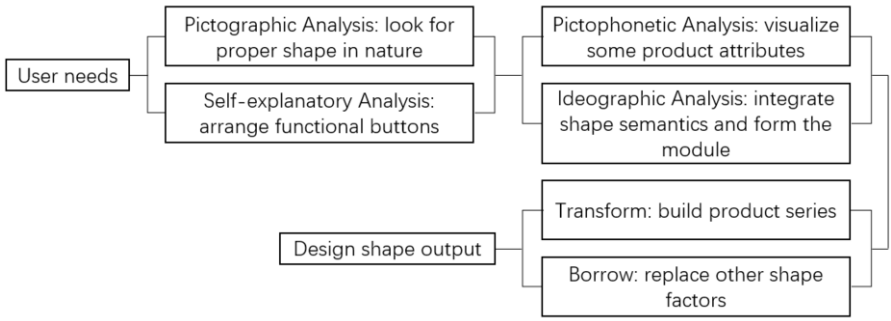


Figure 6. intuitive design schema.

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The Subjective Impression of Bicycle Saddles in Different Contexts

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Abstract. Customers nowadays want not only a functional product but also one can reflect their values and personalities. However, their emotional needs are not easy to be identified because people react differently according to personal experiences. Despite the high efficiency of a structured questionnaire, its validity of pre-defined items has been questioning. In order to address this problem, this study focuses on understanding how customers' subjective impressions are constructed in different contexts. When people show their interests in a certain product, their level of involvement increased along with other contexts of usage. An enthusiastic cyclist, for instance, can use bicycles as a means of sport, transportation and leisure. A case study of bicycle saddles has been chosen and thirty-three women road cyclists volunteered for interview sessions respectively. Accordingly, a semantic database and a conceptual model illustrating an enjoyable saddle experience were proposed. The findings can also help rectify current collecting approaches in terms of the emotional needs for sports equipment.

Keywords. User experience, emotional design, new product development, bicycle saddles

Introduction

The companies nowadays are aware of the benefits of emotional design and appreciate customers' feedback on product satisfaction. In the interest of creating an enjoyable product for a positive user experience, they would conduct several surveys, usually questionnaires, to identify the needs of the target market prior to the production. In the field of product design, researchers have developed an approach applying the semantic database to understand customer's impressions towards the product [1, 2]. Despite it helps designers transfer subjective feelings into technical specifications efficiently, it still has the limitations.

One of the problems is that the semantic items are often prepared to a certain extent by the person who designs the questionnaire. According to the personal construct theory, everyone has a unique way of interpreting the surroundings based on his own knowledge, and it keeps evolving by the events in their individual lives [3]. Therefore, an experienced customer will not perceive the product the same as a first-time customer. Different personal constructs can also lead to the misunderstanding to a structured questionnaire, especially to a semantic differential scale [2]. In a semantic differential test, the customer's subjective impression is often reduced to one simple

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word (e.g., comfortable, happy or good) although there is actually no guideline to select suitable semantic items in the literature.

Recently, the product experience has been treated as a combination of user interactions in different circumstances. For instance, a recreational cyclist prefers to seat on a saddle which makes him/her feel relaxed on the weekends, but a professional cyclist would choose a saddle that can help him/her race competitively. In this study, it is hypothesised that with the help of contextual information, it can give meanings to the semantic items so as to improve the validity of semantic database. The research method will be elaborated in the following paragraphs.

1. Case study

The bicycle saddle has been chosen as a case study. The purpose of this study is to illustrate a conceptual model of saddle enjoyment and its related factors. Therefore, an investigation into the product semantics (saddle) and the context (cycling) was organised.

Basically, the enjoyment of a saddle includes the physical comfort and the psychological comfort. Comfort as an emotional state, there has been a debate on whether its level is measurable [4, 5] whereas feeling uncomfortable suggested a physical discomfort (e.g., pain and soreness). In addition, previous research has shown that cycling comfort can be broken down into several parts, such as the bicycle (frame, saddle, handlebar), environment (road condition and weather), cyclists (position, body parts, adjustment) [6], as well as the cyclists' behaviours and opinions [7].

2. Method

The participants were recruited from local road cycling clubs based in the Midlands regions of England. The experiment was conducted at Loughborough University with ethical approval granted in June 2016. Advertisements for volunteers were posted on Facebook groups and distributed on campus and no specific profession was required as long as they rode on a regular basis. Only female cyclists were included because of gender differences in anthropometry with regard to saddle design [8]. At the beginning of the study, the experiment information sheet was shown to the participants before they signed the consent forms. The first author was the main investigator and also who designed the experiment.

2.1. Warm up: Draw a picture of your saddle

First, participants were asked to think about their saddle and draw a picture of it. They were allowed to draw more than one if they own several saddles. This was not a memory task; rather, it was a way to help them bring out a vivid picture in their minds in terms of the characteristics of bicycle saddles. Participants, therefore, were allowed to check a photo or the bike which she brought on the spot during the sketching process. However, individual sketch skill would not serve as a factor in this experiment. Some examples of the participant's saddle drawings are shown in Figure 1.

In this phase, the participants were also asked to describe their own saddles in three words (along with indicators or captions) regarding how they feel about it. Theoretically, the spontaneous statements can represent the most initial/important product impression. Also, the result can be used as a baseline for the semantic database in saddle design.

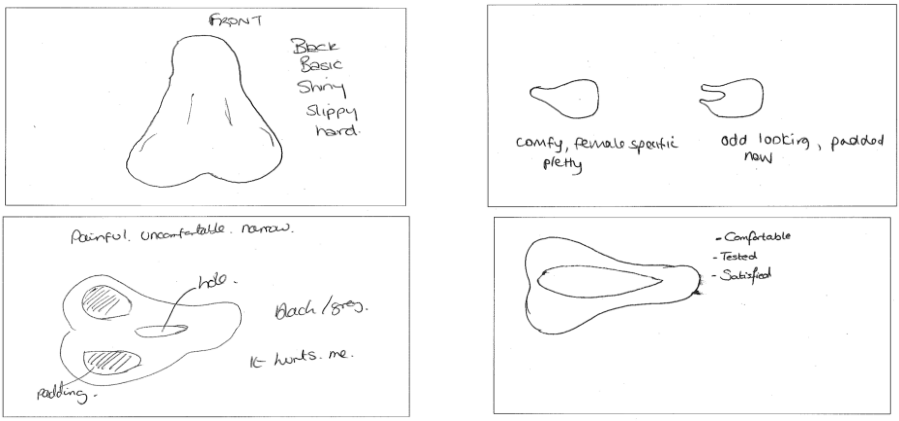


Figure 1. Saddle drawings.

2.2. Interview: Bicycle saddle in contexts

Next, the participants were asked to answer six open-ended questions which were written on a sheet of paper and given to them after the drawing session. In an attempt to minimise interviewer bias, the main investigator only assisted in clarifying the questions participants were confused with. The participants were able to freely express themselves with no time limit; the whole process was audio or video recorded depending on how comfortable they were in front of the camera.

All participants answered the interview questions (Table 1) in the same order starting from the context-based topic. Questions 1 and 2 were designed to learn about each participant's cycling background, including their riding purposes and motivations, which have a major impact on people's concerns and priorities [7]. Question 3 was designed to probe positive product interaction regarding an enjoyable cycling experience since it was the interest of this study. Subsequently, the participant's attitudes (Question 4) and expectations (Question 5) on a bicycle saddle were collected. Lastly, an activity-related topic (Question 6) helped recall how it (the saddle) feels on the bike.

Table 1. The list of open-ended interview questions.

No	Questions
1	What inspired you to use a road bike? How long have you been riding? Share your story.
2	Is this your first road bike? How many bikes do you have?
3	Best moment so far on the bike?
4	How would you describe your saddle? How do you feel about it?
5	What factors do you consider whether these saddles meet your needs?
6	How did you come to your current bike setup? How does it work?

3. Results and discussion

The initial number of participants is 33. All are English, with one German and one Slovenian, with an average age of 38 years old (*SD=11.8*). One of participant turned out not to be a road bike owner, and another two being failed to save full recordings; in total, three participants were removed prior the further analysis.

3.1. Semantic database

The result of words counts is shown in Table 2. It was grouped into three categories, viz., overall impression (34%), product properties (55%) and others (11%). Each category has a number of sub-categories respectively. Over half of the words that the participants used to describe their own saddles fall under the category of product properties, including firmness, texture, the facts-of-shape, the feel-of-shape, colour, weight and status.

Table 2. The counts of words that participants used to describe their own saddles.

Overall impression (34%)		**Product properties (55%)**			**Others (11%)**	
(general) 12 comfortable 7 uncomfortable 4 comfy	(positive) 1 flexible 1 supportive 1 reliable 1 effective 1 suitable 1 satisfied 1 efficient 1 happy 1 good 1 easy	(firmness) 7 hard 4 firm 2 solid 1 stiff 1 flat 5 padded 4 soft 1 cushion	(facts-shape) 5 hole 5 narrow 3 wide 1 slim 1 long	(colour) 7 black 3 white 2 pink 2 grey 1 red 1 strip of pink 1 blue	(gender) 1 girly 1 man 1 woman 1 female	(purpose) 2 race 1 functional 1 tested 1 necessary 1 chair 1 fit for purpose
(negative) 4 painful 1 numbness 1 scratch 1 hurts 1 annoying 1 restricting 1 bad 1 awkward 1 not enjoyable	(neutral) 2 basic 1 okay 1 moderately	(texture) 2 smooth 1 slick 1 slippy 1 slidey 1 leather covered	(feels-shape) 1 odd looking 1 unique 1 stylish 1 strange shaped 1 unobtrusive 1 shiny 1 pretty looking	(weight) 2 light 1 heavy -- (status) 2 new 1 unavailable 1 cheap		(posture) 2 middle 1 position 1 area 1 sweet point/sit

3.2. Conceptual model

The analysis of interview was performed by the main investigator on a transcription website (http://otranscribe.com). The conceptual model (Figure 2) was built on the coded interview responses and three essential aspects were revealed, viz., cyclist, saddle, and context. This finding is not only consistent with previous comfort model [4] but also integrated the activity/behaviours domain from another [9].

It all started from a desire to go faster and further. Once they expected to sit on the saddle over a period of time or distance, the saddle comfort issue became more inevitable.

> *... I want something that is comfortable for long distances, so when I am doing 70-90 miles, I want to be able to sit comfortably in the saddle, and I don't want it to rub and chaff or give me blisters or any of the uncomfortable bit because I want to be able to get on the bike and ride again in next few days. (RRC9)*

> *... but I don't particularly enjoy riding day after day, because I know it's going to hurt. (RRC23)*

Of all participants, 66% said that they are constantly seeking a more comfortable seat. In fact, the more time each cyclist spent in this **trial-and-error** process, the closer her relationship with the saddle became [10]. Some might eventually get attached to a particular one while some admitted it was a decision to compromise.

> *... sometimes I sit on it and feel, I can do better but obviously trying to find a better saddle is not an easy task. (RRC19)*

> *... my saddle is the result of trying many saddles, with a lot of pain. (RRC32)*

> *... I have a bit of love-hate relationship with bike saddles, and I don't think you'll ever get a particularly, or a totally comfortable saddle. (RRC39)*

> *... I've had a specialized saddle which was on my very first bike. I've moved it on every road bike I've had. I am very happy with this, it and I understand each other. (RRC16)*

> *...I've had several. Got one I really like but it don't sell anymore. (RRC30)*

Regardless, the participants tended to figure out her preferences depending on the context. 40% (12/30) of participants were able to express explicitly what type or shape of the saddle they felt more comfortable with Also, 20% (6/30) of participants pointed out the correlation between saddle comfort and riding positions, and acknowledged the benefit of the right bike fit.

> *... For me, I kind of look at the weight and the width, because that's like a big factor, because I am racing. I found that the comfortable part needs to have a cut-out, so anything that is flat and padded, especially when you down the drops and trying to get into aggressive position. (RRC17)*

> *... usually got on with those really well. They are quite hard, and they are quite slim line, and they got kind of dome top. I don't like the one is deep in,*
>
> *I found that they get crap pressure points, and that's really uncomfortable. (RRC12)*

... I think I am always more comfortable on the saddle with a hole in the middle, and I, generally speaking, like a fairly narrow, neat saddle. (RRC16)

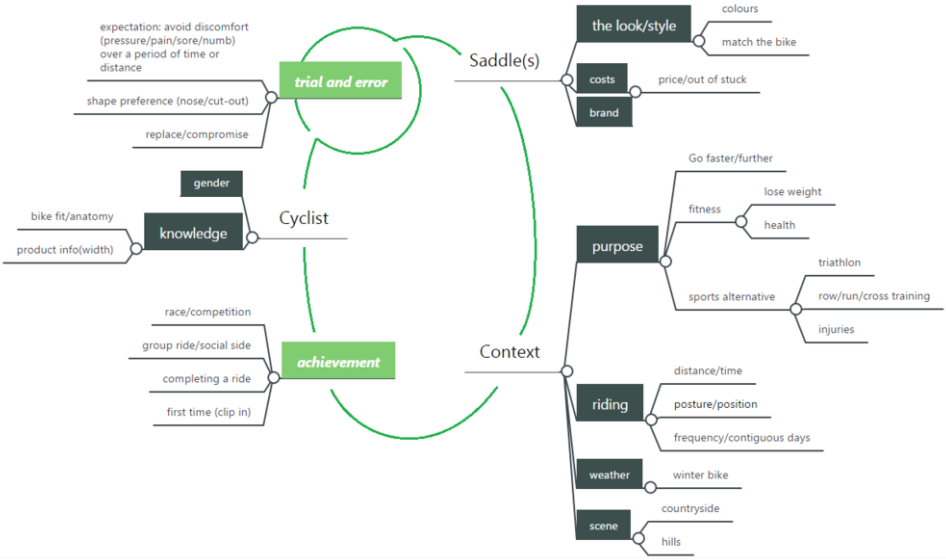


Figure 2. A relationship model of saddle enjoyment and its factors.

In addition to the physical comfort, 30% (9/30) of participants mentioned that it is important that the look of saddle matches the bike style. It is mainly related to personal taste and fashion choices but still contributes largely to an enjoyable saddle experience considering the words frequency in the semantic database.

... because a big part of cycling is you don't want a nice looking bike and then a saddle that just looks too big, doesn't look racing-like, or the colours don't suit it. (RRC21)

... I also want it to look quite nice because the rest of my bike does. (RRC28)

... which I got because it is soft and comfy. I have a black one and white one. White is a terrible colour. (RRC36)

Additionally, how the participants described their best moment on a bike (Question3) threw some light on the unknown cause of cycling comfort in the literature [4-6]. It is noticed that 63 % of participants are also involved in other sports (e.g., triathlon and cross training). Positive cycling experience, therefore, seems mostly to happen in a significant event, such as winning a medal or achieving a personal best. Occasionally, it has nothing to do with riding competitively, such as clipping in and not falling off for the first time. It has been labelled as **achievement** between Cyclist and Context in the model. In other words, it showed their favourite way of riding, weather, road condition, scene or other contextual factors. The riding buddy has some influences as well.

... maybe the one time that I beat mom in the race. It's so good. Only by a little bit but I still beat her in the race. (Cyclist 30)

... only three women, and being able to keep up with other guys (Cyclists 18).

… it was reduced to 80 miles from 100 because of the weather. It rained the whole time, and it was just flooded, but because I was with friends, and it was just hilarious. (RRC21)

4. Conclusion

4.1. Summary

Firstly, the semantic database was built in the participant's own words. The frequency and the percentage of words categories on bicycle saddles were presented. In a way, it shows the cyclist's subjective impression in a semantic level and is expected to be taken as a reference for designing a semantic differential scale.

Next, a conceptual model was proposed. It pointed out the characteristic of dynamic saddle experience in different contexts. Between the cyclist and the saddle, it is an iterative process of balancing the physical discomfort (e.g., pressure, pain, sore) and psychological comfort (e.g., style, preference, cost). The retrieved semantic items were in fact quite similar to those collected during the drawing phase. Judging from the interview responses, the participants knew clearly what negative feelings they wanted to avoid (e.g., chafing), however, they would use words related to preferable product properties (e.g., shape) to support their comfort level because it is more of an abstract concept. Apart from the product itself, 'achievement' can also strengthen cycling enjoyment in terms of positive product experience.

Overall, this study collected and analysed directly from the end-users perspectives. It is concluded that the saddle enjoyment is included, but not limited to the body comfort, and relies heavily on other contextual factors. Without providing the context of its use, user's subjective impression in the form of semantic items, might easily fail to reflect its meanings. The findings can help designers understand the construct of semantic items in an enjoyable cycling experience.

4.2. Limitations and future works

Unfortunately, there is an obvious inconsistency among participants regarding the amount of responded content. The interview length was relatively short in comparison with a general in-depth interview because the main investigator did not interfere during the sessions. It seems to vary with the participant's personality; some of them are very expressive while some provided simple narratives. Nevertheless, most of the participants tended to complain their saddles. It is assumed that due to the nature of this experiment, we are most likely to recruit people who feel discomfort in riding and want to improve the saddle experience at that time.

The fact that only road bike users were investigated may somehow limit the variety of contexts. They seem to have similar riding purposes, going faster. Therefore, it is suggested to look for a greater diversity of participants in a further study. For instance, an enthusiast cyclist can own more than one bike, and not limited to the same type of

bike. We can also invite an additional group of men cyclists in response to the disagreement of gender-specific saddle (e.g., shape preference) in the bicycle industry. It would be interesting to do a cross-analysis at their emotional needs and cycling backgrounds.

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Design a Personalized Brain-Computer Interface of LegoRobot Assisted by Data Analysis Method

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Abstract. In our daily life, the data is ubiquitous. With the advent of the data age, people's lives are closely related to it. Therefore, it is important to use these data for analysis to get effective conclusions. Through the data analysis method, we can analyze the results to do effective decisions-making and applications, more applicable to the interface design. Brain-computer interface (BCI) provides the communicated interface between brain and machines such as computers. It's a technique that the users allowed to interact directly with the machine by using brainwave. The technology includes brainwave (EEG) acquisition, feature extraction and translation algorithm. The researches of BCIs since the 1970s began, the most successful case was Jacques Vidal used brainwave signals to stimulate the visual response and controlled the cursor to take the maze of BCI. Nowadays, it has begun to use in medical aids, and improve the inconvenient situation in daily life. However, the applications in "personalized" BCIs are not popular in our life and less of a data validation to support the user-centric design process to provide. Therefore, this study firstly took the mobile application program of the Lego robot designed by the function as an example.Then used the data of the initial test which was assisted by the Data Analysis Method (DAM). The decision made by DAM was to redesign a data-oriented demonstration and user-centered design process (DAUCD). The Lego robot was integrated hardware and software to develop the learnable and personalized BCI. For usability test, we applied the Lego robots to demonstrate the redesign prototype to conduct the usability test. This study not only designed a personalized BCI but also developed a new data-oriented UCD design process. The brand-new method with DAUCD improved the original design and enhanced the usability test. We expect that this personalized BCI will be applied in medical treatments, businesses and livelihood, promoting the welfare of human being.

Keywords. Brain-Computer Interface, Data Analysis Method, User-Centered Design Method, Data Analysis User-Centered Design Method, Usability Testing, Personalization, Mobile Application

Introduction

With the advent of the era of big data, in our daily life and work, the data is everywhere. And the complex data hidden in many links with the people rely on the increasing degree of dependence on the Internet. The development of the Internet is more international and professional. In the process of network operations, people's life are inseparable from the existence of the network, and data analysis for the operation of the

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network will have an important role. Not only that, data analysis also has a significant role in reality. The so-called data analysis, is the combination of data and analysis. Through a large number of data and information content for effective analysis, many areas also apply the data analytic method to improve the issue. However, there is few data analytic method to support the design of interface, let alone the brain-computer interface (BCI).

In the 21th century, the Internet and communications have always revolved around human being, including foods, educations, traffics, etc., which all connect to interactive systems by computers and communications. As computers and information technology progressed, the human computer interface (HCI) rapidly expansion is driven so that it changes human's life patterns. The development of HCI is intimately related to technology, because new technology then brings new interface. German doctor, Hans Berger first recorded from the human scalp to weak electromagnetic waves (Electroencephalography, EEG) issued by the human brain in 1924 [1]. Then the terms of brain-computer interface (BCI) was published first in one paper in 1973 [2]. BCI provides the communicated interface between brain and machines such as computers or some devices. [3] defined brain-computer interface as follows: "One does not need via the peripheral nerves and muscles can make the brain's communication system." BCI without going through any of the actuator to operate the machine, but directly read the user issued by the brain signals to operate.

However, there're two research gaps. First, the use of brain waves to control the application of relevant examples in daily life is still not universal, the main reason is that the EEG signal accuracy is not good enough, and the extent of each person's brain waves to control are all different. So the BCI may be suitable for some specific communities but not for all. The other question is that the UCD method usually use common rules rather than a process with digitization and constructive framework. We want to develop a digital and logical process with data-driven method, re-design the original UCD process. Thus, there is a need to develop a personalized BCI to fulfill individual person requirement. In the next section, related literature is introduced. Then in Section 2, our method framework is proposed and explain in detail. Then we present the case study, the redesign Lego robots interface and its usability test of the end-users will also be presented in Section 3. Then summarize the contributions and point out the future directions of this research in Section 4.

1 Literature Review

1.1. Interface Design Guidelines and Brain Computer Interface (BCI)

When it comes to the interface design guidelines, a book said that it is apparent that most published reports dealing with the HCI describe applications rather than design principles and guidelines [Smith et al., 1986]. A popular early book on the design of human-computer dialogues offered stimulating examples, covering a range of on-line applications, but was disappointing in its failure to emphasize design principles [Martin, 1973]. Therefore, a later study were suggested ten general design guidelines as following: Visibility of system status, Match between system and the real world, User control and freedom, Consistency and standards, Error prevention, Recognition rather than recall, Flexibility and efficiency, Aesthetic and minimalist design, Help users recognize, diagnose, and recover from errors, Help and documentation [Nielsen et al.,

1993]. It also mentioned that there were some tools to help the interface design as brain storming, paper depicting, affinity map, parallel design and solid model.

Based on the rapid development of technologies and researches on BCI, the machines controlled by brain signal have been widely applied in different fields. Moreover, the applications of BCI contribute greatly to humanity, especially in improving the life quality of disabilities. [11] proposed the use of an environmental control system that electroencephalogram was used to evoke potentials based on steady-state vision to help the handicapped. In addition, [12] proposed the use of the letter to the EEG-based brainwave interface system with FPFA the system via Bluetooth wireless interface to control an electric wheelchair to move, thereby propose ways to help paralyzed patients. However, the applications controlled by personalied brain waves are applied in few fields. In this study, the personalized BCIs will be proposed to provide solutions to meet different needs and enhance the well-being of human life.

1.2 *User-Centered Design (UCD)*

User-centered design (UCD) methods claim to provide an end product, which satisfies the users and enables them to achieve their goal while taking their profile into account [8]. [9] also considered that the user-centered design is a simple and efficient method to design interfaces, evaluative method of virtual environment was developed based on UCD. UCD is a design philosophy and approach that values the direct opinions of the users, meaning that their considerations and participations influence how the design takes shape [10]. A variety of methods have been developed to support UCD including usability testing, usability engineering, heuristic evaluation, discount evaluation and participatory design [10].

1.3 *Data-Driven Analysis-Method (DDAM)*

Data-Driven Analysis Making (DDAM) is an approach to business governance that values decisions that can be backed up with verifiable data [4]. The success of the data-driven approach is reliant upon the quality of the data gathered and the effectiveness of its analysis and Interpretation.

The general five phases of DDAM are (1) organizing for success, (2) building assessment literacy, (3) identifying data sources, (4) aligning data systems, and (5) altering instruction. Rather, they illuminate aspects of the messy, but purposeful, process middle level users and personalized BCI as they seek to analyze and use data [4]. DDAM has been applied to lots of areas. In industry, [5] used the data-driven analysis and process understanding to diagnose a plant-wide oscillation; In medically,analysis of the early role of vascular dysregulation on late-onset Alzheimer's disease, a study based on multifactorial data-driven analysis contributed to the development of preventive therapeutic interventions [6]. In biology, [7] based on the DDAM, they analyzed multi-omics data and subsets thereof to establish reference codon usage biases for codon optimization in synthetic gene design. Therefore, this research want to adopt test-based systems that meet certain criteria with respect to functions and satisfactions, the reporting of test results in aggregated and disaggregated forms, and the accountability of personalized BCI for the improvement of its performance.

1.4 Usability Testing

According to the definition of International Organization for Standardization, usability is defined that the level of specific user use specific products to achieve specific achievement in specific environment. In general, people consider intuitively that usability is how to let users take advantage of products fast and accomplish to their goals easily [13]. Then from observing how people use products to discovering mistakes, reviewing and improving it, usability testing is represented to test how the product useful in fact [14].

However, [15] also defined to the usability that it could be the significant element of computer interface and electronic products. Then [15] also regarded usability as learnability, efficiency, memorability, errors, and satisfaction. For example, [16] took advantage of usability testing to assess user in user interface of engineer educational tools. These are not only major testing data but also a typical method that is used in usability testing questionnaire. This research will conduct the response usability testing after designing the prototype of brain-computer interface.

2. Methodology

The purpose of this research is to design and verify the personalized BCI which re-designed by the DAUCD method. This study is divided into three phases shown in Figure 1, the first phase is the framework of data analysis for original BCI. In order to achieve the purpose of integrating hardware and software, the mobile application program called personalized BCI applied as the bridge connecting hardware and software. The second phase demonstrated the redesign process of personalized BCI based on the DAUCD method. It mainly focused on the design process assisted by the conclusions of data analysis of interface, as well as improved the BCI. The third phase of this personalized BCI is the validation and usability test for the re-design BCI and the details will present clearly in case study.

2.1 Phase 1: User-Centered Design Method Assisted by Data Analysis (DAUCD)

To support rich and dynamic UCD and evaluation of it, we forged the well-established techniques for evaluation and design of human activity. Our methodology of DAUCD process. Before the design stage, there are several steps when applying UCD and we based on sequentially performing that: Step 1) Specify the context of use and user task analysis, produce design solution and heuristics and review. Step 2) Based on the lots of review papers about interface design guidelines, we conducted the 10 design guidelines respond BCI. Then add the phase of data analysis and desugn guidelines to the design phase. Step 3) Expert guidelines-based evaluation, representative user task scenarios and Evaluate designs against requirement. Step 4) Formative user-centered evaluation and summative comparative evaluations and usability test. If the usability test is good, the prototype of BCI can be known as usable and useful BCI. If not, we will back to step 1 and run the all process.

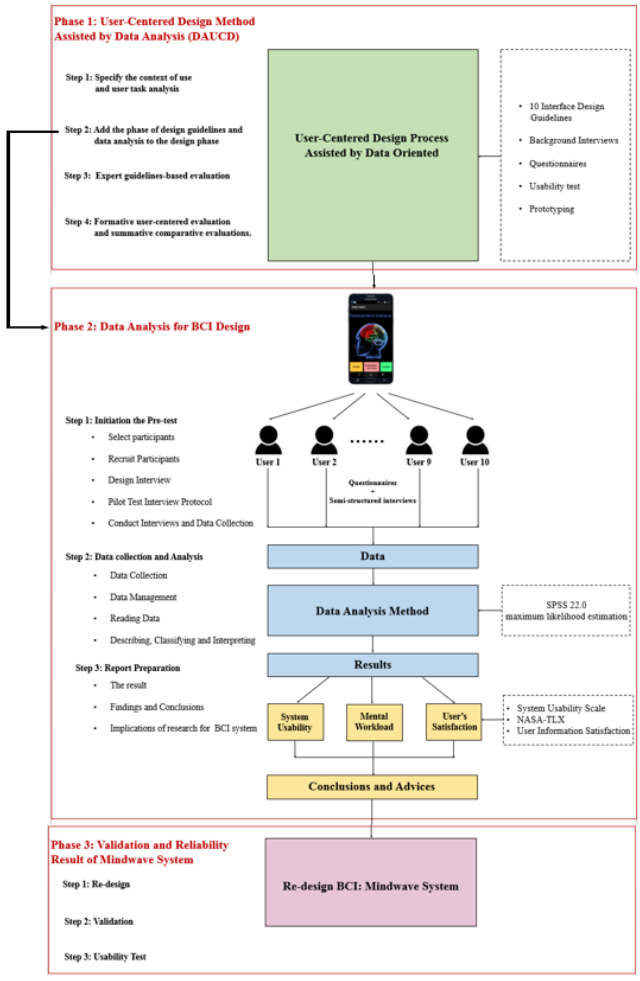


Figure 1. Research Framework

2.2 Phase 2: Data Analysis for BCI Design

This study aimed to establish a useful and efficient BCI to assess the usability of the Lego robot so that we based on the functional properties to develop our original BCI. First of all, in order to emerge the prototype of the original BCI, we mainly focused on the functional properties to design the BCI. In other words, we didn't follow any design guidelines to design the original BCI, just follow which function buttons or icons we needed. Therefore, it's not refer any points and guidelines, not to mention about users' aspects. It was shown in Figure 2.

The study of phase 1 was organized into three sequential steps, each representing a step in the research process. In the step 1, when the original BCI designed by functions was designed, we do the pretest of usability test by questionnaires. First, we invited 10 users who has been used the BCIs then conducted the user survey by interview then analyzing it. Data collection methods were used in this study: semi-structured interviews and questionnaires.



Figure 2. The original BCI designed by functions

During the step 2, to help organize the discussion of data analysis method in this paper, we utilize a conceptual framework adapted from [Ellen et al., 2006]. This conception of DAM recognizes that decisions may be informed by multiple types of data, including: (1) input data, such as the demographics of the original BCI; (2) process data, such as data on pre-test; (3) outcome data, such as satisfied rates or satisfied scores and data; and such as opinions from designers and participants of pretest.

During the step 3, let's sum up our pretest's result and the questionnaires data. The pre-test data and conclusions would shown in next section.

2.3 Phase 3: Validation and Reliability Result

Exploratory factor analysis is to test the convergent validity and discriminant validity of latent variables. Convergent validity is assessed by checking loadings to see whether the items measuring the same construct correlate highly among themselves. Discriminant validity assessed by checking whether the items loaded more strongly on their intended construct rather than other constructs. Items with a factor loading smaller than 0.35 will not considered for further analysis, as it cannot represent a specific construct [Choi et al., 2005].

Reliability or internal consistency refers to the scale's stability and it's assessed through Cronbach's alpha coefficient. Typically, the construct is said to be reliable with the suggest value Cronbach's alpha is 0.7 or higher [Ziebland et al., 2013]. The participants of the validation experiment were asked to operate the developed system to execute validation. The total experiment time was around half to one hour for each participant.

3. Case Study

A case study about the personalized BCI prototype is discussed in this research. Thirty participants will be recruited in this study with age between 20-45 years old. Thirty questionnaires will be presented to participants to collect their satisfactions. We will employ SPSS 22.0 using maximum likelihood estimation for measuring the structural equation models.

3.1 Background: The framework of Personalized BCI Establishment

The original BCI shown in Figure 3 includes three steps: brainwave EEG signal acquisition, signal processing and choreography controlled device in signal acquisition and signal processing stage. We used NeuroSky Mindwave Mobile® to collect and analyze signals. The application software was lunched by Samsung® Galaxy Note 3.

The device receives and filters signal transmitted from the forehead and earlobe clip sensors, and then converts it into calculable value. The value contains respectively Attention, Meditation, and Blink Strength.

Via Bluetooth connection, the device transfers these three values to a mobile phone. We design an App to collect and analyze these values, assuming they are normal distributed. Ten samples are measured for each value and the sample averages and standard deviations are calculated. The parent means for these three values are then estimated by t-distribution in the form of confidence interval under 95% confidence, by equation (1):

$$\overline{X} - t_{\left(\frac{a}{2},n-1\right)} \times \frac{s}{\sqrt{n}} \leq \mu \leq \overline{X} + t_{\left(\frac{a}{2},n-1\right)} \times \frac{s}{\sqrt{n}} \quad (1)$$

The APP will interpret these values as concentration, relaxation degree, blink strength and other values, and use these values to analyze a user's situation, then transmit proper signal according to different using scenarios back to Arduino Bluetooth module for further application. We applied the functional rules to develop the original BCI and used this prototype to collect the pretest data for developing DAUCD method.

3.2 Redesign: Prototype of Personalized BCI

Base on the mentioned brand-new approach, DDUCD method, we conduct this personalized BCI with Lego robot as our prototype demonstrate. The application software interface design of the system would be introduced in this section including setting data and implementation. The main page showed three buttons including start, setting personalized data and exit. Users can press the "setting personalized data" button to set individual data.

Via a Bluetooth connection, the three values include attention data, meditation data and blink data, which is collected and transferred to the APP by the BCI. This APP calculated each these three values assuming the normal distribution. After that, there is a personalized interval for the users. The three personalized data capture interfaces are shown in Figure 3.

After users set the personalized data, the page of all the data is shown in Figure 4. We design two tasks in this APP so that users can choose the situations to control the Lego robot. Every user can keep or change their own constraints. Finally, by pressing the "enter" button the user can start to control the Lego Robot with personalized brain waves. When connecting the Lego robot.

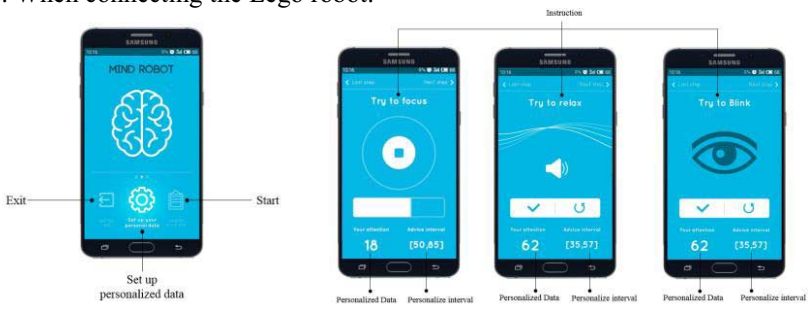


Figure 3. Application of personalized BCI—Main Page and Personalized data capture



Figure 4. Application of personalized BCI—Tasks setting Lego Robot

3.3 Designs of Experiment

Participants were invited to join this experiment and the statistical approach adopted to analyze the data included descriptive statistics such as mean and standard deviation. ANOVA was also used to evaluate the results and eight aspects were included in the questionnaire to analyze presence: effectiveness, efficiency, satisfaction, error, learnability, flexibility, memorability, and sociability.

The participants of this study were total 30, aged between 20-45 years old. Male and female each recruited 15 people by oral recruitment or Internet. During the experiment, the participants were asked to set individual personalized data and then manipulate two tasks: catching and go forward by following the black line with Lego robot. Then we would test three times for each subject. In the process, we record the process time from detecting brain waves to conducting instruction. When the operation was complete, the users required to fill in the questionnaire.

3.4 Validation and Reliability Result

Reliability could measure the reliability, consistency and stability of the questionnaire. In this study, Cronbach's α coefficient were used to judge the reliability of the index. [17] proposed that when Cronbach's α value is greater than 0.7, indicating that the questionnaire has good reliability. [18] suggested that a Cronbach's α value of 0.7, 0.8, and 0.9 represent acceptable, good, and excellent levels of internal consistency for group analysis. In this study, the Cronbach's α value is 0.954. The SUS scores have a range of 0 to 100. To calculate the SUS score, first sum the score contributions from each item. Each item's score contribution will range from 0 to 6 [19].

The mean of SUS score for all surveys is 83.64 (s = 11.75). These scores indicate that the system usability of intelligent music selection system is ranged from OK to Excellent. All in all, the system is usable and it had been tested that the questionnaire of system usability part has good reliability and validity.

We took the 30 samples of data to analyze the five aspect of different genders, the radar chart showed that there not lots differences between males and femalse as ahown in Figure 5. But for both males and females, the aspect of error is the highest because the new BCI can let the users conducted this system without mistakes.

By means of the Regression of Number of times in different gender we can prove that there is only first time has significant influence and from this, we know that if the longer in first time.

The participants were requested to answer the question, "Do you think this system enhance your performance when you are studying?" The score were ranged from -2 to 2, which represented very disagree to very agree. The mean and standard deviation of

the performance questionnaire are 0.743 and 0.426. One-sample t-test (one-tailed) was conducted to validate whether the performance increase or not. The null hypothesis and alternative hypothesis were shown as follows. Since t value is larger than 0, p value is larger than 0.05 and the lower bound of 95% confidence interval is bigger than 0, do not reject H0. Therefore, it could be proved that the users' performances were increased. From the result, this system was validated that it could improve people's performance. The detailed testing results are shown in Table 1.

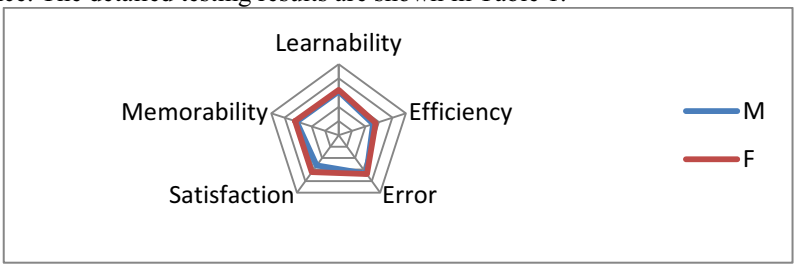


Figure 5. 30 Samples of Radar Chart.

H_0: The users' performances were increased.
H_1: The users' performances were not increased.

Table 1. One-sample t-test of performance.

Performance	Test value = 0						
	t	df	p	mean	standard deviation	95% Confidence Interval of the Distance	
						Lower	Upper
	6.279	29	1	0.743	0.426	0.592	0.981

3.5 Discussion

DAUCD provides an understanding of the user's mental model of the domain, which are the beliefs, concepts and even the language they apply, affects the psychological, social, ergonomic and organizational interpretation of the design and its acceptance. From the validation, in general, the average satisfaction in this personalized BCI is high. And the most reason to influence the satisfaction is time but not gender. Compared with other papers [8], [9], [10], the design method with data analysis would be more satisfaction of the users Because the p value of the new personalized BCI designed by DAUCD method is smaller than old data and 0.01, the test is highly significant and more keeping with the user-centered design method.

In addition, there are some limitations. One is we just collected 30 participants, the data collection has not satisfied to our study so that we can't move forward a step to analysis the usability stronger. The other is there is few type of validation. In the future, we'll recruit total 30 participant for the usability.

4 Conclusion

This is the first study that integrates the application of personalized brain computer interface and robot to conduct instructions. In addition, this is the first study discussing on personalized BCI to adapt individual person, so that everyone can accord, own EEG data to control the device. Another contribution is taking the original BCI designed by function as an example; the Data-Driven Analysis Method (DDAM) was used to analyze the original test data. Combining the User-Centered Design (UCD) method, redesigning a data-centric and user-centric design flow. Moreover, this study integrates the hardware and software to develop a new personalized BCI APP. According to our prototype and usability test, this study validates the usability of BCI to eight phases. This BCI, which is in keeping with human's habits, is simple and easy to learn. Finally, this personalized BCI will be applied in medical treatment, business and so on.

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Integrated Kansei Engineering and FMEA in Innovative Product Design

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Abstract. The social patterns of nations worldwide have exhibited an aging trend and declining birth rates, thus motivating advanced nations and businesses to invest in the development of robots that provide services to people. Because robot-related research is primarily focused on the functionality of robots, considering product aesthetics and brand images have been overlooked. This study is composed of two phases: the first phase establishes the product design images, applies the Kansei Engineering(KE) to analyze consumers' preferences. The second phase applies the Failure Mode and Effects Analysis(FMEA) for product design and production planning, By this research, a systematic approach has been made to integrate the KE and FMEA for product development and taking a Security guard robot as the case study.

Keywords. Kansei Engineering, Failure Mode and Effects Analysis,Innovative design, Product design, Security guard robot.

Introduction

The design of a product is a factor that directly affects the purchase intentions of consumers. Therefore, a designer's task is to design products that combine functional technology and design factors, which influence consumer senses. In addition to producing designs, enhancing product novelty, and emphasizing or integrating various levels of technological innovation, designers must also strive to realize consumers' expectations [1].

Product appearance is crucial in the selection process and product preferences of consumers [2] because product appearance (1) can help companies reveal, explain, or conceal changes to basic innovative technologies, (2) provides visual cues for consumers to understand product operation and purpose, and (3) stimulates the senses, which indirectly impacts the perceptions and emotions of consumers [3]. In the design process [4][5], the research concept of Kansei Engineering has been employed to understand the relationship between product model design and consumer perception. They established design models and executed product development to fulfill design needs. To avoid the hidden errors generated when using verbal survey methods to assess product designs and styles, researchers suggested using human emotion symbols as the tools for analyzing and assessing the emotional image of products. In their model design method, a shape morphing and image prediction method has been used to construct 3D models for assisting designers with completing a variety of designs [6].

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Above literature review, we found that because of business requirements, most studies in the field of model design have focused on the connection between style design and consumers' emotions. Specifically, regarding the survey methods used for determining the relationship between styles and preferences, scholars have proposed rational verbal and nonverbal methods to construct a quantitative model for product designs [6]. Thus, in this study, we used the semantic differential (SD) method of Kansei Engineering to identify factors that satisfy consumer preferences, which can be used by designers to achieve an optimal product design. This study also adopted Failure Mode and Effects Analysis (FMEA) to evaluate the factors that cause product defects during production, thereby enabling product designs to reach perfection.

1. Method

1.1. Kansei Engineering

Kansei Engineering is highly efficient for quantitatively evaluating user experiences. In design-related experiments, Kansei Engineering can be applied to assess the emotional aspect of users' needs for designing products that can closely meet user requirements [7]. The process of Kansei assessment involves engineers, designers, or users evaluating actual design processes for specific products or services by using perceptual or emotional words [5]. The major contribution of using Kansei Engineering in product design is that prior to entering the market, designers can grasp the emotional orientation of the public by conducting research to analyze competitive products. Designers can derive emotional keywords from details and then use such keywords for analyzing product designs, resulting in products that closely fulfill consumer demand. Kansei (emotion or affection) refers to the inner desires of consumers and is a keyword (adjective) that clearly defines individual emotions, which can help designers understand the emotional needs of consumers. Because engineering involves designing the most practical product appearance, material, size, color, and operating interface, most operating practices are devised by conducting questionnaires that can analyze the relationship between emotional keywords and engineering. The operation methods of the design plan proposed in this study are as follows:

- Compile a list of emotional keywords associated with related products by referencing the Internet and related publications.
- Request experts to analyze the emotional orientation that the general public exhibits toward competitive products by using image scale analysis.
- Analyze the engineering conditions of competitive products.

1.2. Failure Mode and Effects Analysis

FMEA is often used in the design development stage as an assessment method for systematically predicting conditions that will cause product failure and malfunction. Thus, FMEA is used for identifying the key factors that may lead to failure. FMEA enables designers to develop a countermeasure in advance to reduce the risks and uncertainties during product design and manufacturing processes. Snooke et al. attempted to establish an FMEA simulation diagnostic system that enables users to create basic models for automatically simulating and producing results [8]. Su et al.

adopted the Dempster–Shafer theory for reliability failure analysis to quantify the inaccuracy and unreliability in the risk priority number (RPN) of a process [9]. Lin et al. adopted the concept of fuzzy numbers to show three features, including the degree of severity (S), frequency of occurrence (O), and chances of detection (D) [10]. To judge RPN risk figures, Oldenhof et al. found that for an evaluation outcome to possess a high degree of consistency, the team must include at least two technical experts who are experienced with FMEA [11]. Although FMEA is frequently used to assess risk at the stage of product design development.

FMEA has been widely applied in risk assessment at various stages of product production, and potential failure modes are mainly analyzed by using systems as a unit. Subsequently, the degree of severity (S), frequency of occurrence (O), and chance of detection (D) of a system were separately assessed by using a 10-point scale, in which 1 represents no effect and 10 represents the highest severity. Finally, Formula 1. is employed to calculate the RPN for understanding the degree of failure of the various stages and for proposing countermeasures.

$$RPN=S\times O\times D \tag{1}$$

FMEA involves first confirming the system that requires assessment, establishing an expert group, sketching system flowcharts (e.g., product development and manufacturing processes), and then assessing the degree of severity (S), frequency of occurrence (O), and chance of detection (D). Finally, problems identified in the product manufacturing flowchart were inputted into the FMEA analysis table Table 1.

Table 1. The Failure Mode and Effects Analysis Conducted in This Study.

Analysis of the object	Potential Failure Mode	Potential Effect of Failure	Degree of severity (S)	Potential Cause of Failure	Frequency of occurrence (O)	Current Control	Chance of detection (D)	Risk Priority Number
	Insufficient frame strength	Break	10	Insufficient structural support	2	Rein-forcement	5	100
	Welding defects	Break	10	Poor welding technology	2	Training	5	100
	Adverse assembly	Loose screws	8	Assembly process is not established	5	Established SOP with Training	3	120
Internal Frame	Steel tube deformed	Bending fracture	10	Steel tube strength is not enough / Metallic material fatigue	5	Increased steel tube thickness / Heat Treatment	3	150
	Nuts assembly not indeed	Loose screws	8	Assembly process is not established	5	Established SOP with Training	3	120
External enclosure	Adverse assembly	Internal water seepage	8	Adverse waterproof design	2	Waterproof design improve-ments	5	80

The FMEA table shows that the RPN of the various components analyzed in the study ranged between 80 and 150. Regarding the method required for controlling various risks, other than the manufacturing process and personnel training that cannot be controlled in the design process of this study, we proposed countermeasures for factors that can lead to component defects as key criteria for product designing [12]:

- Regarding assembling defects, waterproof accessories can be used to strengthen design assembly.
- Minimize the number of screws required.

2. The Verification of the Actual Example

A Security guard robot is defined as a robot that possesses the ability to move and use specified methods to provide security services and assistance for protecting the safety of people, objects, and environments. The technological development of current Security guard robots that are suitable for replacing manpower includes functions such as using environmental sensors to receive and report information, patrolling and monitoring large areas, receiving visitors or deterring intruders, identifying user IDs, and working 24 hours without rest. Robots that possess these capabilities can not only reduce the work burden of security guards, but also enhance the safety of security guards.

2.1. Security guard robot Functional Module and Key Components

In this study, we divided the functional module of a Security guard robot into five categories: multiple sensing and obstacle avoidance capabilities, positioning and navigation functions, smart division of coordination mechanism, smart power supply, and integrated technology and mechanisms of robots and security systems. Each functional module is described as follows Figure 1. The key components of a Security guard robot can be primarily divided into six major categories: distance sensing, environmental sensing, drive system, platform control, power system, and human–computer control. The components are described as follows Figure 2.

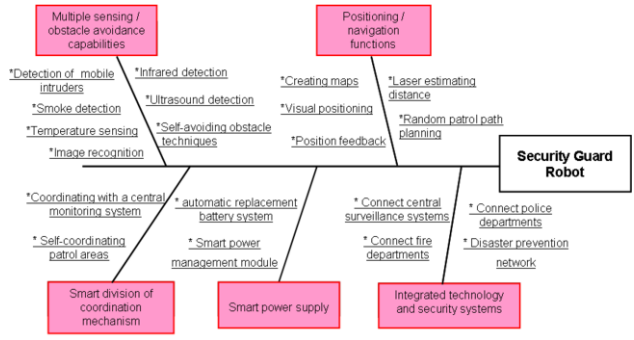


Figure 1. Functional Module of the Security guard robot.

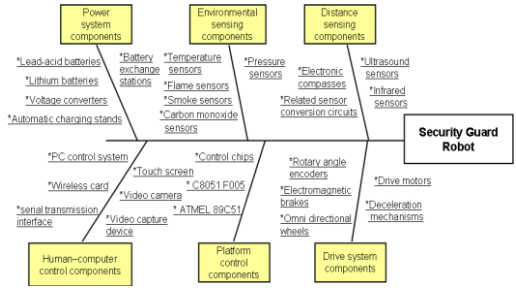


Figure 2. Key Components of the Security guard robot.

Based on the key movement and monitoring functions of the Security guard robot, we further designed and planned two major modules. The bottom part, which is a mobile carrier module, and the top part, which is a monitoring module, were integrated to form the Security guard robot as shown in Fig 3.

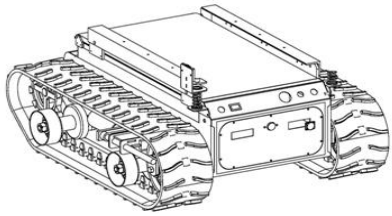


Figure 3. The Mobile Carrier Module of the Security guard robot.

2.2. Kansei Engineering Design of the Security guard robot

The Security guard robot is mainly used for patrolling the outdoor areas of large-scale factories, most of which were remotely located. In addition to possessing basic security and monitoring functions, security guard robots must be intimidating. By using the Internet and periodicals, several security-related emotional words were collected, After discussing with the cooperating manufacturer and experts of this study, the words related to speed and appearance were screened and classified into two groups: responsive/steady and firm/warm, which were designated as the X and Y axes for image scale analysis. These words were used for analyzing public em firm otional orientation toward competitive products, and 22 international and domestic Security guard robotic products were included in the analysis. The robots were used in indoor and outdoor environments. The appearance of most competitive products can be described as friendly and warm. However, products that are used for monitoring a wide range of outdoor locations must feature neat and tough outlines and sturdy body volumes as shown in Figure 4.

2.3. Failure Mode and Effects Analysis for Security guard robot

The mobile carrier module that can be directly applied to robots for research purposes is currently available on the market. The top-part monitoring module is the part that directly influences consumers' visual perceptions and product aesthetics. Thus, we designed the monitoring module for integration with the mobile carrier module to construct a Security guard robot. Structural design plan of the Security guard robot as shown in Figure 5.

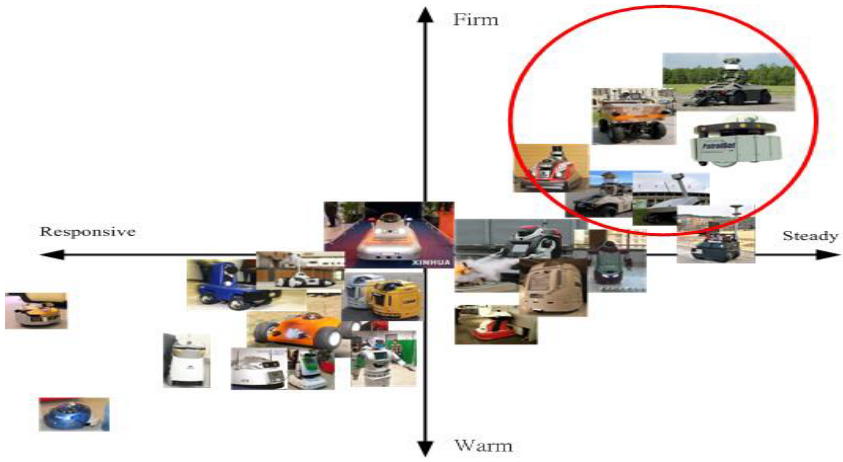


Figure 4. Image scale analysis for security guard robots.

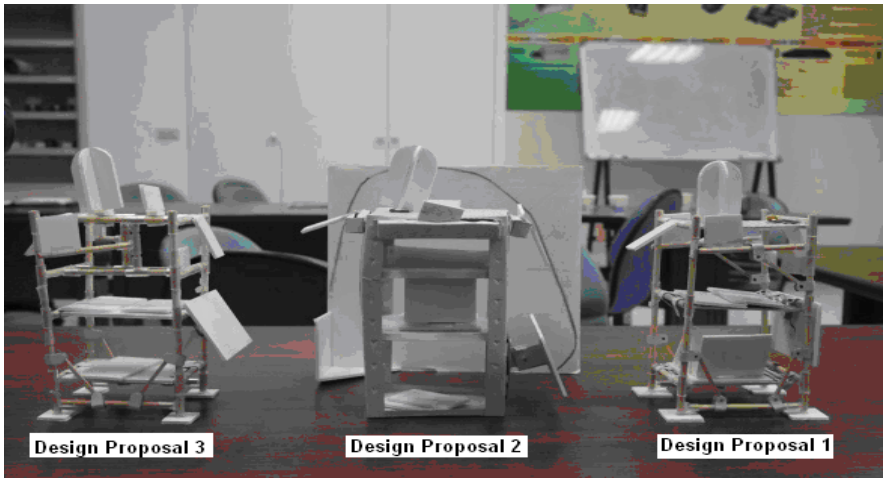


Figure 5. Model of the Proposed Stand Design.

The photographs obtained during the monitoring test can be used to test whether the height of the top of the stand and the view from the Camera 1 are parallel, and to adjust the height of the top stand based on the actual height in the picture as shown in Figure 6. We simultaneously determined whether the angle determined from the test can achieve an unobstructed visual angle as shown in Figure 7.

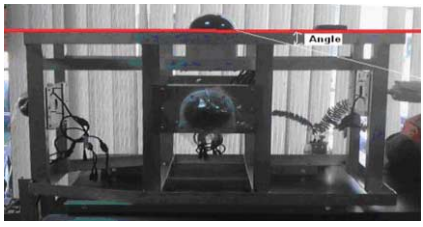


Figure 6. Test Stand and Camera 1.

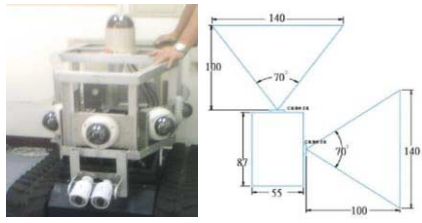


Figure 7. Schematic Diagram of a Panorama Visual Angle Test

2.4. Design Outcome

In this study, we used the SD scale analysis of Kansei Engineering to understand the current needs of consumers. Moreover, after experts used FMEA to evaluate the product, appropriate product design features were planned. After the design was completed and inspected by the manufacturer, the experts reevaluated the revised design to ensure that the RPN value of FMEA has significantly decreased as shown in Table 2.

Table 2. RPN Comparison and FMEA Design Planning

Analysis of the object	Potential Failure Mode	Potential Effect of Failure	Potential Cause of Failure	Before Design Planning				Risk Control Strategies	After Design Planning			
				S	O	D	RPN		S	O	D	RPN
Internal Frame	Insufficient frame strength	Break	Insufficient structural support	10	2	5	100	Reinforcement	3	2	5	30
	Welding defects	Break	Poor welding technology	10	2	5	100	Training	3	2	5	30
	Adverse assembly	Loose screws	Assembly process is not established	8	5	3	120	Established SOP with Training	6	3	3	54
	Steel tube deformed	Bending fracture	Steel tube strength is not enough / Metallic material fatigue	10	5	3	150	Increased steel tube thickness / Heat Treatment	3	3	3	27
	Nuts assembly not indeed	Loose screws	Assembly process is not established	8	5	3	120	Established SOP with Training	6	3	3	54
External enclosure	Adverse assembly	Internal water seepage	Adverse waterproof design	8	2	5	80	Waterproof design improve-ments	3	2	5	30

Following multiple meetings with the cooperating manufacturer, during which design inspections and details were confirmed, the top monitoring module of the Security guard robot was complete and used for actual testing. Subsequently, the mobile carrier module was integrated and the private brand logo of the cooperating manufacturer was designed to achieve a Kansei innovative Security guard robot as shown in Figure 8.



Figure 8. The Kansei Innovative Security guard Robot of this Study.

3. Results and Discussion

After a series of design verification and modification and continuous consultation with the cooperating industry, we proposed the optimal design planning procedures as follows:

- By using the product image scale analysis table of Kansei Engineering, rapidly analyze the design expectations of the target customer group in a current market. Minimize the number of screws required.
- Organize a group of experts that can use FMEA for analyzing potential design risks.
- Use RPN values obtained after implementing FMEA to propose possible risk control and management strategies.
- Based on risk management strategies, plan optimal design conditions and attend to design details.
- Constantly consult with cooperating manufactures to establish design conditions and flexibly modify design plans; meeting minutes must be retained to record the opinions of both parties.
- Construct a design planning and style profile.
- Use a proportional model to negotiate with the industry and confirm the effectiveness of the design.
- Use FMEA to reassess the RPN value of the revised design.
- Propose the final design.

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Reflecting Meaning of User Experience：Semiotics Approach to Product Architecture Design

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Abstract. Research in product architecture design has been addressing user related issues such as usability and affordance in order to enhance product efficiency, accessibility as well as safety. Yet, issues related to the question how people adopt, position and use new products in different environments, situations and modalities of use have not been well addressed. This paper examines how Semiotic Approach to Product Architecture Design (SAPAD) can be applied to the design of spatial organization of functional systems with an example of kitchen that embodies and reflect functional, cultural and lifestyle requirements of different users. First, the Semiotic Ladder framework introduced by Stamper that addresses six levels of interpretive mechanism was applied to the user observation data in order to understand how users interpret individual components and subsystems and to identify structure of meaning and values formed by the user through the usage process. Then the structure was used as a basis for developing the system architecture.

Keywords. Product Architecture, Semiotics, SAPAD, Signification, Culture

Introduction

The concept of product architecture (PA) was introduced by Ulrich and Eppinger (1995) [1] as the scheme by which the product functions are allocated to physical components, aiming to define the basic physical building components. Ulrich (1995) [2] articulated five potential application areas of product architecture: 1) product change; 2) product variety; 3) component standardization; 4) product performance; 5) product development management. Since then, various researches have been developing the foundation and applications of product architecture from engineering design perspectives (Wood, Stone Fadel, Meyer, etc) [3].

Recent advancement in ICT, embedded technology and robotics have been becoming more pervasive and ubiquitous in our daily living and work environments. This enables us to access more functions and information for assisting our activities to become more efficient, safe and pleasurable. On the other hand, new systems have been introducing complex technological infrastructure that imposes us new orders in every aspect of our lives. This implies that products, systems, services, and business need to be coherently designed and operated across all aspects of users' daily lives. In order to

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address such issues, the concept of human-centered product architecture was introduced as a methodological foundation for HCD (Teeravarunyou and Sato 2001, Galvao and Sato, etc.) [4] [5].

Although the importance of user-centric approach has been widely recognized in system development and business, little research has been focused on system usage process as an intensive knowledge generating process critical for successful system design and implementation. For example, the adoption and usage of a new system requires knowledge of interpreting the system properties, knowledge of positioning the system in the existing system of work environments such as physical organization, social organization, information, activities and cultural norms, and knowledge of developing meaning and values for justifying the acceptance of the system and further sustain the process of the evolving system use.

This research focuses on the concepts of signification and experience in the system usage process as a basis for designing product architecture. In order to incorporate fundamental mechanisms of system usage processes and map them on to system architecture design, Semiotic Approach to Product Architecture Design (SAPAD) [6] [7] is applied for bridging user observation data and the interpretation of the user information onto system architecture design. A case study with cooking activities in a kitchen space was developed to demonstrate the analysis of user significations that enables a new approach to developing user requirements and designing system concepts.

1. The SAPAD Framework

In order to understand complex knowledge generation process and human interactive behavior based on the meaning generation in the system usage process, SAPAD framework introduced a semiotic modeling approach. In the semiotics model by Peirce (Peirce,1867) [8], both human behavior and system behavior can be considered as "Media" or "sign" as the first dimension representing the concept of "Object" i.e. the second dimension. The object can be any referable entity such as physical objects, intentions, information, concepts, and actions. Signification produces "Interpretation" of "sign", the third dimension. Pierce's semiotics model explains the signification mechanism at three levels, syntactics, semantics and pragmatics in the linguistic terms.

Semiotic Ladder Model by Stamper introduced six levels of the signification mechanism corresponding to the ontological structure of semiotic processes in organization and information systems design (Stamper, Liu, 1996, 2000) [9] [10]. The six levels of the semiotic ladder are defined as shown in Figure 1) Physical level is about physical attributes which are related to enabling elements of functions such as material, signals, traces and physical distinctions; 2) Empiric level of signification is about "how" to connect the subject with object. It is related to construction of logic, which focus on the operation and control of object, and the users' experience such as mode, way, noise, redundancy and efficiency; 3) Syntactic level of signification is about "how" to connect with each other between the function modules; 4) Semantic level of signification is about "why" to interact between individual and object, which relates to emotional experience and focus on emotion, character and persuasiveness of object, such as theme, expression, and intention; 5) Pragmatic level of signification is about "how" to communicate in interactions, which focuses on sub-culture and group identity; 6) Social level of signification is about social attributes in the interaction,

which focuses on value and ideology and relates to beliefs, expectation, commitment, contract, law and cultural convention.

As "signification" manifests the six levels of hierarchical structure, the dimension of "object" can be divided into four levels: assembly, object, unit and component (Ulrich,1995) [2]. Component includes the activity of all products that was applied for completing the task in the process. Every product can be divided into multiple assemblies, each assembly into units with different behavior or functions and every unit is composed of many components.

The dimension of "Behavior" can be also explained with a hierarchical structure for example, with four levels, activity, process, action and operation (Leont'ev,1978) [11] [12]. SAPAD chose the term "activity" and *i*th-level action for multiple levels since different disciplines have different definitions of terms representing levels of actions.

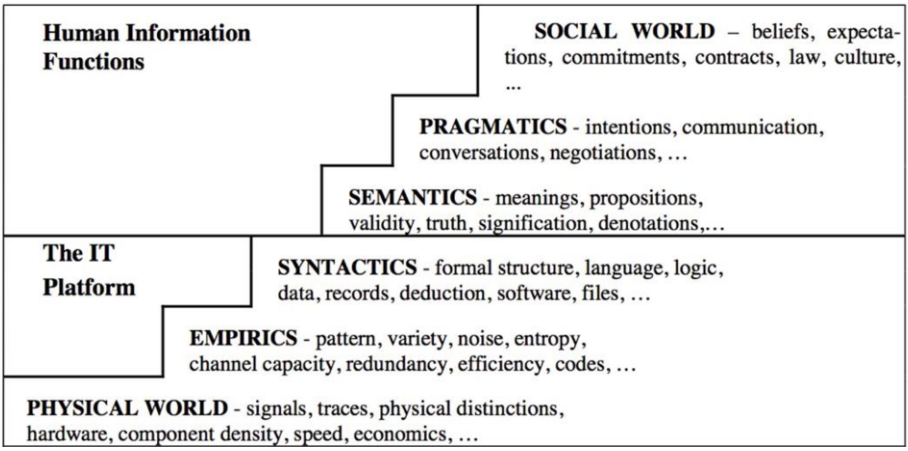


Figure 1. Stamper's semiotic ladder.

2. SAPAD for Bridging User Research and Product Architecture

The process of SAPAD consists of three phases with eight steps. In order to effectively follow through the SAPAD process, templates and tools for information acquisition and analysis have been developed.

Phase 1: Behavior observation and analysis
This phase is composed of the following three steps: 1. Object analysis 2. User observation and 3. Behavior analysis.

Object Analysis produces an architectural description of a product or a system that represents its topological configuration of subsystems and components. First, components (function carriers) and interactions (functional dependency) between them are identified. Then, a hierarchical structure of components is constructed corresponding to different levels of functional modules based on degrees of functional and structural dependency (Ulrich, 1995) [1]. This step can be done after Step 2 or 3 depending on the nature of the project.

User Observation intends to capture the actual situation of product or service system usage. It attempts to capture the usage process, users' states, various environments such as physical, social and cultural, and relevant objects by videos, photos, notes and other means. Questionnaire survey and interviews before and/or after the observation can be also used in order to provide enough information for deeper understanding of the user behavior.

Behavior analysis. to make behavior hierarchy and layer behavior according to activities, processes, action and operation, outlining the structure of the user's behavior and related items clearly.

Phase 2: Signification analysis and construction.

Excavating the under meaning of the user's behavior by analyzing physical level, syntactic level, empiric level, semantic level, pragmatic level and social level.

Signification construction. Making sure of the accuracy and availability of signification through interviewing user again, at the same time, reconstructing signification cluster, insight into the crucial meaning of behavior and core values of the user and possible design directions by hierarchical clustering on the DSM.

Phase 3: Product construction and design:

Signification-Objects Mapping. Combining with 4, 3, 2 to determine the mapping among and between signification cluster (four levels) and things, defining the key objects of signification.

Product architecture bases on signification cluster. Assigning the number to the relationship of object signification base on {0, 3} Brin logic and outputting new units, new products or new groups by symmetric matrix.

Design opportunities. Introducing new function and new architecture of the product, legible design opportunities and concrete paths for innovation based on the new configuration of components, units, objects and assemblies.

3. Case Study: Cooking Activity in a Home Kitchen in Central China

3.1. Step1 Observation and User Behaviour Analysis

This case study observed and examined the lunch-cooking activity of a 60-year-old retired male in a small home kitchen located in a large city area in central China. The observation revealed that the primary cooking activity is composed of six processes: P1, cleaning ingredients; P2, cutting/preparing ingredients; P3, cooking; P4, serving food; P5, cleaning cookware and tableware; and P6, storing cookware and tableware. These six processes can be further divided into thirty-one actions in the same way as Hierarchical Task Analysis (HTA) [12]. For example, the cleaning ingredients process includes taking out ingredients, washing ingredients, disposing garbage.

3.2. Step 2 Behaviour-Signification Mapping and Signification Structure

From the user observation and other studies about user engagement in the cooking process, signification factors on the user's behavioral elements were elicited. In syntactic level, seven signification clusters were identified: 1) disposing garbage 2) arranging ingredients processing area; 3) cooking with heat; 4) washing tableware and

restoring dishes; 5) restoring cooking utensils and pots; 6) restoring oiler and rice container; 7) restoring seasoning boxes and canister.

In empiric level, eight signification clusters were identified: 1) easy access to cooking utensils and condiments: easy to pick cooking utensils, oil container, seasoning canisters, ingredients, and easy operation; 2) preventing corrosion and plasticization in high temperature; 3) easy access to ingredients and rice: easy to pick ingredients, rice, smooth operation, object placed nearby; 4) preventing sink blockage; 5) large operating space; 6) keeping rice container in dry place; 7) placing a cutting board easily; 8) keeping kitchen clean: organize cookware and utensils neatly, keeping kitchen clean, and keeping hygienic. It shows that empiric level reflects users' general guideline for handling and controlling experience during cooking process. For example, user generally places the cooking utensils, spices and other objects nearby each other based on their cooking experience for easy and fast task execution.

In the semantic level, five clusters were defined: 1) healthy diet; 2) less oil and mild taste; 3) safe and clean-ingredients; 4) tableware hygiene and preventing odors; 5) comfortable and pleasurable cooking. From user's perspective, the core of semantic level is "healthy regimen". Through cluster analysis of symmetric matrix of the sematic level, user's expectations can be found in six particular areas: tableware hygiene, comfortable operation, light diet, health, food safety and nutritional balance.

In the pragmatic level and social level, two signification clusters were identified: 1) emotional expression; 2) cooking and eating patterns: regional cooking tradition, family diet styles and regional diet. These levels emphasize the user's value and ideology. For example, people express their feelings and caring for their families through cooking.

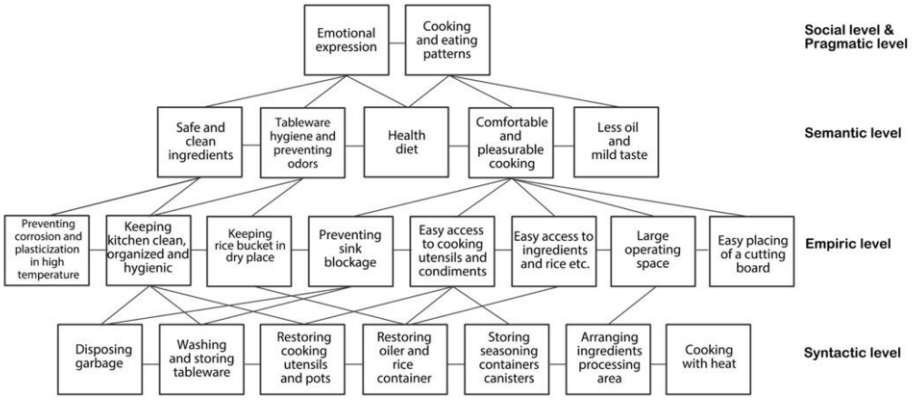


Figure 2. Signification module of user cooking behavior.

Furthermore, all signification clusters in different levels are reconstructed as show in Figure 2. It is obvious that the core concern in the cooking activity includes health, emotional expression and cultural tradition in regional diet.

3.3. Step3 Signification-Object Mapping

According to the eight signification clusters mapped to actions and objects, in empiric level, the key objects included seasoning canister, oil container, cooking surface, ingredients, plates, refrigerator, sink, garbage can, cutting board and faucets. These objects are usually clustered together in the kitchen by the furnishing configuration and

the user's preference to ensure the operability and comfort for the cooking activity as shown in Table 1.

Table 1. Mapping analysis of object-signification in empiric Level.

Signification clusters	Actions	Related objects	The key objects
Easy to pick caster, easy to pick cooking tools, easy to pick oiler, easy to pick seasoning ingredients, easy operation	P3.1: pouring the seasoning to seasoning boxes	cupboard, seasoning, seasoning boxes, placing units	Seasoning containers
	P3.7: seasoning	seasoning containers, castors, pan, spatula, placing units	Seasoning containers
	P3.4: pouring oil	oiler, placing units, frying pan	Oiler
Preventing corrosion, plasticization in high temperature	P6.3: Tidying countertop	operation table	Operation table
Easy to pick up ingredients, easy to pick rice, smooth operation, object placed nearby	P1.1: getting ingredients	ingredients, refrigerators, trash bags	Ingredients
	P2.5: placing the ingredients to the plate	plate, ingredients operation table	plates
	P2.6: placing leftovers to refrigerator	ingredients, refrigerator	refrigerator
Preventing sink blockage	P5.5: cleaning sink	sink, garbage can, rag	sink
	P1.3: throwing away rubbish to garbage can	sink, rubbish, garbage can	garbage can
Enough operating space	P2.4: cutting ingredients	cutlery, chopping board, ingredients, operation table	operation table
	P2.5: placing the ingredients to the plate	ingredients, plates, operation table	operation table
Keeping rice container in dry place	P1.1: getting ingredients	ingredients, refrigerator, trash bag	ingredients
Placing a cutting board easily	P2.1: placing chopping board	chopping board, console operation table, placing station	chopping board
	P2.7: washing the chopping board and knives	chopping board, cutlery, faucet, sink, rag, chopping board, placing units	chopping board
Organizing countertops, keeping kitchen clean, preventing bacteria growth	P5.2：throwing away rubbish	rubbish, garbage can	garbage can
	P5.3: processing the leftovers	leftovers, top drawer, bowls, refrigerator	refrigerator
	P5.4: cleaning tools	faucet, sink, cleaner	faucet

3.4. Step 4 Product Architecture based on signification

The degree of signification relations between objects are evaluated by four values (0, 1, 2, 3) in Likert scale where 0 for no signification, 1 for some signification, 2 for strong signification and 3 for very strong signification. The result was formatted as a DSM and Bertin sort method (Ref) was used to identify object clusters. Bertin sorting uses a series of permutations of rows and columns in order to form clusters of the matrix elements with strong relations visually represented along diagonal matrix cells. [13] [14]

In Empiric level, ten clusters of objects were identified and named as follows: 1) ingredient processing clusters includes ingredients，cooking surfaced, cutting tool and chopping boar; 2) garbage processing clusters includes garbage, garbage can and garbage bag; 3) cookware cluster includes oil container，cooking utensils and frying pan; 4) cleaning cluster includes detergent, wash basin, faucets and sink; 5) tableware & food preservation cluster includes bowls, plates， eating utensils，refrigerator，leftovers， drawers and cabinets; 6) placing clusters includes seasoning bottles, spices，dry seasoning container and placing surface, as show in Figure 3.

	Ingredients	Cooking surface	Chopping board	Cutting tool	Garbage	Garbage can	Garbage bag	Oil container	Frying pan	Cooking utensils	Sink	Faucets	Detergent	Wash basin	Bowls	Eating utensils	Plates	Leftovers	Refrigerator	Drawers	Cabinets	Dry seasoning container	Seasoning bottles	Spices	Pacing table
Ingredients	3	3	2	2	1	1	2	1	3	0	0	3	0	2	1	1	1	3	3	0	0	0	0	2	3
Cooking surface	3	3	3	3	2	2	0	0	2	0	1	1	0	2	0	0	0	0	0	0	0	0	0	0	1
Chopping board	2	3	3	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Cutting tool	2	3	2	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Garbage	1	2	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Garbage can	1	2	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Garbage bag	2	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oil container	1	0	0	0	0	0	0	3	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Frying pan	3	2	0	0	0	0	0	3	3	3	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2
Cooking utensils	0	0	0	0	0	0	0	1	3	3	0	0	1	1	0	0	1	0	0	0	0	0	0	1	1
Sink	0	1	0	0	0	0	0	0	0	0	3	3	2	3	0	0	0	0	0	0	0	0	0	0	0
Faucets	3	1	1	1	0	0	0	0	0	0	3	3	1	3	1	0	1	0	0	0	0	0	0	0	0
Detergent	0	0	0	0	0	0	0	0	1	1	2	1	3	3	2	1	1	0	0	0	0	0	0	0	0
Wash basin	2	2	0	0	0	0	0	0	1	1	3	3	3	3	2	2	2	0	0	0	0	0	0	0	0
Bowls	1	0	0	0	0	0	0	0	0	0	0	1	2	2	3	3	3	2	2	1	2	0	0	0	1
Eating utensils	1	0	0	0	0	0	0	0	0	0	0	0	1	2	3	3	3	2	1	2	2	0	0	0	2
Plates	1	0	0	0	0	0	0	0	0	1	0	1	1	2	3	3	3	2	2	2	2	0	0	0	2
Leftovers	3	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	3	3	3	3	0	0	0	0
Refrigerator	3	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	2	3	3	3	3	0	0	0	0
Drawers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	3	3	3	3	1	0	0	0
Cabinets	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	3	3	3	3	1	2	0	1
Dry seasoning container	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	3	3	3	3
Seasoning bottles	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	3	3	3
Spices	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3	3	3	3
Pacing table	3	1	1	1	0	0	0	3	2	1	0	0	0	0	1	2	2	0	0	0	1	3	3	3	3

Figure 3. A Weighted DSM Representing Relations between Physical Components in Empiric level.

Ten object modules (clusters) were identified in Semantic level: 1) ingredients; 2) placing surface; 3) seasoning storage; 4) bowl storing; 5) refrigerator; 6) eating utensil; 7) cookware; 8) cooking template; 9) garbage processing; 10) cleaning. In the pragmatic and social level, nine object modules were identified: 1) ingredients; 2) cookware; 3) cooking; 4) eating utensils; 5) steamer; 6) food storage; 7) gas stove; 8) the seasoning storage; 9) rice storage. The clustering shows a variety of possibility of grouping the items. Based on the signification patterns, 11 function modules of cooking activity were determined after comprehensive analysis: 1) food processing; 2) cookware; 3) cooking; 4) tableware storage 5) cleaning; 6) garbage processing; 7) dining utensil; 8) refrigerator placing; 9) seasoning storage; 10) rice storage; 11) others. Figure 4 shows more detailed modules hierarchy of the kitchen system.

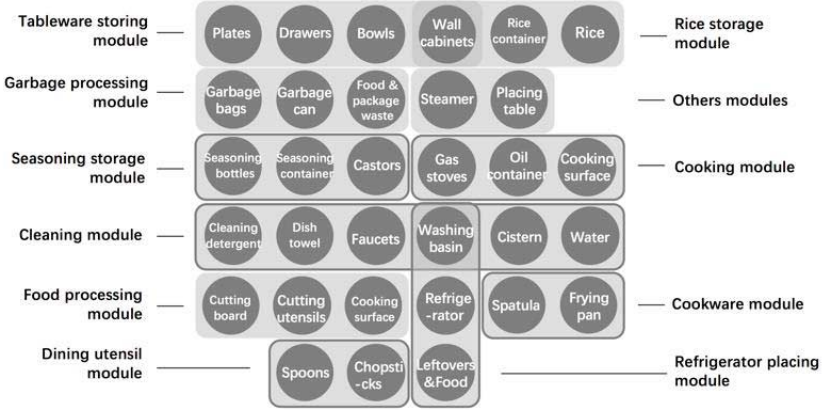


Figure 4. Identification of product modules of the kitchen.

3.5. Step5 Design Opportunity and Product Development

The clustering of the product modules allows the reconfiguration of the cooking activity organization by providing a conceptual basis. At present the cooking activity structured simply a combination between sets of cabinets and the user's conception of the various cooking functions. In this example, the three types of layout configuration, "linear" type, "L" type and "U" type as shown in Figure 5 were selected as potential solutions for the case out of many possible layout patterns.

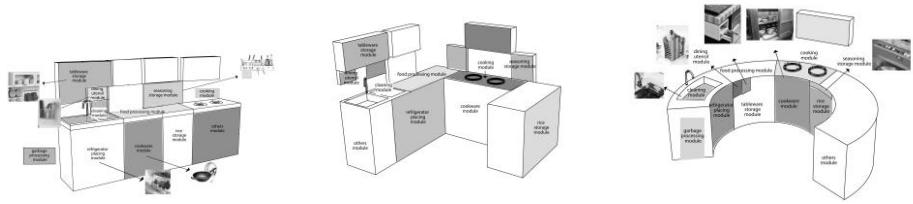


Figure 5. Identification of product modules of the kitchen.

4. Discussion

In the case study, the concepts of health, emotional expression, personal cooking and eating styles are identified as a key meaning factors. Although cooking can be a pleasurable activity for some people but majority of the people living by themselves consider it as burden in their daily lives. Cooking activity becomes more pleasurable if it is motivated by the sense of compaction to family member and friends.

The introduction of semiotics ladder provides effective framework for analyzing observation data with its six categories of signification. Using semiotic ladder, SAPAD framework can capture user knowledge from a more comprehensive range and represent them in more structured forms.

5. Conclusions

Local knowledge, the diversity of different cultural background and historical evolution process lead the different understanding to knowledge interpretation in different situations. Therefore, the concept of "kitchen" is generated in the local culture and must be defined by combining with its contemporary usage patterns and user background. We also need to be aware that the personal knowledge embodied in the Empiric level and Semantic level information is the important clue of local knowledge that implies a range of personal and market level adaptability addressed in the further architectural decisions.

The overall research goal is to construct a methodological frame for applying semiotic approaches to model users and product relations as a basis for the product architecture formation. In order to achieve this goal, functional signification of the physical and syntactic levels, or individual experience and emotion derived from the empirical and semantic levels, or socio-cultural signification derived from pragmatic and social levels, are translated into design knowledge that can be converted into product specification. Local knowledge can be translated into specific functional

descriptions or user needs because it represents solutions when local users encounter problems and it can be passed to other local users when encountering similar problems. Local knowledge can be described as reasonable association with objects, process and usage background.

The future challenge of this research is to integrate insights from multiple system views including semiotic models, operational process models and affordance models as well as other technical views into a coherent architectural configuration. A well-formed architectural solution should provide a flexible design platform for developing further detailed specifications. Most importantly, the further development of this approach needs to address the complexity and dynamics of technological and social changes that the product needs to be positioned and operated as a part of larger systems.

Acknowledgement

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Aesthetics of Experience: Industrial Design in the Era of Design Thinking and User Experience

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Abstract. Industrial design has evolved in the last hundred years, past several design movements, weaving through hi-tech and Internet era into the collaborative design and 3D printing era today. The seeming magic that industrial designers conjure up in designing iconic products such as the Sony Walkman or the IPhone has the world wondering, 'what is design? Several ideas and methods, such as user experience, design thinking, collaborative design, rapid prototyping and 3D printing have become a sort of panacea for innovation for businesses, in their quest to succeed. All these make it look like anyone can design, forgetting that designers are experts in one important aspect of industrial design; giving appropriate beauty and form to the outputs of design. Where has the beauty of design gone? How can we impart the idea of 'appropriate' aesthetics as an important element of industrial design? The goal of this paper is to propose a method to connect the three key elements of design, function), human factors and human emotion that ultimately makes a design successful. This paper starts by discussing on the present trends in design such as design thinking and user experience, before presenting three main points, the first being that, user experience and design thinking are only two items in a designer's tool kit. The second point is that designers use visual thinking methods supported by ideation, representation and verification tools and move towards an appropriate outcome. Thirdly, a visual model for connecting the three key elements of design to the aesthetics, that the author has been using in teaching design, is presented which will aid in in the creation of aesthetics and forms that are appropriate for each project. Finally selected examples of how this method has been used in product design class by the author us highlighted.

Keywords. Design thinking, user experience; aesthetics, visual model

Introduction

Industrial design is hundred years old as a profession, according to the Industrial Designers Society of America (IDSA). The early industrial designers in USA opened their design practice after the first world war, designing everything from buildings and interiors to locomotive engines and buses to lawn movers and vacuum cleaners to refrigerator and washing machines to, name a few. A similar history can be traced back to Europe as well, with the initial influence of the Bauhaus (1919-1933) and later, through Hochschule für Gestaltung Ulm (1953–58). European companies such as AEG and Philips were early adaptors of design during this period. While industrial design as a business thrived in the United States of America (USA) by the work done by its designers and the support given by companies such as General Electric, Greyhound and Boeing, more in-depth thinking on design seems to have come from Europe through designer-educators such as Walter Gropius, Lazlo Moholy–Nagy, and Ludwig Mies van der Rohe who moved from the Bauhaus to USA to establish schools of design.

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Individual designers with their own philosophies and points of view, such as George Nelson, Charles (and Ray) Eames, Ettore Sottsass, Joe Colombo, Philippe Starck, Ross Lovegrove, Karim Rashid, Jasper Morrison and Yves Béhar have lit the field in the last sixty years or so. International design consultancy has seen its own star outfits such as Pentagram, frog design, GK Associates, IDEO, Ziba Design, RKS Associates and Smart Design, to name a few. Added to this mixture are successful in-house design departments in companies such as Apple, Philips, Sony, Samsung, Black & Decker and Whirlpool as well as the studios of automotive companies such as Ford, GM, BMW, Audi, Toyota and others. The final count is that all these players of design, seem to have something that they were/are doing right in order to be successful. Is there a commonality or secret in the way they work? How do the thoughts and practice of design get translated today, with the advent of globalisation? Is there a way to connect today's trends to the pioneering practices of the 20th centrury?

1. Designers on design

In order to understand design and designers, it is important to know what they have said (or, are saying) about design and on their approach to design. The following are some of the oft-quoted comments from key designers in history:

1. Raymond Lowey (1893 – 1986): "I believe one should design for the advantage of the largest mass of people, first and always. That takes care of ideologies and sociologies. I think one also should try to elevate the aesthetic level of society. And to watch quality control always, while insisting others do, too."[2]

2. Henry Dreyfuss (1904 –72): "If the point of contact between the product and the people becomes a point of friction, then the industrial design has failed. If, on the other hand, people are made safer, more ore comfortable, more eager to purchase, more efficient – or just plain happier – the design has succeeded."[3]

3. Charles Eames (1907–78): "To whom does design address itself: to the greatest number, to the specialist of an enlightened matter, to a privileged social class? Design addresses itself to the need."[4]

4. George Nelson (1908–86): "Design is returning humanity to society. If design doesn't work for people then there isn't much point in doing it. I'm not so much interested in designing things as I am in designing systems. That is what is important."[5]

5. Karim Rashid (1960 -):"Design is about the betterment of our lives poetically, aesthetically, experientially, sensorially, and emotionally."[6]

6. Yves Behar (1967 -): "Design is how you treat your customers. If you treat them well from an environmental, emotional, and aesthetic standpoint, you're probably doing good design."[7]

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[2] http://www.raymondloewy.com/about/quotesby.html

[3] http://www.hda.net/hda.swf

[4] http://www.brainyquote.com/

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[6] http://www.rashidglobal.net/?page_id=212

[7] http://quotesondesign.com/yves-behar/

From the quotes above the following can be deduced:

1. Design does not mean the same for each of the designers, although they all seem to signify similar meaning to it.
2. Most of the designers quoted refer to human beings in one-way or the other. It could be consumer, customer, people, humanity, human needs, etc.
3. Several designers mention aesthetics and beauty as an important part of their thinking.
4. There is no clear indication of any affinity or preference for a particular process or methods for design.

In author's opinion, what makes designers/design group successful seems to be their focus on two main aspects:

1. Design itself and
2. The real benefactors – end users/environment/system

How they made their design unique and successful seem to be their specialty, mixing the pragmatics necessary for the design and its benefactors and adding their touch on aesthetics that brought value to the 'commissioners' of design such as the client or the company, much like a chef in a restaurant.

2. Design thinking

The emergence of Apple Computers in the late 1970s and with 'disruptive' innovation centred on the Silicon Valley area of California, industrial design became a 'mantra' during the 1980s and 90s. Several well known design consultancies set themselves along the west coast of USA, which included frog design, Lunar Design, Ziba Design, IDTwo/Moggridge Associates, Matrix, RKS Associates, to name a few.

Advent of innovation, first made famous by Drucker [1] as an essential ingredient for business success, started many a business schools through the 1980s till early 2000s to dissect the design process to identify 'design thinking' as an important ingredient for innovation. This quest for the secret of design was also picked up by the media, as much as by the business/management schools around the globe. BusinessWeek (now Bloomberg BusinessWeek) started highlighting the importance and success of industrial design and others such as the Fast Company and specialized blogs on design thinking, followed suit. It is perhaps Tim Brown, the present President and CEO of IDEO who brought design thinking into the forefront, through his conversations, talks, articles and books. To quote Tim Brown[8]:

'Design thinking is a human-centered approach to innovation that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success'.

This quote seems to have deliberately left out any mention of aesthetics in the process of design thinking, placing priority on people, technology and business alone.

[8] http://www.ideo.com/about/

3. User experience in design

Discussion on human-centred design approach for innovation brings user experience as an important element in this 'neo' design process. In his seminal book titled 'The Design of Everyday Things' [2] Dr. Donald Norman, lays out his six principles for design as follows:

Visibility – The more visible functions are, the more likely users will be able to know what to do next.

Feedback – Feedback is about sending back information about what action has been done and what has been accomplished, allowing the person to continue with the activity.

Constraints – The design concept of constraining refers to determining ways of restricting the kind of user interaction that can take place at a given moment.

Mapping – This refers to the relationship between controls and their effects in the world.

Consistency – This refers to designing interfaces to have similar operations and use similar elements for achieving similar tasks.

Affordance – is a term used to refer to an attribute of an object that allows people to know how to use it.

Where is the experience of 'aesthetics' in all this? Reading Dr. Norman's other works such as 'Emotional Design' [3] and 'Design of Future Things', it becomes apparent aesthetics is a secondary requirement rather than an ingredient for good design. The question that the author poses then is, "suppose that the 'Spongebob Squarepants' game controller shown in Figure 1 meets all the design principles of Don Norman, does it represent a successful design?" Suddenly, 'bad taste' comes to one's mind. What is 'good taste' in design then? In the website of the Interaction Design Foundation[9], Marc Hassenzahl, professor at the Folkwang University in Essen, cites an interesting example of experience nature through a product from Philips that seem to point at good design as well as user experience.



Figure 1. Spongebob Squarepants Game Controller.
Sources: http://www.geek.com/images/mini2/jakkspacific/spongebob.jpg

[9] https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/user-experience-and-experience-design

Philips' *Wake up light* shown in Figure 2 starts to brighten gradually, simulating sunrise, reaching its maximum at the set wake-up time before the electronic birds chirp and sing to make sure that we really get up. Hassenzahl seems to clearly define good taste in design thorugh this light, 'because its contribution is not one to the aesthetics of things, but to the aesthetics of experiences'. In other words, good design is about the aesthetics of experience where the form and the aesthetics is created by understanding the user experience from different angles.



Figure 2. Philips Wake Up Light.
Source: https://www.interaction-design.org

4. How to achieve aesthetics of experience

In the author's opinion, designers are not just interested in 'design thinking' or 'user but focus on the tasks at hand. In doing so, the following are important to designers:

1. Designers have the betterment of the purpose and goal on top of their mind. It could be the user/consumer or the system and its environment. Ultimately the end result(s) have to be reliable at all three anchor points.
2. Designers are sensitized to three important nodes of influence in their thinking, namely, 1) Function 2) Human Factors and 3) Emotion[10]. These three nodes are anchors for any product, system or service.
3. Over and above the three anchors, designers are sensitized to aesthetics, in a more poetic manner. This includes form and shape, proportions, gestalt, type, colors. Each designer has different levels of 'poetic' sensitivity.

[10] Questions may be asked about the simplicity of considering only three nodes of influence. The author feels that all other nodules that may influence design in each design project could be synthesized finally into one of the three nodes. Methods of synthesis such as mind mapping, brain storming, decision matrix, etc., have been dealt with in other texts and research papers.

4. To designers, creativity and innovation are non-linear paths and are not necessarily guided by past exposure and/or experience but by visual thinking and explorations through sketching and representations.
5. Insights gained by visual thinking could be verified / enhanced/ explored further through 3Dimensional models. 3D models can vary from simple ones made from study models to 3d printed prototypes.

The final output to any design engagement is a well-balanced solution that considers the five points, laying emphasis on the appropriateness of the solution rather than on rules of design thinking or study of user experience, etc., only. This ability to arrive at appropriate design solutions that include aethetics, by designers, is usually honed through practice and experience.

The author in his quest for teaching this aesthetics of experience of today's industrial design has been experimenting with possible visible models/ diagrams/ representations that could connect the three key nodes of design, namely; function, human factor (which includes ergonomics) and emotion, with aesthetics in a manner that a direction towards appropriate and reliable design solutions could be extablished. How would this look?

5. A visual model for the aesthetics of experience

Based on the three nodes highlighted in Section 4 which considers the constraints that are placed on the design process, the author proposes a visual model for aesthetics of experience as shown in Figure 3.

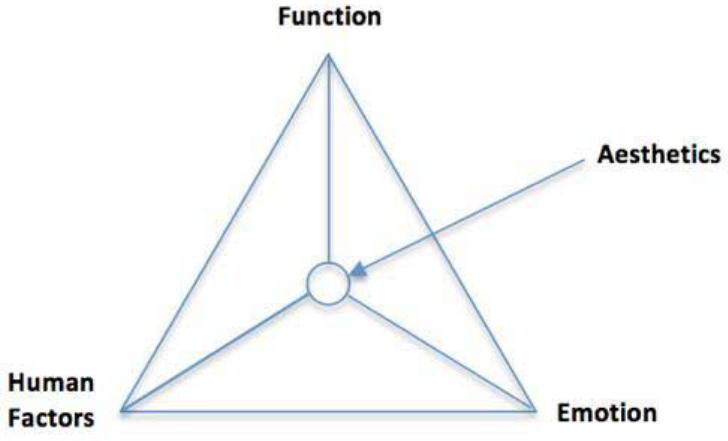


Figure 3. Visual model designing for aesthetics of experience.

In this model, the three apex of an equilateral triangle depict the three anchor points of design. Attached to these anchor nodes is the focal node representing aesthetics, which can be moved around depending on the accent of the project, affecting the structure and form, and hence, the aesthetics of the design. the dominant node indicating the aesthetic direction of that project.

6. Examples of the use of this visual model

Students in the second year of the Bachelor of Fine Arts in product design were introduced to this visual model and were asked to map the position of aesthetics for three different products, the first with heavy empahsis on function, the second with empahsis on human factors and the third leaning on emotions. Figures 4, 5 and 6 gives one exmaple from a student of this class. Hong Seng has chosen three products to highlight the position of aesthetics based on the domination of one node over the other two. Figure 4 shows an executive chair from Herman-Miller that is human factors dominant.



Figure 4. Student's example of Human Factosr dominant project
Picture: Courtesy Herman-Miller.

Figure 5 shows a product that the student describes as function dominant. Nest™ Storage by Joseph Joseph with colour coded, reversible lids which allows user flexibility in using the containers.

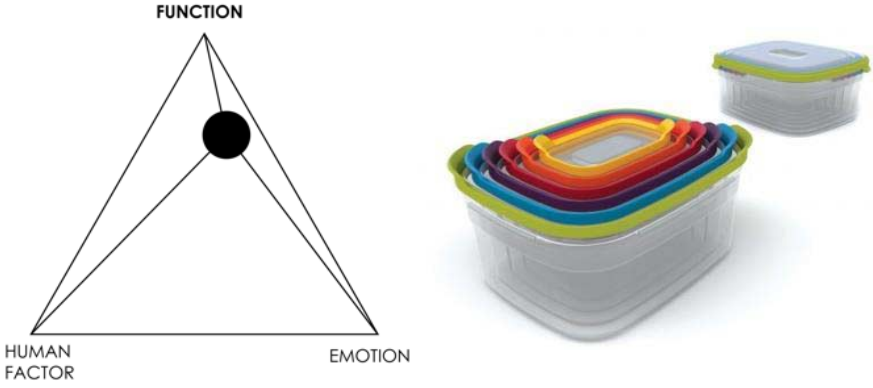


Figure 5. Student's example of Function dominant project
Picture: Courtesy Joseph Joseph.

Finally, Figure 6 shows a product that the student described as emotion dominant. Sonos Play 5 speaker, accroding to the student gives the feeling of control over the whole sound system which is very much an emotional satisfaction.



Figure 6. Student's example of Emotion dominant project.
Picture: Courtesy Sonos

7. Conclusion

The main aim of this paper is to bring forth the fact that aesthetics in design seems tio have taken a back seat, so much so, that even designers seem to forget the comprehensive thought pattern of the pioneering industrial designers. In an attempt to revive this, the author has proposed a visual model for deriving the aesthetic equilibrium. This proposed visual model is a teaching tool by itself, as well as a design tool for practicing designers. The simplicity of this model lies in the ability to place the appropriate accent on aesthetics depending once the equilibrium state is identified. This model also allows non-designers to understand the expected accent of the design outcomes so that they can better appreciate the potentials of industrial design.

The author hopes that this model does not become the 'new norm', another mantra, to practice blindly and propagate. The expectation is that this model will help designers to get back to thinking about design while designing, in order that the end users benefit the foremost, rather than the intermediate market or the corporation alone.

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Part 5

Human Engineering

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Transdisciplinary Engineering: A Paradigm Shift
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An Ergonomics Study on Manual Assembly Process Re-Design in Manufacturing Firms

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Abstract. Nevertheless process automation is a global trend, some specific phases (i.e., assembly) in highly technological sectors (i.e., medical, pharmaceutical, diagnostics, dental) are still managed by human workers, due to high-precision tasks and low production volumes. In this context, operators are forced to work faster and adapt to not ergonomically workstations and workflows. As a consequence, human assembly is frequently the bottleneck of the entire process due a not ergonomic layout and process design. The study was conducted at a medical equipment manufacturer, leader of dental equipment production, and focused on the analysis of the assembly process of the dental units. Workers at the assembly line were observed by experts and involved also by interviews and focus groups to detect the assembly issues and process jam. The research provides a valuable example of how physical, cognitive and organizational ergonomic problems affect the final process performance and how human-oriented re-design actions can be easily defined according to the proposed analysis procedure.

Keywords. Human Factors, Ergonomics, Assembly workstation design, Human-centred design, Design optimization.

Introduction

High competitive markets, time pressure and high productivity rates are pushing modern manufacturing industry to improve process automation and to squeeze production time. However, in manufacturing industry a lot of processes are still manual for different applications, especially when high precision tasks are required and the overall product volumes are low due to the frequent market changes or customized production. In these cases, the majority of assembly operations, cannot be automated, or their automation would be very expensive and not convenient. In this context, the design of the workspace in terms of layout and workstation has a significant impact on the workers efficiency, the overall product quality, and the workers' wellbeing as well [1]. Furthermore, the entire assembly process has to be conceived in order to fit the production demands, flexibility and easy configurability. Usually workers spend a lot of time performing repetitive operations, assuming uncomfortable postures and living stressful conditions. Furthermore, some tasks at assembly workstations require human workers to stand for a prolonged period of time to assemble the products or to check

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that product specifications are respected. In addition, any mistake during the development phase of an assembly system can cause further problems, related not only to the assembly systems but also to the workers' wellbeing [2].

Ergonomics plays an important role in workers' productivity and process efficiency. Indeed, workstation layout and work design are two major factors of ergonomics of worker's efficiency [3]. Low attention to human factors brings to unnatural positions and dangerous actions executed by workers during their task, with consequent lower performances, higher production time, greater absence from work, and a general increase of Musculoskeletal Disorders (MSDs) with a consequence impact on national economies, in Europe as well as in other countries [4]. Different methodologies have been proposed to analyse and classify assembly workplace layout configuration in relation to technological and environmental parameters, and the workstation design [5-7], and numerous studies about the discomfort and stress experienced by workers during the assembly process have been published in the last ten years, all around the world [8-9]. However, only few works have been published about the combination between the detected ergonomics problems and effective re-design guidelines. It is mainly due to the lack of practical and easy-to-use procedures to define the re-design actions.

In this work, an ergonomic study about the manual assembly line of a leader company in the dental sector is presented. The assembly process has been analysed by direct observation and interviews by involving the workers, and modelled by task analysis carried out by a team of ergonomic experts. Furthermore, the workplace has modelled by 3D modelling tools and the assembly tasks dissimulated by digital manufacturing tools, and different design solutions have been considered and assessed with virtual manikins. The study demonstrated how the proposed procedure could easily support the ergonomic re-design to avoid awkward postures, too high cognitive workload and organizational issues, to finally improve productivity and workers wellbeing.

1. The ergonomic analysis procedure

Ergonomic analysis for assembly processes is focused on the assessment of the effectiveness and the efficiency with which activities and tasks are carried out, related to both physical and cognitive workload [10]. The present study proposed a structure procedure to carry out the assessment of the assembly process as described in Figure 1. It starts from the investigation of the assembly lines in order to study the workplace layout, constraints and conditions. After that, it proceeds with the direct observation of real workers during their task execution and their involvement by interviews. Subsequently, task analysis is carried our by experts and the assembly process is modelled by 2D and 3D representations, using schemes and CAD models. On the basis of data collected, the ergonomic assessment is carried out for each task identified considering some of the international standards about physical and cognitive ergonomics. About physical assessment, the study considered the norms about the static working postures (ISO 11226) [11] and the dynamic actions, such as lifting and transportation of loads (ISO 11228-1) [12], towing and pushing actions (ISO 11228-2) [13], high frequency tasks (ISO 11228-3) [14]. Furthermore, the international directive on safety of machinery - ergonomic design principles (UNI EN 614) [15] has been adopted. As far as the cognitive assessment, human interaction is analysed by the

ICAO SHELL model (ICAO 216-AN31) [16], which represents the different components of human factors. The SHELL model is a conceptual model defined in aviation to understand the human factor relationships between aviation system resources, environment, and people [17]. Such a model analyses four entities: the "hardware" that refers to the materials and tangible objects like devices and supporting tools, the "software" refers to intangible items like norms, procedures, and constraints, the "environment" refers to external factors that cannot be changed by changing the design, and finally the so-called "liveware" that indicates the people involved. It is rarely used in manufacturing, ever for cause of an accident. However, the systems perspective considers a variety of contextual and task-related factors that interact with the human operator and has been found very useful to study interactions occurring during complex assembly tasks. Furthermore, the ISO 100075 [18] and the UNI EN 894 [19] standards about cognitive ergonomics are referred. For human virtual modelling, the ISO 7250-1[20] standard about the basic human body measurements for technological design is adopted. As a result, for each analysed task the OCRA and NIOSH indexes are calculated action by action and the SHELL model is defined.

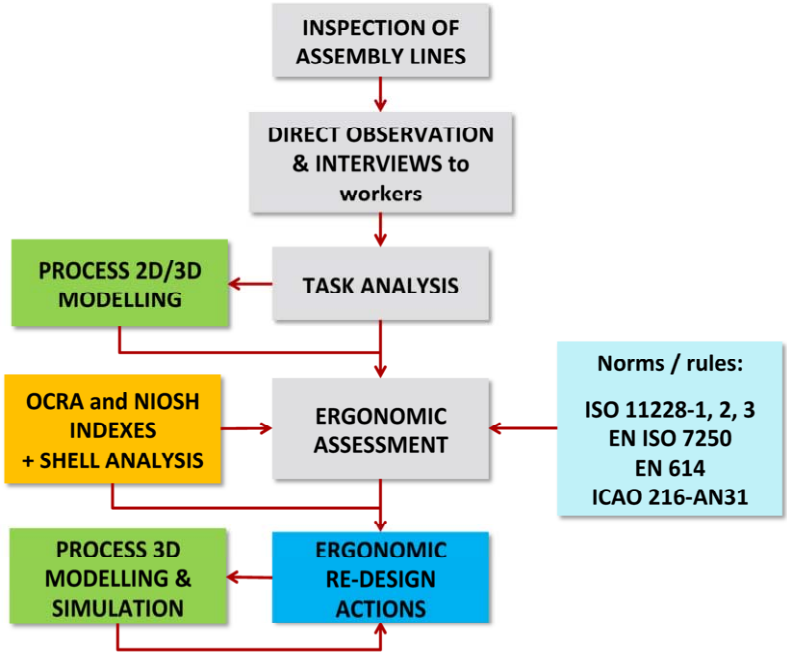


Figure 1. The procedure for ergonomic analysis of manual assembly process.

2. The industrial case study

2.1. The assembly process

The case study was developed in collaboration with an Italian company that is world leader in dental equipment design and production. In particular, the process under investigation related to the assembly of dental units. The dental unit usually

comprehends: the hydro-unit, the swivel arm, the dentist's instrument board, the dentist's control console, the tray-holder module, the assistant's board, the assistant's board control console, the electrical box, the multifunction foot control, the cup water delivery spout, the bowl, the self-balancing arm, and the dental chair. Some devices such as the tray-holder module on assistant's board and an X-ray viewer can be included, as optional.

The specific line is composed by 25 workstations, 16 of them are dedicated to pre-assembly and 9 of them to assembly. The line can process a maximum volume of 16 units per day, with a takt-time of 30 minutes. The turnover is once a week. Figure 2 shows the line investigated in the case study. The pre-assembly phase consists of preparing the subassemblies, which to be assembled in the following assembly phase. Each cart refers to one dental unit. The carts are filled from the warehouse using RFID technology.

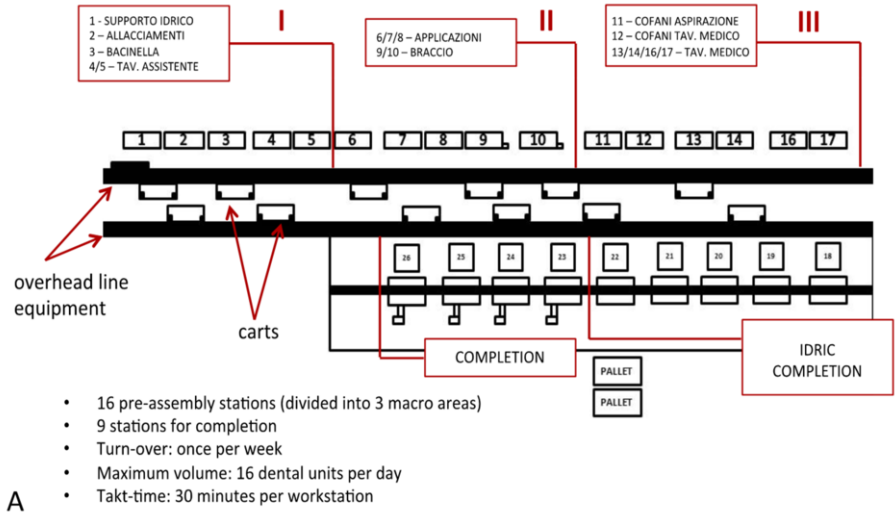


Figure 2. The assembly line for dental units: the 2D layout (A) and the real shop-floor (B).

The carts are organized according to a standardized procedure: the upper shelf of the carts are filled by the lighter components, the second shelf is a sliding shelf with the heavier components, the third shelf contains hydraulic parts and custom component, and the bottom shelf is filled by specific medical components. Such organization should guarantee that the heaviest components are handled in safety conditions, according to ISO 11226 and ISO 11228. The carts run along the overhead line equipment throughout the pre-assembly stations first, and the assembly stations secondly. When the pre-assembly is completed, the carts are positioned on the second overhead line equipment dedicated to assembly. This line is parallel to the first one, as shown in Figure 2. Each workstation is equipped with the necessary tools, from screws to supporting checklists to support the workers in their actions. Training videos are also available in some specific workstations. The most common tools are usually highly visible and easily accessible. Each workstation is also equipped with assembly manual. When the carts are full, they are pulled to the next station. Every two carts completed, the worker requests new material to the warehouse.

2.2. The process analysis

The process analysis started with a preliminary inspection of the line, followed by interviews to assembly managers and workers, and direct observation of operators at work. Workers were video recorded during task execution and interviewed in order to define their tasks, monitoring their actions, identifying the tools and the procedures adopted. After that, a more detailed task analysis was carried out by experts in physical ergonomics and human factors. Each workstation was described according to: 1) sequence of tasks and procedures (i.e., software), 2) equipment and devices used (i.e., hardware), 3) interaction and communication with other people, both managers and other workers (i.e., livewere), 4) problems elicited by the workers. Tasks were then listed into and excel file and a detailed task analysis was carried out. After that, the process as well as the task sequence were digitised by 2D and 3D models.

2.3. Main criticalities and re-design actions

The ergonomic study was based on the adoption of the proposed procedure as presented in Figure 1. A first inspection of the assembly line was carried out by two experts in ergonomics and human factors. Subsequently, experts spent two weeks at the shop floor to monitor and video recording the workers and interview both workers and managers to collect useful information. Workstations and tools were also analysed and measured.

The main criticalities identified are as follows (some of them are depicted in Figure 3):

- the workers are frequently ask to carry heavy parts to/from the carts to the workstation, requiring uncomfortable lifting actions and frequent trunk rotations (see Figure 3-A);
- the carts have a fix height so that shorter workers, usually female operators, difficultly access to the higher shelf. They need to tiptoe and they have an high stress on the arms (Figure 3-B);
- in the assembly stations the workers are seated and assume un-ergonomic postures to assemble some parts (Figure 3-C);



Figure 3. Examples of the human-related criticalities during the assembly process in the case study

- some supporting equipment available at the workstation, introduced to assist the workers in lifting parts or assemble complex groups, are not adjustable according to the user needs. As a consequence, they can be used comfortably only form middle-height workers (almost 50° percentile), while are not ergonomic at all for higher or lower percentiles of the population (Figure 3-D);
- the assembly checklist available at the workstation are not highly visible due to their position (inclined to the roof) and the dover material (that reflects the light) (Figure 3-E);
- some tools available at the workstation are not easily accessible for short workers, due to a wrong and not adjustable positioning (Figure 3-F);
- the task analysis also revealed a weak time organization and some problems in the activity synchronization among the workstations can occur, so that some stations are too early and others are late. It is mainly due to the high level of customization of the products that generates an extremely high variability of the assembly tasks.

Finally, the collated data allowed the creation of 3D models of the workstations and the simulation of the human interaction also by digital mock-ups. The most critical tasks were simulated and some re-design actions proposed and tested. During re-design,

both product and process are involved in design changes. Indeed, the only process line optimization and workstation re-design can bring to limited benefits, due to the assembly constraints due to the product design. Only combined corrective actions on both process and product design can bring high advantages for the company, in terms of workers' wellbeing, product quality and process efficiency.

The main re-design actions carried out for the case study are as follows:

- workbenches' re-design according to physical ergonomic principles;
- carts' re-design, in particular by reducing their depth and having adjustable shelves;
- work re-organization in order to avoid lazy and too crowed workstations, mainly by modifying the assembly sequence of tasks in combination with part design changes;
- checklist supports' re-design, using adjustable and rotational supports, that each worker can regulate easily at the beginning of the shift;
- addition of adjustable auxiliary equipment to support the workers' actions;
- product modularization in order to re-organize its sub-assembly and to facilitate the assembly tasks.

Moreover, workers were directly involved in the re-design process according to participatory design principles. By observing the obtained results, the improved involvement and satisfaction of the workers greatly affected the process performance and the workers' safety and wellbeing. Experimentation is on-going and experimental results will be presented in future works.

3. Conclusions

The paper presents an ergonomic study about dental units' assembly process using a procedure to structure the analysis phases and to analyse easily physical and cognitive issues. The study highlighted the main ergonomic issues to be solved and demonstrate how human-oriented re-design actions can solve physical, cognitive and organizational problems, and improve the final process performance. Experimental results are still under investigation, and will quantify such preliminary results. Future works will be focused on the creation of human-centered immersive simulations by using virtual reality technologies and experimental set-up with users for a more impressive and realistic verification of re-design solutions [21][22]. Furthermore, biometrical sensors could be introduced to monitor the workers' physical and mental stress in order to define and test the more comfortable solutions [23][24][25].

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EEG-Based Mental Workload Recognition in Human Factors Evaluation of Future Air Traffic Control Systems

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Abstract. With growing air traffic density, air-traffic controllers (ATCOs) are facing more challenges in interpreting and analyzing air traffic information. As one of the solutions to this problem, automation supports such as tactile human computer interface, interactive 3D radar displays, and conflict resolution aid (CRA) are proposed for the enhancement of the current air traffic control (ATC) systems. To evaluate the proposed ATC systems, questionnaires are commonly used to get the feedback from ATCOs. However, the questionnaires are usually administered upon completion of each ATC simulation task thus provide only overall ratings towards the new ATC systems. In this paper, we propose and implement a novel Electroencephalogram (EEG)-based neurocognitive tools for evaluation of ATC systems. The nature of EEG-based technique is that the brain states can be monitored in a high resolution time, fitting the nature of time-critical ATC tasks. Thus, such EEG-based human factors study allows for real-time monitoring of ATCOs' mental workload during the task performance in ATC systems. We designed and conducted an experiment to evaluate the costs and benefits of the CRA and tactile user interface in future ATC systems. Thirty six participants participated in the experiment and were assigned into three groups of different display modes: Non-Display, Display, and Trajectory Prediction. In each group, three CRA conditions were given: Manual, Reliable and Unreliable. The EEG data were recorded during the tasks, and the traditional workload evaluation method NASA Task Load Index (TLX) was administered at the end of each task. The result shows that the ratings obtained from NASA TLX and from the EEG labeling are highly correlated. Thus, the EEG-based system is reliable to recognize workload during the task performance. With the proposed EEG-based system, we found that 1) relatively high workload was observed at the beginning of the experiment in each group which could be due to participants' unfamiliarity with the interfaces; 2) participants in the trajectory prediction group had much higher workload as compared to vertical display and non-display groups, which could be attributed to its complexity. The changes of workload are due to interaction between the type of display modes and time ($p<0.05$); 3) workload varied slightly with different CRA setting. The results show that the proposed EEG-based system for human factors study can provide better understanding of real-time mental workload changes during the task performance in new ATC systems, therefore enables the evaluation of current and future ATC systems.

Keywords. EEG, human factors, neuroergonomics, mental workload, air traffic control

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Introduction

Air Traffic Control is one of the key components in ensuring low occurrence of aviation safety incidents and it has remained 'human-centered' even until today. Human factors are an important element in air traffic control as Air Traffic Controllers (ATCOs) are responsible in coordinating aircrafts in the airspace. In addition, the need to provide information such as weather and traffic information as well as the need to provide assistance when it is requested by pilots, have made their job more demanding and stressful. From the statistics provided by Changi Airport Group (CAG), the number of air flights movements and commercial aircraft movements stands at 1.84 million and 341.4 thousand respectively [1]. Moreover, from the statistics, there is an upward trend in the number of aircraft movements in Singapore through the years [1] and we will not expect this trend to change in the near future. This poses a great challenge for air traffic control because safety risks will steeply increase when air traffic doubles.

There has been increase in the use of automation aids such as conflict alert and minimum safety altitude warning which enable controllers to take immediate action to eliminate disastrous accidents [2]. Moreover, more researches are dedicated to the evaluation and implementation of better automation aids such as Conflict Resolution Aid (CRA) [3] and Automatic Identification of Risky Weather Objects in Line of Flight (AIRWOLF) [4] which help to improve performance of controllers. It has been shown that workload contributes to a significant 24% to incidents [5] and workload will become even more relevant when air traffic density increases in the future. There are many different methods available in the evaluation of workload experienced by ATCOs. In this paper, the main focus will be the use of Electroencephalography (EEG) due to real time monitoring and its potential to provide better workload evaluation [6]. We conducted an experiment in the span of four months at Air Traffic Management Institute, Nanyang Technological University, which aims at assessing the conflict resolution automation and tactile user interfaces in future ATC systems. By using EEG, we monitored the brain states such as workload when the ATCOs were performing ATC tasks. Subjective evaluation methods such as questionnaires were also given to ATCOs upon completion of the tasks. However, this kind of method can only provide an overall evaluation instead of continuous monitoring.

The paper is constructed as follows. Section 1 presents review on common workload evaluation methods. Section 2 introduces the real-time EEG based mental workload recognition system. Section 3 gives the details of the experiment. Section 4 shows the results, and Section 5 concludes the paper.

1. Related work

The controller's workload is an important consideration in determining the maximum capacity of enroute air traffic [7]. Thus, there is a need for higher accuracy methods in evaluating ATCOs' workload which is able to provide a comprehensive feedback considering the different factors affecting workload. Usually, the measurements of workload can be subjective and objective.

1.1. Subjective workload evaluation

Subjective workload is based on the judgement and memory of a person's perception of his performance in a task [8]. However, there is a limitation to the accuracy of this method in workload estimation since numerous factors, such as a person's plan greatly affect the selectivity of consciousness [9]. Nevertheless, subjective workload measures are widely accepted within research and industrial domains due to low cost and ease of administrating procedures for such measures [10].

The common use of subjective workload measures for air traffic control research, is based on the use of ratings on unidimensional or multidimensional scale to determine the workload of an individual [11]. NASA-TLX is a well-known method which includes six factors such as mental, physical, temporal demands, frustration, effort, and performance. It assumes that the combinations of these factors can reflect the level of workload experienced when people are performing tasks [12]. NASA-TLX provides the highest sensitivity and obtains the highest acceptance among operators despite on it requires the longest time to complete [13].

1.2. Objective workload evaluation

Objective workload evaluation is often associated with the performance of the tasks including the primary and secondary task measures. The primary task measure estimates workload based on the capability of an individual in performing a primary task, while the secondary task measure estimates workload based on the capability of an individual to perform two tasks concurrently [14]. Better performance of secondary task could indicate that more residual capacity is available to it from the primary task, and the demand of cognitive resources of the primary task is also low [15]. Situational Present Assessment Method (SPAM) is associated with performance-based workload estimation via secondary task measure as well as situational awareness [16].

1.3. Psychophysiological workload evaluation

Psychophysiological methods in evaluating workload involve the analysis of the effect of physiological behavior due to changes in psychological variables [17]. Common psychophysiological methods used in workload evaluation for air traffic control include monitoring of cardiac activity, respiratory activity, eye activity, speech measures and brain activity [11]. EEG possesses many advantages in measuring workload due to its high time resolution, and it is considered to be the best among other workload evaluation methods that use eye tracking, pulse rate, etc. in human-machine interaction [18].

2. EEG-based workload recognition

We presented the real-time EEG-based brain states monitoring system CogniMeter in [19] which can identify brain states such as workload, emotion, and stress. In this study, the same algorithm which employs fractal dimension [20] and statistical features [21] are used to recognize ATCOs' mental workload. The Support Vector Machine (SVM) is used as the classifier. The algorithm is validated in [22] and the best accuracy is

90.39% for 2 levels mental workload recognition and 80.09% for 4 levels mental workload recognition. Since the SVM-based machine learning is a supervised one and the proposed mental workload recognition algorithm is subject-dependent one, a calibration is needed to train the classifier model. During the calibration, stimuli are given to the user to elicit different levels of workload and the EEG data are recorded. Fractal dimension and statistical features are then extracted. Together with the self-assessment labels indicating the workload levels, the features are fed into the SVM classifier to train the model. In the real-time recognition phase, the processing steps also include feature extraction and classification. Same features as in the calibration phase are extracted. Then these features are used as the input to the SVM model obtained from calibration. Finally, the current workload level can be identified.

3. ATC Experiment

3.1. Experiment settings

An experiment was carried out to study human factors in ATC work place. There were a total of 36 ATCO participants from the Civil Aviation Authority of Singapore (CAAS) and the Republic of Singapore Air Force (RSAF) controllers and students with prior knowledge in ATC. The participants were divided into three groups in this experiment: non-display, vertical display and trajectory prediction group. Besides the main radar display and two pseudo pilot display, a secondary touchscreen display, was used for either vertical display or trajectory prediction depending on the set-up. The vertical display provides information on the current and predicted flight level of aircrafts against time. The trajectory prediction provides information on the current and predicted flight level, plan view, speed (knots) and rate of descent and climb against time. No touchscreen display was available in the non-display group. Each group had to perform ATC tasks under three conditions: without Conflict Resolution Aid (CRA), with reliable CRA, and with unreliable CRA. Under the condition of reliable CRA, all conflict resolution provided by the system had perfect accuracy in resolving potential conflict, whereas under the condition of unreliable CRA, conflict resolution advisory provided by the system may not be able to resolve a potential conflict. The experiment session under each condition lasted for 1 hour.

3.2. Data Collection

Two types of data were collected in this experiment: the EEG data recorded during calibration and each session and NASA-TLX data collected after each session.

3.2.1. EEG Data

A wireless Emotiv EPOC is used for the collection of EEG signals in this experiment. The Emotiv EPOC is mounted on the head and has 14 channels (AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, and AF4) following the international 10-20 electrode system with CMS/DRL references. The sampling frequency of Emotiv EPOC is at 128 Hz with a bandwidth between 0.16 Hz to 43 Hz [23]. As a calibration is needed, a series of Stroop Colour-Word Test is given as the stimuli to evoke different levels of workload and the EEG data are recorded at the same time. Together with the data

obtained during performing of the ATC tasks, these two sets of data are used as the input to the EEG-based mental workload algorithm introduced in Section 2.

3.2.2. Questionnaires

Participants were also required to complete two sets of questionnaires after each task. The first one is NASA-TLX. Besides NASA-TLX questionnaire, we also include one more workload rating which is usually used in the proposed EEG-based system to label EEG data (ranges from 1 to 9 for low to high workload).

4. Results

In our previous study [24], we showed that results of the method used for labeling of the EEG data with workload levels is significantly correlated with NASA-TLX workload ratings results, and the EEG-based workload evaluation is reliable to be used in the recognition of workload level in the ATC tasks. In this paper, we continue the analysis using the continuous workload levels recognized from EEG.

For real-time continuous workload analysis, three levels of workload were used for a trade-off between higher accuracy and wider spread of the mean. The three levels of EEG-based recognized workload for each of the one-hour session was split into the interval of 5 minutes with an average taken for each 5 minutes interval.

We first apply mixed ANOVA test to the collected data, where "time" is the within-subjects factor, display mode and CRA conditions are the between-subjects factor. The results are given in Table 1. The factor of time ($p= 0.025$) and the interaction between time and display mode ($p= 0.04$) were significant (both p values < 0.05 as shown in Table 1). It can be concluded that ignoring the CRA setting and display mode, the workload values measured through the 12 time intervals are significantly different. Likewise, ignoring the CRA setting, the effect of display modes on workload is significantly different for different time intervals. The focus will be placed on the analysis of the effects of automation aids on workload at different time intervals. To analyse the effects of automation aids on workload, the mean and standard error of the workload measured for different time intervals are shown in Figure 1, for display modes and time intervals are shown in Figure 2, and for CRA settings and time intervals are plotted in Figure 3.

Table 1. Mixed ANOVA test for within-subjects effect analysis.

Factors	**F**	**p**
Time	3.493	0.025*
Display Mode * Time	2.438	0.04*
CRA * Time	1.914	0.083**

*Significant at α =0.05; **Significant at α =0.1

In the red box of Figure 1, it can be observed that the mean workload is relatively high at the start of the session and from the 20th minute to the 45th minute. The significance value obtained from the mixed ANOVA test for time factor is 0.025, which means that ignoring the CRA setting and display mode, the workloads measured through the 12 time intervals are significantly different. The workload was highest in

the middle of the simulation task. This finding could be due to higher number of aircraft after ramp-up period. Afterward, however, the workload was getting lower along the time as ATCOs became more familiar with the aircraft and airspace structure.

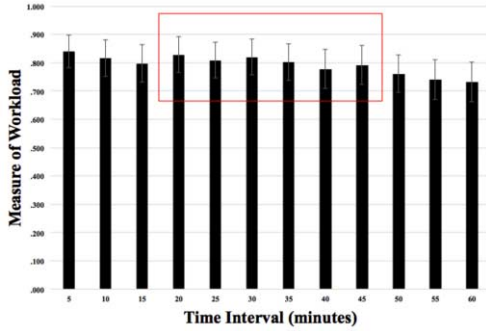


Figure 1. Measure of workload ignoring the CRA setting and display mode in 12 time intervals.

In the red box of Figure 2, it can be observed that the mean workload measured is the highest under the trajectory prediction and similar for the display and non-display mode. It can be associated with the information overload in the trajectory prediction where ATCOs also need time and effort in interpreting the complete information regarding aircraft status.

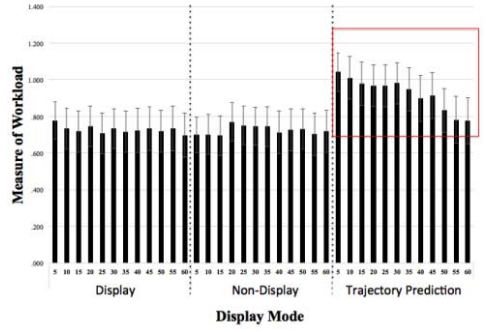


Figure 2. Measure of workload based on display mode Non-Display (ND), Display (D), and Trajectory Prediction (TP) in 12 time intervals.

In Figure 3, the mean workload obtained from the interaction between CRA setting and time intervals similar to the trend observed in Figure 1 except that the mean workload at the start of the unreliable CRA setting is relatively low, as shown in red box of Figure 3. In addition, no physiological workload difference was observed across different CRA conditions, indicating that the CRA brings neither benefit nor cost on ATCOs' physiological workload. In [25], lower objective workload as indicated by shorter ready response latency in SPAM was found under the CRA conditions as compared to manual condition. Here, the results of our physiological-based workload measurement contradict to this finding in [25]. However, the subjective workload was not statistically different across the CRA conditions in [25], which is consistent with our EEG-based results. We can infer that the physiological workload was in line with the subjective workload but not with the objective workload. This fact deserves further investigation on different workload measurement methods.

EEG-based workload evaluation method includes the continuous measurement of a subject's workload, which allows a more detailed analysis of experiment results

obtained. From the current ATC study, it could be found that the complexity of trajectory prediction has resulted in a higher workload compared to other display aids in all time points, and the reliability of CRA has minimal effect on workload. Therefore, the trajectory prediction aid needs to be redesigned to meet the aim of reducing workload experienced by air traffic controllers.

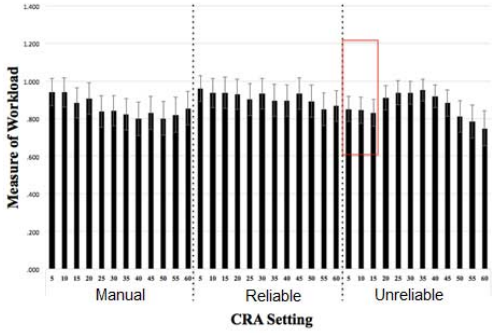


Figure 3. Measure of workload based on the CRA settings Manual, Reliable and Unreliable in 12 time intervals.

5. Conclusion

In this paper, we presented the EEG-based mental workload recognition for human factors study in ATC systems. An experiment was carried out with three display groups and each group completed the ATC tasks in three CRA conditions. We analyzed the continuous workload changes in a 5 minutes interval. It was discovered that the workload was highest in the middle of the simulation tasks. In addition, workload was the highest with the trajectory prediction. This could be due to information overload that was encountered by ATCOs. This opens a possibility to further investigate the provision of the trajectory prediction display given a longer training period to familiarize ATCOs with the new display. Lastly, no physiological workload difference was found across the CRA conditions.

Therefore, by utilizing the proposed EEG-based system, true understanding of ATCOs' working pattern along the time can be obtained. Based on the analyses of the objective recognized brain states together with the subjective feedback from ATCOs, we are able to reliably evaluate current ATC systems and refine new concepts of future ATC system. However, the further analysis between EEG and objective workload measurement methods deserves continuing investigations.

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An Innovative Interface Design and Customized Usability Testing Method: Case Study of Internet of Things Integration Platform Interface

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Abstract. User Interface (UI) plays a critical role to a successful product, since UI provides the first impression to users when they use the product. UI will directly affect the experience of customers, and then influence the satisfaction of the product. Despite an interface includes a large amount of information and complex processes, the current interface design method rarely concerns about the aspects of the process and information capacity. This results in bad accessibility. In addition, the existing usability methods fail to customize criteria for different types of the interface. Therefore, this study proposed an IDEF (ICAM DEFinition Language) based interface design method along with a customized usability test method which is called ANP(Analytic Network Process) to calculate the weights of usability metrics so as to better assess the designed interfaces. A case study of IOT(Internet of Things) platform website UI will be provided to demonstrate the advantage of the proposed method, which can reduce the development time of UI and improve user satisfaction.

Keywords. IDEF, Interface design, ANP, Usability

Introduction

User Interface (UI) plays a critical role to a successful product and significantly affects the usability of the product and different interface designs of service system will make a different impression on users. Therefore, user Interface (UI) not only affects user's satisfaction but also affects the willingness users want to visit again [1]. So the usability test is an indispensable process that can help us examine whether the user interface can provide a good user experience or not.

In order to evaluate whether the interface is good or not, the usability is the important issue. Usability is now widely recognized as critical to the success of an interactive system or product. And Usability inspection has seen increasing use since about 1990 as a way to evaluate user interfaces [2]. But we find that there are also varying definitions across different sets of standards or authors concerning more specific attributes of usability [3]. Some of these definitional sets are summarized in Table 1. This situation will confuse decision makers to select right usability criteria and

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increase communication barriers between coworkers and then we find there are so many different types of the interface, but the existing usability methods fail to customize criteria for them.

However, in this competitive society, the rapid and effective design of a system interface is very important.

So we are not only just pursuing interface's usability but also reducing the time of design. Despite an interface of service system includes a large amount of information and complex processes, the current interface design method rarely concerns about the aspects of the process and information capacity.

Hence, in this study we are discussing an example of one case. We will use the IDEF to build a structure of interface, including the information of all main functions, how to link pages, the input and output on each page, and the support of back-end technology. Finally, we use ANP to calculate the weights of usability metrics so as to better assess the designed interfaces. We hope to use systematic methods to reduce the waste of time in UI designing, communication barriers between coworkers, and improve user satisfaction at the same time. This paper is organized as follows. In section 1, we discuss the interface design, IDEF method and usability testing. Section 2 illustrates the methodology and the framework of this study. A case study of IOT platform website UI will be provided to demonstrate the advantage of the proposed method, are discussed in section 3. Conclusions and potential research issues for future study are given in section 4.

Table 1. Different standard of usability.

Schneiderman (1992)	Nielsen (1993)	ISO 9241-11 (1998)	Constantine & Lockwood (1999)	ISO-9126 (2000)
Speed of performance	Efficiency of use	Efficiency	Efficiency in use	Functionality
	Learnability (Ease of learning)		Learnability	reliability
			Rememberability	effectiveness
Rate of errors by users	Memorability		Reliability in use	usability
	Errors / safety	Satisfaction (Comfort and acceptability of use)	User satisfaction	maintainability
Subjective satisfaction	Satisfaction			portability

1. Literature review

This section introduces the interface design , IDEF, and usability test.

User guidance refers to error messages, alarms, prompts, and labels, as well as to more formal instructional material provided to help guide a user's interaction with a computer. The fundamental objectives of user guidance are to promote efficient system use (i.e., quick and accurate use of full capabilities), with minimal memory load on the user and hence minimal time required to learn system use, and with flexibility for supporting users of different skill levels.[4] A research proposed by Magers (1983) has

demonstrated persuasively that good user guidance for interface design can result in faster task performance, fewer errors, greater user satisfaction, and will permit accomplishment of information handling tasks otherwise impossible for novice users.

User interface design (UI) is the design of user interfaces for machines and software, such as computers, mobile devices, website. The aim of user interface design is to maximize usability and the user experience. So User Interface (UI) plays a critical role to a successful product, since UI provides the first impression to users when they use the product. So when we design the interface, we need to refer some principles to develop a usable interface. Because there are so many kinds of interface, in this section, we divided interfaces into two types, such as large screen(computer website) and small screen(mobile device).In designing the user interface, many related studies have discussed the principles of interface design. Principles make UI design for new applications easier by transferring knowledge and previous experience in a condensed format, but principles are also loaded with implicit assumptions about the nature of the user experience [5]. There are six factors for interface design(1) Conceptual Model (2) Visibility (3) Mapping(4) Affordances and Constraints (5) Feedback(6) Error Recovery (Norman 1988)[6] .The meaning of each of them you can see the table 2. Follow this principles, we can easily develop the usable interface. But these principles are not enough to follow to achieve a more usable interface. And then There are also 10 criteria of interface design have been proposed by Nielsen and Molich 1990 for successful interface. (1) Uses a simple and natural dialog.(2) Speaks the user's language.(3) Minimizes memory load on the user.(4) Is consistent.(5) Provides feedback.(6) Has clearly marked exits.(7) Employs understandable and useful error messages.(8) Prevents user errors.(9) Provides shortcuts for frequent/experienced users.(10) Has useful help and documentation [7]. Though above principles are useful to us to develop a good design, the small screen devices are prevalent today. For this reason, except above principles, we need to consider other factors, including (1)simple look-up (2) Screen size(3) Context (4) Scrolling and click-cost for the small screen interface [8].

By review many studies of interface design, we find there are many principles about user interface, but the current interface design method rarely concerns about the aspects of the process and information capacity. This results in bad accessibility. So we want to integrate the IDEF method and some interface design principles to develop a usable interface with the clear process.

IDEF was created by the United States Air Force and is now being developed by Knowledge Based Systems. IDEF0 is the functional modeling technique. By working backwards along the chain from output to inputs, much data and control can be defined. Thus it can be analyzed and improved . Within IDEF0, main functions are represented by boxes, and there are some arrows representing different meanings, as shown in Figure 1. The boxes represent functions such as activities, actions, processes and operations [9]. IDEF0 provides a means for modelling the functions (activities, actions, processes operations) required by a system or enterprise, and the functional relationships and data (information or objects) that support the integration of those functions [10]. The arrows entering and leaving the boxes on the left and right represent Inputs and Outputs, respectively. Inputs represent elements that are needed to perform the function. Outputs show the data that is produced as a result of the function. The function transforms the inputs into the outputs. Arrows which enter from the top indicate controls, or things which constrain or govern the function. Arrows entering the bottom of the boxes are mechanisms. Mechanisms can be thought of as the person or

device which performs the function. The IDEF0 method is the popular process-modelling on the market and IDEF methods have been widely adapted for software development and manufacturing environment. In the past, no one apply the IDEF to the interface design. This is the first time we use IDEF in interface design. Therefore we wish this method can effectively solve the problem of large information and complex processes, and reduce the develop time.

Table 2. The meaning of six factors for interface design.

Efficiency	The capability of the software product to enable users to expend appropriate amounts of resources in relation to the effectiveness achieved in a specified context of use
Satisfaction	While using a software product, it is a subjective response from users
Productivity	The different level of effectiveness related to resources.
Learnability	The software product enable users to productively use the software product .
Trustfulness	The faithfulness a software product offers to its users
Accessibility	The capability of a software product to be used by persons with some type of disability
Universality	Whether a software product accommodates a diversity of users with different cultural backgrounds
Usefulness	Whether a software product enables users to solve real problems in an acceptable way.
Aesthetics	An immediate pleasurable subjective experience that is directed toward an object and not mediated by intervening reasoning

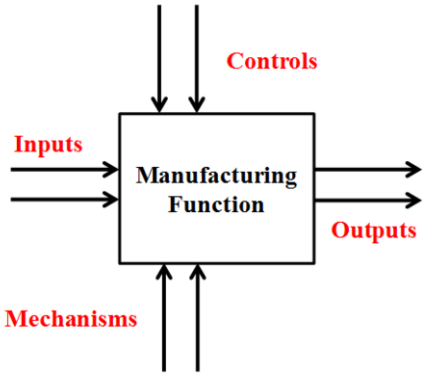


Figure 1. The diagram of IDEF.

Nowdays, aesthetics of visual is a key point to the interface design. Baumgarten 1750 propose the first definition of the term aesthetica [11]. And then Moshagen and Thielsch (2010, p. 690) also provided a definition which describes website aesthetics as "an immediate pleasurable subjective experience that is directed toward an object and not mediated by intervening reasoning" [12]. The influence of aesthetics on perceived

usability has already been addressed in several studies. These studies reported a positive correlation between perceived attractiveness and perceived usability for a range of products, such as computer-simulated cash machines [13]. Other studies relate aesthetics to affordances and user experience. Relations between visual aesthetics and usability indicate the possible need for more detailed design decisions and consideration of applying aesthetics evaluation methods in interface design [14]. Then when we test the usability, we need to consider the aesthetic as the main factor in the usability test.

Now that every product design is focus on it's usability, in the other word, the human-centered design is the most important issue in today's trend [15]. So we need to test the usability of the product in order to improve the usability of a product [16]. For each test, you also have specific goals that articulate when implementing the test. The primary goal of a usability test is to omprove the usability of the product that is being tested. Another goal is to improve the process by which products are designed and developed, so that we can avoid having the same problem again in other design [17]. And then the usability test must have five standard gulidine.

- The primary goal is to improve the usability of a product and we also have more specific goals and concerns that we articulate when planning the test.
- The participants represent real users
- The participants do the real task
- Record and observe what the participants do and say
- Analyze the data we recorded, find the real problem and recommend change to figure out the problem.

First ,we find the participant which can represent the real users [18]. Second , we let participants do some task about our product to collect data we want to analysis. Final, we analyze the data and find the problem to improve the product. However, there are so many different usability criteria to evaluation. This situation will confuse decision makers to select appropriate usability criteria and increase communication barriers. Furthermore, we find the existing usability methods fail to customize criteria for different kinds of the interface. Therefore, this study will provide 9 usability factors among the 10 existing in QUIM model [19] and use ANP to calculate the weights of usability metrics so as to better assess the designed interfaces. The 8 usability factors based on the QUIM model are summarized in Table 3.

Although there are so many interface design guideline, the current interface design method rarely concerns about the aspects of the process and information capacity. In addition, the existing usability methods fail to customize criteria for different types of the interface of the product. So in chapter 3, we will use IDEF to develop the structure of interface and then use ANP to calculate the usability criteria weight for different kinds of interface, such as computer website(large screen) or mobile device(small screen).

2. Method

The aim of this paper is to establish a systemic method to develop the user interface and evaluate the usability, which could develop the user interface through the information flow and select appropriate usability criteria to be tested .The methodology

in this paper is divided into two parts. In phase I, we follow the user interface guideline proposed by Nielsen and Molich and utilize the IDEF method to design the interface. Through the IDEF method ,we can define the major function of the each page and establish the clear structure of the interface. Moreover, we also can realize each input and output of each page by IDEF.

Table 3. The 8 usability factors based on the QUIM model.

Efficiency	The capability of the software product to enable users to expend appropriate amounts of resources in relation to the effectiveness achieved in a specified context of use
Satisfaction	While using a software product, it is a subjective response from users
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Usefulness	Whether a software product enables users to solve real problems in an acceptable way.
Aesthetics	An immediate pleasurable subjective experience that is directed toward an object and not mediated by intervening reasoning

Phase II is appropriate criteria selection. Use ANP to give weight to every usability criteria , and let us realize the priority of these criteria. Then we can know which criteria have priority that we need to evaluated for this product. The structure of methodology is shown in Figure 2.

We will have the case study in section 4, tacking the Internet of Things integration platform interface for example.

2.1. Phase I: Establish the structure of interface by IDEF and follow the guideline of interface design

IDEF0 was developed in order to represent activities or processes (comprising partially ordered sets of activities) that typically are carried out in an organized and standard manner [20].

Before we design the interface, we need to analyze the main function of the interface, in order to realize the whole concept of the interface.

After defining the main functions, the next step is to analyze the flow of each step. The method used is consistent with the analysis of the overall flow chart, is based on IDEF method. The right and left arrows represent the output and input, too. Arrows which enter from the top indicate controls, or things which constrain or govern the function. Arrows entering the bottom of the boxes are mechanisms. Mechanisms can be thought of as the person or device which performs the function.

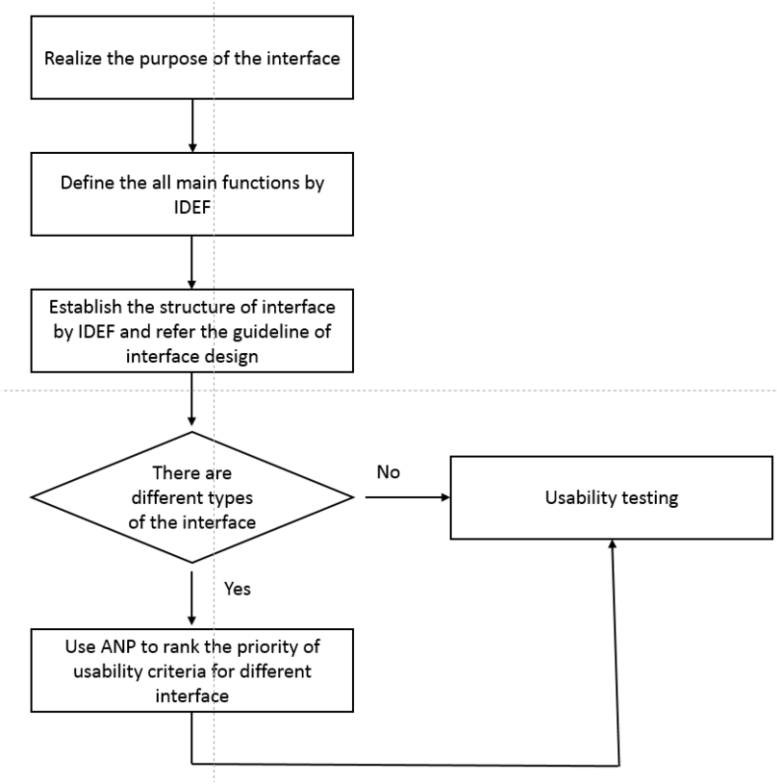


Figure 2. The structure of the methodology.

2.2. Phase 2: ANP (analytic network process)

AHP assumes that there are no correlation and direct influence between each factor in a hierarchical relationship. But there is a more generation approach defined as analytic network process, can be used to evaluate a dynamic relationship among each factors. It allows for the capability to model more complex and dynamic enviroments, enviroments that are more evident at strategic planning levels with are influenced by ever changing external forces [21].

The large number of criteria to be usually evaluated in the interface evaluation makes it very difficult for the evaluators to make an objective, unbiased decision [22]. So we use the ANP to rank the priority of the usability criteria in order to make the good decisions for product.

First, we have to determine the relationship between each criteria. When the arrow A points at B, which means A affects B. On the other hand, when the arrow C points at B and B also points at A, which means B and C affect each other. The diagram was shown in Figure 3.

Step2.1:Without assuming the interdependence among criteria, the decision makers are asked to evaluate all proposed criteria pairwise. They responded questions such as: ‘‘which usability criteria should be emphasized more in our interface, and how much more?’’ To make comparisons, we need a scale of numbers that indicates how many times more important or dominant one element is over another element with

respect to the criterion or property with respect to which they are compared [23]. So the responses were based on Saatys proposed 1–9 scale , where 1 represents indifference between the two criteria and 9 is extremely preferred of the criteria under consideration over the comparison criterion. . Once the pairwise comparisons are completed, the local priority vector w1 is computed as the unique solution to

$$A*w1 = \lambda max*w1 \tag{1}$$

λ_{max} is the largest eigenvalue of pairwise comparison matrix A.

Step2.2: Next step is to consider the effects of the interdependence between the evaluation usability criteria. The decision makers determine the impact of all the criteria on each other by using pairwise comparisons as well. Questions such as: ''which criterion will influence criterion A more: B or C? and how much more?''

(3)The final step is to determine the overall prioritization of the usability criteria of the interface.

The ANP method consists of the following formula:

1. Establish a decision matrix for alternative performance

$$r_{ij} = \frac{f_{ij}}{\sqrt{\sum_{j=1}^{n} f_{ij}^{2}}}, j = 1,....,n : i = 1,...,m. \tag{2}$$

Ai: Denotes the possible alternatives, i = 1,…,m
Fi: Attributes or criteria relating to alternative performance, j = 1,…,n
fij: The performance rating of each alternative Ai with respect to each criterion F

2. Calculate the normalized decision matrix R (=[rij])

$$v_{ij} = w_j r_{ij}, j = 1,...,n : i = 1,...,m, \tag{3}$$

3. Calculate the weighted normalized decision matrix by multiplying the normalized decision matrix by its associated weights.

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_i \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccccc} F_1 & F_2 & \cdots & F_j & \cdots & F_n \end{array} \\ \begin{bmatrix} f_{11} & f_{12} & \cdots & f_{1j} & \cdots & f_{1n} \\ f_{21} & f_{22} & \cdots & f_{2j} & \cdots & f_{2n} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ f_{i1} & f_{i2} & \cdots & f_{ij} & \cdots & f_{in} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ f_{m1} & f_{m2} & \cdots & f_{mj} & \cdots & f_{mn} \end{bmatrix} \end{array} \tag{4}$$

3. Case study

The case study of this paper is take IOT platform for example.

3.1. Build the structure of IOT platform.

This platform includes maker, engineer, and manufacturer. Maker is someone who needs manufacturing service can quickly find the manufacturing resources on this platform. Furthermore, if maker want to find some partner to cooperate, he can find the engineer on the platform.

Consider all main function of the IOT platform. In this part, the left arrow represent the input and the right arrow represent the output. The other arrows represent the all function we need in the interface. A diagram was shown in Figure 3.

After realize all main function of the interface, we need to analyze the flow of each step. The method used is consistent with the analysis of the overall flow chart, is based on IDEF method. A diagram was shown in Figure 4.

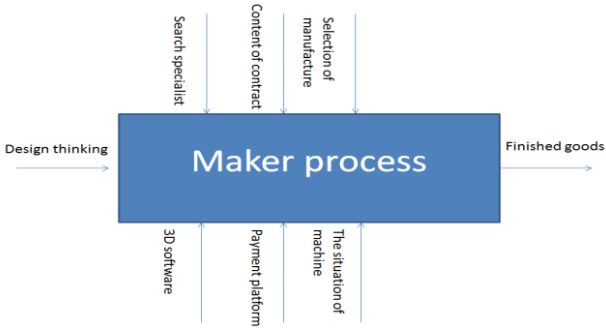


Figure 3. The all main functions of interface by IDEF.

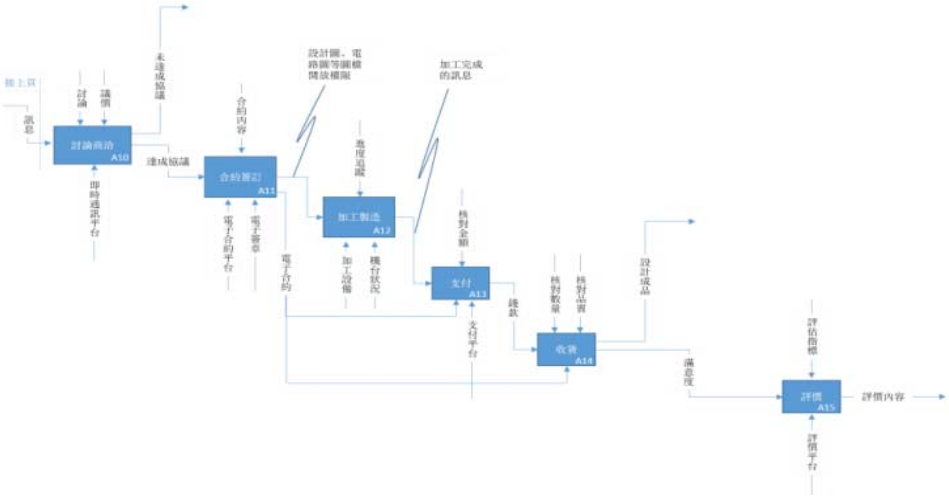


Figure 4. The structure and functions of the interface.

In this step, we consider the 10 interface guideline which are proposed by Nielsen and Molich (1990) and also refer the structure of interface developed by IDEF in order to make a more usable interface.

1. In each interface, we consist to the use the simple dialog, to avoid excessive information increase user's psychological burden.
2. The colors, icons, of the each page are consistent so that users can quickly accustomed to the operation of each page, and do not spend more attention to adapt to the new page.
3. Avoid to use too much text. We use the different color to represent the different of meanings.
4. We also provide the process navigation. This design not only tell you the correct process but also if you want to back to a step, just click the icon which can give you the feedback like the color will change. This design can prevent the user error.

3.2. Use the ANP to calculate the usability criteria of different kinds of interface.

Because the mobile devices is popular today, we have two version of the interface, computer website and mobile devices. Because the monitors of the mobile devices are tiny, the way to design a mobile interface is different from designing a PC monitor and the main goal of different interface is different, too. For this reason, the usability criteria of different types of interface we considered will be different. However, existing usability methods fail to customize criteria for different types of the interface. So we take the interface of computer website and interface of mobile device for example, using the ANP to count the weight of usability criteria of different kinds of interface to let decision makers know the priority of these usability criteria and utilize the consistence index(C.I) to check whether our logistic is reasonable or not. The following is the detail of the process of the ANP method and you can see the result on the Table 4.

- Step 1: The team members were asked to evaluate all proposed criteria pairwise without interdependence among them
- Step 2: Analyzed the dependence among the selection criteria..
- Step 3: The relative importance of the criteria considering interdependence now can be obtained by synthesizing the results from Steps 1 and 2
- Step 4: Team members were asked to establish the decision matrix by comparing candidates under each of the criteria separately.

From the results, we can clearly realize that different types of interface will have different priority of usability criteria, such as computer website or APP. The comparison diagram was shown in Figure 4.

In this case study, we can find satisfaction is more important in the website interface than mobile interface. In addition, from the results, we can find that the interface of website is focus on the satisfaction, learnability, and usefulness and the interface of mobile is focus on the learnability, efficiency and usefulness and accessibility.

3.3. Discussion

Through the IDEF, we clearly realize the all resources of the interface and the completed structure of the interface. This results can help us realize what is we must focus on and reduce the time of development. In addition, through the Figure 5, we easily find the weight of usability criteria will be different in different kinds of interface. Hence, we utilize the ANP to solve this problem to let decision makers know the priority of these criteria. However, this systemic method has not been validated, we can't know whether this method is more effective or not. In the future research, we will test the usability of these interfaces to compare the difference with other interface design methods.

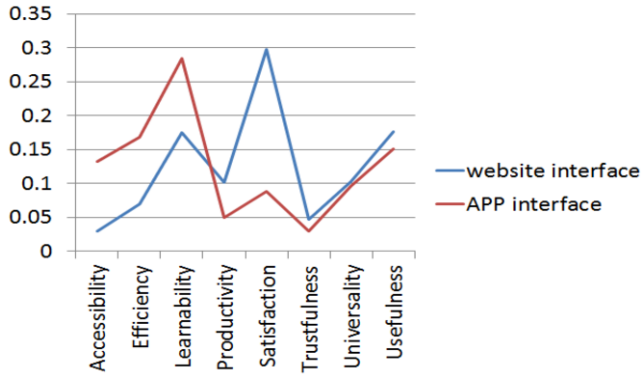


Figure 5. The comparison between website interface and APP interface.

Table 4. The consistence index(C.I) of different types interface.

Interface	Consistence index
Mobile interface	C.I = 0.02648(<0.1 is acceptable)
Website interface	C.I = 0.07034(<0.1 is acceptable)

4. Conclusion

Nowadays, many platforms have a great deal of complex information. To these kind of platforms, we use IDEF to arrange the process architecture and the main function of each interface before starting designing interfaces. Analyzing those described above to design interface in a clearer and more efficient way. Furthermore, we can find what message functions the users care about the most in this interface through IDEF. Then, complete the interface design with usability guideline, for example, in the design of computer website, they add process navigate so as to reduce website users' learnability. Due to the popularity of mobile phones, interfaces are divided into two parts, web version and mobile version. We use ANP to count the weights of usability criteria of different kinds of interfaces, so let the makers decide the order of different interface usability criteria. Through IDEF and ANP with systematic method of interface design principle, we hope to reach customer satisfaction, enhance development efficiency, and increase customized interface usability evaluation.

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The Effect of Insole Padding System on Muscle Activity, Plantar Pressure and Subjective Responses

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Abstract. The purpose of this study was to evaluate the immediate effect of the three insoles including general flat insole (G), ergo-insole (E) and insole padding system (IPS). Fifteen healthy females participated in this study. The response measurements included muscle activity, foot plantar pressure, subjective discomfort, and overall preference rating. One-way ANOVA was conducted to evaluate the insole effect on the response measurements. The results showed that no significant differences between the three insoles were obtained in the four muscle activities of a leg. It means that using the IPS insole would not lead to the higher muscular load or cause fatigue of lower extremities. Significant differences among the three insoles were found in plantar pressures and the results indicated that the lower pressures were obtained in the area of 2nd – 5th metatarsal, midfoot and heel region when walking with IPS insole. For subjective discomfort rating results, significant discomfort was found in the arch and midfoot area while wearing E and IPS insoles. Nevertheless, wearing E and IPS insoles had better performance on overall subjective preference rating. The results of this study could be a consideration to improve the design of the insoles. Moreover, the findings suggest that walking with IPS insole might enhance the usage of toes in order to improve walking performance without any discomfort in toes and leg fatigue in a short time.

Keywords. Insole padding system, plantar pressure, product evaluation, human factors

Introduction

Many foot problems, including plantar fasciitis, corns or chronic pain, are caused by ill-fitting shoes, high plantar pressure or prolonged standing at work. Providing comfortable, functional or proper insole is essential in decreasing discomfort and fatigue in the lower limbs [1].

Most studies have been conducted on investigating the effects of different exterior parameters, for example material [2, 3], hardness [4], thickness [5] or size [6], of

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insoles on plantar pressure distribution, contact area, reaction force, muscle activity and join motion. Generally, applying different characteristics, especially material, of the insole in different regions can increase wearing comfort and performance, and redistribute the foot plantar pressure evenly [5]. In addition, various functions of heel cup [7, 8], arch support [9, 10], metatarsal support [11] and heel cushion [12, 13] of insole designs were proposed to increase the fit and comfort in order to prevent fatigue and foot illness occurrence. Moreover, using functional insole could also enhance the performances in sports [14, 15]. On the other hand, small pads were used for the specific region, such as metatarsal or heel, could facilitate comfort, pressure reduction, slip prevention or hygiene problem. Studies reported that using heel pad or metatarsal pad could provide lower plantar pressures, thereby increase comfort [16, 17].

In recent years, insole padding systems (IPS) have been developing to improve gait performances in order to provide orthotics for foot problems. The IPS are more complicated and have a specific process to develop an insole. Miyamoto and Sasaki [18] reported a case study on reducing foot plantar pain of a girl with congenital foot deformity after using the IPS insole in 41 weeks. Shimizu et al. [19] evaluated the short-term effect of arch support of the IPS insole on improving hallux valgus deformity and reported that angle of hallux valgus was decreased from 29.7° to 26.4° after 3 months treatments. Additionally, the long-term effect on hallux valgus angle reduction by using the IPS insole was confirmed by a four-year follow-up survey with 572 subjects [20].

However, the effect of IPS insoles have been investigated through clinical surveys and reported in their own languages, for example in Japanese or German. The evaluation of IPS insole effect is still rare in the field of biomechanics. Thus, it is interesting to compare the insole effect between IPS insole and other commercially available or well-designed insoles on muscle activity, plantar pressure distribution and subjective measurements.

1. Method

1.1. Subjects

Fifteen healthy female students were paid to participate in this study. They were 23.6 ± 4.0 years old, 158.3 ± 4.5 cm in height and 49.5 ± 4.9 kg in body weight. All subjects were selected without any musculoskeletal disorders and without any pain or medical conditions affecting their lower extremity or discomfort problem. Each subject signed the informed consent before the study.

1.2. Experimental design

Experiment with the single factor in the completely randomized design was conducted to collected data. The independent variable was the insoles. The muscle activities, plantar pressures and subjective responses were selected as dependent variables.

The three insoles used in this study were general flat insole (G), Ergo-insole (E) and commercially available IPS insole. The characteristics of the three insoles are illustrated in Table 1. The G insole was a normal flat insole without any design, provided by general footwear retailers when buying new shoes. The E insole had arch support and heel cup design based on human foot characteristics with lower pressure

and lower discomfort rating performances developed and evaluated by Lee et al. [21]. The IPS was developed by NPO Orthotics Society of Japan based on Dynamic Move Control System (DYMOCO). The main concept of DYMOCO is to attach different shape and size pads (thickness: 1-3 mm) to the bottom of an insole to correct walking posture, keep walking balance (gait stability) and prevent foot problem according to walking behavior diagnosis of each person. In fact, using the IPS to create an insole for users may not be easy due to the specific knowledge and professional experience requirement. To deal with this limitation, one special-designed pad was proposed, named DYMOCO business full insole, to simply use for general users (as shown in Table 1). The only thing needs to do was to attach a full pad along the edge of the bottom of insole before placing the insole into shoes. In addition, in order to simulate prolonged standing worker, such as nurses, three different insoles were placed in a professional nurse footwear for evaluation. The footwear (M&G, C-080670), which had better performances with low foot pressure distribution, impact force and better shin and ankle comfort reported by Chiu and Wang [22], was used in this study.

Table 1. A comparison between the three insoles evaluated in the study.

Nursing shoes	General flat insole (G)	Ergo-insole (E)	DYMOCO insole padding system (IPS)
			
Material	PU	PU	PU
Weight	20 g	53 g	30 g
Thickness	2 mm	4.6 – 7 mm	2 + 3 mm
Arch support	No	Yes	Arch pad
Height of arch support	No	27.0 mm	3 mm
Heel cushion	No	Yes	Heel pad
Heel cup	2 mm	10.9 – 21.3 mm	2 + 1 mm

An electromyography (EMG), an insole pressure sensor and the Borg CR-10 rating scale were used to collect measurements as dependent variables. For EMG measurements, the NeXus-10 system (Mind Media BV, Roermond-Herten, Netherlands) was applied to measure muscle activities from the four muscles. Plantar pressure data were measured by using an inserting insole pressure system (Hong-Zam, Taiwan). Seven zones of plantar pressure were measured including the hallux, 2^{nd} - 5^{th} phalanges, 1^{st} metatarsal, 2^{nd} - 3^{rd} metatarsal, 4^{th} - 5^{th} metatarsal, midfoot and heel zones. The mean peak pressure of each zone was recorded and analyzed. Moreover, a discomfort rating scale was applied to assess the discomfort level of the feet and plantar areas determined by Borg CR-10 rating scale while scoring 10 for “very uncomfortable” and 0 for “no discomfort”. Besides, subjective overall preference ratings of each insole were recorded.

1.3. Procedure

Before the evaluation experiment, the three insoles were randomly assigned and then inserted into the experiment footwear before wearing. For measuring the MVC and muscle activity, subjects were instrumented with four pairs of disposable electrodes placed on the muscle belly of the four muscles including the rectus femoris, tibialis anterior, biceps femoris and medial gastrocnemius. Subsequently, all participants walked on a treadmill for 10 min with walking speed at 3 km/hr at beginning, in order to simulate working condition and familiarize with each insole. After walking, the subjects were asked to walk and turn back on a walkway (length: 8 m, width: 1.2 m) under the same walking speed. The EMG of the four muscle groups and plantar pressure were collected when subjects walked through the center of the walkway. Each condition was repeated five times. After collecting objective data, at least 10 min was given to each subject for completing a subjective discomfort/preference rating questionnaire and resting.

1.4. Statistical analysis

Statistical comparisons were made by using one-way ANOVA (alpha = 0.05). The insole effect was determined on the subjective and objective measurements collected in the study. Duncan's multiple range tests were applied for post-hoc testing of significant main effects.

2. Results & Discussions

2.1. Muscle activity

Table 2 indicates that no significant difference on muscle activity of rectus femoris ($F = 0.72$, $p = 0.53$), tibialis anterior ($F = 1.11$, $p = 0.39$), biceps femoris ($F = 0.83$, $p = 0.44$) and medial gastrocnemius ($F = 1.53$, $p = 0.23$) was found. For no significant difference was found in the four muscles, such an explanation may account for the walking time. For time limitation, all subjects were asked to perform only 10 min walking on a treadmill. Then, subjects started to walk straight on a walkway and the EMG data was recorded at the same time. The experiment in this study took about 15 min for each insole condition from warm up walking to 3 times of data collection. It means that the insole effect on muscle activity may be not effectively reflected in a short time. However, the findings here are congruent with those reported for no significant insole effect on muscle activities in previous studies [21, 23].

2.2. Plantar pressure

The insole effect was significantly different from plantar pressures in the seven selected zones (see Table 2). According to Duncan's MRT results, walking with G insole showed the highest plantar pressure in 1st metatarsal, 2nd – 5th metatarsal, midfoot and heel zones than walking with the other selected insoles. This is in agreement with the fact that the higher plantar pressure was generated by walking with flat insole [24, 25]. In addition, walking with E insole has the lowest plantar pressure in the all selected

plantar pressure zones. Kato et al. [26] reported that the use of customized insole could generate a reduction of foot pressures. Characteristics of the E insole design based on the human foot, such as foot dimensions, features and arch shape. Thus, the E insole can be seen as one kind of customized insole. This can be a reason to explain that the E insole has the lowest plantar pressure comparing with G and IPS insole.

In addition, walking with IPS insole had the relatively lower pressure in 2^{nd} – 3^{rd} metatarsal, 4^{th} – 5^{th} metatarsal, midfoot and heel zone. The pad attached on IPS insole has arch support and heel cup design. Using insole with adequate arch support design can decrease pressure in forefoot zone [27] and one with heel cup design can reduce pressure in heel zone [7]. The result implies that the arch support and heel cup design of IPS insole provided greater contact area to disperse the pressure in midfoot and heel pressure, compared to the G insole without arch support and heel cup design. It is interesting to note that the largest pressure in Hallux and 2^{nd} – 5^{th} phalanges zones were obtained when wearing IPS insole. The definition of pressure is the force applied uniformly to a unit area of a surface (e.g. Nt/cm^2). Therefore, pressure and force are directly proportional. It means that wearing the IPS insole lead to Hallux and 2^{nd} – 5^{th} phalanges perform more strength while walking. In addition, the concept of DYMOCO design is a method to attach various pads to the bottom of the insole in order to improve the walking posture and balance through increased the usage of toes. The results of this study support the DYMOCO concept as well.

Table 2. The ANOVA results for three different insoles on selected measurements.

Measurements	df	F-ratio	Probability of significance
EMG (muscle activity, %)			
Rectus femoris	2	0.72	0.53
Biceps femoris	2	0.83	0.44
Tibialis anterior	2	1.11	0.39
Medial gastrocnemius	2	1.53	0.23
Plantar pressure (N/cm^2)			
Hallux	2	4.41	0.01*
2^{nd} – 5^{th} phalanges	2	6.64	0.00*
1^{st} metatarsal	2	3.61	0.03*
2^{nd} – 3^{rd} metatarsals	2	3.46	0.03*
4^{th} –5^{th} metatarsals	2	5.35	0.00*
Midfoot	2	11.84	0.00*
Heel	2	5.41	0.00*

* Significance level at $p < 0.05$

2.3. Subjective response

Table 3 shows that the insole effect was significant on the subjective discomfort ratings in the arch and midfoot regions ($p < 0.05$). Wearing IPS insole has the higher discomfort rating in the arch (2.20) and heel (1.90) compared with G and E insole. The scores are categorized in "slightly discomfort" level. It was probably due to that the subjects were requested to walk with the insole with specific arch support pad, which was very different from walking with conventional insoles in daily life. The discomfort feeling might be decreased by increase wearing time. However, only the immediate effect of the insoles was evaluated in this study; further research should be undertaken to evaluate the long-term effect on subjective responses. In addition, the overall subjective preference ratings of the three insoles were analyzed. The significant

difference was obtained in the measurement (see Table 3). The E and IPS insoles had higher preference rating score (E insole with 6.47 and IPS insole with 5.53) than the rating score of G insole (3.73). Although the E and IPS insoles had significantly higher discomfort in the midfoot and arch region, most subjects still reported higher preference ratings of E and IPS insoles. The result reveals that subjects were more willing to wear the insole with specific designs more than general flat insole.

Overall, walking with IPS insole generated higher pressure in toes region, but it would not lead to any subjective discomfort. It means that wearing IPS insole for walking can increase the usage of toe without any subjective discomfort and low limbs fatigue. It should be noticed that walking with IPS insole could reduce the plantar pressure of midfoot and metatarsal zones due to the arch support design, but the subjects reported high discomfort rating in the arch and midfoot region. It might due to the inadequate fit in the arch support design for Taiwanese subjects because IPS insole was originally developed for Japanese population. Lee et al. [28] suggested that Taiwanese female's foot shape and dimensions had significant differences with Japanese females. If the arch support can be redesigned according to the subjects' foot morphology, the level of foot comfort and fit will improve.

Table 3. The ANOVA results of subjective discomfort rating.

	Ankle	Hindfoot	Instep	Forefoot	Hallux	$2^{nd} - 5^{th}$ phalanges	Metatarsal	Arch	Midfoot	Heel	Overall preference rating
G	0.57	0.60	0.47	0.20	0.23	0.23	0.60	0.77 A[#]	0.50 A	1.20	3.73 A
E	0.20	0.27	0.37	0.17	0.33	0.10	0.77	1.93 B	0.87 A	1.67	6.47 B
IPS	0.27	0.47	0.30	0.07	0.07	0.07	0.27	2.20 B	1.90 B	1.10	5.53 B
p-value	NS	NS	NS	NS	NS	NS	NS	*	*	NS	***

[#]: Duncan's post-hoc test; *: $p < 0.05$; NS: non-significant

2.4. Limitation

It is noted that there are some limitations in this study. The first limitation concerns the sample size was relatively small and only female subjects were recruited. Due to this reason, it might have limited the generalizability and representatively of the results. Moreover, Zhang et al. [29] claimed that wearing improper shoe or insole in daily (8 hr) work lead to the worst working performances due to leg fatigue, discomfort, and foot pains. The second limitation was rooted in the short time allowed for the walking and data collection in each insole condition. It is recognized that only the immediate effect of wearing the insoles was evaluated in this study. Perhaps future research could examine the long-term effect of wearing insole padding system on physiological and psychophysical performances.

3. Conclusions

The specific aim of this study was to understand the physiological and psychophysical differences when wearing the IPS insole and the other commercially available insoles. The findings of this research reveal that wearing IPS insole showed no difference on muscle activities of low extremities, lower plantar pressure but had higher discomfort rating in the arch and midfoot regions, and higher overall preference rating score comparing to G and E insole. Moreover, the result shows that walking with IPS insole

had no difference of muscle activities with general and Ergo-insole and no discomfort reporting in toe areas. It means that the toes could perform more strength when walking with IPS insole without any discomfort and leg fatigue, although the concept of development, the method of usage, and the manufacturing process of IPS insole might be very different from the commercially available insoles. In general, the study provides preliminary evidence on the effect of walking with IPS insole, thereby suggests that IPS insole could take into consideration for improving walking performance. On a more specific basis, these findings can also serve to provide useful information for improving the IPS insole in reducing the discomfort, especially in the arch and midfoot regions. In addition, applying human-centric or emotional design also can be a way to increase the satisfication of users [30, 31].

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A Wearable System Designed for Chinese Traffic Police Based on Gesture Recognition

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Abstract. The body language and gestures of the traffic police can be difficult to identify accurately, especially in China, where there is often fog and haze. Poor judgment and slow recognition will reduce the efficiency of traffic management, and can even cause traffic accidents. To solve this problem, a wearable system has been designed for the traffic police. This wearable system consists of two main parts: a pair of data gloves and a vest with a light-emitting diode (LED) display. The data gloves were utilized to recognize and record the gestures of the traffic police. The gesture signals were converted into traffic instructions and displayed on the vest. The effectiveness of this wearable system was verified through a comparison experiment between only gesture and gesture plus displaying text on the vest. To achieve best effects of recognition, according to the results of further experiment, the simple instructions (stop, move straight, turn left waiting, turn right, and change lane) should be displayed in the form of an image, whereas the complex instructions (turn left, wait, slow down, and pull over) should be displayed in text form.

Keywords. Wearable system, data gloves, vest with LED display, gesture recognition, traffic control, traffic instructions, efficiency of text and image

Introduction

With the increase of car use and car owners, the total fuel consumption of private cars has been increasing [1]. This trend leads to two serious social problems: traffic jams and environmental pollution. In China, the situation is even worse. For example, because the number of cars has long been beyond the amount that Beijing can accommodate, coupled with the bad driving habits of the Chinese, traffic jams happen every day on the main roads of Beijing. In such chaotic traffic situations, the automatic computerized traffic light system cannot control the traffic flow. In most cases, it is necessary for police officers to guide the traffic flow using manual arm and hand gestures. Poor illumination, bad weather, and haze caused by environmental pollution mean that the drivers are unable to read the gestures quickly and correctly. This not only reduces the efficiency of the traffic guiding but can even trigger accidents.

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The Chinese traffic police gesture system, defined and regulated by the Chinese Ministry of Public Security includes eight gestures: stop, move straight on, turn left, turn left waiting, turn right, change lane, slow down, and pull over (see Figure 1) [2]. These gestures look similar and it can be difficult to distinguish between them. To solve this problem, recognizing the gestures and converting them into visual information is a possible method.

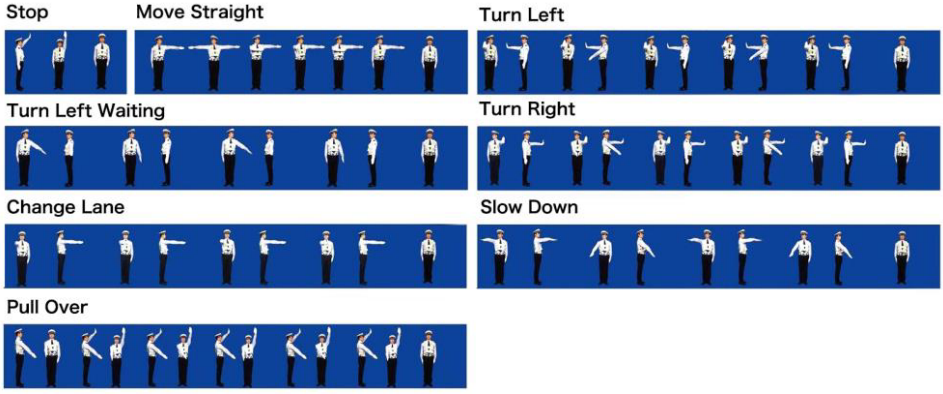


Figure 1. Chinese traffic police gestures.

Two main recognition systems are currently used in gesture recognition: visual gesture recognition and motion gesture recognition. Visual gesture recognition involves using cameras as the input device to obtain a video of the gestures, the frames are then extracted from the video, and then these frames are analyzed [3]. Leap motion and Kinect are the most commonly used equipment for visual recognition [4]. A vision-based system for gesture recognition has also been widely investigated. The gestures of the body are also used as an interactive mechanism between video games and their players. In a study by Kang (2004), ten gestures were successfully recognized and applied as commands [5]. A vision-based writing recognition system was developed to enter words into a computer using the movements of the fingertips [6]. Using cameras as input, visual gesture recognition brings the user's natural interaction without any extra hindrance. However, visual gesture recognition is strongly influenced by background colors and illumination. Its calculation process is complex, and the recognition rate and real-time performance are poor [7].

Motion gesture recognition is based on body sensors, using accelerometers, and gyroscopes to measure the motion and posture of the body. A microelectro mechanical system (MEMS) accelerometer has been widely applied in investigations on gesture recognition [8, 9]. Two typical applications use gloves or remote controllers. A glove with 2-axis accelerometers fixed on each finger could recognize 21 English letters with a 100% recognition rate [10]. Based on the spatial-temporal gestures, the remote controllers with 3-axis accelerometers have been applied for TV controlling and game playing, e.g., Wii (Nintendo). The motion of the hands is recorded using the remote controller and transferred into one-dimensional prototype vectors [11, 12]. This remote controller is used to train and recognize gestures based on the hidden Markov model [12]. These motion gesture recognition systems have a high recognition rate, but the equipment required is relatively expensive [7].

Visual gesture recognition is not suitable for traffic police gesture recognition for two reasons. Firstly, the traffic guidance places have strong motilities and every place

has a different background and illumination. Plus, sometimes because of the influence of the prevailing weather conditions, it is impossible to extract the arm movement and hand posture from the video. Furthermore, it is not convenient for policemen to take cameras everywhere with them and fix the cameras at a certain angle. Secondly, it is impossible to recognize the gestures in real-time, because the process of extracting the movements and postures from the video is complicated. Because of the portability and ease of use, the data glove is the solution that is preferred rather than the remote controller. Therefore, based on the research and analysis above, this paper attempted to propose a feasible system design solution to assist the Chinese traffic police guiding traffic with the recognition of police gestures using data gloves and then transferring the gestures into visual information. Furthermore, the significance of the design solution and which is the most effective form of the visual information: text or image, were verified from the experiments described in this paper.

Wearable system design



Figure 2. Data glove.



Figure 3. Vest with LED display.

A prototype of a wearable system for Chinese traffic police was designed. This prototype contained a pair of data gloves and a vest with a light-emitting diode (LED) display (see Figure 2 and Figure 3). The data gloves were used to collect gesture data, detecting inactivity and motion. A program was compiled to calculate the orientation of two hands and to recognize the gestures. The gesture signals were transmitted to the LED display. This display is embedded on the vest to maintain the uniformity of the traffic guidance actions. Traffic police do not need any additional actions to operate this system. In addition, the safety vest itself is a standard piece of equipment for traffic police. The combination of vest and display completely reduces the burden of the police to have to carry multiple devices. In order to most effectively utilize the display area, 48 × 32 LED lights (33.6 cm × 22.4 cm) were installed on the front of the prototype vest (see Figure 3). This wearable system can be charged from a solar power module fixed on the back of the vest or from a portable source.

Experiment 1: Verification of the effectiveness of the design solution

1. Methodology

To verify the effectiveness of the wearable system for Chinese traffic police based on gesture recognition, a comparison between the normal Chinese traffic police gestures and this design solution was carried out.

The participants of this verification process were 24 Chinese university students (13 male and 11 female, age range 19-25). All participants had a Chinese driver license,

and had not participated in any similar experiment before. Their vision was normal or was corrected to a normal level (wearing glasses). All of them had passed the Ishihara test for colorblindness. Before the experiment started, all the participants were required to read a short introduction about this experiment and sign consent forms. At the end of the experiment, they were given a recompensed for their time. The study was approved both by the Beijing University of Posts and Telecommunications and the Beijing University of Technology.

Two groups of stimuli were employed in this experiment. One group was eight animations of eight Chinese traffic police gestures. The other group was eight animations of Chinese traffic police wearing the designed vest and displaying corresponding traffic instructions in Chinese text while they were making normal control gestures. All the texts were designed in the same font (Dongqing Heiti). Considering of the recognition in different weather conditions and backgrounds, the LED display was a red color (see Figure 4). The duration of each animation is same (1 second). They repeat playing automatically.



Figure 4. Traffic instructions in text displayed on the vest.

This experiment used a driving simulator that provided 130 degree horizontal vision and a vertical view of 40 degrees and could stimulate a virtual environment of driving a car. By adjusting the size of the stimulus, two distances between the traffic police and the car were stimulated: 50 m and 20 m. In order to ensure the accuracy of the experimental results and to eliminate other interference factors, the background of the gestures was set to a white color (see Figure 5). The participants were divided into two groups, and each group consisted of 12 people. One group watched the animations of the normal police gestures, while the other group watched animations of policemen wearing the vest with the LED display.

A timer was started from the beginning of each animation. The participants used a sensitive button (5 ms reaction time) to stop the timer after they had made a decision about the meaning of the animation. The length of time taken to make each decision was recorded in order to make comparisons later. There were five practice sessions before the real experiment. In order to avoid effects from the training and prediction, the eight animations in each group were performed randomly.

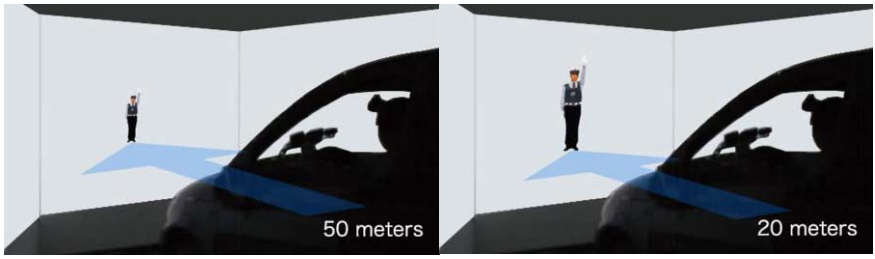


Figure 5. Experimental scenarios used in Experiment 1.

2. Results and discussion

For each situation (50 m and 20 m), a MANOVA analysis was conducted to test the hypothesis that the recognition of police gestures with the Chinese text signals displayed on the vest would take shorter time than the recognition of only police gestures.

1.1. 50 meters

When the distance was 50 m, result for overall time length showed that there was no significant difference between only police gestures and police gestures with displaying text, $F(2, 10) = 3.10$, $p = .13$ (see Figure 6).

These results suggest that the design solution did not have significant effect on the enhancement of the recognition of police gestures when the distance was 50 m. After the experiment, all the results of the participants showed that they were unable to read the texts displayed on the vest. There are two reasons for this. Firstly, because of the limitation of the display area, the text size was not big enough. Secondly, Chinese characters are complicated. From far away, they form into blocks that cannot be recognized. Therefore, this design solution lost its effect. English characters and images might be recognizable at this distance, but, for most Chinese drivers, it is hard to read English. In the next experiment, the effects of images would be examined.

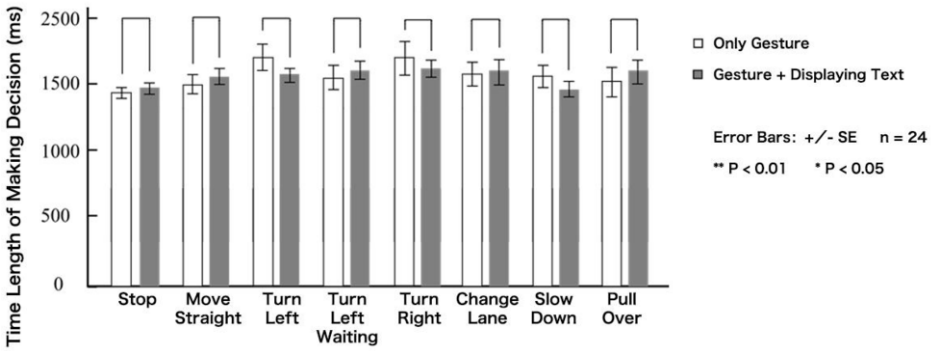


Figure 6. Comparison between only gesture and gesture plus displaying text (Experimental Condition: 50 m).

1.2. 20 meters

When the distance was 20 m, result for overall time length showed that there was significant difference between only police gestures and police gestures with displaying text, $F(5, 215) = 18.22$, $p < .01$. For each dimension of time length, all Maulcy's tests indicated that the sphericity was met. There were significant main effects between only police gestures and police gestures with displaying text in the level of stop $F(1, 43) = 74.98$, $p < .05$, move straight $F(1, 43) = 3.31$, $p < .05$, turn left $F(1, 43) = 7.38$, $p < .05$, turn left waiting $F(1, 43) = 3.96$, $p < .05$, turn right $F(1, 43) = 6.34$, $p < .05$, change lane $F(1, 43) = 51.20$, $p < .05$, slow down $F(1, 43) = 22.17$, $p < .05$, pull over $F(1, 43) = 12.82$, $p < .01$ (see Figure 7).

These results prove that the design solution did have effects on enhancing the recognition of police gestures when the distance was 20 m. The texts helped the participants recognize the police guidances easier and more quickly.

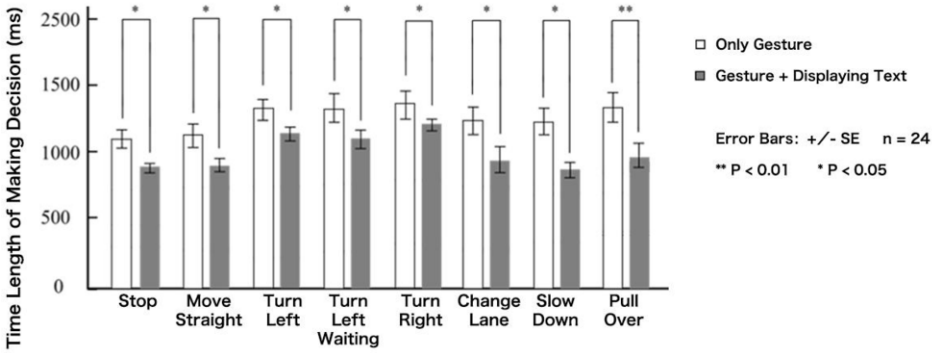


Figure 7. Comparison between only gesture and gesture plus displaying text (Experimental Condition: 20 m).

Experiment 2: Comparison of the effects of text and image displayed on the vest

1. Methodology

To identify which is the most effective form of the traffic instructions displayed on the vest: text or image, a comparison experiment has been implemented.

The participants in Experiment 2 were 24 Chinese university students (12 male and 12 female, age range 19-24). None of the participants had taken part in Experiment 1, but they met all the same requirements as in Experiment 1. This experiment was also approved both by the Beijing University of Posts and Telecommunications and the Beijing University of Technology.

Two groups of stimuli were employed in Experiment 2. Except the traffic instructions in the form of text (see Figure 5), a new group of stimuli with the traffic instructions in the form of image were designed (see Figure 8). All 24 participants watched the eight text stimuli and eight image stimuli randomly at both distances of 50 m and 20 m. The experimental conditions and procedure was the same as that used in Experiment 1. The time taken to make a decision about each traffic instruction was recorded.



Figure 8. Traffic instructions using images displayed on the vest.

2. Results and discussion

For each situation (50 m and 20 m), a MANOVA analysis was conducted to test the hypothesis that the recognition of police gesture with displaying image would take shorter time than the recognition of police gesture with displaying text.

1.1. 50 meters

When the distance was 50 m, result for overall time length showed that there was significant difference between police gesture with displaying text and police gesture with displaying image, $F(5, 235) = 22.42$, $p < .01$. For each dimension of time length, all Maulcy's tests indicated that the sphericity was met. There were significant main effects between police gesture with displaying text and police gesture with displaying image in the level of move straight $F(1, 43) = 15.35$, $p < .05$, turn left $F(1, 43) = 18.27$, $p < .05$, turn right $F(1, 43) = 26.87$, $p < .05$, and change lane $F(1, 43) = 13.47$, $p < .05$ (see Figure 9).

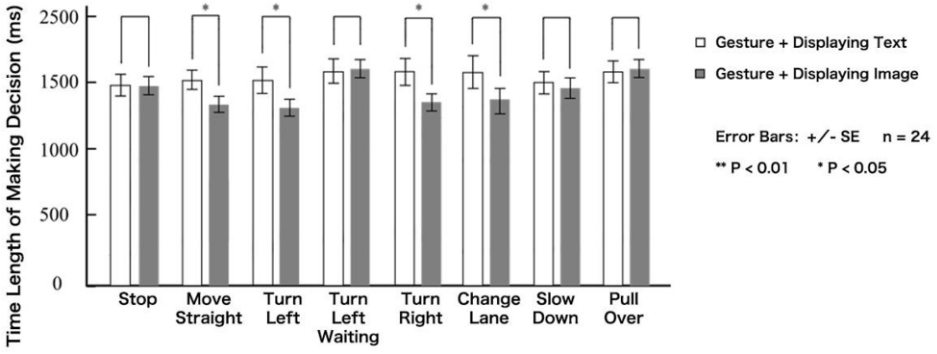


Figure 9. Comparison of the effects of text and image displayed on the vest (Experimental Condition: 50 m).

The images of "move straight", "turn left", "turn right", and "change lane" might be easier to identify than texts at this distance. Therefore, the instructions in the form of images had better effects in enhancing the recognition of police gestures than in the form of text.

1.2. 20 meters

When the distance was 20 m, result for overall time length showed that there was significant difference between police gesture with displaying text and police gesture with displaying image, $F(5, 235) = 14.61$, $p < .05$. For each dimension of time length, all Maulcy's tests indicated that the sphericity was met. There were significant main effects between police gesture with displaying text and police gesture with displaying image in the level of stop $F(1, 43) = 12.92$, $p < .05$, move straight $F(1, 43) = 5.68$, $p < .01$, turn left $F(1, 43) = 20.01$, $p < .05$, turn left waiting $F(1, 43) = 51.16$, $p < .05$, turn right $F(1, 43) = 21.87$, $p < .05$, change lane $F(5, 235) = 28.67$, $p < .05$, slow down $F(1, 43) = 27.17$, $p < .05$, pull over $F(1, 43) = 19.82$, $p < .05$ (see Figure 10).

The results revealed that, when the distance was 20 m, the simple instructions (stop, move straight, turn left, turn right, and change lane) in the form of an image could be more easily identified, whereas the complex instructions (turn left waiting, slow down, and pull over) had better recognition effects when they were in the form of text.

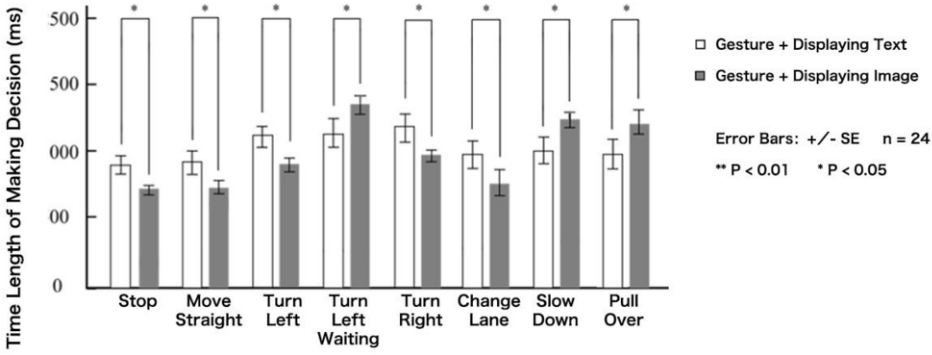


Figure 10. Comparison of the effects of text and image displayed on the vest (Experimental Condition: 20 m).

Conclusion

In this research, a wearable system was designed for traffic police to solve the problem of the fact that police gestures are hard to identify. This system contained a pair of data gloves and a vest with an LED display. The data gloves were employed to recognize police gestures and then these were translated into instructions that were dispalyed on the vest. By a comparison with normal police gestures, the effectiveness of the design solution was proved. Furthermore, an experiment was implemented to identify which form of the traffic instructions displayed on the vest was the most effective: text or image. The results revealed that the simple instructions (stop, move straight, turn left, turn right, and change lane) should be displayed in the form of

images, whereas the complex instructions (turn left waiting, slow down, and pull over) should be displayed in the form of texts.

This wearable system is only a prototype and it has many deficiencies. Because of cost, the display was fitted with LED lights, however, there might be a better display device that could provide clearer visual effects. In these experiments, all the texts displayed on the vest were in one font. The effects of using different fonts will be examined in next part of the study. In addition, the effects of different display colors influencing the decision about police gestures in different weather conditions, time periods, and backgrounds will also be examined in the future. It is uncertain at present whether the red color is the best one to use.

The results obtained using this wearable system completely agree with the traffic police gestures being tested without need for any additional operations and in this way, a good user experience was achieved. Although, translating the gestures into visual instructions is only a basic application in gesture interaction, it was a reasonable solution to the actual problem. This wearable system can assist the Chinese traffic police in guiding the traffic, by enhancing their efficiency, and it will reduce the rate of accidents. This innovative design has a strong practical significance, and provides a new possibility for related design research.

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Real Time Bio Signal Interface for Visual Monitoring of Radar Controllers

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Abstract. A projection of annual increase in air traffic of 4% to 2020 will exceed current capacities within a decade. Air traffic controllers are greatly challenged to handle this growth in air traffic on present approaches. Automation aids via new technologies and procedures are being developed to assist controllers to better monitor the air traffic and make decisions accordingly. Even so, air traffic controllers may still lose their situational awareness by failing to observe the appropriate flight parameters or data within the tactical control timeframe. Such problems are further compounded owing to the fatigue of controllers in an increasingly forseeable congested airspace. This paper presents a proposed approach via a real-time bio-signal interface of radar controllers, where their visual monitoring behaviour and mental workload is captured during tactical control. These data are then processed and converted into eye tracking metrics and Electroenchepahogram (EEG) workload levels which serve to guide and alert controllers on their active monitoring engagement with the traffic situations on display. Preliminary tests revealed that the approach is able to time stamp, track and replay the eye movement location accurately to within 0.5 degree angular deviation on 2K monitor display while assessing the mental workload during every second of operation. On number of eye fixation counts, gaze duration and EEG workload levels, noticeable difference in their monitoring behaviour when dealing with varying traffic flow at crossings could be observed.

Keywords. Air Traffic Controllers, Situation Awareness, Eye Tracking, EEG, Mental Workload

Introduction

Global air traffic is forecasted to increase by 4% annually to 2020 and projected to exceed current capacities within a decade [1]. Based on existing approaches, it is envisaged that air traffic controllers (ATCos) will not be able to handle traffic at 25% above present traffic level [2]. This is a key challenge, as the performance of ATCos would likely be affected and possibly degraded due to the overload of air traffic, in turn, resulting in safety lapses and incidents [3].

Various technologies and procedures have been proposed for different aspects in Air Traffic Control (ATC) by automating some operations and procedures, dynamic airspace re-sectorisation in pre-tactical about two hours in advance and new short term

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conflict alerts like Tactical Separation Assured Flight Environment (T-SAFE) [3-6]. ATCo roles would also tend towards active monitoring rather than controlling in future [6, 7].

Federal Aviation Administration (FAA) highlighted six aspects of concern influencing operational errors (OE) of ATCOs namely data posting, radar display, communication error, coordination error, position relief briefing and aircraft observation. Majority of the aspects are associated with radar operations. Misidentification and inappropriate use of displayed data were found to be the key contributing factors of OEs involving the radar display [8]. OEs occurred more often during the en-route portion than the terminal manoeuvre area, which could be attributed to the longer flight duration over the entire flight path [9].

Human errors is the main cause of OEs [10]. Further research on radar operations revealed that 95% of human induced OEs are due to skill-based errors (a result of habitual actions associated with individual's attention, memory and/or technique execution) [11]. Deeper human factors investigation shows such errors involves 'no visual detection', 'late visual detection' and 'forgetting previous actions', in the 'planning and radar monitoring' tasks, which relate to the cognitive skills of perception and vigilance, later known as situational awareness (SA) [12, 13]. Thus, efforts to reduce OEs should be focused on the ATCo's SA, in monitoring of radar display. In addition to ATCo's SA, these monitoring tasks are also likely to place great demand on their workload due to its cogntive nature [14]. As a result, it is equally important to study ATCo's monitoring of radar display while relating this to their corresponding workload, as problems associated to the lost of SA, like unawareness or failing to observe the appropriate flight parameters or data, are further compounded owing to the fatigue of ATCos in an increasingly forseeable congested airspace.

1. Approach

This section presents a proposed approach that seeks to provide visual monitoring feedback and guidance, while analysing the changes of ATCos' brain state, for mental workload assessment in their radar execution operations and tasks. Such is done through real-time bio-signal interface of ATCos, as it is able to readily register and measure the appropriateness of ATCos' SA and mental workload in real time, while ensuring that ATCos are aware of their present state without disrupting the natural flow of tasks. The approach composed of four main modules namely the real-time human machine interface input module between ATCos and radar display monitor, information capture model schema, data conversion module for eye tracking metrics and

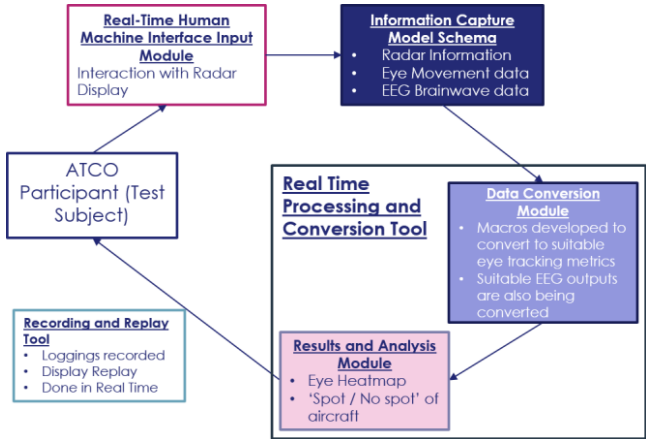


Figure 1. Information flow of the Proposed Approach

Electroencephalogram (EEG) data, as well as results and analysis module that display logging records, eye tracking replay and eye heatmap display. A framework of the proposed approach is seen in Figure 1.

1.1. Real-Time Human Machine Interface Input Module

The interaction activity between the ATCo and the radar display is conducted via an eye tracking device and a wearable EEG device. Eye tracking and EEG brainwave measurement techniques are chosen as the bio-signals as they are the most direct form of measurement for both the visual scanning and mental workload of ATCo on the radar screen via recording the movement of eye balls and brainwave signals [15, 16].

To ensure accurate data and information being captured, several design considerations would need to be made for both the eye tracker and the EEG. Firstly, the physical arrangement of eye tracker and the radar display need to be calibrated to ensure that the output pixel co-ordinate values from the eye tracker and radar display are well aligned. The distance and angular deviation between the participant's eyes to the eye tracker are set at 55 centimeters, with a 0.5 degrees sighting angle.

Secondly, a 3D boundary space is defined in which all eye ball movements of the participant are scanned at a rate of 30Hz so that appropriate amount of eye data can be captured for later data analysis. Measures such as adjusting the sitting position of the participant, checking the head position of the participant at all times are also considered.

Thirdly, the interface module needs to take into account the dynamic traffic flow resulting from the participant's interaction with the radar display like the zooming and panning motion along with the constant position updates of the set of aircrafts. Macros would need to be written by recording and updating initial range and geometric center of the radar display, so that the eye tracking metrics can be registered and matched with these traffic positions in the radar display. On every of such updates, the pixel value captured by the eye tracker in relation to this new traffic picture is being “normalised back” to the equivalent pixel value at its initial state.

Lastly, EEG headset has to be well calibrated in order to capture accurate and valid brainwave signals through the proper channels as such signals are subject dependent. In this project, brain waves are scanned at a rate of 128Hz, with the bandwidthof 0.16 to 43 Hz, to capture such signals wirelessly. The EEG device with 14 channels was mounted on participants’ head. Calibration was then performed to train model of classifier that could result in different workload levels given prior stimuli. Subsequently, the EEG data are recorded according to the different workload levels.

1.2. Information Capture Model Schema

In this module, three different sets of data are captured. One relates to information captured from the radar display which are then processed and converted to pixel information having a geometric centre with range limit values. For the aircraft's track and label position, its pixel values would be based on the distance of the aircraft from the geometric center using the standard haversine formula plus the center pixel value of the screen. The pixel value of the aircraft on the radar display for every update would then be computed taking note of the size and track of the aircraft.

The second set of information involves the remote eye tracker in which the eye movement data is captured according to the format of, 'timestamp, Pixel_X, Pixel_Y,

left_pupil_diameter, right_pupil_diameter'. These data were being captured by the eye tracker at the rate of 30Hz, which would be post-processed.

The third set of information involves the EEG headset, where the different EEG signals are recorded through the available channels of the EEG.

1.3. Data Conversion Module

In this module, eye tracking metrics like overall fixation count, overall gaze duration, and EEG output like mental workload are chosen as dependent variables (observation). These metrics are chosen as they are deemed to be good measures in capturing the visual monitoring behaviour and mental workload of ATCo. The definitions of these metrics are explained in Table 1.

Table 1. Eye Tracking Metrics, Definitions and meanings.

Eye Tracking Metric	Description
Fixation	Eye movements which stabilise the retina over a stationary object of interest > 250 ms [17]
Fixation Count	Count of number of fixation Suitable visual monitoring measure as participants detect cues on the radar screen by fixating on particular spots [18]
Overall Fixation Count	Total fixation counts within the whole radar screen
Fixation Duration	Indicates the amount of processing time needed
Gaze Duration	Sum of all successive fixation duration Measure of difficulty in information processing from participants' processing time in assessing traffic information during visual monitoring [19]
Overall Gaze Duration	Total gaze duration within the whole radar screen

In this work, macros are developed to compute the fixation value in which for every similar Pixel_X and Pixel_Y value in each successive row, Pixel_X and Pixel_Y are being compressed together, while the duration is calculated by taking the difference between timestamp of the first and last row of this same pixel value. If this duration is more than 250 milliseconds and the Pixel_X and Pixel_Y are valid (within the radar display), a fixation count is registered. The corresponding duration of every fixation, known as fixation duration, is also computed. If there is an occurrence of any interaction on the radar display by the participant, the fixation computation would be terminated and a new fixation count is initiated. As zooming and panning actions by the participant is expected to be low, such disruptions are not envisaged to make much impact on the overall fixation counts.ental workload datawere obtained real-time using the EEG-based mental workload recognition algorithm [20]. I already put the ref below).. To do so, EEG data are first filtered. During feature extraction, such statistical feature are extracted using a 4 seconds sliding window with 3 seconds overlapping. These new data features are then sent into the support vector machine (SVM) classifier model trained in calibration, before mental workload is recognised in levels. The workload levels varied from 0 to 3 reflecting low to high mental workload for a time instant of every second, respectively. The mean EEG was used in this, which is actually the average of EEG workload level over a fixed time interval.

1.4. Results and Analysis Module

For analysis, the results of the eye tracking metrics in terms of fixation count and gaze duration are presented, together with the EEG workload levels for every second.

Besides this, an eye heatmap of the participant's fixation count and fixation duration can also be generated with varying colour tones to denote the difference in total fixation count and fixation duration over a pixelated region by superimposing on the radar picture. This module is also able to plot the 'spot / no spot' of aircraft with its callsign over a given time period by matching the area formed by the fixation grouping to the pixel value of the aircraft's track and position on the radar display. If the pixel value from the aircraft's track or label is within the area formed by the fixation grouping, a spot of the aircraft's track or label will be registered accordingly.

2. Concept and Test Validation

2.1. Experimental Setup

To validate the proposed approach, Figure 2 shows the experimental setup that composes of a real-time Air Traffic Control simulator, NARSIM used to generate and simulate various traffic flow scenarios, while the aircrafts and flight paths are displayed on a 2K radar screen display. A remote eye tracker, Tobii X2-30, is used to capture the eye ball movement characteristics of ATCos, while an EEG device, EMOTIV EPOC+, is used for recording of brainwave signals.

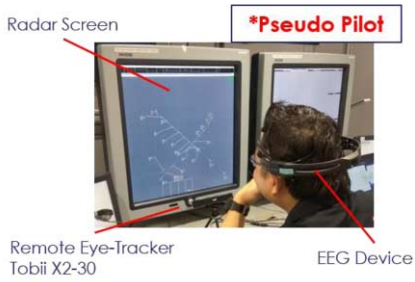


Figure 2. Controller Working Position with equipment required

2.2. Experimental Design

For the test validation, a 1 factor, 2 level experimental design is adopted. The studied factors are 2 (number of crossings: 1, 2) and repeated within subject with 2 replications per participant. There are therefore four 1-hour experimental scenarios conducted for each participant, which each test case running for 15min. All the traffic for the 15min scenarios are flowing in non-conflict situation and has a traffic flow of 1:1. The definitions of each experimental scenarios are described in Table 2. Definition of factors for Experimental Scenarios with their pictorial illustration shown in Figure 3 accordingly.

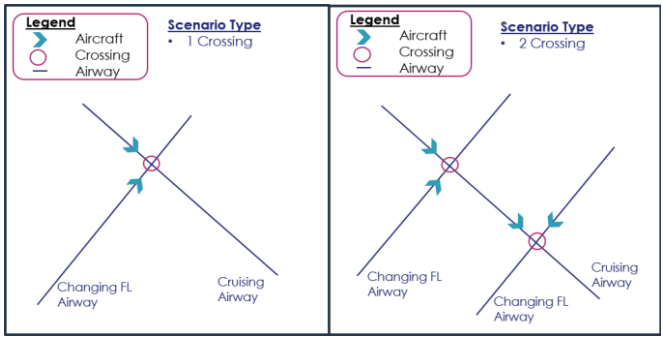


Figure 3. Illustration of Experimental Scenario

Table 2. Definition of factors for Experimental Scenarios.

Factors and Levels	Defintions
1 crossing	1 Crossing = 2 aircraft crossing a waypoint spatially within 10 seconds
2 Simultaneous Crossing	2 crossing = 2 different crossing point on the radar screen Simultaneous = Occurrence of 2 crossing are within 10 seconds of each other
1:1 Traffic Flow	1:1 = every 1 aircraft on cruising airway, 1 aircraft on changing FL airway Trailing aircraft on each airway is 2min behind Total of 7 pairs of aircraft in 15min

3. Discussion of Results

The proposed real-time bio-signal interface approach can successfully capture the eye ball movement characteristics and brainwave signals of ATCos operating on the radar display. Test results on the overall fixation count, overall gaze duration and EEG perceived mental workload levels, in terms of mean were generated in real time for all four experimental scenarios.

In each 15min interval, results comparing the number of crossing of 1:1 non conflicting scenario is seen in Table 3.

Table 3. Test results of 1:1 non-conflicting scenario at the time interval of every crossing for eye metrics and EEG workload levels.

1:1 Non conflicting Scenario		Time Interval of Every Crossing in 15min						
		0 to 2min	2 to 4min	4 to 6min	6 to 8min	8 to 10min	10 to 12min	12 to 14min
1 crossing	Fixation Count	16	23	13	15	7	12	5
	Gaze Duration (ms)	10121	11394	9068	6010	2818	3782	2104
	Mean of EEG Perceived Workload Level	1.15	0.83	0.97	0.94	0.23	0.06	0.06
2 Simultaneous Crossing	Fixation Count	21	9	23	17	5	5	3
	Gaze Duration (ms)	25935	10055	34188	23174	1601	3477	851
	Mean of EEG Perceived Workload Level	1.84	1.81	1.02	1.60	2.12	1.86	1.85

From these results, relationships between eye tracking metrics, EEG perceived mental workload levels with the number of crossing could be derived. This would be discussed in the ensuing sections.

3.1. Relationship between Eye Metrics, EEG Perceived Mental Workload and Number of Crossing

Eye ball movement characteristics, overall fixation count and overall gaze duration, and EEG perceived mental workload were captured for scenarios in 1:1 traffic flow with non-conflict condition for both 1 crossing point and 2 simultaneous crossing points scenarios, which are presented in Table 3.

For an increase in the number of simultaneous crossings from 1 to 2, twice as many aircraft are expected to cross on the radar screen simultaneously. In the first 8 minutes, more fixation counts and a longer gaze duration were registered as additional visual cues and processing of additional information on the radar screen as a reuslt of the 2 crossings were required. This is consistent with the findings of other literature [19, 21].

A similar observation can be seen for the mean value of the EEG perceived mental workload level. More aircraft crossing represents more monitoring and controlling of aircraft on the radar screen, which adds more workload to the ATCos [22]. This affirms that the increase in the number of crossing will cause an increase in the visual monitoring and mental workload of the participants.

3.2. Relationship between Eye Metrics and EEG Perceived Mental Workload

From the observations of eye metrics after the 8min in Table 3, it can be seen that there is a more than 50% decrease in the overall gaze duration as compared to the first 8min for both 1 crossing point and 2 simultaneous crossing point scenario. As for the mean value of EEG perceived mental workload, a similar decrease in mean value is only observed for 1 crossing point scenario.

Such a tampering off in the overall gaze duration likely indicates the limited visual attention spell of the participant at the 8min mark. This similar tamper off for the mean value of the EEG workload level at the 8min mark for 1 crossing point shows the lack of brain activity, which could be signs of boredom [23]. However, this effect is not seen for 2 simultaneous crossing point scenarios. A plausible explanation would be the importance of 2 simultaneous crossing points that is keeping the participants alert, despite the limited visual attention span.

This correlation shows that a longer gaze duration does not necessarily lead to a higher mental workload. A larger brain activity leading to a higher mental workload does not necessarily mean that such a brain activity is solely dedicated to the attention span of the participant to process visual information.

4. Conclusion

A new real-time monitoring approach has been established, involving the development of a bio signal interface with eye tracker and EEG device, that can provide constant feedback to the ATCos. Eye ball movement characteristics and brainwave signals has been successfully captured while the ATCos were performing their tasks with the radar display. Test results on the overall fixation count, overall gaze duration and EEG mental workload levels have been successfully generated in real time under four varying experimental test scenarios.

Based on the test results, the proposed approach highlighted significant differences in visual monitoring behaviours across time, with regards to fixation count, gaze duration and brainwave signals due to increase in number of simultaneous crossing. Furthermore, it also highlighted the differences between gaze duration and brainwave signals, where a longer time spent in visual monitoring does not always equate to a larger brain activity, and vice versa.

Hence, such measures could serve as a useful guide to assess the visual monitoring performance and mental workload of radar controllers, with further studies to be conducted. ATCo work environment could potentially be improved, whereby aids can be developed to help them on instances of overload, should their EEG workload levels be above their regular operational norm.

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Influence of Spatial Information for the Representation of Temporal Order Information

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Abstract. In this age of big data, there is a discrepancy between limited display space on devices and the virtually unlimited information available to the user. This research focused on this contradiction, which we have called "space limitations". This study employs the theories of working memory and cognitive load in two experiments that investigate the consistency of temporal order and space series to seek possible spatial representation methods for dynamic temporal order information. Using the judgments of the relative recency experiment paradigm, this study collected data on working memory performance and eye movement for consistency or inconsistency of temporal order and spatial sequence under two different conditions of system complexity. Data analysis revealed that the information of temporal order and spatial sequence were stored separately in working memory. However, in the complex system conditions, the sequence features of temporal order and spatial sequence were related, and an ordered spatial sequence improved the recall of the temporal order of information. Therefore, to improve cognitive performance, we should consider the orderly arrangement of the spacial position during the process of temporal order information visualization.

Keywords. Big data visualization, Temporal order information, Working memory, Visuospatial sketchpad, Judgments of relative recency

Introduction

In the big data epoch, information visualization interfaces are a unique way for the user to perceive data regardless of the technology used to process the data. Large-scale big data collection is highly relevant to temporal order in the real world. The temporal dimension, so to speak, is a basic descriptive unit of the dynamic real world. The high-dimensional and pluralistic features of data information enable the users to understand complex data and remember through visualization graphics. For issues of the presentation of homogeneous temporal order information, the temporal order of the information could be extracted as metadata［1］, playing a role as the basis of layout dimension for visualization. Parallel displays of temporal order information within a certain period were beneficial for discerning the consistency of information over time and the particular node information. Three representation dimensions, including the two spatial dimensions of the screen plane and a temporal dimension, work together to present temporal order data in high-dimensions. In the era of big data, the principal contradiction of visualization presentation on the screen lies between the extremely limited screen capacity and the virtually unlimited high-dimensional and pluralistic

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information, which we call space limitation. Although a dynamic presentation with a temporal dimension could partially alleviate the problem of space limitation by overlaying the frames, it also creates a new problem related to cognitive load. Furthermore, research [2-4] has shown that dynamic visualizations will create high extraneous cognitive load because during reading the users are not only processing novel information in the present but also simultaneously recalling and integrating important past information, resulting in a decrease of available working memory resources to understand the meaning.

Working memory is the basis for temporary storage and the controlling of complex information that definitely influences human ability to understand [5,6]. Working memory is also a key factor in determining the consequent cognition. Studies have shown that working memory span is highly correlated with learning ability [7,8]. Because working memory span and sustainability is far below the demand of other intellectual human activities, the working memory could be observed as a short board of human understanding. It has been proposed that the representation method that best served working memory performance would significantly improve human perception of large-scale data. To understand the temporal order of information more effectively, we investigated the consistency of temporal order and spatial sequence from the microscopic perspective. More specifically, we are interested whether temporal order and spatial sequence resonates in our working memory and the conditions under which they interact. Also, how do we represent temporal order information with a spatial sequence in a way that is more suitable for human working memory in terms of cognitive load theory?

Being a system with limited capacity for holding and storing transient information, as well as the link to perception, long-term memory and movement, working memory could be a fundamental supporting structure of the thinking process [6]. People always talk about time sing spatial languagem, but most studies have demonstrated that the temporal order and the spatial location information stored are separated in working memory by the judgments of the relative recency paradigm [10,11]. In addition, by allowing users to wander in a virtual city and observing their brain activity in the hippocampus, Ploner and Gaymard [12] have also deemed that the temporal order and spatial location of information are stored separately. Further, people show a significant decline in recalling temporal order with advancing age but maintain a certain level in spatial location memory [13]. Research on damaged memory has indicated that damage to the frontal lobe led to impairment of time-related memory [14] while damage to the temporal lobe led to impairment of spatially related memory [15], further corroborating the separate storage mechanisms on a physiological level.

In contrast, several investigations have shown that the recalling and maintaining of temporal order information in the mind can be interfered with or influenced by other cognitive resources, especially by spatial information [16]. A study on physiological psychology also suggested that temporal order information and spatial information eventually aggregate storage in the hippocampus [17] and that damage to the hippocampus leads to a significant decline in the retrieval of both temporal order and spatial information [18]. A recent study showed that the interaction between temproal order and spatial information is asymmetrically dependent on one another [19]. The possible correlation between them led us to test the possibility of enhancing the memory abilities of temporal order information by spatial sequence.

1. Experiment 1

Based on the working memory model proposed by Baddeley, temporal order information in working memory utilizes the strategies given by central executive command and is conveyed between the two subsystems of phonological loop and the visuospatial sketchpad. To investigate the relationship between temporal order information and visual-spatial display location, we emphasized the subsystem of visuospatial sketchpad and tried to remove the influence of phonological loop. Adopting the paradigm of judgments of relative recency, in this experiment we asked subjects to judge the appearance order of two similar elements. We considered their memory performance of temporal order information, which was related to the working memory span under the specific conditions. In this study, time information was discretized to time steps, equivalent to the concept of frames in an animation. Each frame represented a single time step T(x), and the basic element of the frame also represented the information of the current step. The accuracy and reaction time of judging the order of two elements reflected working memory performance in the specific condition, i.e., cognitive performance.

1.1 Materials

To investigate the effects of concentration on the memory ability of the visuospatial sketchpad, this study also used the non-voice code as the experimental material. The basic elements of each time step were designed as five black circular rings with different opening directions against a white background (Figure 1). The angle between these five circular rings was 72^{o} while avoiding horizontal opening directions at 0^{o}, 90^{o}, 180^{o}, and 270^{o} to make it more difficult for the subjects to convert the visual elements to simple phonological elements (such as up, down, left, and right). Furthermore, the complexity of the visual experimental material contained structural complexity, quantity complexity and path complexity. In this study, the structural complexity of the experimental material was homogenous (the rotator of the same visual elements), and the quantity complexity was equal (presented five elements per trial), so the path complexity, i.e., spatial position in between, is the unique independent variable. One of the important discoveries in Parmentier's study [20] noted the evident impact of path length between the adjacent nodes on the subject performance. Therefore, all the path lengths between the adjacent nodes in this study were designed to be equal. The experimental materials were produced in Adobe Illustrator and Adobe Flash, and the custom software was written in Tobii Studio.

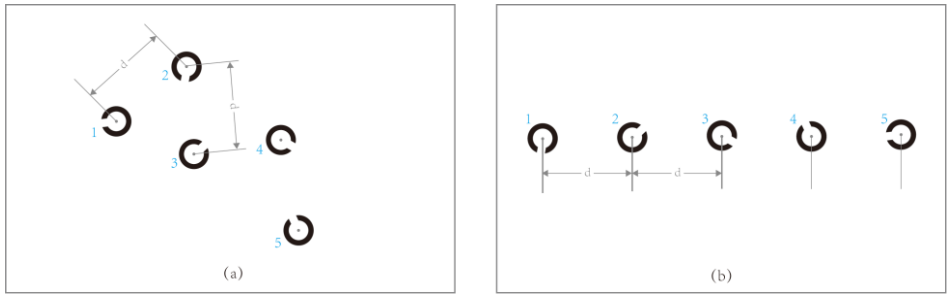


Figure 1. Experimental materials. The number represents the displayed sequence in a trial that was not displayed on the screen. The distance between any two adjacent elements maintained the same d. (1-a): Control group without linear spatial guide; (1-b): Experimental group within linear spatial guide.

1.2 Procedure

The Tobii X2-300 compact non-contact eye tracker was used to collect subjects' eye-tracking data. The effective subjects were 57 graduate students, of which 45 were men, and 12 were women. There were 10 PhD students and 47 Master's students, and they ranged in age from 22 to 33 years. All had normal or corrected-to-normal vision. Before the formal experimental trials, there were three exercise trials to make them familiar with the experimental procedure.

In each trial, the instructions were first displayed on the screen, in which the subject was told about the experimental procedure and how to react (two keys on the left and right sides of the keyboard were assigned corresponding to the two options displayed on the left side and right sides of the screen). The subject was asked to put their forefinger of each hand on the assigned key and press any key when they understood the instructions and began the experiment. Then, a cross was displayed in the center of the screen for 500 ms to encourage fixation. The experimental materials were displayed in six frames with five elements successively appearing after a blank frame. Each frame was displayed briefly for 800 ms. At the end of each trial, a judgment page appeared containing two options of elements that been shown on the prior screen. The subjects were asked to choose the prior or post appearing element and press the corresponding key on the keyboard. The experimental trials were arranged at random and the homogeneous trial design was applied four times. Not counting the 180 exercises trials, there were 480 formal experimental trials in this stage. Figure 2 illustrates the experimental procedure.

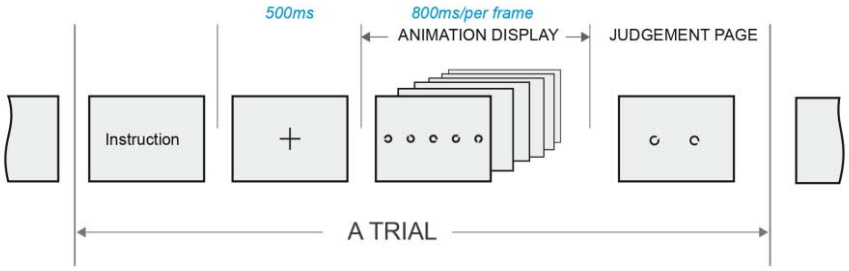


Figure 2. Experimental procedure.

1.3 Results and Discussion

The ability of the visuospatial sketchpad subsystem of working memory played a major role in the experimental results, and the phonological loop subsystem had been restrained as originally intended. The correct rate of recency judgments in the control group (no linear spatial relation) and experimental group (with linear spatial relation) were 80% and 81%, respectively. T-test showed the difference was not significant, t=-0.237, df=454, sig.=0.813>0.05. The reaction time (from the judgment page displayed to the subjects pressing the designated key) difference of the two groups was also insignificant, t=1.310, df=454, sig.=0.191>0.05: the control group had a reaction 3878 ms ± 2698 m compared the experimental group with 3539 ms ± 2567 ms. The results showed that their performance was slightly increased in the linear guide condition,

illustrated by a slight increase in the average correct rate of recency judgments and a slightly decline in the average reaction time. However, this slight increase did not reach the criteria of a statistically significant difference, so it may be that the independent variable of spatial linear guide factor has no significant effect on the performance of judgments of temporal order, which is consistent with previous experiments [10-12].

2. Experiment 2

2.1 Procedures and Design

The results of experiment 1 showed that the spatial linear location of the temporal order information could not strengthen the working memory of temporal order in the conditions set by experiment 1. Next, we investigated whether we could take advantage of the spatial layout to aid the memory of temporal order information in practical applications. We propose a hypothesis that the spatial guide is valid in the high cognitive load condition and designed a second experiment to test it. We added a prospect guide in experiment 2 to increase the overall cognitive load as seen in Figure 3. Before the appearance of the temporal order information (seen as the notched circle rings in black solid filling), we prospected the location of the five elements with virtual shapes (displayed as the notched hollow circle rings with fine black lines). Afterwards, the temporal order information was displayed in frames and presented sequentially as same as experiment 1.

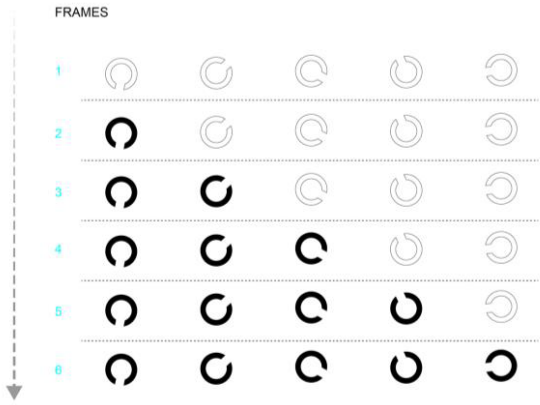


Figure 3. The illustration of experimental materials with prospect information guide (the trial in the linear spatial sequence guide).

The tests in experiment 1 were treated as the control group to experiment 2 as the elements displayed in the two experiments corresponded one-to-one except for the prospect guide information. The aim of this stage of the study was to investigate the correlation between the temporal order and spatial sequence in working memory under the condition of increasing the system complexity by increasing cognitive load in the process of working memory. The equipment, subjects and procedure of this experiment were identical with the previous one. Not counting the 180 exercises trials, there were 480 formal experimental trials in this stage.

2.2 Discussion

The reaction time of the experimental group (with prospect guide) was average at 4016 ± 3236 ms, compared to the control group (no prospect guide), which was 3759 ±2731 ms. The T-test results showed that this difference was not statistically significant (t=-1.238,df=830,sig.=0.216>0.05). However, the average of correct rate difference between the control group (no prospect guide) at 81% compared to the experiment group (with prospect guide) at 73% was statistically significant (t=2.456, df=910, sig.=0.014<0.05). The interpretable reason for such an outcome might be that the increased overall capacity of memory led to a higher degree of cognitive load, resulting in a significant decline in cognitive performance.

We compared the correct rate and reaction time between the group of spatial linear guide and the group without spatial linear (random spatial position) in the common condition of prospect guide. In this condition, The difference of average correct rate was significant (t=-2.031, df=454, sig.=0.043<0.05) between in the linear guide group (78%) and in the random spatial position group (70%). Although the comparison of the reaction time indicated no significant difference between the two groups (t=0.536, df=414, sig.=0.592>0.05), there was a slight decline in the linear guide group (3923 ± 2855ms, compared to 4094 ± 3594ms in the random spatial position group). We suggest, therefore, that the performance of working memory of temporal order in the linear guide increased with the prospected guide condition. With the prospect guide, performance was markedly reduced (sig.= 0.034 <0.05) in the condition without the linear guide while it remained stable (sig.= 0.516 >>0.05) when the linear guide was added.

Figure 4 illustrates the performance distribution of Experiment 2. The bottom left corner represents the worse performance with lower accuracy and higher response time while the upper right corner represents the better performance with higher accuracy and lower response time. The bubble map in Figure 4-b compares the mean performances in the different displayed experimental material conditions. Although the bubbles do cross to some extent, we are still able to distinguish the red filled bubble; that is, the bubble indicating the data of the group with no prospect guide (lower system complexity) and the linear guide (the consistency between temporal order and spatial sequence) showed the overall highest performance. To contrast, the blue open bubble, which had both a prospect guide (higher system complexity) and no linear guide (the inconsistency between temporal order with te spatial sequence), behaved with the lowest performance. Furthermore, we set the judgments of relative recency into three types of span: within two-temporal order span, three-temporal order span and four-temporal order span. Because the entire span was five in each trial, the within two-temporal span was set to compare the recency of the intermediate elements. The three-temporal span was bound to the sequence of the first four or the last four, while the four-temporal span had to be compared between the first frame and the last frame. Several classic studies of experimental psychology [21-23] have demonstrated the clear primacy effect and recency effect in that the elements presented at the beginning or at the end of a sequence are easier to remember than the intermediate ones. It is obvious to see in Figure 4-c that judgment performance improved from span 2 (yellow bubble) to span 3 (green bubble) then to span 4 (blue bubble), with the correct rate increasing and the reaction time decreasing. It indicates that the first and the last elements were less likely to be forgotten, reflecting the impact of the primacy effect and the recency effect on the effectiveness of working memory. The open interviews after the formal

experiments showed that the subjects could not organize the valid subvocal rehearsal to support their memory, meaning that the phonological loop subsystem had little effect on the performance of subjects' working memory as we expected. So working memory span was bound to decline when the phonological loop subsystem was blocked.

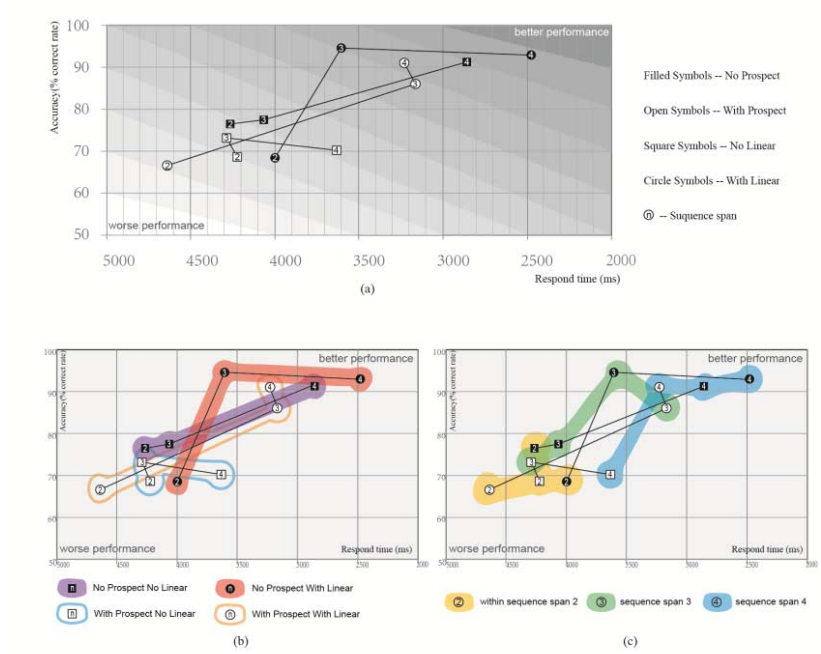


Figure 4. Comparison illustration of the mean performance in the same trial (4-a) show the overall distribution of means performance among the trials; (4-b) the bubbles represent four different displayed experimental material conditions; (4-c) the bubbles represent three kinds of temporal order span

3. Conclusions

Working memory is a key factor in the comprehension of dynamic visualization. Based on this concept, we investigated the effects of different materials on the visuospatial sketchpad subsystem of working memory. The results of experiment 1 showed that the linear spatial sequence had no significant effect on performance in judgments of relative recency in the condition of low system complexity, implying that temporal order information and spatial sequence are separately stored in working memory. However, in the condition of high system complexity (experiment 2), the added linear spatial guide could improve the performance on memorizing temporal order. The results indicate that the memorization of temporal order information and spatial sequence information is associated in a complicated condition. Because the system complexity of large-scale data visualization in practice is always much higher than the conditions set by experiment 2, the linear spatial arrangement of the temporal order information contracted as a metadata provides a possible method of visualizing the dataset in cases where the key targets of the visualization are temporal order changes. This approach may improve the understanding of a visualization by enhancing working memory performance while reading the dynamic visualization graphics. In addition, the

primacy effect and recency effect were strongly reflected in this study; thus, we could set the important nodes at the beginning or end of the displayed sequence to improve the expression ability of the visualization.

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The Effect of Using Video-Based Advertising and Stop-Motion Video to Evaluate Auto Emotional Menu in Recognition Tasks and Communication

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Abstract. Autism spectrum disorders (ASD) has the ability to understand the emotions and expression of other people to identify obstacles, one of which is to recognize the emotional signal. This study attempted to capture the basic emotion feeling in the Video-Based Advertising (VBA) video scene and Stop-Motion Video with Advertising (SMV). Then, it were adopting the Multiple Baseline Across Behaviors Design, focusing on a wide range of nonverbal social hints to promote cognitive attitudes and cognition in children with autism. We designed an auto emotional menu (AEM) to help children with ASD improve their emotional identification ability and make it easier for them to operate answered correctly mood. A speech-generating device (SGD) with AEM designs was intervened on twelve children with ASD, and their improvements were assessed to compare the effects of the AEM intervention strategy. A multiple baseline design and reversal design were used. We studied the effects of two types of advertising videos: Video-Based Advertising (VBA) and SMV, from all developing children (n = 38) and those with ASD (n = 12). Evaluating the differences in their manipulation of AEM judgments to match different facial expression data with the paired mood response. to communicate with others and their accuracy rate, improved their involvement in moods expressed by AEM, and identified facial cues from two different kinds of graphic emoticons.

Keywords. Autism spectrum disorder, Video-Based Advertising, Stop-Motion Video with Advertising, Speech-generating device, Intervention strategy, Multiple baseline design, Reversal design

Introduction

Non-verbal ability in association with autism spectrum disorder (ASD) disables the "patients" expressing basic wants and needs, making communication very difficult. ASD entails a series of cognitive and emotional deficits that might make it difficult for an individual to know their own thoughts and the thoughts of others [1,2,3]. Although people with ASD might be able to understand and identify basic emotions, they still have difficulty understanding other and their more complex emotional and social information from facial stimuli [4,5,6,7]. According to Theory of Mind (often abbreviated "ToM") [8]), ASD lacks the ability to sympathize with others from the

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perspective of others. Despite some people with ASD being high functioning, children. ASD often struggle in educational settings and have difficulties reaching their full potential [9,10]. Because most people with ASD are already cognitively impaired and unable to understand others, their capacities for social interactions and verbal expressions are directly affected, which leads to communication disorders.

Among the AAC systems, speech-generating devices (SGDs) (also known as voice output communication aids (VOCAs)) are a type of electronic aids that can support or replace language and writing by indicating images or sounds. The users can press the buttons on the SGD interfaces to facilitate communication with others [1,11].Numerous studies have explored the effect of AAC systems on social interaction, cognition, and assessment. Flores et al. [12] reported that SGD and iPad interactive game could enhance social interaction and promote cognitive development and communication behavior among peers. This demonstrates the advantage of SGD intervention. [13-17].

Boesch et al. [18], Flores et al. [12], and Sigafoos et al. [19] compared PECS, SGD picture cards, and iPad usage. They found that all of those tools could enhance social interaction and natural language output, however, without significant difference among them. A further analysis into the PE, PECS, SGD, and other AAC system interventions found significances in the proximity and continuity aspects of social interaction [15]. The reasons for the differences may be related to interface design and teaching methods.

Autism-related language disorder, including lack of sentence organization ability, makes it difficult for those with ASD to communicate with others [21,22]. However, few studies have explored the effectiveness of the interface designs (such as hierarchical menus, pull-down menus, message formulation and retrieval mechanisms, and content presentation methods) of PE, PECS, VOCA, and SGD in AAC systems [18,19,23]. Hence, the research into organizational design content is particularly important.

This study is designed to clarify ASD people's recognition of face expressions through video-based advertising (VBA) and stop-motion video with advertising (SMV) experimental design. Their recognition ability is further compared with the typically developing (TD) children ability to recognize common functional icons. The experimental results are expected to serve as a basis of future designs for the autism spectrum disorder minority.

Accordingly, previous studies in autistic spectrum disorder (ASD) have focused on the use of facial stimuli which combined the specific attributes of social-emotional function can as a means to encourage adolescents with ASD to develop social emotional function. Bauminger [24] considered some intervention treatments for ASD which resulted in effective performance was due to the fact that a small part had been trained or learned before. However, there are broad-ranging deficits in the ASD present across a range of stimulus domains in the visual modality. When the autistic people try to apply the acquired knowledge to recognize emotions in real life, they are still unable to communicate properly, the patients with ASD hard to generalize their knowledge of the learnt material to relate social ability [25]. Therefore, computer-based interventions for ASD mentioned the materials need to more stable, efficient, and easy to obtain visual strategy stimuli for training, it is possible that the use of more realistic stimuli could improve the knowledge transfer.

Because most people with ASD are already cognitively impaired and unable to understand others, their capacities for social interactions and verbal expressions are directly affected, which leads to communication disorders. The second stage of this study are: (1) Using VBA and capturing SMV key emotional short films, training to

identify the correct rate of emotional recognition, evaluate the outcomes of the AEM intervention in improving operational identification and facilitating the progress of coherent expression and compare before and after AEM operation training, whether there are differences in face emotion; (2) Using VBA and capturing SMV key emotional images, training assessment of emotional recognition AEM identify the emotional correctness of the operation, the problem before the test response, post-test communication assessment, comparison can improve their ability to respond correctly.

1. Methodology

1.1. Participants

The participants of this study (all given pseudonyms to guarantee anonymity) were 38 TD children (25 boys and 13 girls) and 12 children with ASD (10 boys and 2 girls). All members of the ASD group had previously been diagnosed with an ASD by clinicians using the multidisciplinary assessment of clinical services in Taiwan; the Wechsler Intelligence Scale for Children (WISC) was used to determine physical and sensory incapabilities that might affect their speech and language development. ASD participants (mean age = 10.42 years old; age range: 8-12 years; intelligence quotient [IQ] scores: [a] full scale IQ [FIQ] = 81.0 ± 16.52; [b] verbal IQ [VIQ] = 83.25 ± 17.77; and [c] performance IQ [PIQ] = 81.75 ± 19.69). Moreover, their sensory abilities were within the normal range: e.g., the mean FIQ was higher than 80. All participants had a disability identification card issued by a medical institution in Taiwan and had been counseled in special education schools and institutes in Taiwan. All participants signed a youth consent form, and parental consent forms were obtained before the participants were enrolled in the study.

1.2. Settings

All instructional and probe sessions occurred in computer classroom located in Kaohsiung Municipal Hanmin Elementary schools, and Kaohsiung Municipal Kaisyuan Primary School, selected by their classroom teachers during times. The procedures associated with this study were conducted at a table in the computer classroom. Participants sat at the table and the trainer sat across from him. To begin the intervention test, a therapist showed the emotion question paper to the children and asked them to look at the pictures of each scene. These emotional types are based on VBA and SMV. The participants answered each test question after looking at the pictures, selected an appropriate emotion for the SMV basic facial expressions and 1 of 4 adjectives to answer each question that corresponded to the scenes. An independent observer was present during all sessions to collect inter-observer agreement data.

1.2.1. Video-Based Advertising (VBA)

We selected three advertisement videos from internet and World Wide Web for the expressed purpose of emotion-communication between the people's intimate social of appropriate length, with low levels of metaphor, distinctive themes, and profound emotional feelings. The advertising stations included significant body movements and clear facial expressions to vividly express characters' emotions. In addition, there were

interactions and dialogue among the characters in each story. Each video source, through the software to cut and edit, and output the final testing materials approximately 1.5 minutes, and three ads broadcast in Asia were selected (see Figure 1).

1.2.2. Stop-Motion Video with Advertising (SMV)

Stop-Motion Video with Advertising (SMV) was created from frozen images captured from VBA. In each video we selected 10 to 15 freeze-frames sequentially in accordance with video context and story development, including 3 to 5 close ups of facial expressions, situations, and body movements to develop SMV materials for participants with ASD [26]. (see Figure 1).

1.3. Auto Emotional Menu and interface design

The AEM target skills: (1) Understanding and recognizing feelings and emotions;(2) Awareness that others have their own state of mind;(3) Reading of nonverbal communication/cues;(4) Create awareness/review different perspectives of others;(5) Practice social situations/role play/rehearse;(6) Support abstract concepts with scripts and visual aids. [7].

Afterwards, taking Adobe Illustrator, Flash as tools to design the AEM menu (Figure 2). Interface for the users is comprising of icons, image codes or alphabetic codes, and it supports multi-code learning strategies.

1.3.1. Steps of usage

The AEM UI provides icons for four parts of speech (subject, verb, object, and adjective). The user can arbitrarily select the icons, but each image will appear only in its specific part-of-speech place. After the user has finished selecting the icons, they can use the UI buttons to organize the sentence content into a complete sentence. Finally, the user can select the AEM's pronunciation button to answer the experimenter's or caregiver's questions, or to request assistance.

1.3.2. Operation definition

The trials were scored as either correct or incorrect, the participants were asked to (a) select the subjects, verbs, objects and adjective picture symbol depicting the sentence (e.g., ''I feel him happy'') (Figure 2); (b) select the four images that they needed that the AEM interface will automatically organize as a complete sentence(e.g., ''Subject, Verb, Object, Adjective''); and (c) play the sentence to send the digitial voice message. If the participant did not perform the above chain of responses in the correct order, made an error in the selection of the sentence, or did not respond within 20 seconds of presentation, the response was scored as incorrect.

1.4. Intervention strategy

This study adopted the combination of multiple baseline and reversal design-A-B-C-B. (e.g., [27-30].), A multiple baseline design is a style of research involving the careful measurement of multiple persons, traits or settings both before and after a treatment; The AEM interface content was based on VBA and SMV basic social cues. Only indicate that the SMV visual strategy is used to attract their attention on those

nonverbal facial cues related to situations in emphasis to indicate concern their performance. Each training session lasted for approximately an hour. Each participant received a 2-hour training on a weekly basis over the period of four months, totaling 50 training session and carried it out once a week for four months. Each of them was assessed in terms of their target behaviors in the session until these behaviors showed a stable level. After that, the first participant was intervened, while other participants stayed in the session. When the target behavior of the first participant improved about 80% and was stable, intervention for the second participant began, etc. Based on the expert interviews, the settings included "the need to express oneself" and comprehending tasks.



Figure 1. Example of SMV materials were created from VBA.

1.4.1. Selection method of standard answer

Our selection method used the main emotional adjectives chosen by 38 TD children as the standard answer for perception judgment. Because the perception judgments and experience of TD children was more consistency and accuracy, and their comprehension of situations was generally accurate (comprehension rate for 38 TD

children in both VBA Test and SMV Test was 96% and 96.43%, respectively), it represented that they could correctly judge their perceptions toward the videos. Thus, the perception of the TD children was also used as the selection criterion for the children with ASD. In addition, the selected answer was also agreed by the experts and therapists.



Figure 2. Auto Emotion Menu Design.

1.4.2. Correct judgment rate of children with ASD

The emotional adjectives were chosen by the TD children were selected as the standard answer for VBA Test and SMV Test. The answer chosen by children with ASD in those questions; correct and incorrect answers were identified and recorded, and the correct rate was determined.

1.5. Training and evaluation of procedure

1.5.1. Baseline (A1)

In the baseline phase, the therapist first explained to the children the meanings of the 10-18 adjectives for the basic emotions [31]. In the baseline phase, the therapist asked questions about do emotion expression without any intervention. The ten questions were recognizing facial expression from basic emotion questions. During the baseline session, the experimenters selected with the emotion picture, which was positioned in front of participants. If the participants did not respond within 20 seconds or made an error in the behavior chain described as above, the response was scored as incorrect. All materials were then removed, and the trial was ended.

1.5.2. Treatment (B1)

The training course focused on the execution and degree of independent completion of the tasks of "operational identification". Ten questions were designed based on VBA and SMV scenes (Figure 1), The children had to select the correct icons sequentially, recognize facial expressions from photographs, and recognize emotions from schematic drawings. The children answered the questions on ASUS Transformer Book T200TA tablet devices (Figure 2). To maintain the consistency of the training conditions, the same questions were used when the context is identical. Training continued in this manner until the participants reached the criterion of at least 80% correct responses in three consecutive sessions.

1.5.3. Reversal (C1)

In Phase 2, the researcher returned to the Baseline to see whether the intervention led to different responses. The status of the children who had not begun the intervention was used as the reference questions. To determine whether they could respond to the questions by VBA, SMV identification and answered correctly mood with their ability of communication.

1.5.4. Treatment (B2)

The second intervention used the AEM UI to evaluate the children's accuracy identifying situation-based emotions, desire-based emotions and answered correctly mood with their experimenter to communication (Figure 1)." children have to operate AEM to answer the experimenter and make a pair the VBA, SMV emotion." and identifying desire-based emotions. This section contained ten questions, all of which need to be answered using the AEM UI (Figure 2). This phase was conducted in a discrete trial format until participants reached the preset criterion (i.e., 80% correct responses in three consecutive sessions for each question response)

1.5.5. Maintenance phase

Between the intervention and maintenance phases, there was a month hiatus to reduce recall interference in order to determine, using the baseline phase procedure, but not the AEM materials, whether the children had maintained the skills that they had acquired.

2. Results of VBA, SMV and AEM Training and evaluation

2.1. Perceptions judgment

Among the children with ASD (n=12), their correct judgment rate on their perceptions of others also improved from 37% in VBA, SMV to 74% in AEM. This finding demonstrated an improvement between the two tests (VBA, SMV and AEM). The average correct judgment rate in AEM Test was increased, indicating that in AEM Test, the correct judgment rate on their perceptions of others increased.

To perform a paired t-test were used to compare the relationship between the two test values [32]. The difference in assessment performance between the VBA, SMV

and AEM tests was significant ($p < .05$) for ASD group, indicating that the AEM interface was effective.

2.2. Situational comprehension

Among the children with ASD, their situational understanding rate also increased from VBA 34.45% to SMV 72.27%. In the AEM intervention, to determine the correct expression of SMV expression from 37% also significantly increased by 74%. The positive phenomenon was observed in children with ASD : the simplified and structured freeze-frames with advertising helped them become sure of their feelings and improved their judgments related to empathy. To perform a paired t-test [32]. were used to compare the relationship between the two test values.

3. Discussion

3.1. VBA, SMV and AEM intervention effect

In this study, we found that VBA and SMV can be applied to ASD children to help them focus on the situation and other people's views on specific non-linguistic social clues, which means that ASD children can test ads through the SMV The structure attracts judgment of facial expressions, gestures, and situations. Through SMV combined with AEM can help ASD children develop communication concepts and enhance the ability to judge sympathy, as well as different facial expressions to determine the difference between the understanding. At the beginning of the VBA test, the participant ASD case was unable to focus on watching the entire film, and they felt too complicated to understand the story of the scene and were eventually bored. Because it could not explain the meaning of the story and confuse it in different situations emotional interaction, however, when applying SMV, they improve their ability to judge and be able to determine the relationship between roles and activities with AEM, they are more likely to judge others' attitudes to cognition and views to AEM. They prefer to manipulate the answer about the story and communicate with the therapist. It shows that a limited amount of information with structured and specific close-up images was found to help children with ASD improve their situational awareness and perceptions of others. As a whole, although children with ASD may encounter other barriers, the visual support and structured situational characteristics of advertisements were beneficial to their perceptions awareness, and also helped them to develop social-emotional function.

4. Conclusion

Finally, we found that SMV and AEM collocation is beneficial to improve ASD children's awareness of others 'attitudes towards others and to others' facial awareness. SMV sends ASD children's attention to non-verbal social hints such as facial expressions, physical movements and situations to add other perceptions. The study also confirms that SMV paired AEM facial expressions that can help ASD children focus and focus on details in detail.

In addition, the study shows that AEM can enhance its ability to distinguish between different facial emotions, guide the case to select the corresponding image in SMV, and further organize the content of the expression of data to deconstruct the way, through the program will be the subject, verbs, nouns and adjectives and other organizations The way in which the case is reorganized is chosen to understand what it wants to express and recapitulate, and then interpret the inner thoughts that are analyzed and found to be expressed. The training results also effectively link the gap between the language and cognitive behavior. In the form of a structured operation mode, the automatic organization design is selected to achieve the convenience interface of the linked vocabulary, which can significantly improve the autism expression ability.

In general, these results show that AEM with SMV intervention to improve facial emotions, and further enhance the empathy, so AEM is a promising new interface design. The caregiver expresses a significant change in their expression, and after they use AEM, autism exhibits more interest and clears the ability to recognize emotions more clearly. In addition, caregivers also said they noticed significant improvement in the language skills of autism; these improvements have affected the relationship between autism and family members, classmates and others. Finally, hope that this study found that for the new research project, learn more about how to reshape the visual media to enhance the attitude of ASD children's awareness, sympathy and other facial expressions.

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Perceived and Physiological Mental Workload and Emotion Assessments in En-Route ATC Environment: A Case Study

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Abstract. One of the largely important focuses in Air Traffic Control (ATC) operations is radar-based operation in enroute facilities. Many aspects in enroute facilities including airspace and Air Traffic Controller (ATCO) factors need to be further investigated in dealing with the continous air traffic increase. Moreover, ATCOs mental workload and emotion were two important constructs that need to be continually assessed to deal with the increase. This study aims to examine the effects of different enroute factors including number of crossing, traffic flow, and separation on ATCOs' perceived and physiological mental workload and emotion as well as to assess the relation between ATCOs' physiological and perceived mental workload and emotion. The results revealed that the number of crossing significantly affect ATCOs' mental workload. Regarding the mental workload and emotion assesments, ATCOs perceived mental workload was generally higher than their physiological mental workload. However, ATCOs perceived emotion was more positive than their physiological emotion. Further, high mental workload was highly associated with negative emotion in enroute ATC environment. This study offers several implications for human performance enhancement in future ATC operations including investigation of airspace factors, appropriate assessment methods, as well as ATC system design for positive emotion.

Keywords. Mental workload, emotion, EEG, air traffic control

Introduction

Air traffic density has been increasing and bringing challenges to current ATC operations [1]. Air traffic, particularly in the Asia Pacific Region, is in the phase of developing growth and is expected to increase significantly. The traffic statistics in Changi Airport showed an increasing trend of commerical aircraft movement in Singapore from 301.7K in 2011 to 360.5K in 2016 [2]. Dealing with such increase that may jeopardise air traffic quality and security will be the major challenge of the ATC. ATCOs, as a main component in ATC operations, have been imposed with high mental workload due to complex, simultaneous and time constraining tasks. In addition, the current ATC facilities are approaching its maximum capacity and existing ATC operation procedures may not be able to sustain the imminent growth [3].

Action plans for various aspects of ATC including automation, human, and operation have been proposed and some of the plans have been implemented to deal

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with the traffic increase. New technologies (such as ADS-B, SWIM and GBAS) are being introduced to deal with the traffic increase which could affect current operational standards and procedures. Separation standards between aircrafts would be reduced significantly within an increasingly congested airspace. Under current arrangements, this would call for more sectors to be created within the same airspace.

ATCOs' tasks to control aircraft within these sectors are cognitive in nature since those include monitoring, control, and decision making [4]. These tasks are likely to place great demands on mental workload as well as emotional consequences thus affect ATCOs' performance and systems' safety. Mental workload assessment is essential to gain understanding of the mental workload level within sectors, to keep it within acceptable limits and to reduce human errors. ATCOs' emotional state is also a construct that deserves a continuing investigation for the reduction of stress inducing situations and this is an essential goal in the ATCOs' daily work with the traffic [5].

In en-route ATC environment, ATCOs' mental workload and emotion could be influenced by numerous factors. Among the factors, the number of traffic crossing, traffic flow, and separation are of greater importance. With the increasing air traffic, demands on interaction with technical systems are also increasing, hence knowledge of relation between mental workload and relevant emotions towards the systems and traffic situations will be even more vital. This is a prerequisite for designing the ATC systems that support adequate recognition of and response to human variables including their mental workload and emotions.

Therefore, the main objectives of this study were (i) to examine how the different enroute factors including number of crossing, traffic flow, and separation would affect ATCOs' perceived and physiological mental workload and emotion, (ii) to examine the different mental workload and emotion assessment methods, and (iii) to investigate the relation between ATCOs' mental workload and emotion in enroute ATC environment. Five main hypotheses were proposed and tested with 2 participants in this study.

H1: The number of crossing, traffic flow, and separation would significantly affect ATCOs' physiological mental workload and emotion.

H2: The number of crossing would significantly affect ATCOs' perceived mental workload and emotion.

H3: ATCOs' perceived mental workload would not be different from their physiological mental workload.

H4: ATCOs' perceived emotion would not be different from their physiological emotion.

H5: ATCOs' mental workload would be negatively corellated with their emotion such that positive emotion would be observed with low mental workload and vice versa.

1. Methods

1.1. Participants

Two (2) ATCOs from the Civil Aviation Authority of Singapore (CAAS) participated in this case study: one male participant, age 31 with 5 years work experience, and another one age 35 with 7 years work experience. Two replications with sessions counterbalancing were obtained from each participant.

1.2. Apparatus

1.2.1. The ATC Simulator

The experiment scenarios were generated and simulated using NLR ATC Research Simulator (NARSIM) [6]. It presented the Sector 6 of the enroute environment in Singapore airspace. An ATCO's and three pseudo-pilot's positions were set up for the experiment. The ATCO participants were provided with one monitor screen showing the primary radar (Figure 1).

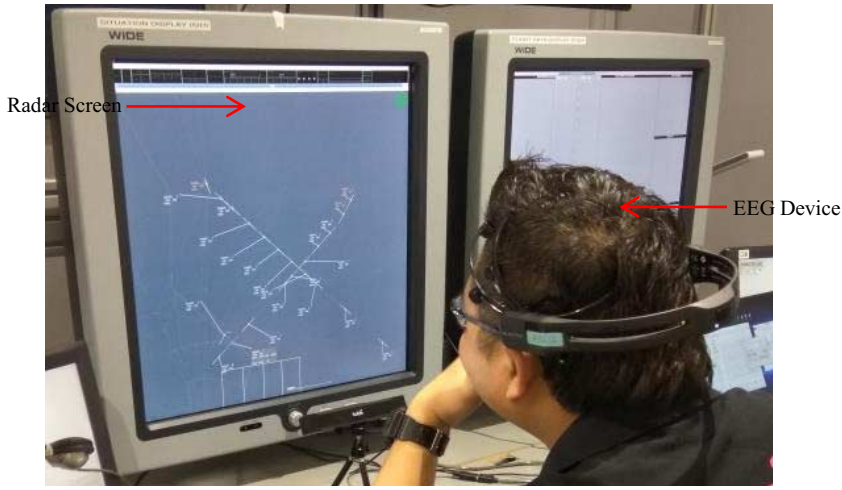


Figure 1. The Experiment Setup

1.2.2. The Electroenchepalogram (EEG) Device

An Emotiv [7] headset with 14 channels was used to wirelessly capture ATCOs' EEG signals. The EEG data were recoded during calibration and ATC tasks. As the proposed EEG-based mental workload [8] and emotion recognition algorithms [9] are subject-dependent, a calibraition is needed to train the classifiers for each ATCO. Different types of stimuli such as sound clips and stroop color test were given to the ATCOs to evoke various emotions and mental workload levels. When the ATCO were exposed to stimuli, their EEG data were recorded and labeled with emotion (e.g. positive, neutral, negative) and mental workload level (e.g. low, medium, high) according to the self-assessment ratings. In the calibration phase, the EEG data are firstly filtered by a bandpass filter. Then, the Fractal Dimension [10] and statistical features [11] are extracted using a 4 seconds sliding window with 3 second overlap and finally fed in to the Support Vector Machine (SVM) to train the classifier. In the recogniton phase, the same bandpass filter is applied and features are extracted. The features are then used as the input to the previously trained classifier model, and finally, the emotional states and mental workload levels are identified during task peforming by ATCOs. In this work, the EEG-based recognition is done offline. However, the algorithms can also be applied in real time [12].

1.3. Experiment design

Three within-subject factors were of interests: number of crossing, traffic flow, and separation. The traffic flow included two levels: aircraft flow per airway, 1:1 (1 aircraft on changing Flight Level (FL) airway and 1 aircraft on cruising airway) and 3:1 (3 aircraft on changing FL airway and 1 aircraft on cruising airway) as shown in Figure 2. There were two levels of number of crossing: 2 and 3 crossings. The scenario combinations of traffic flow and separation factors were placed in every 15 mins, resulting in an hour experiment scenario [13] for each number of crossing. The separation also included two levels: conflict (overlapping FL during crossings) and no conflict (no overlapping FL) conditions. The ATCO participants were assigned to all combination of the conditions with 2 replications for each participant.

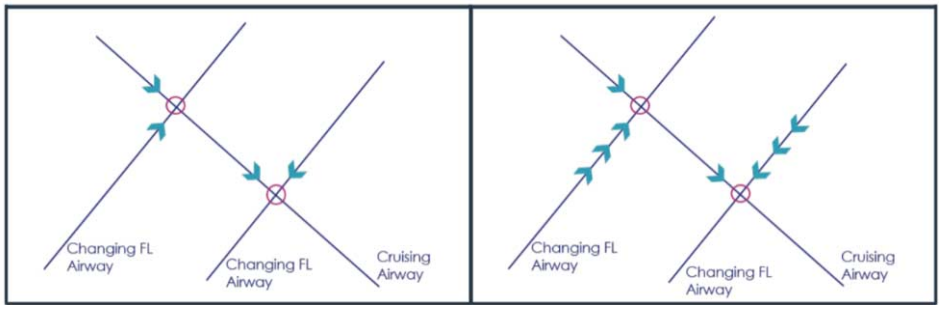


Figure 2. The Example of Experiment Scenarios (left and right parts show the 1:1 and 1:3 traffic flow with two crossings, respectively)

1.4. Procedure

A briefing including EEG mental workload and emotion training and six one-hour experiment sessions were conducted in two different days. Participants were requested to control the air traffic and to maintain safe separations among aircraft with the traffic density of 90 and 115 aicraft in 2 and 3 crossing conditions, respectively. Participants verbally communicated with the three pseudo-pilots through remote radio-telephony. During the experiment, participants' mental workload and emotion states were obtained using the EEG device [14]. Upon completion of each experiment session, NASA-TLX [15] and Valence-Arousal-Dominance (VAD) [16] questionnaires were administered.

1.5. Analysis

2 (number of crossing: 2 and 3) x 2 (traffic flow: 1:1 and 3:1) x 2 (separation: conflict and no-conflict) mixed-design ANOVAs were performed for the EEG mental workload and emotion data, respectively. Paired t-tests were conducted for examining the effect of number of crossing on perceived mental workload and emotion. Furthermore, paired t-tests were also conducted to compare the perceived and physiological mental workload and emotion data. Lastly, correlation analysis was also performed for EEG mental workload and emotion data to see the relation between both constructs.

2. Results

2.1. Effects of Number of Crossing, Traffic Flow, and Separation on Perceived and Physiological Mental Workload and Emotion

Table 1 presents the data (mean) for main effects of the factors on the physiological mental workload and emotion. Physiological mental workload was higher in 3 crossing than in 2 crossing condition, $F(1, 3)= 21.41$, $p= 0.02$. Mental workload was higher in 1:1 traffic flow although this trend was not significant, $F(1, 3)= 0.24$, $p= 0.66$. Mental workload was also not significantly different in both conflict and non-conflict conditions, $F(1, 3)= 1.26$, $p= 0.34$.

Physiological emotion was not significantly affected by number of crossing, $F(1, 3)= 0.41$, $p= 0.57$, traffic flow $F(1, 3)= 0.14$, $p= 0.74$, and separation $F(1, 3)= 0.13$, $p= 0.75$. However, the data showed that emotion was more negative in more number of crossings and 1:1 traffic flow. Suprisingly, emotion was also more negative in non-conflict condition.

Table 1. Data for main effects of the crossing point, traffic flow, and separation on physiological mental workload and emotion.

Factors	Levels	Physiological Mental Workload	Physiological Emotion
Crossing point	2 crossing	1.78	1.07
	3 crossing	0.81	1.38
Traffic flow	1:1 traffic flow	1.32	1.25
	3:1 traffic flow	1.27	1.20
Separation	Conflict	1.27	1.24
	Non-conflict	1.32	1.21

The effect of number of crossing on perceived mental workload was significant, $t= 3.18$, $p= 0.01$. Higher mental workload was observed with 3 (M= 71.17%) than 2 (M= 48.83%) crossing points. For the perceived emotion, the effect of number of crossing was not significant, $t= 0.75$, $p= 0.51$.

2.2. Comparison between Perceived and Physiological Mental Workload and Emotion Assessments

Perceived mental workload (M= 60.00%) was marginally higher than physiological mental workload (M= 44.26%), $t= 2.36$, $p= 0.06$. Perceived emotion (M= 0.33) was significantly more positive than the physiological emotion (M= 1.10), $t= 2.99$, $p= 0.03$.

2.3. Relations between Mental Workload and Emotion in ATC Context

There was a high correlation between mental workload and emotion constructs, $r= 0.91$, $p= <0.01$. This indicates that high mental workload was highly correlated with negative emotion.

3. Discussion

The objectives of this study were threefold. First, some of enroute factors including number of crossing, traffic flow, and separation on ATCOs' mental workload and emotion were investigated. The results shows that only number of crossing significantly affects ATCOs' physiological mental workload, showing that H1 was partially upheld. Perhaps, this was due to the small sample size. Moving forward, the trends were discussed instead.

For the number of crossing, the finding is inline with the expectation that more crossings generates higher mental workload and more negative emotion. This is because with more crossings the ATCOs has to handle more aircrafts and they less feel in control of the aircraft [17], producing higher mental workload and more negative emotion. Next, the trends shows that the physiological mental workload and emotion was higher and more negative with 1:1 traffic flow, respectively. These findings might be associated with the finding in [13] where ATCOs allocated longer gaze duration on the 1:1 traffic flow due to the increase in aircraft pairs flying across the crossing points for the same period of time as compared to a 3:1 traffic flow, thus increasing visual monitoring and mental workload as well as negatively affecting their emotion. However, non-conflict situation also triggered more negative emotion as compared to conflict situation. This somewhat surprising result is not readily interpreted.

Regarding the perceived mental workload, more crossings were associated with higher mental workload. This finding was as expected since more cognitive resources were required for monitoring and controlling aircraft on different crossing points. However, the perceived emotion between different number of crossings was not different, indicating that H2 was partially supported. It seemed true that perceived emotion only showed a "snapshot" [18] of ATCOs' emotion data making it to be insensitive to the experiment manipulations.

When we compared between perceived and physiological mental workload, we found that perceived mental workload was marginally higher than physiological mental workload, suggesting that H3 was not upheld. It could be inferred that ATCOs reported higher mental workload although they still have more cognitive resources. They probably would like to allocate the cognitive resources to deal with possible off-nominal situations that may occur in a dynamic and complex enroute ATC environment. ATCOs could still manage 115 aircraft that pass through 3 crossing points with medium mental workload level although they reported much higher mental workload. Hence, for the mental workload assessment, it is arguably safer to use perceived mental workload assessment method to estimate the mental workload level within a sector.

Moreover, perceived and physiological emotion also revealed different results, showing that H4 was also not supported. Here the results shows that perceived emotion was more positive than the physiological emotion that mostly exhibited neutral emotion. This may be because perceived emotion data obtained from the questionnaire elicited socially desirable responses [18]. ATCOs were found to rate more positive emotion, answers that they thought were desirable although might not be really accurate, as reflected in the difference between perceived and physiological emotion. Consequently, physiological measurement through EEG recognition could be seen as a more appropriate assessment method for emotion.

Lastly, a high correlation between mental workload and emotion constructs in enroute ATC environment was clearly observed, supporting H5. High mental workload was strongly associated with negative emotion and vice versa. This finding was supported by the finding in [19] that participants mostly exhibited negative emotion during the tasks that involved mental process under stress where the difficulty level was high.

4. Conclusion

This paper investigates the effects of number of crossings, traffic flow and separation, on ATCOs' mental workload and emotion in enroute ATC environment. In addition, we found that ATCOs' perceived mental workload was generally higher than their physiological mental workload. However, ATCOs' perceived emotion was more positive than what their brain revealed. High correlation between physiological mental workload and emotion was also observed in the ATC environment.

This study has positive implications for the human performance enhancement in future ATC operations. First, the results revealed that the number of crossing significantly affected ATCOs' mental workload. This implied that resectorization to reduce the number of crossings within a sector could help reduce ATCOs mental workload. Second, the comparison between perceived and physiological mental workload and emotion also offers some implications for appropriate mental workload and emotion assessments method. For mental workload assessment, perceived mental workload assessment method should be used for safer estimates of ATCOs' mental workload. For emotion, physiological assessment method through EEG recognition is more appropriate to reveal what it is in the brain. Lastly, high mental workload was strongly correlated with negative emotion. Hence, it is advisable for system designers to consider ATC system's interface design that could evoke positive emotion, that possibly would help lower ATCOs mental workload, besides the considerations on aircraft and airspace factors.

However, the findings of this study should be interpreted with cautions since there are some limitations. First, only two ATCOs participated in the study. The effects of the factors could have more statistical power with greater ATCOs participation. Second, environmental factors such as weather were not considered during the ATC tasks simulation. Based on the case study results we conclude that the investigation of mental workload and emotion in enroute ATC environment deserves more attention to deal with the imminent traffic growth, and the findings presented in this study highlighted the stepping stone toward the future ATC research and improved ATC systems.

Acknowledgment

This work has been supported by the Civil Aviation Authority of Singapore (CAAS) and Air Traffic Management Research Institute (ATMRI), Nanyang Technological University (NTU), Singapore (ATMRI:2014-R5-CHEN) and by the National Research Foundation, Prime Minister's Office, Singapore under its International Research Centres in Singapore Funding Initiative.

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Design and Simulation of Lower Limb Rehabilitation Robot Based on Human Physiological Characteristics

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Abstract. Lower limb rehabilitation robot has showed great potential in improving human walking ability. The purpose of this study is to compare the differences in human muscle activity of the lower limb while walking with different patterns. In order to meet the individual needs of different kinds of patients with lower limb dysfunction, an end-effector hybrid rehabilitation robot concept with multi-degree freedom is designed based on human factor. Human-robot coupling model is established in the *AnyBody Modeling System*, inverse dynamic analysis of movement and muscle activity of the human body is simulated. Effects of gait trajectory and the degree of freedom simplification of rehabilitation robot on human physiological parameters are discussed. The results indicate that foot trajectory, ankle posture, and mobility of robot is of vital importance and can be realized according to specific human factor in rehabilitation robot design and trajectory planning. Analysis methods and results are meaningful for lower limb rehabilitation robot design and rehabilitation evaluation.

Keywords. Lower limb rehabilitation robot, Human-robot coupling, Inverse dynamic simulation

Introduction

The number of people aged 60 and over has reached 600 million in 2000, 700 million in 2006, 810 million in 2012, and is projected to reach 2 billion in 2050 [1-2]. There are many diseases that will affect mobility function of lower limb, among which stroke is a major disease that may lead to mobility disorder. Nearly three-quarters of all strokes occur in people over 65 years old, which seriously impacts their life qualities [3]. Therefore, improving motor function for individuals after stroke is an important task of rehabilitation treatment [4].

The rehabilitation effect of the lower limb rehabilitation robot on the patients with motor dysfunction has been widely affirmed [5-6]. Lower limb rehabilitation robots can be divided into two categories according to their structure, i.e., exoskeletons and end-effector rehabilitation robots [7]. Exoskeletons such as Lokomat [8] and LOPES [9] are motorized orthoses placed over a person's limb with joint parts corresponding to

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those of the human body to facilitate standing and walking. End-effector rehabilitation robots such as LokoHelp [10] and HapticWalker [11] drive the patient's foot by an end pedal. Compared with the exoskeletons, this types of rehabilitation robots can provide more kinds of trajectories. However, most of them can only provide 2 or 3 degree of freedom in the sagittal plane, sacrificing the motion in the coronal plane and the horizontal plane as well as the foot pose. That may result in the movement mode of lower limb muscle groups different from ordinary people, and it is difficult for patients to receive the correct movement sensory stimulation in the rehabilitation period. In terms of product design method, Margherita presents a valuable example of a successful system definition according to the specific needs of end-users based on user-centred approach [12]. It has been proved that each design phase in the development cycle of a product requires strategic planning to seek the best solutions to meet the specificity needs of users [13].

From the performance of lower limb dysfunction, it is usually manifested as neurological damage and lower limb muscle weakness. Therefore, it is of great significance to study the rehabilitation training effectiveness according to parameter changes of the patient's skeletal muscle in the rehabilitation process. The Fugl-Meyer Assessment of the lower extremity (FMA-LE) is widely used to evaluate lower extremity motor recovery and predict functional recovery in individuals with stroke based on impairment outcome [14-15]. The Berg Balance Scale (BBS) is the most commonly used assessment tool across the continuum of stroke rehabilitation [16]. However, the assessment indicators mentioned above only consider the degree of recovery of the human joint movement and they can't objectively assess the effect of muscle training.

To study the effect of different walking patterns on human muscle activities of the lower limb, data acquisition experiment of human normal walking movement is conducted and analyzed firstly. Then an end-effector hybrid rehabilitation robot concept with multi-degree freedom based on human motion characteristics is designed. Next, human-robot coupling model is established and simulated in the *AnyBody Modeling System* [17]. Effects of gait trajectory and the simplification of the degree of lower limbs on physiological parameters (muscle length and contraction rate) are discussed. Finally, conclusions and future work are drawn in section 4.

1. Gait data acquisition and processing

In order to study the relationship between muscle activity and movement of lower limbs and provide a meaningful reference for robot design, we need to understand the characteristics of human movement firstly. Human movement is a very complicated activity, which is the co-driven results of multiple muscles of human body. The walking movement of the human body's lower limb occurs in the sagittal plane, the coronal plane and the horizontal plane, but mainly occurs in the sagittal plane.

Most of the lower limb rehabilitation robots are designed to only take the movement of human in the sagittal plane into account, and ignore the movement in the coronal and horizontal plane. This paper mainly study the effects of different motions in the sagittal plane on the muscle activity of the lower limbs, and then explore the effect of different foot angle on the rehabilitation effect. Normal walking movement data acquisition of human gait is essential for simulation and contrast.

Data collection experiment is conducted by an optical three-dimensional motion analysis system named LUKOtronic-AS100 combined with the COSMOS treadmill. The subjects is a healthy male adult whose age is 24, height is 180 cm, weight is 75 kg, thigh length is 423 mm, and shank length is 412 mm. Let the subjects walk on the treadmill at the speed of 3.6 km/h for 1 minute, and there are altogether 46 sets of complete joint angle cycle data are obtained. Figure 1 is the kinematics model of lower limb, and the kinematics equation of lower limb can be formulated as follows.

$$\begin{bmatrix} X_A \\ Y_A \end{bmatrix} = \begin{bmatrix} -\sin\theta_H & \sin(\theta_K - \theta_H) \\ -\cos\theta_H & -\cos(\theta_K - \theta_H) \end{bmatrix} \begin{bmatrix} L_{th} \\ L_{sh} \end{bmatrix} + \begin{bmatrix} X_H \\ Y_H \end{bmatrix} \tag{1}$$

$$\theta_{plt} = -\theta_H + \theta_K - \theta_A \tag{2}$$

where (x_A,y_A) is the position of ankle joint; (x_H,y_H) is the position of hip joint; θ_{plt} is the angle between foot and ground; L_{th}, and L_{sh} are the length of the thigh and shank; θ_H, θ_K, and θ_A are hip angle, knee angle, and ankle angle, respectively. L_{th} =0.423m, L_{sh} =0.412m. Let the hip joint be the origin of the coordinates and substitute the average value of θ_H, θ_K, and θ_A into the equation, the ankle coordinates and the foot attitude angle can be obtained as shown in Figure 2 and Figure 3, respectively.

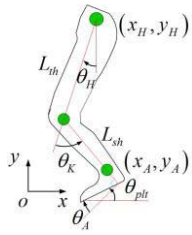


Figure 1. Gait coordinate system for kinematic modeling.

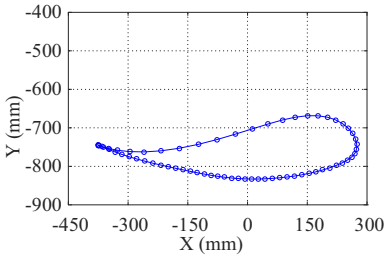


Figure 2. The trajectory of ankle joint.

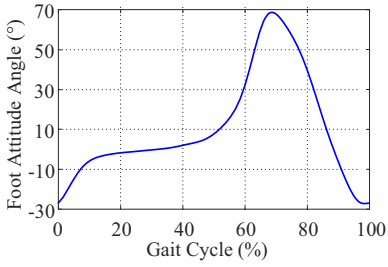


Figure 3. The posture of foot

2. Human-robot modeling system

Human-robot model includes 3 parts, i.e., human part, environment part and constraint part. The biomechanical model of human body and the CAD model of the robot established in SolidWorks are integrated. Simulation cases are specified for a certain application. The motion of the musculoskeletal model uses the motion capture data of people's activities of daily living.

2.1. Concept design of the end-effector hybrid rehabilitation robot

In order to do simulation with various kinds of trajectories. The rehabilitation mechanism utilizes a hybrid mechanism which combines the advantages of parallel

mechanism and series mechanism ,i.e., high stiffness and large workspace. Figure 4 shows the solid model of the mechanism. This mechanism can realize 3 rotation mobility around ankle joint rotation center and 2 translational mobility in the sagittal plane so that it can match of real motion of the lower limb to a large extent, which also provides the possibility for multiple movement patterns to realize individualized rehabilitation training needs.

2.2. Human Musculoskeletal model

This paper uses the human biomechanics software AnyBody (AnyBody Technology A/S, Aalborg, Denmark) to simulate the physiological parameters of the lower limbs of the human body under robot assisted training. The first step is to establish human model in *AnyBody Modeling System*. The model is derived from the repository models in the software. Then Modify the body size by using the scaling function *Scaling Length Mass* according to the specific body parameter information shown in Table 1 to meet personalized needs. This human model includes 62 segments, 42 degree of freedom, among which 20 in upper limb, 12 in lower limb, 6 in pelvis, 3 in thorax, and 1 in neck.

Table 1. Length and mass of the human segments.

limb	head	trunk	thigh	shank	upper arm	forearm
length/mm	220	620	423	412	340	269
mass/kg	6.134	32.100	10.587	3.381	2.107	1.103

2.3. Human-robot coupling system

The human-robot modeling system is developed through integrating the human model and the robot. Firstly, a musculoskeletal model of the human model derived from the repository models is built in the *AnyBody Modeling System*. Set the size of the human model according to the measurement results. Secondly, export the robot model built in SolidWorks to AnyBody. Several reference nodes are defined on the human model and robot for integrating them together. Thirdly, redefine all joints in AnyBody. Figure 5 is the coupled human-robot model.

3. Human-robot simulation

The movement of the human body is the result of skeletal muscle contraction and extension. When the lower limb moves, the value of joint torque is related to the value of muscle strength and the posture of the lower limb. According to hill muscle model [18], muscle strength is related to the muscle elongation and contraction rate. So this paper takes muscle elongation and contraction rate and muscle length as criterion to study the relationship between different movements of lower limbs and muscle activities.

3.1. Human-robot simulation with different movement patterns

To analyze the effects of lower limb rehabilitation robots on human walking function, literature [19-20] analyzed the muscles that play a major role in the motor function of the lower limbs. In order to analyze the effect of the trajectory and the degree of freedom simplification of lower limb joint on the physiological parameters of lower limb, this paper selects the length and contraction rate of 8 main muscles of lower limbs as a reference for comparison, i.e., gastrocnemius, tibialis anterior, vastus medialis, rectus femoris, biceps femoris, semitendinosus , biceps femoris, gluteus maximus and adductor longus.

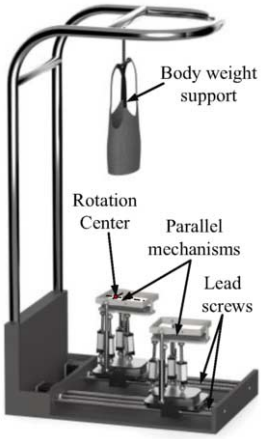


Figure 4. CAD model of the rehabilitation robot.

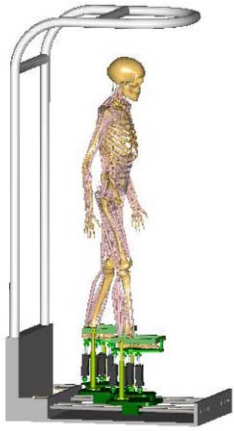
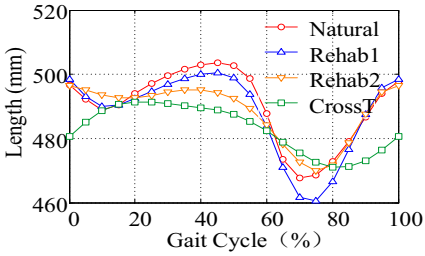


Figure 5. Human-robot coupling model.

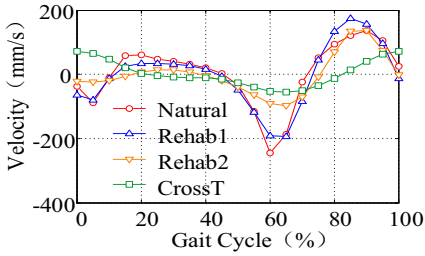
The *AnyBody modeling system* is mainly focus on the human and human-machine interaction instead of the mechanism itself. In order to improve calculation efficiency, the rehabilitation mechanism is simplified and the end-effector motion data is used to drive the human-robot coupling model in AnyBody to calculate inverse dynamics. To compare the effect of different motion patterns of lower limbs on human muscle activities, three different patterns based on rehabilitation robots is used to drive the human-robot coupling model, i.e., normal gait trajectory considering the foot pose (denoted as Rehab1), normal gait trajectory with the ankle joint angle fixed (denoted as Rehab2); elliptical trajectory with the ankle joint ankle fixed (denoted as CrossT). Besides, natural walking simulation is also analyzed as a contrast based on the example in the software (denoted as Natural). Motion data is gotten by data acquisition experiment and calculation in Matlab.

After inverse dynamic calculation, the main muscle length and the contraction rate of lower limbs under three kinds of training gait based on end-effector rehabilitation robot and normal walking are shown in Figure 6 (a1) ~ (h1), Fig. 6 (a2) ~ (h2), respectively.

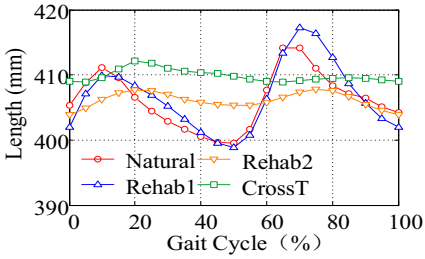
In order to analyze the effect of ankle posture on the physiological parameters of lower limbs, we can compare the differences between Rehab1 and Rehab2. As is shown in Figure 6 (a) and (b), the length and contraction rate of gastrocnemius and tibialis anterior between the two training gait have some significant differences. The length change of the two muscles for the Rehab2 gait is smaller than that of the Rehab1 gait,



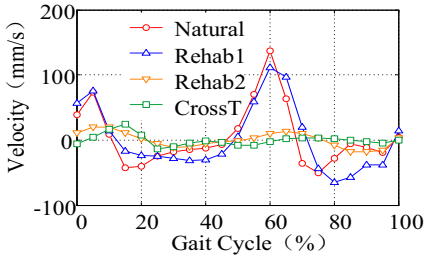
(a1) Comparison of Gastrocnemius length



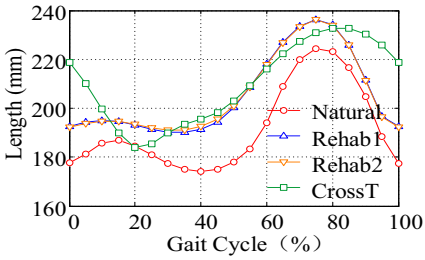
(a2) Comparison of Gastrocnemius velocity



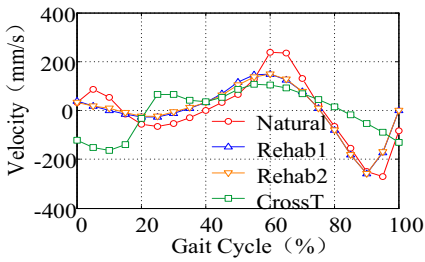
(b1) Comparison of Tibialis Anterior length



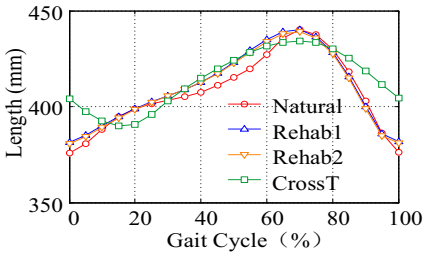
(b2) Comparison of Tibialis Anterior velocity



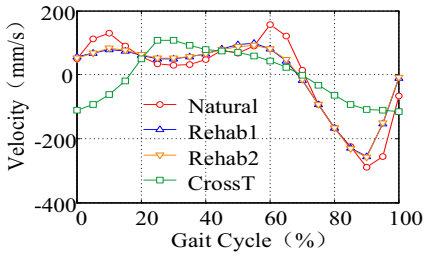
(c1) Comparison of Vastus Medialis length



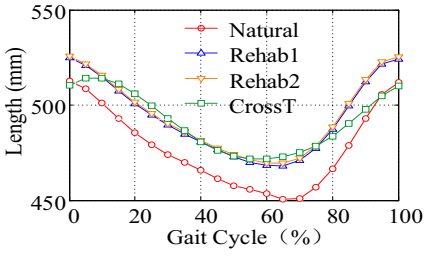
(c2) Comparison of Vastus Medialis velocity



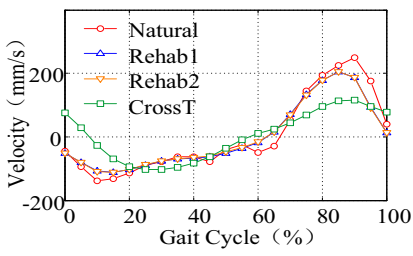
(d1) Comparison of Rectus Femoris length



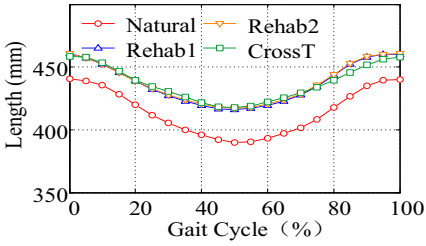
(d2) Comparison of Rectus Femoris velocity



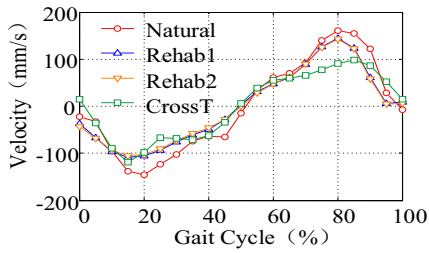
(e1) Comparison of Semitendinosus length



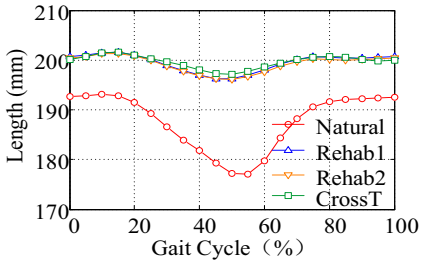
(e2) Comparison of Semitendinosus velocity



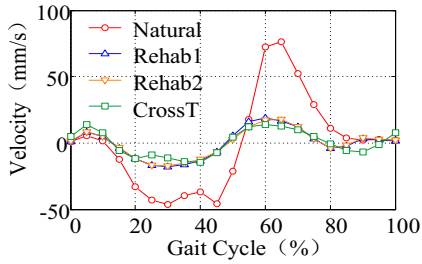
(f1) Comparison of Biceps Femoris length



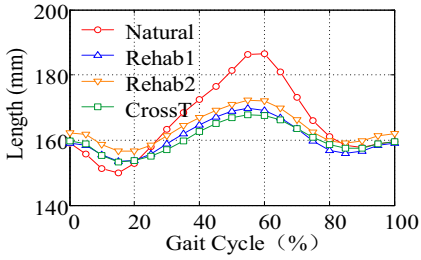
(f2) Comparison of Biceps Femoris velocity



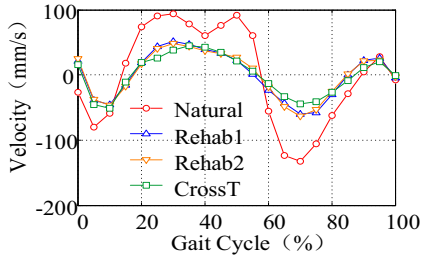
(g1) Comparison of Gluteus Maximus length



(g2) Comparison of Gluteus Maximus velocity



(h1) Comparison of Adductor Longus length



(h2) Comparison of Adductor Longus velocity

Figure 6. Comparison of the length and contraction velocity of the lower limb major muscles.

and the muscle length change in the Rehab1 gait is closer to the normal walking gait. Taking into account that the gastrocnemius and tibialis anterior muscle are calf muscles, it can be concluded that foot posture is important for calf muscles in lower limb rehabilitation. From Figure 6 (e), (f), it is not difficult to find that the length change and contraction rate of the semitendinosus and biceps femoris are similar in three cases, and are close to normal walking pattern. Therefore, from the perspective of muscle length and contraction rate, the effects of three training gait on semitendinosus and femoral biceps are certificated. By comparing the differences between Rehab2 and CrossT, the effect of the ankle trajectory on the physiological parameters of the lower limbs can be analyzed. As is shown in Figure 6 (c) and (d), it can be seen that the Rehab2 training gait is closer to the normal walking than the CrossT training gait.

However, it can be seen from Figure 6 (g) and (h) that although the trend of the length and contraction rate of gluteus maximus and adductor longus in the three training gait is similar to the normal walking, the amplitude of the muscle length and contraction velocity vary greatly from the normal walking. Taking into account the role of gluteus maximus and adductor longus, it can be speculated that the deviations from the three training gait are occurred because only the foot movement in the sagittal plane

is considered during inverse dynamic simulation of human-robot coupling system. This question will be discussed in next section.

3.2. The effect of mobility simplification on muscle length change

Considering that lower limbs move mainly in the sagittal plane, the existing lower limb rehabilitation robots simplify the movements of the lower limbs to the sagittal plane. Exoskeleton robot, such as Lokomat, usually neglects the abduction, adduction, internal rotation and external rotation motion of the hip joint. The G-EO is a foot-driven robot that drives the foot through the left and right pedals moving in the sagittal plane.

The lower limb rehabilitation robot mentioned above did not take into account the distance between the two legs along the direction of the coronary axis (hereinafter referred to as foot distance) and the rotation along the sagittal axis and vertical axis. In order to study the effect of the above degree of freedom on the physiological parameters of the lower limbs, the simulation system takes the neglected degree of freedom as the variables to conduct simulation. Take adductor longus as an example, simulation results are as follows. Figure 7 shows the effect of the distance between feet on adductor longus length. Figure 8 shows the effect of the foot angle around sagittal axis on adductor longus length. Figure 9 shows the effect of the foot angle around the vertical axis on the adductor longus length. All simulations are carried out in one gait cycle.

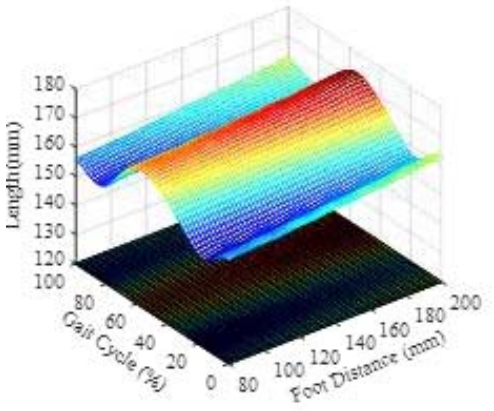


Figure 7. The effect of distance between feet on Adductor Longus

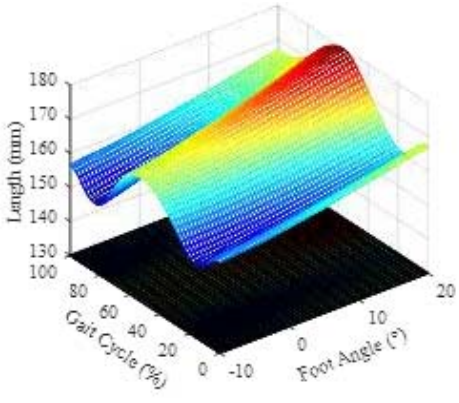


Figure 8. The effect of the foot angle around the sagittal axis on Adductor Longus.

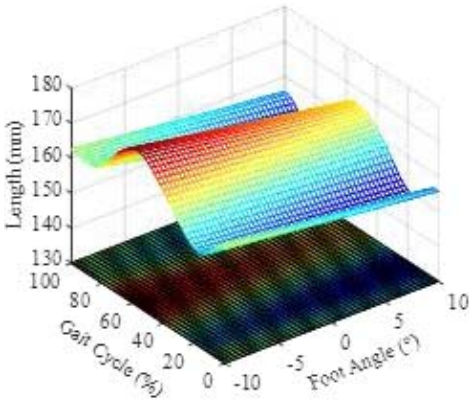


Figure 9. The effect of the foot angle around the vertical axis on Adductor Longus.

It can be seen that the distance between the feet can greatly affect the length of the adductor longus from Figure 7. The maximum length of adductor longus changes from 166.84 mm to 172.77 mm while the foot distance changes from 80 mm to 200 mm. When the foot distance changes, the hip will produce adduction/abduction movement. Considering that the adductor longus has the function of adduction and external rotation of hip joint, it is not difficult to find out the reasons for this result. The foot distance will change during the swing phase of walking process, but there is no displacement during general robot-assisted training, so there will be a certain difference in muscle activities between robot-assisted training with normal walking.

Figure 8 and Figure 9 show that the foot angle around the sagittal axis and the vertical axis have evident influence on the adductor longus muscle activities. The maximum length of adductor longus increases from 166.42 mm to 174.35 mm while the foot angle around the sagittal axis changes from -10° to 20°, and decreases from 174.43 mm to 165.52 mm while the foot angle around the vertical axis changes from -10° to 10°. It is known that the adductor longus is one of the muscles to promote external rotation and adduction movement of the hip joint, which is related to the foot angle around the sagittal axis and the vertical axis, and that can explain the simulation results in Fig. 6 (h). As there is no rotation motion during general robot-assisted training, there will be some differences in muscle activities from normal walking to robot-assisted training. In order to achieve better rehabilitation training effects, more degree of freedom rehabilitation mechanism is useful.

4. Conclusion

In this paper, an end-effector hybrid rehabilitation robot concept with multi-degree mobility is designed in terms of human motion characteristics. Effects of gait trajectory and the degree of freedom simplification of rehabilitation robot on human physiological parameters are discussed. To get the movement data of human walking, gait data experiment is conducted and processed. In order to compare the effect of different motion patterns of lower limbs on human muscle activities, three different patterns based on rehabilitation robots are used to drive the human-robot coupling model. 8 main muscles of the lower limbs are chosen for analysis and comparison. The results show that ankle posture have significant impacts on gastrocnemius and tibialis anterior and it is essential to take the foot posture into account for better rehabilitation training. Besides, the feet distance, foot angle around the vertical axis and sagittal axis have evident influence on some muscle activities. In order to achieve better rehabilitation training effects, multiple degree of freedom rehabilitation mechanism is helpful. However, increasing degree of freedom will make the rehabilitation robot system more complex and costly. Therefore, personalized lower limb rehabilitation robot mechanism with different mobility and different movement patterns can be designed according to the individual needs of various patients with lower limb dysfunction to train specific muscle groups and realize better rehabilitation effect.

Future research will be focused on making physical prototype of the rehabilitation robot and experiment. Different movement patterns should be designed to conduct experiment, verifying the validity of the inverse dynamic simulation results. Furthermore, more simulations and experiments should be conducted to find alternative motion patterns to meet the individual needs of stroke patients in different period and degree.

Acknowledgement

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Part 6

Design Methods and Tools

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Transdisciplinary Engineering: A Paradigm Shift
C. Chen et al. (Eds.)

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Automated Design Assessment as a Strategic Part of Design Platforms

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Abstract. This paper presents a general model for businesses to work with their engineering assessments to challenge fluctuating requirements which is the result of a recently finished research project. The model is presented together with a case study of a company with a product that continuously is and must be adapted to a changing market to be alive at all. The company has developed a streamlined development process that is configured based on current needs from time to time. One keystone to make the mass customization possible to this company is the augmented synthesis and the automated assessment of the product variants rendered through the configured development process. The automated process of making the assessments and how it connects to the general model is also presented in the paper.

Keywords. Product platform, Product development, Customisation, Requirements, Design Knowledge Reuse, Information Retrieval, Engineer-to-order, Engineering design, Traceability, Set-Based Concurrent Engineering (SBCE), Design Automation, Simulation-Based Design.

1. Introduction

Companies in industry maintain their competitive edge by continuously and systematically modularize and standardize their products. This is however a challenge for sub-suppliers due to the large difference between the various systems their products are to be integrated to, the markets the product are intended for, the use of the product and the customer's individual preferences. These companies face the challenge of product requirements fluctuating in an unpredictable manner. The mass customization in such companies must be treated as a part of the development process putting focus on configuring engineering and manufacturing tasks rather than prefabricated components. Automation of manufacturing and production has been an ever-ongoing research activity for more than a hundred years making the automation of engineering tasks the bottleneck for achieving mass customization for companies facing unpredictably fluctuating product requirements.

This paper is organized as follows: First a frame of reference is provided to give a short brief of previous related work. Then a general model is presented for businesses to work with their engineering assessments to challenge fluctuating requirements. At end of the paper a case study of a company is described. The company manufactures a product that continuously is and must be adapted to a changing market to be alive at all.

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The company has developed a streamlined development process that is configured based on current needs from time to time. Two keystones to make the mass customization possible to this company are the augmented synthesis and the automated assessment of the product variants rendered through the configured development process.

2. Frame of reference

Product development refers to a set of well-defined processes performed to transform market needs and opportunities into financial success for a company and its stakeholders [1]. The introduction of product platforms as a strategy for product development has made manufacturing companies more effective in meeting shifting market needs to a low cost. The driving force to develop product platforms is to reuse company assets which can mean anything from released components to more abstract descriptions containing knowledge, people and relationships. Two types of platform approaches were proposed by [2]: 1) Module based platform, constituted by a product architecture into which well-defined and often pre-manufactured modules can be assembled into a finished product. 2) Parametric platform, creates product family by introduction design parameters that are changed to specify product family members.

These two type of platforms requires the product to be at a high level of realization, i.e. the embodiment of all components is complete and can be configured or parametrically changed. This is far from true for many products and to overcome this problem a knowledge platform was proposed by [3]. A knowledge platform is built by reusable knowledge that is continuously gained through the different development processes [4].

Set-Based Concurrent Engineering (SBCE) is a lean product development method and is in this context an interesting mindset for product development. Opposed to a traditional point based approach it is instead encouraged in SBCE to develop sets of solutions in parallel [5]. In a point based approach a concept is chosen early in development and then iterated towards reaching a feasible solution. With SBCE on the other hand a wider spectrum in the design space is covered, making it more likely for the solution to be found. The focus is to eliminate unfeasible solutions when enough knowledge about the solution exist as opposed to early picking a solution when not enough knowledge exists. Positive effects when applying SBCE has been observed in industry [6]. Ward [7] summarises the benefits as: enabling reliable and efficient communication, allowing for greater parallelism in the process, basing the most critical decisions on data, promoting industrial learning and allowing for a search of globally optimal designs.

The knowledge value stream, aiming at capturing and reuse knowledge regarding markets, customers, technologies, product and manufacturing capabilities, is central in lean product development [8]. To make good use of the gained knowledge it should be generalised and visualised as far as possible to flow across projects and organisations. Knowledge can be of two kinds according to Kennedy [8]: First, we have knowledge that is conserved in people and secondly, we have knowledge that can be stored outside people. In the course of developing methods and tools for mass customization the knowledge of the latter one is utilized as far as possible [9].

3. Research method

This paper reports a research project entitled *Challenge Fluctuating and Conflicting Requirements by Set-Based Engineering* (ChaSE) that ran 2014 through 2016 aiming at understanding the challenges mentioned in the previous section and further to develop new methods for increasing the ability to efficiently develop and describe adaptive technology solutions to meet changing and conflicting requirements [10][11]. Three large companies were engaged in the research project and served as testing areas for the ideas. This paper presents the final, general model in short and expands on one of the three case examples.

4. A general model for sub-contractors to work with their products to challenge fluctuating and contradicting requirements

As seen from the frame of reference manufacturing companies are encouraged to working with their products as platforms and with their knowledge in a structured way. There is however a need of a coherent platform model that support customization and easy adaptation to fluctuating and contradicting requirements during a development project, especially for companies with products not suited for pure configuration (that is based on prefabricated components). Through the research project of which this paper is reporting it has been shown that this ability can be gained by the following 10 actions [12]: 1) Define solutions as design spaces (continuous or discrete). 2) Generalize product structures. 3) Mapp existing solutions (components/assemblies) and projects. 4) Develop parametric geometry models. 5) Assess trade-offs. 6) Retrace, improve and publish engineering processes. 7) Define tasks with supporting methods and guidelines. 8) Build knowledge, skills and abilities (competence teams). 9) Improve by experience from product development. 10) Organize management of the platforms.

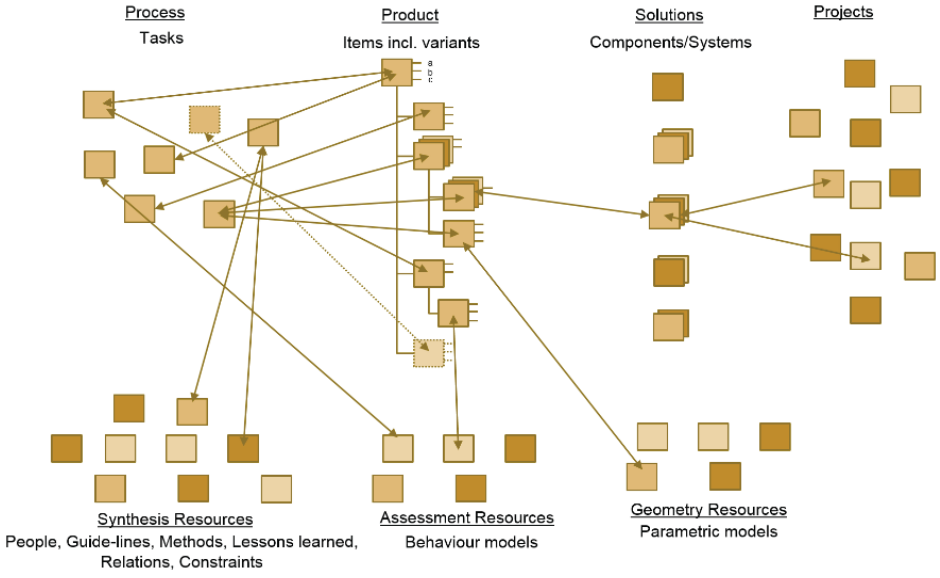


Figure 1. A model of the generic Design Platform. Arrows indicate associations in general.

The sum of the results from taking these actions is (when put together in a structured way) called a Design Platform, which is more abstract when compared to a product platform. The main theme in platform thinking is the reuse of components or modules to keep the design effort efficient and at a manageable level. Design platform, even though more abstract and less tangible, supports continuous evolution and the reuse of knowledge and experience but also items used in previous projects.

A Design Platform is composed of different assets related to Process, Synthesis Resources, Product Constructs, Assessments Resources, Solutions and Projects (see Figure 1).

The Design Platform structure consists of Items (parts and sub-assemblies) at different levels of realization. Standard Items (Geometry) are components that are purchased or made to stock. These components are released to production and cannot be changed. Automated adaptable, flexible or tailor made Items (Geometry + Logics + Constraints) are components that are mathematically defined in CAD-models so that they can easily be changed and still have a sound geometry and be manufactured. Tasks to complete the embodiment for these parts are partly or fully defined. These components are normally developed and produced by the company. Non-automated adaptable, flexible or tailor made Items (Geometry + [Logics] + [Constraints], surrounding brackets indicates optional parts) are components that are mathematically defined in CAD-models so that they can be changed and still have a sound geometry [and be manufactured]. These components are developed and produced by the company. The logical model might not be complete. The constraints definitions on these models are normally scars. The focus is often on the adaptable geometrical model. Specialized or engineered Items (Logics [+ Constraints]) are components that are developed from time to time at the company but where the geometrical differences are that big that no general geometrical model can be developed. The focus is on developing the logical model, including tasks, and to some extent the constraints. When demanded the logics and tasks are configured into a process that is executed (manually, semi-automatically or automatically) to render the components.

During the development of the design platform the scope is extended to include the definition of a feasible design space of the underlying technology. These definitions include supporting documentation, methods, models and tools and is developed through or constituted by: 1) activities that govern the work of generating an adapted solution, 2) methods to define properties, 3) parametric CAD-models (constitutional models), 4) simulation ready behaviour models, 5) trade-off curves, 6) rules for controlling product constructs, 7) guide-lines for manual work, 8) structures for lessons learned and other supporting documents, and 9) expert support.

The Design Platform should be managed as an important asset and it should be able to evolve as knowledge is gained of its application in PD. Its completeness and the maturity of the different constituting parts should be continuously reviewed to ensure and improve the platform's usefulness.

5. Case study

One of the companies studied in the ChaSE research project and that we focus on in this paper, develops and manufactures products that support an active life style. Some of the products are transport centred, e.g. roof boxes and bike carriers, which makes car

roof racks an important product to the company, which is product picked for the case study.

Both safety and geometrical requirements are put on the product, since it must be tightly mounted on the car roof so that it does not fall off in case of a crash, even if loaded with several bicycles or a heavy roof box. Still the car body must not be damaged, buckled or scratched, when mounting the rack. These two strict and contradicting requirements set a very tight design space making it necessary to adapt the product for each new car model introduced on the market.

Since the company policy is to provide roof racks for 95% of all car models worldwide and due to the selling curve for peripheral car equipment peaks quickly after the release of the car model puts high pressure to make the adaptions of the roof rack product very quick (some few weeks). This together made it hard but still necessary to the company to develop a platform strategy. The trade-off was to make a design platform, that is a product platform with components not yet embodied but with processes and resources to do so when needed (see section 4). We will look at the company's adaption process and resources to synthesis and analyse new variants of roof racks at high speed. Each of the subsection correspond to one category in the general model presented in Figure 1.

5.1. Product structure

What the customer really buys when buying a roof rack is the ability to carry load on the roof. To achieve that two bars are supported by four feet which in turn are mounted on the car roof. There are several types of roof/rack interfaces: rails, flush rails, fix points and clamping (for cars with no rails at all). It is the latter type, clamp racks, that was selected for the case study.

The strategy when developing the design platform was to embody as many components as possible and isolate the upcoming changes to just two components. The adaption is hence done by changing two components, the bracket and the foot pad. The foot pad is a rubber pad on which the rack is standing on the roof, and the bracket is used to fix the rack by keeping around the roof end where the doors are.

High requirements are put on these two components, especially the bracket, to keep the rack on the roof in case of a crash but still not buckle the car body when mounting the rack. The company acts on the open market competing with car manufacturers and therefore can get no nominal data of car roofs. Instead they must collect geometrical information about the car roofs using a scanner.

When the roof geometry is collected for one particular car model a foot-pad is selected or developed and the rack is placed on the foot-pad in the CAD-model. Finally, a bracket is selected or developed and mounted into the CAD-model. It can be concluded that there are three components in the product structure that cannot be predefined. The roof, the foot pad and the bracket.

5.2. Adaption process

The process of adapting the roof rack to a new car model is a streamlined development processes with four gates: Start up, Tool Release, Product Release, Project Closure. The scoping step includes market analysis and project budget specification. Then the roof of the car model to adapt the product to is scanned (since the company works on the open market they cannot get CAD-data from car manufactures since they are their

competitors). The roof data is used to try to find existing foot pads and brackets that can be used to clamp the rack of the new car model. If there are no existing foot pads or brackets applicable new ones are developed. A set of standardized crash scenarios are simulated to make sure the roof rack is safe. If it is safe and existing components were found to use, then the project is finalized by updating the standardized packaging and mounting instructions. If there are no existing components applicable to the new car roof, then new brackets and foot pads must be developed and in turn tooling must be developed, manufactured and tested. The process is configured and managed by a semi-automated spread sheet where the manager selects what process steps must be taken and who is responsible. When tasks are completed emails are autogenerated from the spread sheet to inform managers and initiate downstream activities.

5.3. Synthesizing of variants

Reusing components can make big short cuts in the adaption process. In fact, four process steps can be cut in such cases. These process steps consume up to 50% of the maximal project time and can make a project unprofitable. Previously this save in time was not obvious to engineers in the early steps to whom it was easier to develop new components rather than searching for existing ones (the CAD-models are not so complicated and the number of existing components to search is big). Case Based Reasoning (CBR) was applied to make it easier to retrieve existing brackets and footpads [13,14]. The CBR system was integrated to the CAD-system to interactively indicate search criteria and to visualise results in context of the CAD-assembly.

5.4. Assessing variants

The roof rack product is a safety component and it is hence necessary to assess each new product variant through testing. Since the company policy is to provide roof racks for 95% of all car models worldwide the testing cost is extensive, which calls for virtual testing. One problem with virtual testing through FEM-simulations in this case is the extremely short project lead-time (some few weeks from a car entering the market to launching the roof rack production). Therefore, it was necessary to automate the virtual testing process, a task that was adopted as a case study in the ChaSE research project.

Full functioning prototype software, under the workname AutoCRASH, was developed during the research project to make it possible to flexibly automate the process of transforming the roof rack CAD-models to crash simulation models. The software includes automated methods and processes performed in Solidworks (CAD-software), Ansa (pre-processor) and LS-Dyna (post-processor). The system is based on programmable features in the CAD-system [15], which is a more general type of feature than user-defined-features. The AutoCRASH features carry geometrical data as well as numerical and textual data and are used as a base for the transformation from CAD-model to crash simulation model. This method can be viewed as having the simulation model stored within the CAD-model, making it a simulation ready CAD-model. When making the transformation the AutoCRASH-features are interpreted into a python script executed in ANSA to render a LSDYNA model that can be executed. The script includes meshing commands based on pre-defined meshing and mesh quality parameters, material definitions, component interdependencies (such as contacts,

joints, and constrained rigid bodies), boundary conditions and simulation execution preferences (such as reporting frequency, and execution time).

Once the model has been defined the user can create the FE-model by a single click in the menu-bar.

5.5. Geometry resources

One share of the ChaSE-model in Figure 1 is geometry resources and in the studied company these includes CAD-models of the foot, foot pads, brackets and roofs. The geometrical resources are not limited to CAD-models but also includes light-weight representations of roofs, foot pads, and brackets used when geometrically searching for existing components to reuse. Further there are geometrical models to support crash simulations which are pre-meshed components of the foot that are reused in every crash simulation. (Components that are unique for a simulation are automatically meshed by the AutoCRASH software.) Standard geometrical models of tooling for new brackets and foot pads can also be included in the category of geometrical resources.

5.6. Solutions

In this specific case, the roof rack product, solutions and car models are mapped one to one. In everyday language, the engineers indeed say they “solve a car”. What is most important to share as solution between projects is light-weight geometrical information regarding the brackets and foot pads. This information is collected during the follow up process. The information is collected by selecting certain features of the CAD-models which are interpreted and indexed to be searchable by the geometrical search engine.

5.7. Projects

Components checked in to the PDM-system include the foot, brackets and foot pads. But during a project there are more information than so. A project folder contains a CAD-model of the car roof with the roof rack mounted on top of it with brackets and foot pads (only one side of the car as the model is symmetric). The project folder also contains budget information, a local copy of a semi-automated spread sheet with the process and, crash simulations.

5.8. Supporting Set-Based Concurrent Engineering

Two resources make it affordable to introduce set-based concurrent engineering at the studied company. It is the geometrical search engine and the automated crash simulations. When having these tools at hand it is possible to select sets of candidate solutions (foot pads and brackets) and automatically execute crash simulations for each combination of these to develop trade-off curves to make decision of which one to select.

6. Conclusions

This paper summarizes one of the case studies in the research project entitled *Challenge Fluctuating and Conflicting Requirements by Set-Based Engineering* (ChaSE). The case study was performed at a company that develops and manufactures car roof racks to the open market. The company actively works with their products to develop design platforms (that are more abstract than product platforms) by introducing standardized workflows that can be configured for each project, automating parts of the processes and storing solutions to reuse in new projects. This way of working has enabled the company to work in a set-based way and standing strong on the global market.

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Modern Chair Innovative Design Approaches and Paths Based on Economic Considerations

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Abstract. To design driven innovation strategy furniture firms, diversified product design can improve the market competitiveness on the one hand, and may cause the disturbance of the brand identity and the increase of production cost on the other hand. How to effectively reduce the production cost on the premise of increasing product diversity and remaining the brand identity is one of the major challenges faced by the modern furniture manufacturing enterprise. In this paper, a total of 199 types of chair products from 8 international well-known furniture enterprises were selected as research objects. Case studies were applied to investigate the relationship between the three indicators mentioned above. On this basis, modern chair innovative design approaches and corresponding realization paths were discussed.

Keywords. Chair, Innovative Design, Economic Considerations

Introduction

Design driven innovation strategy was proposed by R. Verganti at 2003, and is regarded as the third and the latest innovation strategy [1]. Differing from the two traditional innovation strategy including technology push innovation strategy and market-pull innovation strategy, design is taken as the innovative driving source in this strategy. The strategy is not only profitable for traditional industries, but also serves deeper purpose in enhancing the lives of individuals. At its best, the design movement seeks to bring innovations-sometimes radical innovations-to product language that have to adapt to new circumstances of economic competition, patent user needs, social expectation and deeper cultural understanding [2]. Referring to literatures, more and more traditional furniture firms adopted this strategy to upgrading in recent years [3].

To design driven innovation strategy enterprises, the high market competitiveness was mainly achieved by developing a strong brand identity through designing diversified products. However, diversified product design may create a disturbance on the brand identity on the one hand, and cause the increasing of production cost on the other hand, both of which conversely reduce the market competitiveness. Hence, to effectively reduce the production cost on the premise of increasing product diversity and remaining the brand identity is one of the major challenges faced by the modern design driven innovation strategy enterprises [4].

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Up to now, a limited number of papers address the relationship between diversified product design on the premise of specific brand identity and the production cost, which do not match with the significance of the problem [5]. In addition, to the best of our knowledge, modern chair innovative design approaches based on the economic considerations mentioned above were never discussed in previous studies.

In this paper, a total of 199 types of chair products from 8 international well-known furniture enterprises were selected as research objects. Case study was used to analyze the relationship between product diversity, brand identity and production cost. Further, modern chair innovative design approaches and paths to realize diversified product design on the premise of coherent stylistic brand identity with controlled production cost were discussed herein.

1. Research method

Case study was performed in this work. Chair products from representative design driven innovation furniture firms were selected as cases firstly. CMF tool, which refers to the abbreviation of three key words, color, material, and finishing, was then launched to analyze the relationship between product diversity, brand identity and production cost of all chair products in each firm. On this basis, modern chair innovative design approaches were discussed. Subsequently, case cards for each chair products were prepared, and 5W1H tool, which is also an abbreviation of six key words including who, where, when, why, what and how, was used to extract the information concerning about innovative design paths and corresponding production costs. Through comparing the collected information mentioned above, paths to realize diversified product design on the premise of coherent stylistic brand identity with controlled production cost were discussed.

1.1. Case selection

Italy modern furniture is famous all over the world for its high quality and extraordinary design. The distinctive development pattern also becomes to be the template for small and medium-sized furniture enterprises [6]. In this paper, a total of 199 chair products from 8 Italian furniture firms were selected as cases based on Milan design week field study [7]. The detailed information is listed in Table 1.

Table 1. Chair case cards summarization.

No.	Brand name	Chair sample number
1	Arflex	24
2	Driade	41
3	Edra	16
4	Kartell	28
5	Lago	4
6	Moroso	44
7	Porro	9
8	Zanotta	33

1.2. Case study

As mentioned above, CMF tool was used to investigate the relationship between product diversity, brand identity and production cost of all chair products in each firm [8]. Further, 20 experts from institutes and industries were invited to perform the questionnaire survey for the three indicators based on the CMF analysis results. Figure 1 shows the survey results to Porro.

As shown in Figure 1, each indicator were divided into 5 grades. The higher grade to the three indicators indicates the higher product diversity, brand identity and the lower production cost, respectively.The triangle area shown in the Figure can then be used to evaluate the relationship between the three indicators. That is, the bigger triangle area indicates the better balance of the three indicators. Further, through analyzing the common approaches to achieve the balance of the three indicators, potential design approaches were suggested.

Moreover, to obtain the corresponding paths to achieve the approaches proposed above, case cards for each chair products were prepared, and 5W1H tool was used to extract the core information concerning the production process.



Figure 1. Sample for CMF analysis.

2. Results and discussions

Based on the investigation on each firm, the following two approaches have been put forward to reduce production costs on the premise of high product diversity and brand identity.

2.1. Optimization design approach

The optimization design approach is to seek rational design strategy that can im-prove the product diversity on the premise of meeting the product requirements. This design strategy is established on the basis of optimization theory on mathematics and solved by means of computer programming. Case studies based on the above design strategy give the following three design paths:

1. Seeking alternative materials and hardware.
2. Determining reasonable product size and improving the utilization rate of material.
3. Developing alternative production process.

The corresponding discussions for the 3 paths are listed in Table 2.

Table 2. Design optimization approach.

Design methods	Supporting cases
1.Seeking alternative materials and hardware.	 Case 15 from brand Zanotta: Designer Marco Zanuso was the first furniture designer who tried to replace the original fabric and sponge material by plastic and foam as the filler in sofa.
2. Designning product in a reasonable size to improve the utilization rate of materials.	 Case 02 from brand Lago: By calculating the dimension of the chair and basing plate size, designer maximized the utilization rate of panel sheet.
3. Developing alternative production technology	 Supplementary case: VÄRDE collection in IKEA. IKEA developed the fiberboard painting technology. It reduced costs and was suitable for low-cost products with low scalability surface materials.

2.2. Family design approach

Product family design serves the dual purposes of improving product diversity and reducing production cost. Application of components with the same or low varia-bility is the key to reduce the production cost, and the product diversity is mainly realized by the combination of different components and changes on background environment. The essential concept of designing family is to follow the "mushroom" model. With respect to this design method, the above cases were studied and the fol-lowing seven kinds of chair product family design paths were suggested:

1. Derivative design and development under the same theme. Namely, design of series of products with different appearance under the same theme.
2. Replacement of component materials. For example, the surface material of chair product can use different textile of leather.
3. Changes on components. For instance, chair with caster wheel is suitable for office space, and ordinary chair can be set in other interior space.
4. Changes on external color.
5. Changes on pattern of the back and the seat of chair.
6. Extension of product function to meet the requirement of public space environment.
7. Changes on size. Such as the adjustment in height and seat surface of the chair can satisfy the demands of different users.

The corresponding discussions for the 7 paths are listed in Table 3.

Table 3. Product family design approach.

Design methods	Supporting cases
1.Designning a collection with the same DNA	 Moroso case 40
2. Replacing component materials of the original chair.	 Zanotta case 27
3. Replacing some elements	 Driade cases 26 and 27
4. Changing on external color	 Kartell case 05

5. Transforming the pattern



Kartell case 14

6. Extending chairs in one direction



Kartell case 28

7. Changing size



Moroso case 02

3. Conclusion

To seek design approaches to improve the product diversity on the premise of high brand identity and low production costs, a total of 199 chair samples from 8 well-known Italy furniture firms were taken as samples. Then, CMF tool was used to investigate the relationship between the three indicators of all chair products in each firm and subsequently proposed the potential design approaches. Further, case cards for each chair products were prepared, and 5W1H tool was used to extract the infor-mation concerning the production process. Finally, a total of 10 potential paths to realize the two approaches were discussed.

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New Methods of Designing Stamping Dies Assemblies by Using Generative Models

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Abstract. Designing stamping dies assemblies must obey strict rules and requires a lot of technological knowledge and experience. Designed dies exhibit strong similarity and the process, in spite of the complexity and the need to take into account the specifics of pressed shape, is repeatable. Therefore, the design of stamping dies assemblies can be accelerated by applying Generative Modeling method. The paper presents the process of building Generative Model of stamping dies assemblies in the environment of Siemens NX Knowledge Fusion. In addition, the paper presents a method of building a engineering knowledge base for stamping dies assemblies and the user interface for controlling elaborated Generative Model. Knowledge base and its conceptual model is adapted to acquire knowledge from experts by significantly simplifying the structure of the knowledge base and the use of common computer tools. In addition, the results of Generative Model verification and the process of improvement in the performance on the basis of practical design tasks and the introduction of changes resulting from errors that occur during verification are presented. The constructed Generative Model includes knowledge base, software written in Knowledge Fusion and the user interface. The paper also shows the benefits of using Generative Models in designing stamping dies assemblies.

Keywords. Knowledge-based Engineering, stamping dies, generative model, knowledge base, knowledge fusion

1. Introduction

While designing stamping dies a great role is played by the technological experience of a designer. Nevertheless, many parts of the newly designed die are routinely chosen and parts and subassembly are designed. In order to use technological experience of a designer it is necessary to ease him/her on routine designing tasks [1][2][3].

So far in order to speed up routine tasks commonly used CAD tools have been used and in particular catalogues of ready-made and hand-made elements as well as parametrization. The models of previously used stamping dies or their parts have also been used as a base for newly elaborated dies. It is great improvement but nevertheless, routine tasks still take up a lot of specialist's time. Therefore, a new method has been put forward which uses Generative Models for complete elimination of routine

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designing tasks. In addition, the use of this method can help with other problems occurring in die designing companies e.g.: a) standardization and die design unification in company, b) elimination of human errors in design, c) fast deployment of new designers into the design process in the company using stored knowledge and experience of older workers. This approach gives good results in case of repeated and modular designing tasks of technical systems [4][5][6][7] with specialized modules in advanced CAD systems such as Knowledgeware in CATIA or Knowledge Fusion in Siemens NX as great facilitators. However, in order to use these modules in a systematic way requires specialist skills of a designer and must be preceded by detailed overhaul of designing process and acquiring knowledge on the process and its record. Specialist methodologies [8][9] such as e.g. MOKA [2][10][11][12] together with additional tools for recording and processing knowledge are often used for that purpose, beginning with simple tools such as Excel and then proceeding to complex systems as e.g. Protege OWL [13][14][15][16] or PCPACK [2][17][18][19][20].

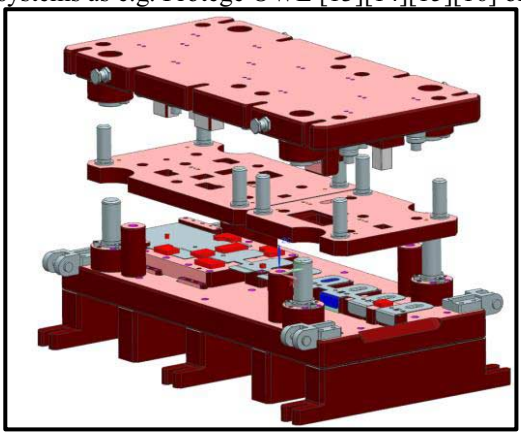


Figure 1. Multi-stage stamping die.

The use of this method for designing a multi-stage stamping die has been presented in this paper and the die presented in Figure 1 realizing nine consecutive technological operations (Figure 2) for producing an element from sheet metal.

The elaborated Generative Model should become a useful tool for everyday use for designers in a company dealing with designing stamping dies for plastic forming of sheet metal elements.

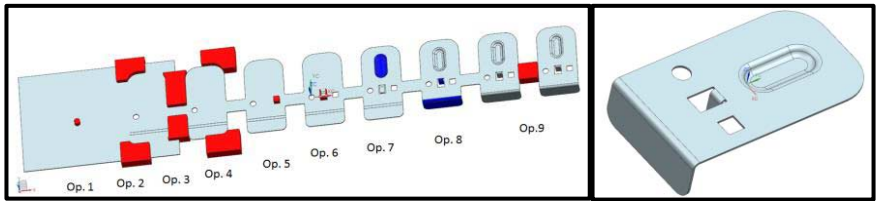


Figure 2. Plan of stamping technology and ready sheet metal element.

Due to complexity of the structure of the stamping die and Generative Models as well as protection of intellectual property the details of the model design are presented on the part of the design i.e. a subassembly of guide pillar mount unit.

2. Method of designing stamping dies based on Generative Modeling

The origin of every GM is knowledge acquisition, which is necessary for Generative model building [14][18].

Because there are many types of knowledge and many sources of knowledge, knowledge engineers developed numerous different techniques to make the process of knowledge acquisition easier. Among these many techniques of knowledge acquisition,

the most popular are [1][2][10][13]; acquisition of knowledge through interviews, diagram technique of knowledge acquisition, technique of process and concept maps, backpropagation learning technique, matrix method or 20-question technique. In acquisition of knowledge for the construction of generative models, it is advantageous to use a method that is interwoven into standard operations, provides opportunities for direct control of generative model, is potentially simple, and utilizes commonly used computer tools. These possibilities are included in the method presented below.

2.1. Knowledge acquisition

Knowledge acquisition for Pillar mount unit was done using MS Excel software, that is compatible with Siemens NX [21], The complete knowledge contains:

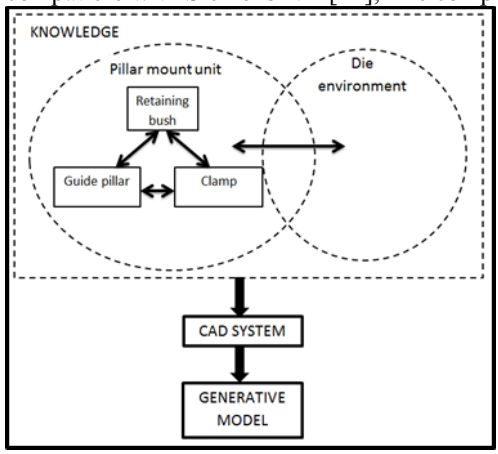


Figure 3. Structure of Pillar mount unit GM.

- All information regarding design, material and dynamic features of Retaining bush,
- All necessary catalogue data about Guide pillar and Clamps,
- Relations between all elements and design procedures,

Figure 3 shows the structure of GM for Pillar mount unit. Figure 4 shows a top-down diagram of die design, with focus on relations between elements of Pillar mount unit and influence of assembly on Die environment.

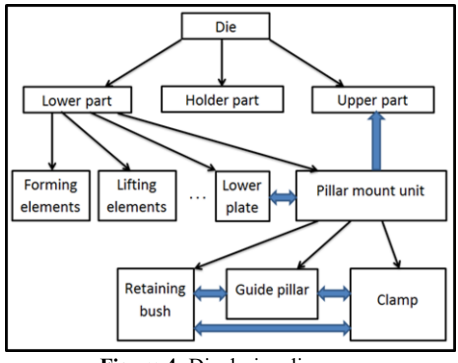


Figure 4. Die design diagram.

Underlined pointers in the diagram indicate particular relations between the elements. These relationships as well as in particular design features were defined using a dialog box in excel sheet in MS Excel. Complete design features of each unit have been recorded using separate file in MS Excel. In the created file design features of each element have been described in separate spreadsheet. Additionally, all relations between design features of every elements of unit are shown in separate spreadsheet.

Exemplary record of design features in spreadsheets is shown in Figure 5:

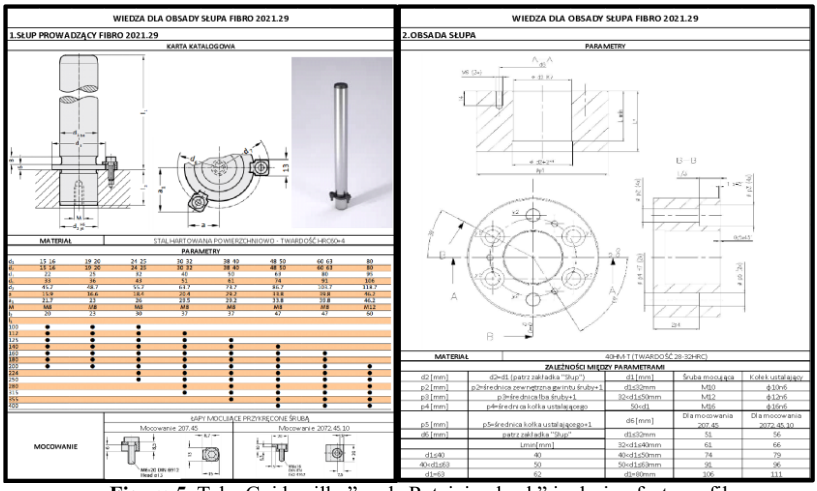


Figure 5. Tab „Guide pillar" and „Retaining bush" in design features file.

The separate spread sheet containing relations with respective controlling formulas can be found in the figure 6. It is a table that integrates all the data from spreadsheets *Guide pillar* and *Retaining bush* and contains procedures that process this data and cooperating with CAD tool.

d2	Lmin	p1	Sruba	p2	p3	Kolek	p4	p5	y1	y2	d6 dla 207.45	d6 dla 2072.45	d3	l2	M
30	40	85	M10	11	17	10	10	11	16	30	51	56	40	37	10
32	40	85	M10	11	17	10	10	11	16	30	51	56	40	37	10
38	40	92	M12	13	20	12	12	13	17	35	61	66	50	37	10
40	40	92	M12	13	20	12	12	13	17	35	61	66	50	37	10
48	50	100	M12	13	20	12	12	13	20	41	74	79	63	47	10
50	50	110	M12	13	20	12	12	13	20	41	74	79	63	47	10
60	50	130	M16	17	25	16	16	17	25	50	91	96	80	47	10
63	50	130	M16	17	25	16	16	17	25	50	91	96	80	47	10
80	62	160	M16	17	25	16	16	17	30	60	106	111	95	60	12

Figure 6. Tab „*Parameters table*".

2.2. Construction of the Generative Model

To create GM model there was used „*Knowledge Fusion*" module [22]. To build models in this module the specialist Object programming language in used, as it allows to add Engineering knowledge to the element by creating suitable Rules. Rules are basic blocks creating program code of GM construction. The programming language used is declarative not procedural, what means that Rules are performed only when we refer to them or we demand performing. In addition to that in KF language we can access external knowledge base such as: Knowledge base or Spreadsheets. [22], [23]

2.2.1. Structure of the Generative Model

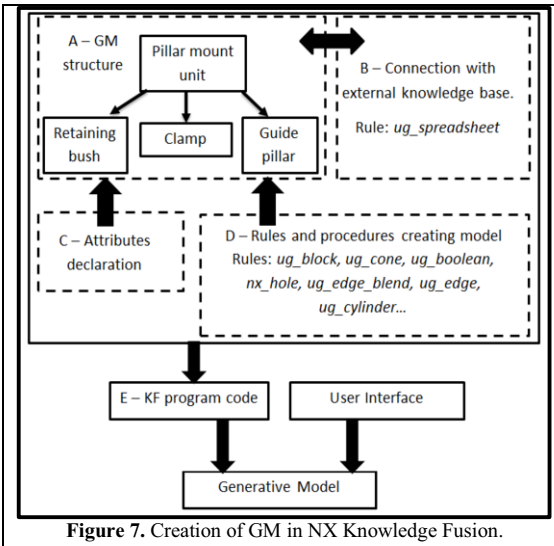


Figure 7. Creation of GM in NX Knowledge Fusion.

Stages of building the GM and its structure in NX software is shown on the diagram below (Figure 7) [21]. The example includes structure and following steps of building GM for construction part – simple Pillar mount unit. The first step to creating the model is designing right structure to a whole unit. For Pillar mounting unit the structure will consist of main file assembly and following components:

- Retaining bush,
- Clamp (there is a choice of Clamp type),
- Guide pillar,

In order to do that the following template was created: Pillar mount assembly including: retaining bush, pillar, clamping.

The structure of model should be designed in a way so that all components of assembly are controlled by corresponding Rules main assembly file.

The Rule *ug.spreadsheet* that links model with external knowledge in the Spreadsheet was entered in main assembly file in order to link GM model with external Knowledge base (Figure 8).

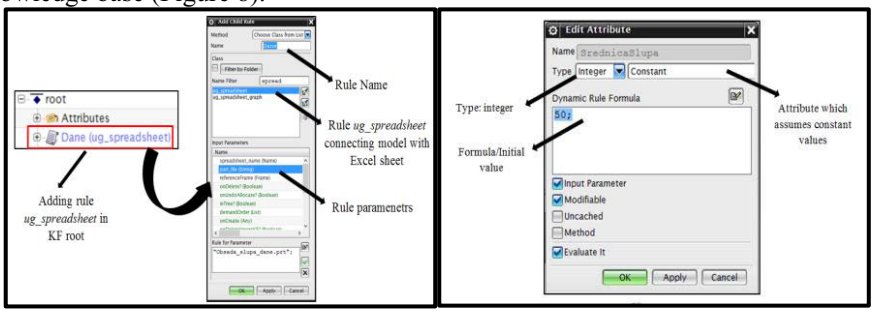


Figure 8. The Rule managing external data and PillarDimension attribute.

The next step in creating the model is inserting suitable attributes managing the model in the root of KF program of main construction file. Figure 8 also presents the exemplary declaration of an attribute in KF language. The following step in creating a GM model is creating rules responsible for particular components of assembly.

Figure 9 shows the structure of subprogram KF that generates Retaining bush geometry. Using classes: *nx_cylinder*, *ug_block*, *ug_boolean*, *ug_cone* the Retaining bush geometry was modeled referring to previously declared attributes (Figure 9). Next step in GM model creation is inserting a managing Retaining bush in main assembly – adding main program root rule *ug_child_in_part* and a rule *ug_component* generating Retaining bush (Figure 9). After having written subprograms for each components and managing them the entire code of GM model can be generated.

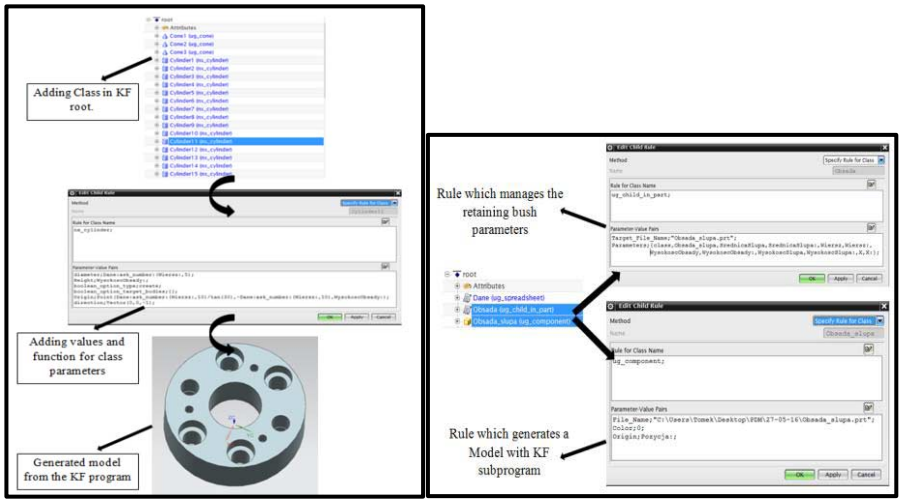


Figure 9. Retaining bush geometry (left) and rules managing retaining bush (right) in KF.

2.2.2. User Interface of the Generative Model

User interface of a program used to generated GM model was created in PRE-NX6 UI STYLER module. It uses previously written program code for building Generative Model of Pillar mount unit model [24]. The structure of user interface is divided into tabs regarding particular elements in assembly.

After having defined entry data according to dialog box of a program and performing calculation using knowledge recorded in database the model is generated (Figure 11).

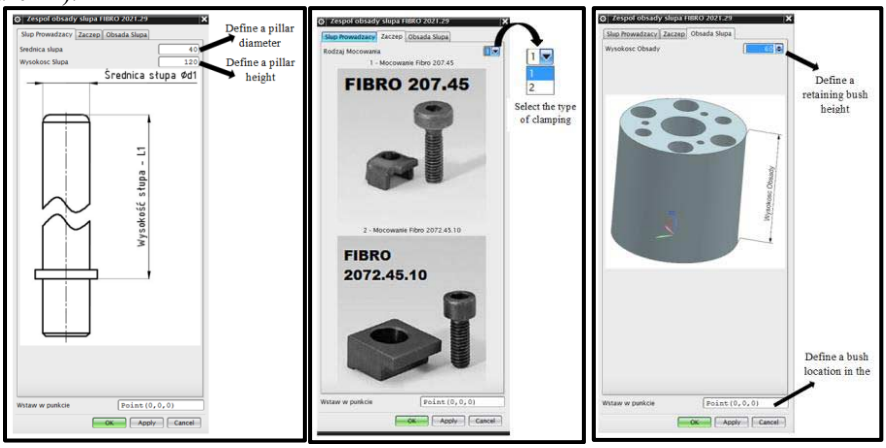


Figure 10. User Interface for Pillar mount unit GM.

2.3. Verification and development of Generative Model

The verification of the GM model was performed for 3 real cases of Die design. Each of the cases has different working parameters and functionality. For each of the verification cases there was a distinct Pillar mount unit generated using GM.

Generated model for cases A, B and C was provided in Figure 11.

During model verification some problems occurred including: lack of messages for dialog with user, lack of some dialog windows in UI. In the next versions of Generative models all problems were addressed.

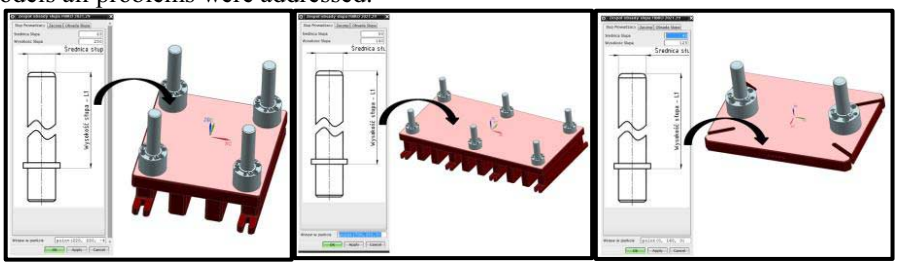


Figure 11. Verification of GM model-cases A, B and C.

3. Conclusions

The paper presents the process of creating Generative Models in the Siemens NX Knowledge Fusion environment on the example of a selected stamping die assembly.

In particular, knowledge acquisition methodology for Generative Models creation has been presented, adapted to the needs of a company specificity. It is especially beneficial to use Excel system for knowledge base creation for Generative Models since special structure of Excel sheet segregates data of particular elements and their relations. It facilitates the process of knowledge acquisition and at the same time releases a designer, who creates Generative Models, of the duty to transfer knowledge from knowledge base to Siemens NX system because the sheets are directly used for managing both model elements and their assemblies. Additional benefit of knowledge acquisition in Excel sheet is its widespread use in companies.

The knowledge base has been equipped with a suitable interface which enhances communication with the user. Additionally, Generative Model verification methodology has been pointed out, which should be extended in practice for constant improvement of these models.

Finally, the following elements constitute our Generative Models: knowledge base, CAD files, program written in KF language and user's interface.

The design of Generative Models is very beneficial for parts of structure which are of repetitive character and are designed in a routine way. Among advantages of Generative Models one can mention: a) *Significant time reduction for a designer in case of stndard designing about one hour, with Generative Models about two minutes*, b) *Reduction of routine and monotonous tasks,* c) *Possibility of faster and automated change of model parameters,* c) *Correctly designed Generative Model additionally limits possibilities of errors which are likely to occur while designing,* d) *Usefulness in standarization and unification of designing process in companies.*

Generative design also has some disadvantages associated with preparation of GM such as: a need to have a special module in your CAD system and a specialized skills to prepare Generative Model and knowledge base.

The created Generative Models of a stamping dies, presented as an example of assembly of guide pillar will be used on an everyday basis in a company which designs dies for plastic forming of sheet metal elements. Furthermore, in the future the project will be developed and next options models will be made for widening the range of applications of stamping dies.

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Study on the Characteristics of Japanese Bamboo Product Design

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Abstract. Bamboo gets favors of designers around the world because of its unique physical properties, art form, the cultural implication and ecological significance. Japan absorbs Chinese bamboo culture, together with inherent Japanese bamboo culture, forming a unique Japanese bamboo culture. With abundant bamboo resources, Japan is leading the world in terms of bamboo product design and development. It is crucial to take advantage of advanced technologies to accelerate the development of bamboo culture. This study attempts to analyze the characteristics of Japan bamboo product design to provide the reference direction of bamboo product design development to China and even the world.

Keywords. Japan, Bamboo product design, China

Introduction

Japan is a fine tradition of the country with developed. Throughout its history of civilization, from the 7th century, it absorbs China's tang dynasty culture and learns German engineering technology, the Meiji restoration period, the British system of social management, it is not hard to see Japan's civilization development based on constant study and draw lessons from foreign advanced technology, complement each other, and the moderns in essence, base on their own excellent results to improve the strength of their own country. Although Japan based on other countries' experience in many aspects, but never give up on their own excellent traditional culture protection, it combining experience of all countries and digestion itself , forming a unique cultural system. The dual nature of the cultural spirit of also deeply influenced the design of the Japanese culture. Through the analysis of the reasons for the formation of Japanese regional culture, combing the scale of bamboo industry summed up the Japanese bamboo product design features by using the experience evaluation method.

1. Japan's natural geography and bamboo resources

Japan is located in northeast Asia, it has Hokkaido, honshu, shikoku, and kyushu and more than 3900 islands, and is a typical island country. Japan's land area is about 37 square kilometers and population 126 million (2013), the per capita area is nervous, this makes Japan had a great survival pressure. In addition due to seismic belt in the

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Pacific rim of fire, Japan also referred to as the "state of the volcanic earthquake" frequent geological disasters. It was also because Japan has such geographical defects, that makes the Japanese people are born suffering consciousness, they have saving consciousness deeply of nature, resources.

Japan's forest area huge, its coverage rate reached 66.8%, per capita is very high. Japan belong to the temperate maritime climate, no cold winter and summer heat, rainfall, it is very suitable for the growth of bamboo. In Japan the world's largest bamboo including Thailand, Vietnam, India, China and other countries growing on the edge of the forest and lush bamboo forest has the most prominent feature of the distribution of plants. According to relevant data shows that: Japan's existing bamboo forest area of 141300 hm2, 13 genera, there are more than 240 kinds of bamboo, thin bamboo, bamboo, bitter bamboo, bamboo ryukyu and dwarf bamboo categories. In addition to Hokkaido, other areas have the bamboo growth, 60% concentrated in kyushu. Most Japanese bamboo is very hardy. 97% of them are privately owned, intensive management, with an annual output of 200000 tons - 200000 tons. Japan still imports bamboo from foreign countries.The bamboo is carefully processed into products and then export, the price increases 5-10 times.

2. The design features of Japanese bamboo

It is because of Japan's historical and cultural development in the process of formation of the dual nature, making the design of the Japanese culture coordinate well with the traditional design and modern design, the relationship between the east and the west. Brings the convenience of high speed development of science and technology, on the one hand, push the modernity transformation of traditional design, it makes the design of excellent traditional culture with new vitality, on the other hand also it develop of respecting nature, traditional material and the pursuit of excellent quality, it provides a different paradigm for consumerism trend of bamboo product design.

2.1. The traditional craft combined with modern design

With abundant resources, plus bamboo slender and tenacious, it gives person with a natural affinity, the Japanese have a special liking to bamboo products like China, that also has long history country. As early as in ancient times, the Japanese people have used materials and properties of bamboo to make technology appliances, tools, toys, a lot of life (as shown in Figure 1) ,use them for agriculture, forestry, fishery, animal husbandry and other necessities, including some religious and traditional folk ritual activities of Japan are. For example, at the feast, the families have the door up and act the role of the practice of bamboo; Every year in Japan Tokyo, June 20, the side horse temple held under the venom of serpents "will cut bamboo", etc. Modern Japan no doubt is a high degree of industrialization of developed countries, however, in the process of the industrialization and development, they emphasizes their own traditional culture is also quite seriously. Japan country is narrow, lack of resources, frequent natural disasters, it has created the innate sense of crisis, the Japanese are good at this kind of crisis consciousness into an active and enterprising consciousness, and then into a kind of innovation and breakthrough. Kyoto, Japan, now still have a lot of large and small bamboo craft workshops, a lot of craft masters seek the road to the modernization

of traditional crafts more than ten years like one day , trying to give the new appearance, letting more bamboo products into the modern people's life.



Figure 1. Articles for daily use of Japanese traditional bamboo.

KOSUGA BAMBOO is a brand of Kyoto, which is a typical representative. It is also the biggest of the five old Kyoto of Beijing's traditional decoration brand, it begins in 1898, has made more than 100 years of bamboo products and won many international awards, including the award at the world expo in 1904 and 1911. on one hand ,It is inheriting traditional ancient technology, most of the bamboo products still use manual weaving, and is equipped with Japan's unique bamboo craft artisan training school. On the other hand, it blends in classical into modern again, gives a new form of bamboo to adapt to the modern way of life. Japan three dao of art in the tea ceremony, ikebana, there are bamboo is a kind of attitude is blended in among them to be reckoned with. We can say that bamboo products involves all aspects of life, in addition to some traditional bamboo products, various kinds of tableware, handbags, wallets, receive products and so on. In recent years, they are more committed to develop more new products bamboo, trying to break into the market of young people.



Figure 2. Handbag.

Tokyo Tribal Collection is space furniture series designed by team nendo, at the invitation of Singapore industry + design company to adapt the contemporary urban living, the tables and chairs, benches, simple shelf has a small and compact size, handmade by craftsmen woven bamboo rattan elements is one of the biggest bright spot,

the material of natural flexibility makes it very suitable for as a back support, and the structure of the tables and chairs and create a sense of humor, it is also a supporter of actual use. The essence of bamboo rattan with idiomatic Japanese elegant tonal is forming a sense of lively, humorous. The whole furniture shows relaxed, happy, natural life interest, completely free from the traditional sense of bamboo weaving art.



Figure 3. Tokyo Tribal Collection series of furniture design.

2.2. Pay attention to the exploration of materials

Historically, in the navigation technology has not yet developed, Japan as its unique natural environment, make them preserve their traditional national culture, after sailing technology development, the Japanese use convenient sea transportation promoted with Eurasian countries on the technology of communication and cultural collision. Because of this, the features of the status in Japanese culture grafting and pursue the, it can pursue unique quality. This laid the Japanese is a strong inclusive country, and Japanese innate sense of crisis and makes them have a kind of autonomous learning one's consciousness, they always combine with its own characteristics of independent innovation in a rapidly after absorbing the essence of other countries, seeking breakthrough. Chinese bamboo culture spread to Japan, the Japanese did not blindly copying, but combined with the Japanese inherent respect for the culture of the worship of nature and natural temperament, continuously explore on bamboo timber, trying to break through the limitation of material itself, maximize the essence of natural materials. In terms of technology of bamboo weaving (as shown in Figure 4), China decoration spread to Japan, the Japanese craftsmen first learn Chinese artists to implicit expression, after they have been exploring the weaving method, making track for to express characteristics of bamboo timber from multiple perspectives. At the beginning

of the 20th century, early sichuan ancient times initiate a coarse lawmakers, completely abandoned Chinese artists that the implicit expression, bold highlight ecru bamboo rigid-flexible economic; Vearly sichuan ancient times lent to "make up" breakthrough attempted to start the parallel lawmakers. Just rely on its own physical properties such as elasticity and tension; Japanese bamboo artists of the younger generation is more suffering bamboo sprout, in his abstract works, seemingly irregular lawmakers contains the bamboo strength and create a feeling of turbulent flow.



Figure 4. Japanese modern bamboo weaving.

In addition to art law, Japan also continuously explore its processing technology, especially to promote the bamboo integrated timber in household products. Bamboo integrated timber, it is a kind of bamboo as raw material for a certain specifications of the rectangular spring, after anticorrosion, moth-proofing, drying and coating process, according to the design requirements in the same group of embryo mating material fiber direction. Bamboo integrated design is by the Japanese famous brand TEORI young designers cooperation with okayama university, focusing on the application of bamboo in household design, and the material design and explore constantly. Works in DESIGNTIDE TOKYO for display, there are lots of good design, acclaimed. Figure 5 is one of the two works. We can see, this kind of bamboo timber for cutting, molding process, repression, split and other modern mechanical technology can make traditional crafts to meet the complex, they have interest to make the products more and more lively.



Figure 5. Bamboo products of Japanese TEORI.

2.3. Reflect national culture temperament

Japan is the only country with Oriental cultural background in world's developed countries. Leading international design in the western developed countries, the Japanese design is always a place with its unique national characteristics. Japanese design of this unique charm lies in the Japanese design work, often with a distinctive "Japanese national temperament" : simple, remove the flashy, matches the essence, showed a static, virtual, ethereal artistic conception. And in the modern high-tech impact the traditional ethnic style is not dead, but combined with modern design, as the spiritual pillar of contemporary design concept rooted in Japan. Japanese national temperament by wabi sabi, shibu traditional culture, such as the former is the basic spirit of zen, then because of the tea ceremony in the spirit of zen, and into their lives, forming a broad view of the universe and aesthetic system, it deeply influenced generations of Japanese. Wabi is empty, simple, nothing at all; Sabi is elegant, refined, that is, "after precipitation which traces"; Shibu "astringent" refers to the convergence of, don't show off, or simple elegant refined appreciation ".Their common characteristic is to highlight the simple. Is in the pursuit of "light, quiet" under the influence of Japanese designers always preach-that creation concept of simple is better than complicated, the solitude is better than the noisy, light is better than that of heavy, scarce is better than that of abundance.

There is no doubt that the Japanese national style also deeply influenced the Japanese bamboo product design. The Japanese bamboo furniture design is the pursuit of a kind of contracted design style, removing all unnecessary frills, through geometric shape form and pointing to the functionality of the furniture. Overall model contracted and not simple furniture, implicative, highlighted a contracted, fashionable and elegant style. This seemingly "simple" design form is reflected the zen thought's that pursuit of "plain Jane", making people can gain in this minimalist environment state of mind. Figure 6, for example, TeppeiMihara "recogniton" series of furniture design, its removed all excess model, the chair frame and panel article only keep straight lines and square design elements, through the slit between the surface and support structure, it has the effect of buffer body pressure, and make sharp visual effect and comfortable experience exist side by side in the conflict. Model is concise, simple, soft, smooth lines; Emphasizes the natural texture of bamboo itself at the same time, which reflects zen style. Tables and chairs design although simple, but emphasizes the mastery of product details, through the reasonable structure and material to form and the function of art. The plain Jane and does not lose contemporary sense.



Figure 6. TENSION (dining room chair).

Mr Fukuda shigeo once pointed out: "there can be in the design of excess". From this point, it's not hard to see that the design concept of Japan pursues "quality culture", it is not a kind of form and means, but wash many unimportant details and process, taking the essence. When design gets rid of the essential elements of all components, all of the details and all connections are compressed, the essential characteristic of the object will be displayed.

2.4. The pursuit of natural situation

Japan is an island nation, relatively scarce natural resources. Due to the worship of nature, Japanese design pursuits of natural situation, the nature is actually "supernatural", namely through artificial make second nature, it is condensed natural essence. It is not simply to simulate natural form, but rather a blend of sentiment and scene. Japanese designers often as the main language of natural materials, using of various materials reflect the high quality of design, this work presents a unique design effect, and created a nature in the design of the artistic conception. Such as TEORI studio design of lamps and lanterns of water lily (as shown in Figure 7), not only USES the natural material, keeping the nature of the material properties, the model of product structure is taken from nature - water lily. Stylist makes full use of bamboo materials physical properties, bending of bamboo and the base completely with Mosaic fixed together. Bamboo texture color and soft light set each other off becomes an interest and lightsome beauty.



Figure 7. Water lily.



Figure 8. Bamboo house at the foot of the Great Wall.

Famous Wei enquiry from zen enlightenment thinking space formIing, he will always focus on building internal build on "artistic conception", make full use of the nature of the material properties. Figure 8 is the design of the bamboo house at the foot of the Great Wall. Mainly in a whole space inornate retains the original bamboo uneven natural material, through the space of the linear model, the minimalist furniture style, simple but elegant color jointly build the atmosphere that gives a kind of "empty". Building is around the mountain, it makes people to live in a tense airy environment, looking for a free and at peace to achieve a kind of spiritual transcendence and the return of the nature.

3. Conclusion

Japan belong to the maritime climate, relatively abundant bamboo resources. The Japanese also have a special liking for bamboo products, as early as in ancient times, Japanese people who made a lot of the traditional bamboo weaving technology living appliances, tools, toys, applied in agriculture, forestry, fishery, animal husbandry and other necessities. Chinese culture was introduced into Japan, Japan absorb Chinese bamboo culture, together with inherent Japanese bamboo culture, forming the unique Japanese bamboo culture.And in the process of rapid development of modern, Japan can well coordinate the traditional culture and modern design to carry forward the traditional arts and crafts, the perfect combination of traditional handicraft and modern design methods make the traditional handicraft appears in the form of a kind of modernization; Design work can embody national cultural temperament, and do not break vogue; For another, they constantly explore the processing technology of bamboo itself to develop bamboo integrated timber,with more means of mechanized ,bamboo products is better in modern life.

Compared to Japan, China's bamboo resources are more abundant.In the long river of history, the Chinese people has created a wealth of bamboo culture experience. But in recent decades,China's bamboo product design and development has been stagnant.China's bamboo products companies do not have the enthusiasm to develop new products.Such as bamboo mat, almost every enterprise to produce this product, but these companies did not form their own product characteristics and brand image.Therefore, in view of the existing problems of bamboo products in China, we can learn from Japan, which has the same long history of bamboo culture.We can use high-tech to increase the development and utilization of bamboo, while learning to use Western modern design techniques, to revitalize China's bamboo product design.

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A Study on the Packaging Design of Agro-Food Using a Qualitative Research Technique

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Abstract. This study aims to systematically identify the problems of packaging design with 6th industrialized agro-food and to prepare improvement plans. The research method is to collect the 5 experts' evaluative opinions about the packaging design of the 41 agro-food products and to analyze systematically using Nvivo 11, qualitative data analysis software. The significance of this study is that it provides an empirical basis for improving the packaging design and that it suggests a methodology for logical analysis through qualitative research using unstructured data on design evaluation in the field of design.

Keywords. Agro-food, package design, Nvivo, qualitative research

Introduction

In recent years, in Korea, for the purpose of reducing the income gap between urban and rural areas and increasing the added value of agriculture, there has been a move to build a 6th industrial system that combines the primary industry of agricultural production with the secondary and tertiary industries such as processing, distribution, and tourism. The 6th industrialization is a business which creates a new value that vertically integrates processing, sales, and exchange in production by utilizing various resources (agricultural products, natural resources, talent, history, culture, etc.) [1].

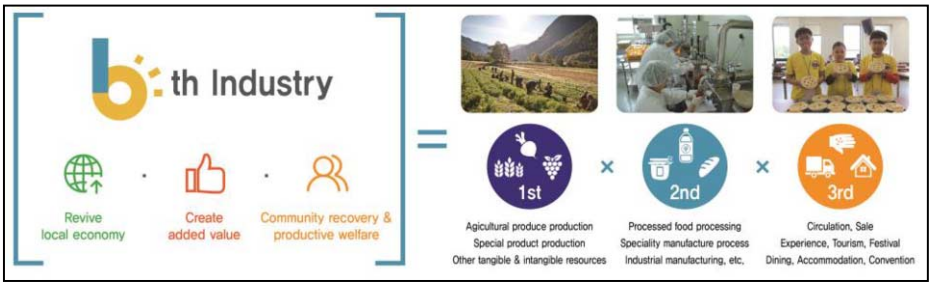


Figure 1. The Significance of 6th industrialization

As 6th industrialization has been promoted, the agricultural products that are developed and processed by the farmers are increased, which necessitates the market competitiveness with the foods distributed by the large enterprises (Figure 1). In the

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interest and policy support of the 6th industrialization of agriculture the most visible area of change is packaging design of agro-food products. Especially, in the consumer survey, packaging design is the most important factor for the purchase of the 6th industrialized agricultural products, but consumer satisfaction is rather low [2]. Thus, it is an important task to improve the packaging design as a way to encourage sales of the 6th industrialized agricultural products.

1. Background and necessity of research

Packaging design is an essential marketing tool to improve product quality [3], and packaging design for agro-food products needs to effectively map out various elements to attract consumers' attention, and aims to fulfill various roles such as accommodating user's convenience by enhancing product value, and so on. Thus, it is necessary to study a systematic analysis of actual situation and improvement plans for the development of the 6th industrialized agricultural product packaging design which can stimulate consumers' purchase desire and contribute to direct income generation of farmers.

Previous studies have focused on exploring the characteristics of packaging design through various academic approaches. The studies related to agro-food packaging design are, an analysis of conscious effects of consumers' satisfaction [4], an analysis of the nervous system such as visual stimuli [5][6], and research that analyzes the effects of marketing [3]. This new academic approach helps to secure the objectivity of analyzing and evaluating the design of agro-food packaging, and broaden the understanding of the analysis results.

In this study, we try to point out the problems and seek improvement plan by using a qualitative research method on the packaging design of agricultural products. We have described the opinions of related experts on the packaging design of the 6th industrialized agricultural products in Korea, and systematically analyzed those opinions in order to draw improvement plan for enhancing the competitiveness of agro-food products.

2. Purpose

This study aims to systematically analyze the opinions of related experts on the packaging design of 6th industrialized agricultural products in Korea, and provide improvement of the packaging design to generate the competitiveness of agro-food products. Understanding the current level of agro-food packaging design and seeking development plans will contribute to improving the competitiveness of agro-food products and ultimately to the competitiveness of agriculture.

It will try to grasp the overall evaluation contents of the 6th industrialized agricultural product packaging design, and organize the problems to derive a systematic improvement plan accordingly. The specific purpose of this study is as follows.

1. Confirm the contents of 6th industrialized agricultural product packaging design evaluation.
2. Define the problems and derive improvement plans of 6th industrialized agricultural product packaging design.

3. Methods

3.1. Subjects

The subjects of this study can be summarized in two aspects. First, there are research participants who have participated in qualitative research and described the analysis data. Second, there are evaluation objects for having comments on package design by the research participants.

The study has used a survey method targeting experts. The experts are the professionals who are highly educated and have a lot of practical experience. Research experts should have skills and high motivation to participate in research by communicating in writing in a timely manner, and they need to be consisted of various stakeholders [7]. In order to meet the requirements, 10 experts of academic experts who have more than 20 years academic career, journalists and consultants have been contacted. Then the final 5 experts have been selected after confirming their time and intention to participate through the advance telephone call.

Qualitative research is basically understanding and giving the meaning to the participants' view from the perspective of cultural relativism. For the objective results of research, we used an objective sampling method which is not limited to a specific scope but can represent research topic. Thus, in order to examine the general tendency of 6th industrialized agro-food in Korea, we have used 41 works from 2016 entries of the 6th industrialized agricultural product packaging design competition hosted by the Rural Development Administration (RDA) of Korea.

3.2. Data collection

The data collection of this study is to summarize the problems of the agro-food packaging design based on the questionnaires completed by the experts. A focus group interview has been conducted with 41 items of the RDA's 2016 agro-food packaging design contest, and 5 experts have individually examined the design manuals for each of the 41 entries and completed a questionnaire.

The questionnaire is, based on the theoretical basis of the agro-food packaging design, composed of open variables to describe the evaluative opinions of the four major fields of brand design, visual design, packaging and marketing as a basic classification. Brand design and marketing are based on the principle of establishing a firm relationship between brand and consumer. Thus, we try to understand the philosophy and value of the company as a whole through the concept of branding, which means sharing with the consumers through product and brand communication. Apart from these, additional summary is made for a practical question about mandatory labeling that should appear on the packaging related to environmental considerations and food hygiene.

The participants are free to describe the open questionnaires and freely select the method and quantity of the description, but are requested to faithfully reflect the direction of the improvement of the package design for each product based on the expert's experience. They are given more than five to six hours to describe the expertise as much as possible, rather than to produce an improvisational response to the question.

41 photos of the 2016 agro-food packaging design contest of RDA prepared as evaluation targets are used as additional explanatory material for expert evaluation.

3.3. Data analysis and validation

Data analysis is conducted according to qualitative data analysis procedure in the order of transcription, coding, and subject discovery [8], and NVivo 11, qualitative data analysis software, is used to enhance the reliability of data analysis. Nvivo is the most sophisticated research tool that researchers can use to analyze data in all unstructured forms such as text, audio, images, videos, spreadsheets, online surveys, social media, and so on [9], and it is useful to view the semantic structure of objects because the information revealed in the text can be structured into core subjects by making nodes [10].

In this study, we formulate the category of the problems of agro-food package design by using Nvivo to individually categorize the textualized experts' opinions into words, phrases and sentences, and link the image data related to the categorized contents to establish grounds on the subject. Based on the theory of Strauss & Corbin (1998), the bottom-up open-ended coding method is applied to categorize the data directly from the data collected by the researchers, and generate codes that have implied meaning. Saving is done in Nvivo 11's 'Resource' space and put in folder by each expert using the 'Import' function. This process is an indispensable task because most of the qualitative data analysis in this study has been done through Nvivo 11.

For detailed analysis of the evaluative opinions of the questionnaire, it is necessary to make sure that the opinions of the experts in the meta-categorization process through codes and nodes are included as much as possible without missing, and the subdivided factors that make up the problem are analyzed inductively. Through this process, we have named and categorized representative words that could well explain package design problems. Nvivo is a useful function that can identify the items that are meaningful to the experts by comparing the coding frequency between the coded items which are especially scattered and wide large [11].

In order to improve the reliability of data analysis among researchers, we have conducted peer debriefing sessions with three design experts to read, discuss and review the data repeatedly more than three times in order to find out the opinions of the experts within the data [12].

4. Results

Through qualitative research method, this study aims to analyze the problems of agro-food packaging design which promotes the 6th industrialization. First we have collected data from in-depth interviews with experts who were research participants then analyzed the evaluation opinions using Nvivo11. With this process the problems of agro-food packaging design are organized by the categories and the systematic basis for the improvement plan is summarized.

4.1. Trend of agro-food packaging design problems

A total of 227 nodes are formed as a result of the analysis of the experts' evaluation of the agro-food packaging design. Among the categories, the most classified is the main words for visual communication, followed by mandatory labeling, packaging and branding, in that order. The core words of visual communication are logo type problem, lack of total design concept problem, problems of suitable illustration and photos,

layout problem, color problem, symbols and character problems that are information providing problems, awareness of visual communication problem, and lack of visual communication differentiation problem, in that order. Among the core words in the whole categories, problem of packaging material is most pointed out, then problem of brand naming that is marketing problem, problem of packaging material, problem of logotype, problem of packaging structure, insufficient total design concept, problem of slogan that is brand image, illustration and photo problems, omission of required labeling, layout problem, quantity problem that is color problem, in that order.

In the second phase of analysis, the results from the first analysis are further subdivided into branding, packaging and visual communication, excluding mandatory labeling. For example, brand naming is divided into four aspects of lack of functions, lack of differentiation, lack of uniformity, and recognition as general terms. By deriving such detailed classifications, we attempt to establish a systematic basis to draw an improvement plan. The analysis results for the itemized problems are shown in Table 1. For each category for specific problems, we cite the problems pointed out by experts, summarize the analysis results which are categorized by themes, and present them with images.

Table 1. Categorical Problems of Packaging Design Nodes (N=4).

Categories	Nodes		Sources	Frequency (%)
Mandatory labeling		Faulty barcode printing	1	1(1)
		Incorrect recycling label	1	15(7)
		Possibility of trademark registration	2	3(1)
		Nonstandard displayed letter size	2	3(1)
		Omission of required labeling	4	30(13)
	Subtotal		4	52(23)
Branding	Brand naming 10(36)	Unsatisfactory function of brand naming	1	2(1)
		Insufficient brand naming differentiation	1	4(2)
		Lack of brand naming uniformity	1	2(1)
		Recognized as general terms	1	2(1)
	Slogan 4(14)	Inappropriate slogan use	1	1(0)
		Need of slogan	1	3(1)
	Marketing 10(36)	Lack of understanding user's convenience	1	1(0)
		Lack of marketing consideration	2	4(2)
		Insufficient target selection	3	5(2)
	Brand image 4(14)	Insufficient image conveying	2	4(2)

	Subtotal		3	28(12)
Packaging	Container 11(31)	Inappropriate container use	2	2(1)
		Lack of container differentiation	2	6(3)
		Breakage risk	3	3(1)
	Volume 4(11)	Need of single package	2	2(1)
		Need of small package	2	2(1)
	Packaging structure 7(20)	Excessive packaging	2	4(2)
		Insufficient cushioning packaging	1	3(1)
	Packaging material 13(38)	Lack of recyclability	2	2(1)
		Need of additional cushioning materials (refrigerant)	1	2(1)
		Costly packaging materials	2	3(1)
		Changes in packaging materials	1	3(1)
		Need of packaging material improvement	2	3(1)
	Subtotal		5	34(15)
Visual communication	Layout 12(11)	Inadequate placement of design elements	2	4(2)
		Inadequate sizing of design elements	3	4(2)
		Layout mismatch	1	4(2)
	Logo type 24(21)	Inappropriate use of logo and font	3	11(5)
		No logo applied on outer package	1	2(1)
		Insufficient letter spacing	1	5(2)
		Mixed use of product and company names	1	1(0)
		Mixed use of Korean and English	1	5(2)
	Colors 11(10)	Color disharmony	4	6(3)
		Insufficient control of color tone	1	5(2)
	Lack of visual communication awareness 8(7)	Lack of aesthetics compared to functionality	1	1(0)
		General overview	3	5(2)
		Poor design compared to products	1	2(1)

	Lack of visual communication differentiation 4(4)		1	4(2)
	Symbols and character 10(9)	Inappropriate use of symbols	2	2(1)
		Inappropriate use of characters	1	3(2)
		Inappropriate adjustment of symbol color tone	1	1(0)
		Missing symbol meaning	1	2(1)
		Insufficient adjustment of symbol size	2	2(1)
	Illustrations and photos 16(14)	Use of unsophisticated image	1	2(1)
		Use of passive illustration	3	9(4)
		Use of unrelated illustration	3	5(2)
	Information 10(9)	Excessive information	2	6(3)
		Lack of information	1	3(1)
		Duplicated information	1	1(0)
	Lack of total design concept 17(15)	Lack of formative design story	1	3(1)
		Lack of integrated design development	3	14(6)
	Subtotal		4	112(50)
Grand total			5	227(100)

4.2. Mandatory labeling

Four out of the total of 5 experts describe the problems of the required legal marking. They are, missing the notation (57.7%), omission of the recycling label (28.8%), possibility of trademark registration (5.8%), inadequate letter size (5.8%) and bar code printing error (1.9%).

4.3. Branding

Three experts describe the problems of branding. In the first analysis they are divided into four items of brand naming (36%), marketing (36%), slogan (14%) and brand image (14%). Second subdivision process is used to draw out the details of those four items.

- Marketing (36%)
  Marketing problem is subdivided into three categories: lack of target selection (17.9%), lack of consideration of products (14.3%), and lack of user convenience (3.6%)
- Brand image (14.3%)
  As for the brand image problem, no further subdivision has been done, but it is pointed out that the delivery of the brand image is insufficient.



Figure 2. Example of 'lack of user convenience'.



Figure 3. Example of 'lack of consideration of product'.

Figure 2 shows a problem of recognizing whether the design to be for domestic or overseas. It seems that domestic consumers may find it difficult to recognize or purchase the product (Comment by Expert 5). Figure 3 is a product of 'light bulb rice' that shows creativity. However, the marketability of rice seems somewhat difficult (Comment by Expert 1).

4.4. Packaging

The problems of packaging are described by all five experts. In the first analysis, it is divided into four categories: container, capacity, packaging structure, and packaging. The detailed analysis of these four items is derived through second subdivision process.

- Volume (11%)
  The problems of volume are subdivided into two categories: need of single packaging (5.7%) and need of small packaging (5.7%).
- Packaging structure (20%)
  The problems of packaging structure are subdivided into two categories: excessive packaging (11.4%) and inefficient cushioned packaging (8.6%).



Figure 4. Example of 'need of single packaging'.



Figure 5. Example of 'excessive packaging'.

Figure 4 shows a problem of volume. This requires s smaller individual packaging for effective sales (Comment by Expert 3). Figure 5 is the example of using excessive packing materials and cushioning which may causes environmental issue (Comment by Expert 5)

4.5. Visual communication

All five experts describe the problem of visual communication. In the first analysis, it is divided into nine items: the logo type (21%), lack of total design concept (15%), illustrations and photos (14%), layout (11%), color (10%), symbol mark and character (9%), lack of awareness of visual communication (7%), and lack of visual communication differentiation (4%). Second subdivision process is used to derive the details of these nine items.

- Logo type (21%)
  Logotype problems are classified into five categories: inappropriate logos and fonts (9.8%), lack of alignment (4.4%) = mixed use of Korean and English (4.4%), no logo on external packaging (1.8%), and mixed use of product name and company name (0.8%).
- Symbols and characters (9%)
  Symbol marks and character problems are subdivided into 5 items: inappropriate character used (2.7%), inadequate symbol used (1.8%), missing symbol meaning (1.8%), insufficient symbol sizing (1.8%), and symbol color tone (0.9%).



Figure 6. Example of 'lack of alignment'.



Figure 7. Example of 'excessive packaging'.

Figure 6 is a package to require improvement in design aspects, such as logo, letter space, etc. (Comment by Expert 3). Figure 7 is for a packaging for melon. This requires an overall consideration on the character (Comment by Expert 3).

5. Conclusion and Suggestions

The purpose of this study is to identify the present situation of the packaging design of agro-food products developed in the process of 6th industrialization of agriculture, and to prepare the improvement plan based on the logical basis by systematically analyzing the problems. An in-depth evaluation by five experts was conducted on the packaging design of 41 agriculture products presented in the '2016 Agricultural Product Design Competition' of RDA in Korea. In order to accommodate the experts' systematic evaluation, a set of questionnaires for open-ended response is composed based on previous studies. In addition, the evaluation sheet of the 41 products made by the five experts is collected, and a qualitative analysis on specific problems of each field is carried out using Nvivo11.

The result shows that half of the problems of Korean agro-food packaging design is related to visual communication, followed by mandatory labeling 23%, packaging 15%, and branding 12%. The fact that visual communication is most frequently pointed out in the packaging design seems that it still has a limit for the agro-food products which have entered into commercialization in pursuing 6th industrialization to attract consumers' attention and to induce to buy. The next mostly pointed out problem, the legal marking seems to be due to the lack of expertise in the process of direct commercialization by farmers. This requires, in terms of policy, to provide expert consulting support or related guidelines to 6th industrialization site. Since the problem of packaging is directly related to the consumer convenience such as product use and price, it seems there is a limit to induce repurchase and continuous sales. Thus, it will be necessary to seek consumer opinions from the product development process, and for a policy, 6th industrialization promotion management should establish a window to communicate with consumers at the product development stage. The problem of branding seems to have limits in the development of marketable products and the promotion of larger-scale projects. Thus, it is necessary to educate the development and utilization of brand in the preparatory stage of 6th industrialization.

The results of this study can be used as empirical evidence for recognizing the systematic problems of the agro-food products packaging design of 6th industrialization and for preparing improvement plans. However, this study is limited to understand the actual consumer consciousness because it has conducted design evaluation from the professional point of view, further research is needed to complement.

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Innovation Design of Organic Waste Processor

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Abstract. Environmental and economic capability of current organic waste processor is need to be promoted under the background of advocating the development of circular economy. And thus a new design of organic waste processor integrated grinding and granulating is proposed through the application of TRIZ theory and the analysis of organic waste resource characteristics. This would effectively solve problems of resource waste and secondary pollution caused by current organic waste processor. And the operation efficiency can be improved. All this can provide references for other applications of this product.

Keywords. Product design, innovation design, organic waste processor, TRIZ theory

Introduction

In the context of sustainable development, recycling of organic waste can not only reduce the cost of domestic waste disposal, but also be able to convert it into available resources and energy [1]. Furthermore, it is of great significance to echo era background and strategic layout of china. Many developed countries, including America and Japan, studied organic waste treatment technology early and achieved good results. Recently, they mainly tend to develop and popularize organic waste resource processing technology and related products [2]. Some developed areas in China have also begun the development of processor products, mainly used for home and factory, those designed for home have achieved the reduction of organic waste, but it is bound to have a certain impact on the urban sewage system by applying crushing straight row technology [3]. Accordingly, with environmental protection, high efficiency and easy operation as the goal, we design and evaluate an organic waste processor through the application of creative design methodology-TRIZ theory (Theory of Inventive Problem Solving) and the analysis of resource characteristics of organic waste. The application of TRIZ theory may provide effective resolutions for the whole design process and reduce the time spent on traditional methods, and it should enhance the design availability, versatility and ease of use [4].

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1. TRIZ theory

TRIZ theory is an English translation of Russian abbreviations of "Theory of Inventive Problem Solving" [5], and a theoretical system formed on the basis of the laws and principles of multidisciplinary fields, which is mainly composed of 39 general engineering parameters, 40 inventive principle and 39×39 matrix to solve the conflict.

The general process of solving inventive problems by applying TRIZ is shown in Figure 1. First of all, combined with specific products for problem analysis, to find problems to be solved. Secondly, to describe the identified problems through the application of 39 general engineering parameters of TRIZ, and to find the corresponding engineering parameters. Then, to find the corresponding standard solution by using TRIZ tools. Finally, on the basis of a deep understanding of the principles of invention and separation, combined with acquired knowledge, to find the best solution to the problem.

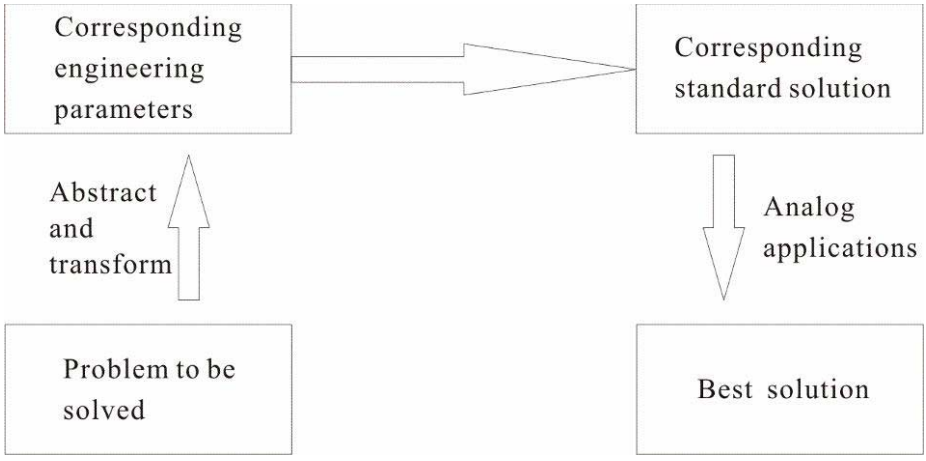


Figure 1. Flow chart of TRIZ method to solve inventive problem.

2. Application of TRIZ theory

2.1. Problem description

The organic waste processor should meet varieties of requirements simultaneously during it's use, including use environment, recycling of organic waste, and mechanical behavior. Organic waste processor target user- middle and high-end consumer groups (aged from 30 to 60) needs were analyzed, and the results were sorted by using analytic hierarchy process, the organic waste processor user requirements hierarchy was established from bottom to top (see Figure 2). Finally, user requirements were converted into organic waste processor product design concepts [6]. At the same time, according to the target user demands, and the current organic waste processor function (waste conversion treatment), this new organic waste processor design concepts were described as the following 3 questions after further concluding and summarizing.

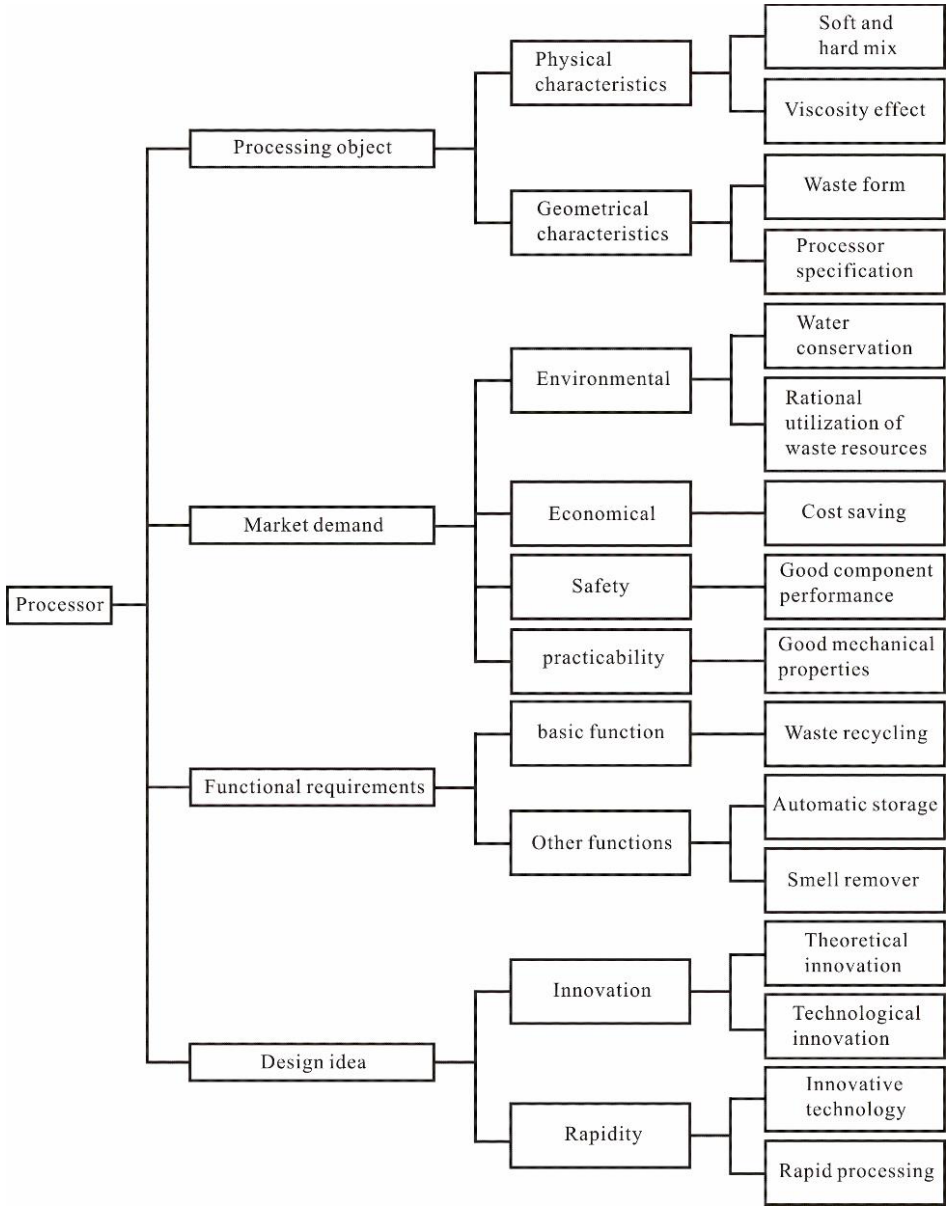


Figure 2. Organic waste processor user requirements hierarchy.

- The current organic waste processor device can complete the conversion treatment of organic waste according to the requirements. Its structure is compact and weight is moderate. But it is asked to realize recycling of organic waste resources, and to realize processing quickly. So it's necessary to add new functions to organic waste processor to meet users' actual needs, but this design will increase the overall weight of organic waste processor.
- After completed organic waste conversion treatment, the current organic waste processor device needs to discharge the waste into the sewer pipe by means of

hydraulic power, which resulted in a great waste of water resources [7]. Under the background of advocating green design, the organic waste processor is required to have the environmental performances of water conservation. Therefore, in the process of product design, we can improve the automation of the organic waste processor, to make it discharge waste automatically without the help of water after the completion of organic waste conversion treatment. However, this would complicate the organic waste processor morphological structure.

- Usually the organic waste being converted was drained into the sewer through the drainage pipe, which is likely to cause secondary urban water pollution. So the harmful factors of the organic waste processor itself should be improved to ensure rational layout of organic waste processor structure, and the discharge mode of the current organic waste processor should be changed to take advantage of the treated organic waste. However, this would complicate the organic waste processor morphological structure.

2.2. Conflict analysis

1. Physical conflict analysis

Physical conflict means that in order to realize a certain function, a subsystem or component should have a characteristic, but there will still be the opposite characteristics at the same time [8]. By using TRIZ theory, we defined the physical conflict in the design of the organic waste processor as follows. On the one hand, the organic waste needs to be discharged after grinding and granulating. On the other hand, the organic waste should be utilized reasonably.

2. Technical conflict analysis

Technical conflict refers to the optimization of one or more parameters in the system, while the other one or more parameters will be deteriorated simultaneously [9]. Applying TRIZ theory, we summarized the above technical conflicts of the organic waste processor, and listed it's decision process, see Table 1.

Table 1. Organic waste processor technical conflicts decision process.

Name	Judgement Reason
Function increase and overall weight increase	While meeting the characteristic of function increase, it makes overall weight increase characteristic deteriorated.
Automation and complex morphological structure	While meeting the characteristic of automation, it also leads to the deterioration of the complex morphological structure.
The harmful factors of an object and complex morphological structure	While meeting the characteristic of the harmful factors of an object, it also leads to the deterioration of the complex morphological structure.

Transforming the existing technical conflicts into 39 general engineering parameters of TRIZ theory [10]. Namely:

- No.35 Adaptability and utility is the possibility that the object or system performs its functions in various ways under the influence of many external factors, which belongs to improved parameters. No.1 The weight of a moving

object refers to the force that a moving object in gravitational field acting on the support to prevent it from falling freely, which belongs to deteriorated parameters.

- No.38 Degree of automation refers to an ability that the object or system realizes its own function without human intervention, which belongs to improved parameters. No.12 Appearance refers to the external outline or looks of an object, which belongs to deteriorated parameters.
- No.31 The harmful factors of an object means that the object or system's quality and efficiency was declined due to its operation, which belongs to improved parameters. No.12 Appearance refers to the external outline or looks of an object, which belongs to deteriorated parameters.

2.3. Conflict analysis

1. Determination of separation principle

Because both sides of physical conflict exist in the same object at the same time, so we need to separate both sides in different space, time, condition and level, to effectively solve the physical conflict [11].

Applying the principle of spatial separation, the different requirements of the same parameter are satisfied in different space [12]. The organic waste processor recycling system was divided into two parts, of which the crushing and grinding equipment mainly for organic waste's preliminary working, to make comminution granularity smaller than the gap between grinding pan and peripheral grinding chamber of 4～6mm, and entered the granulating bin, and then squeezed under the action of double roll gear granulation and agglomerated into dense hard particles. Finally, to be used as animal feed or organic fertilizer. The whole structure was mainly composed of four parts, respectively feeding part, grinding storehouse, granulation warehouse and material output, the intelligent operation mode was used during the whole process.

Through the combination of grinding and granulating, many numerical values, including power, motor speed, tool parameters and gear parameters can be calculated according to functional requirements, so as to ensure the realization of organic waste processor function and security function.

2. Determination of inventive principle

By finding the conflict resolution matrix list of TRIZ theory, we got the inventive principles needed to solve the above technical conflicts, and intercepted the sub matrix suitable for this problem from the conflict matrix, as shown in table 2.

Table 2. Organic waste processor conflict matrix.

Improved parameters	Deteriorated parameters	The commendatory inventive principle
35 Adaptability and utility	1 The weight of a moving object	1 6 15 8
38 Degree of automation	12 Appearance	15 32 1 13
31 The harmful factors of an object	12 Appearance	35 1

Aiming at the practical problems need to be solved during the organic waste processor innovation design, combined with product design principles and the connotation of each invention principle, and after a detailed analysis, principle No.6

(general principle), No. 13 (reverse function principle), No.35 (parameter variation principle) can effectively solve the conflict in organic waste processor design.

- Applying innovation principle No.6 general principle, the solution we obtained was increasing organic waste processor's function, namely, increasing the granulation function besides its basic grinding function.
- Applying innovation principle No.13 reverse function principle, the solution we obtained was reversing organic waste processor's drain off system. The current organic waste processor drain off system is located outside itself, and connected to the sewer pipe through the drainage pipe, and also, transported the crushed organic waste to the sewer pipe with water. Inspired by reverse design, we placed organic waste processor drain off system inside itself, to make the granulated organic waste products entered into retractable material tray through the inclined baffle under the influence of gravity. See Figure 3.
- Applying innovation principle No.35 parameter variation principle, the solution we obtained was changing the geometric parameters of the discharge pipe, or even cancel it. That is, using different collection tools and collection methods. By setting the retractable material tray under the granulation bin, we collected the treated organic waste for the secondary use, hence to avoid the secondary pollution for urban sewage system. See Figure 3.

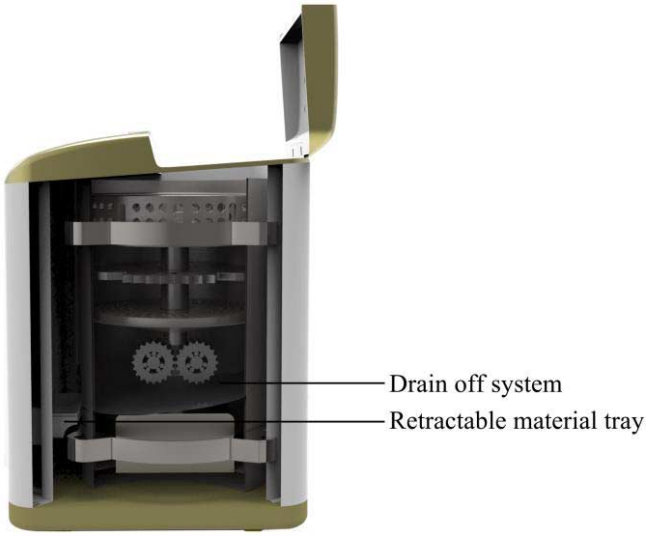


Figure 3. Drain off system and retractable material tray of organic waste processor.

3. Solution design

3.1. Organic waste processor innovation design

Combined with the solution of physical conflicts and technical conflicts mentioned above, we obtained the innovation design scheme of this organic waste processor device, its structure is shown in Figure 4.

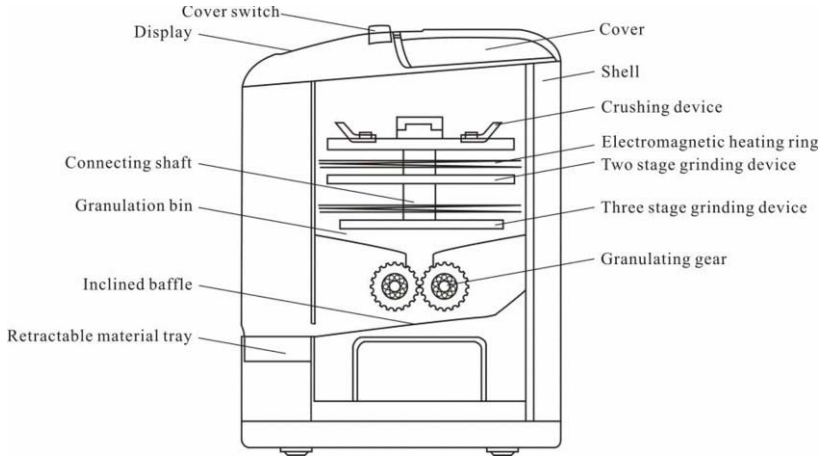


Figure 4. Structure diagram of organic waste processor.

The working process of the organic waste processor is as follows: pressing the cover switch, opening the cover, pouring the organic waste, and then starting the organic waste processor by operating the display. Firstly, the organic waste is crushed in the crushing device. Then, of which the acceptable organic waste enters the two stage grinding device through the gap around the cutter, and these acceptable organic waste is further crushed under the action of the high speed rotary impact of the crushed alloy blade. Finally, the qualified organic waste particles continue into the three stage grinding device to be crushed. In the process of the organic waste is crushed and falling, it is heated through the electromagnetic heating ring to reduce the influence of water on crushing rate and effect of organic waste. The finished small particles will enter the granulation bin, to be squeezed and reunited to form granular product through the double roll granulating gear, and finally slide into the retractable material tray through the inclined baffle. By operating the display, the small particles will be transported through the retractable material tray to be packaged. Ultimately, the whole process is completed.

3.2. Organic waste processor innovation scheme evaluation

Compared with current kitchen processing equipment, this processor had the following innovative points in concept machine making and performance. First of all, it solved the renewable utilization of organic waste resources from the source, and saved water resources. Specific performance in the organic waste being crushed was granulated, to be used as the raw material of animal feed or plant fertilizer, instead of draining into the sewer with the aid of use water. In this way, it can not only exert the potential nutritional value of organic waste, but also save water resources and avoid the secondary pollution. Secondly, its operation was more convenient. Specific performance in the intelligent design ideas were incorporated into the whole design process. Firstly, the organic waste processor didn't need to be installed before its use, thus reduced the confusion caused by the tedious installation process. Secondly, in the interactive design of the product, the mobile phone terminal APP was designed from the perspective of the user experience, so it can be operated from mobile phone or interactive interface. The whole process was carried out in a sealed environment to avoid the emission of the peculiar smell, and the finished products were transported

through the retractable material tray for packaging. Finally, its appearance design and materials were selected from user needs, to minimize environmental pollution caused by the use of products. Specific performance in the appearance of the product was designed from the perspective of international style, to close to the user subjective aesthetic, psychological and emotional needs [13]. Choosing ABS engineering plastics, it is easy molding, light environmental protection, not easy to corrode, hence to avoid a sense of indifference and serious corrosion problems caused by current kitchen processing equipment's pure metal texture. Accordingly, this innovation design scheme has reached the goal of environmental protection, high efficiency and easy operation.

4. Conclusion

Through TRIZ theory and tools, we carried out an innovation design practice of organic waste processor, the main results were as following:

- The organic waste could be used effectively by integrating grinding and granulating into a whole body.
- Through the reform of current organic waste processor's drain off system, its automation degree was prompted, and the water resource was saved.
- By changing the geometric parameters of the organic waste processor's drain off system, and adopting the retractable material tray, the secondary pollution on urban sewage system was avoided, and the packaging of the organic waste material was more convenient.

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Research on the Analysis of the Morphological Attributes of LED Lighting Units by Type

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Abstract. This study took used the example of LED lighting units that have two types of morphological characteristics and performed a categorization of similiar products based on their functional similiarity. And the study was carried out with the goal of creating a criteria that can assist in the initial directionality settings for development when developing a lighting unit by extracting the categorization typicality by classification pattern. A total of 3 rounds of surveys were conducted: the 1st round included the morphological classifications, the 2nd round the typicality extraction and the 3rd round design attributes be consecutive design. The surveys were about LED lighting unit products that were released prior to July 2016 and were administered in 6 major cities throughout Korea to people who had either been employed in related industries or who majored in the subject. The surveys were conducted based on the criteria of functional and morphological classifications and formative principles. By conducting joint research with a business to determine the industrial application of the research results, such tangible effects could be expected such as the establishment of effective roles for design technology and the classification of typical models.

Keywords. Stereotype, Properties of Design, LED Lighting Fixture

Introduction

When considering the areas of research and the present state of research at major corporations in Korea and abroad, Philips is by far a leading company in red LEDs and high output packages and sells everything from modules and completed lighting products. By focusing on securing LED bulb standardization and securing standard technology, the company was able to take a favorable position in the general household lighting market. Meanwhile Nichia pioneered the LED market and is the company that possesses the highest levels of technical capabilities. In early 1996, the company developed and produced white LED and is supplying this to roughly 50% of the world market. The company possesses about 200 domestic patents and more than 10% of GaN patents worldwide. Then there is Osram Opto Semiconductor which is is well known company among general domestic consumers. This company is a leader in interior LEDs and the alternative market of three-wave length bulbs, which accelerated its share in the LED lighting market and is ever increase its marketshare.

Policy changes took place across various countries [1]. In Japan, there was the "21st century light project," which sought to expand the supply of white LED, and thanks to the development of 120 ㏐/W LED in 2010, lighting energy was reduced by about 20%, and through research and the country is striving to grow as a country of

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leading technology through research and development support [2]. China, in 2005, designated and has been fostering "national light emitting diode industrialization bases" across 5 regions, and manages LED and has included the development of LEDs and light emitting diodes in the 13th National Economic Development Plan. In the United States, the "Next Generation Lighting Initiative" is underway, which pursues the development of 200lm/W LEDs with the goal of securing 50% of global marketshare by 2020 [3].

When it comes to choosing LED alternative lighting, consumers have differing opinions of each manufacturer. This is because LEDs are consumer goods and the decision to make a puchase of one type or another is based on a good guaranteed on the lifetime of the product and design [4]. Consumer preference is reason a wide gap exists among domestic LED lighting units and lighting products companies that compete with Osram and other leading companies and still remain popular [5].

The LED applied field that includes the global LED lighting field has seen annual growth of 20% for the past three years, and the global lighting market grew by 48% annually.

In this study, these figures were observed in the interview results that were performed in the integrated research process for developing an industrial-educational integrated type curriculum over the span of about 4 months from September 2013 until the beginning of January 2014. For the survey, interviews were conducted of 45 people from a total of 27 companies including 11 in the metropolitan area, 5 in Busan, 2 in Daegu, and 9 in Gwangju, and interviews were also conducted for of 14 experts in 3 fields at university. Also interviewed were 124 consumers that were involved in visiting 2 retailers that sell LED lighting units. And of these the Town Watching Method was employed for analyzing the surveys of 31 consumers that completed a purchase.

In the case of engineers belonging to professional groups and employed in the industry, 86.44% complained of diffculty with product differentiation. And 90.20%, or some 46 of those with complaints, replied that problems arose in the product planning stage or that they had difficulty.

In the Investigation technique survey intended for consumers, 124 consumers that visited stores during the survey period, the answers to the question of what influenced their purchase the most, included "design focused (41.94%), "price focused" (32.26%), "function focused (13.71%), and brand focused (12.10%). Out of the 31 consumers that completed a purchase at a retailers, the majority of 18 consumers or 58.06%, asked the sales clerk questions about the "difficulty in recognizing any differentiation by design."

An average of 4.68 of the actual purchasers that employed a "detective technique," mentioned that they considered whether to make a purchase or not based on the product comparison aspect of their purchasing pattern. And when the final moment was upon the purchaser to choose from one of the two, the respondents said they had the greatest difficulty when considering "conflicting images (83.87%)" or when there was the issue of price among products with similar functions. In the interview with purchasers, the overwhelming number of respondents, or 87.10% that stated that they had to think over the design mentioned that the absense of a differentiation between products was the main reason they preferred the product with a similar design, but middle-low priced. Also, 25.81% of these consumers mentioned that many of the similar designs conflicted with other's products or greatly lacked in appeal. And 61.29% of purchasers were of the opinion that they preferred products that had fuctions that were easy to understand from a product for by designers. Such a majority sharing the same opinion

was what led to the conclusion of the dire need for the design differentiation and the appropriate visualization of the functions [6][7].

1. Theoretical considerations and the establishment of a hypothesis

1. 1 Theoretical considerations

The product formalization process for extracting the design attributes could be understood as a process of communicating the morphological shapes that make up the product. And depending on the relationship between consumers similiarities and preference, the relationship between the level of preference in selecting a product and the level of preference according to morphological curves can be measured as either having positive similitarities or negative similarities [8].

The classification of attributes by Garner (1974) are divided into component attributes and holistic attributes [9]. The holistic attributes used for this study, meaning the categorization typicality could be extracted by classifying the product versus product cyclical morphological differentiations, which are intended for complete expressions of the subjects, with a show card survey of design-related participants.

Component attributes describe a part or abstraction of an object, or an objects purpose. In this study, it is possible to restrict the scope of attention or exclusion between product development by have attributes classified based on the recognition of a development subject, which is split by the purpose of the object part [10].

In Nosofsky's (1986) Schematic Illustration [11], the lower the level of relative involvement between each different subject and the identity separation phenomenon, the greater the form or character was recognized causing a disconnect from typicality. or, separation phenomenon, lack of, involvement, trait, typicality, categorical, According to research conducted by D.E. Kornbrot (1978) regarding judgments on selection model and categorical judgments [12], in the process of delaying the physical information of a subject, empirical comparison is a major factor that influences a consumer's choice. And shows that the gap between the information presented by psychophysics and interference is greatly affected.

1.2 Establishment of a Hypothesis

The guidelines by specific product type quantified in the product development process minimizes overlapping task performance, and securing the diversity of each type of morphological typicality model makes it possible to quickly ascertain a prototype in the planning stage. Also, the extraction of the design attributes allows for effective design input while at the same time induces encouraging performance through communication with the engineer [13].

To better accomplish this, in this study, the pendant type and ceiling hanging type were targeted, which both currently have the highest product demand, and have the highest frequency of use in public spaces among LED lighting units, and performed a total of 3 rounds of surveys and analysis processes after which the design attributes were categorized. While designing, the designer choose the information on a typical product's distance and the design development was performed within the selected category [14]. And in the process of creating a new typicality, the sense of difference for the holistic attributes, which deviated from the identity within the category by the

consumer, and the component attributes were both used to establish an emotional common value [15].

2. Research method and content

2.1. Research method

To verfiy the above hypothesis, the morphological classification of the LED lighting unit must take precedence [16]. This is performed by classifying the retail products through preceding research and advice from industry experts. And the two types to be used in this experiment and the applicability were selected as the basis for the pendant type and ceiling hanging type [17][18] (Table 1).

Table 1. Morphological classification.

Item	Research method	Implemented strategy
Preceding research and literature review	Theoretical background of typicality and design attribute	Formative principles, Research of related literature and data from Korea and abroad
	Research of LED lighting unit design and design development data	Literature review of books related to LED lighting units, research of internet data, case review of business fulfillment
Survey design	Typicality and attribute extraction method design	Target area for survey: 6 major cities Survey range: pendant/ceiling hanging type Interviewer (11 people), interviewees (differentiated according to disparity) result extraction method: statistical analysis by using SPSS (Frequency, factor analysis)
Survey implementation	Sample survey of LED lighting units in Korea and abroad	Two types of sample gathering for this research of the LED lighing units released in Korea and abroad (released in Korea and Japan)
	Experiment according to disparity	1st round: morphological classifications of lighting units (for 300 design experts and those who majored in in the subject)
		2nd round: design typicality extraction by morphology of 2 types of lighting units (targeting each of the 50 design professionals with 3 years or more experience and a total of 100 people)
		3rd round: morphology design attribute extraction (targeting 50 people with lighting industry and lighting design related experience)
Expert advice	Advice from professionals in related industry, design, and statistics	Advice from 3 design experts and 3 industry experts 1 statistical analysis expert was targeted and validated

Also, functional understanding and classification was carried out by literature review and engineer advice. Starting with a sample survey, a 1st round morphological classifications for lighting units, 2nd round design typicality extraction by morphology

for 2 types of lighting units was performed before selecting the final prototype for the 3rd round, morphology design attribute extraction.

To verify the research process and results, a group of 7 experts and 2 LED related companies were consulted and consultations were given. From the design attribute extraction stage, and in tandem wtih the 2 participating companies, LED lighting unit development ran parallel with what was echoed in the research results.

2.2. Research content

The 1st and 2nd rounds of experiments were performed with survey cooperation and advice, side-byside. To do this, it is necessary to grasp the structure of change factors in the formative principles by applying Won Wucius's concept of "formative form elements" [19][20].

A 1st round survey for the interview and typicality classification phase was perfomed for a total of 366 out of 1,388 collected samples (635 in Korea, 753 from abroad of the released products were extracted by experts)of pendent type and ceiling hanging types that were released and sold in Korea and Japan prior to July 2015 using photos classifying the directly collected image data and product information by type, which was useful in the analysis results.

The surveyed samples were adjusted in gray scale to eliminate any suggestion of color from the experiemental design. And to prevent a survey error due to the scale, a 10 X 10 standard scale was set, and the image was processed by deleting whatever was in the background. In the 1st round of surveys, by separating into 2 types of morphological classifications using a show card, the pendant type was composed of 13 categories, and of these 6 valid categories were selected. The ceiling hanging type was composed of 8 types, and of these 4 valid categories were selected.

In the 2nd round survey, the equal-appearing interval scales were used to separate the morphological classification of the survey participants into conceptual, structural and visual forms using the isometric method performing a work type classification on 200 samples in the actual development stage. After, a total of four prototypes were derived from the show card survey, and the data was visualized again through expert group consultations before summarizing the final three models. To perform the 3rd round experiment for design attribute extraction, a vector image processing task was performed create data for attribute extraction [21][22].

In the second survey, it was classified into conceptual element, visual element, correlation element, and structural element, which are all the morphological elements of emotional engineering aspect [23]. And the main categories of design attributes were classified by independence, salience, importance, and determinacy based on the division of balance, proportion, rhythm, unification, and emphasis [24]. With the participation of 59 experts (38 agencies / companies) consisting of industry experts, researchers and those who majored in the subject hailing from research institutes, related organizations and industries in six major cities in Korea, the morphological main features were largely divded into proportion, shape, scale, disposition and corner.

In 3rd round of experiments, a specialist group survey was conducted to extract design attributes [25]. And based on the survey results as shown in the figure below, the criteria for designing morphological design guidelines were divided into 27 elements via 11 design attributes and factor analysis based on the 5 major morphological categories. Each factor of design attribute extracted factors were based on the vocabulary composition of adjectives and nouns (Table 2).

Table 2. Morphological analysis.

Morphological features	Design attributes	Element	Factor
Shape	overall morphology	complex	dizzying, complex outline
		ambiguous	hard to explain
		simple	easy to understand, monotonous
	structural morphology	single structure	simple structure, easy to understand
		complex structure	overlapping, combination of several parts
		dual structure	appears as if there are two
Proportion	split face structure	complex	multi-faced, complex partitions
		simple	small face, hidden divisions
	split face ratio	impending	sharp, deft, chancy
		boring	loose, comfortable, sense of stability
Scale	actual scale	large	tall
		reasonable	appropriate, reasonable
		small	short
	visual scale	appears large	appears to have been enlarged
		average	not unusual, appears normal
		appears small	appears shrunken
Disposition	functional attribute	fixture	attaches to wall or mounting surface
		joint	connects fixture with body
		control part	power, lift control, movement
	selective attribute	lighting joint	lighting fixture, lighting shift
		lighting	diversity of lighting types
	aesthetic attributes	body	hidden, thin, sturdy
		cover or shade	brightness/color tone adjustment, elegant
Corner	edge	deft	enterprising, urgent, instable
		stable	modern, honest, stable
	round	round	quite, soft, comfortable
		moderate	dynamic, tension

The result of using the Delphi technique [26] for verifying the validity of the elements investigated by collecting expert opinions for the verification of the appropriate elements for each extracted design attribute were as follows: out of the 27 items obtained from the 1st round of open-ended opinion gathering, a suitable

evaluation could be obtained for 23 of the items in the 2nd round, which were closed-end questions.

All elements of the ideal design attributes are applied to the pendant type, which is relatively complex in composition, yet, for the ceiling hanging type, there were 3 factors because of the installation method and the usage that partially or entirely fill the space.

3. Conclusion

The result of the interviews and expert consultations, LED lighting fixture products have not been able to keep up with the sudden change in light sources, and either traditional types were maintained or originality was lost by trying to keep up with comparatively novel products that have been released. And consumers are often unable to receive appropriate price appreciate. This is caused by empirical and intentional problems in the industry that occur when following a new market rather than the disparity that arises in the traditional design development process.

This study began by peforming a limited number of interviews asking about morphological aspects to manufacturers/developmers in the market, design management staff and consumers that have completed a purchase to determine the problems that exist. And in order to propose a quantitative approach using form and function correlation in the product design development process, we conducted experiments on LED lighting fixtures with two specific morphological shapes.

Unlike industries where information has been accumulated through the consulations and advisory process of expert groups within the respective industry and the experiment results have been acquired sequentially, when applying the suggesting process from the research in the field of LED lighting unit products, where little research has been performed and there are few established terms, it was the majority opinion that product development would be appropriate if carried out at the planning stage, and the effect of reducing failure rates for is highly expected. However, the research to date has a near limit in the definition of terminology that associates formal aspects with functions, so if the number of a more diverse typical morphology could be increased, the expectation is that this would greatly benefit the development process.

This study, which was conducted for two years, was conducted in parallel with the development process reflecting the results of research with two companies. One design project for each type was developed and after receiving positive review and given the go-ahead by the company, they were mass produced. When comparing the development process with the existing process, the time it took to apply the research result reflection process it was found that the efficiency of the data survey applied allowed the product development concept to be applied 243% faster, with the efficiency of communication between engineers and designers improving by 47%. It was reported that the prototyping process of the designer and the efficiency of the design work of the engineers were accelerated thanks to the interviews. This part is expected to yield reliable and meaningful values when accumulating much development or carrying validation experiments.

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A Design Method of Icon Based on Semantic Research of Universal Symbols

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Abstract. With the advances in computer technology, graphical interfaces improve substantially software operability and readability. Good icon converts series of complex system commands into an intuitive symbol and enhances software usability by reducing users' cognitive load. In this paper, we study the semantics of universal symbols, the Time to Fixation Mean and Heat Map are carried out by the eye-tracking experiment, then the corresponding icons are designed according to the results of eye-tracking experiment, finally we analyze the efficiency (Reaction time and accuracy) of user's recognition in the e-prime experiment. This paper provides designer with a design method of icons after a quantitative verification.

Keywords. Icon, semantic, universal symbols, E-prime experiment, Eye-tracking experiment

Introduction

With the development of computer technology, software interfaces have undergone tremendous changes in the sense that the graphical user interface (GUI) have improved in operability and readability terms; and one of the most important elements are 'the icon'. Icons are easier to remember than words because they are more concrete [1]. As there are usually large number of icons being used in software, the achievement of a successful, user-friendly and popular GUI relies on icons at a large extent [2]. Icons have become an important interactive media between software and users.

Compared to the asthetic aspect, whether the icon can be recognized quickly and accurately is the primary concern. A good icon is intuitional and figurative as an abstract symbol, which can greatly reduce the memory load and improve the efficiency of visual search behavior [3-4]. Icons with incorrect semantics affect the user's cognition, they can lead to lower efficiency and motivation, and may mislead users too.

Nathalie Cindy Kuicheu pointed out that the semantics of an icon was not the linguistic equivalent associated with the image, but a set of attributes which can be used to describe the given icon [5]. For example: Y. Batu Salman designed a set of icons according to the semantic abstract graph of the emergency medical information system [6]. Sarah Isherwood pointed out that by focusing on interface users' understanding of icons, recent research has shown that it is the closeness of the relationship between icons and functions, known as the semantic distance, that is of prime importance in determining the success of icon usability [7]. Likewise, Fabrizio

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Lambertia pointed out that semantics-based optimization mechanism was used to find the best mapping between icons and functionalities and to expand the set of valid commands [8]. Moreover, Zhou Yuxiao used the Design Semeiology to interpret the four dimensions of the digital interface icon, such as semantics, structure, context and pragmatics [9].

Several theories on the semantics of icons have been proposed. We have also concucted research on the semantics of icons. We empirically evaluated four types of icons semantics (icons in the military system), namely function-metaphor, operation-metaphor, object-metaphor and semantics-metaphor icon [10]. This paper can be seen as a follow-up of our previous work. All in all, we can see that many research focus on semantics of icons, and reveal the importance status of semantics recognition.

In this paper, we studied the semantics of universal symbols and gave a quantitative description on icon semantics. We provided a design method of universal icons to designers, which can be varified in a quantitative and scientific way. Specifically, our method follows three steps. First, symbols are selected based on expert score and Likert scale. Data of response time and eye-gazing duration of different types of symbols were collected by the eye-tracking experiments, symbols are good for icons design are found. Second, we design icons depend on the selected symbols referring to the results of eye-tracking experiments. Third, we assess the efficiency of user's recognition of these design icons. Our design method can be varified by analyzing the reaction time and the accuracy in the e-prime experiments.

1. Experimental factors

1.1. Icon size

In order to exclude the impact of interference factors, the density of interface information needs to be carefully considered. The general size are 16 * 16px, 32 * 32px, 64 * 64px, 128 * 128px, 256 * 256 px. The 256 * 256 px is more common in the windows version of the system. Low operating system version are not supporting large size icons, so the selection of the icon is according to the background size. In order to match the experimental equipment, the device screen size has been set to an unified size 1024 * 768 px, so the size of interface will be set to 1024 * 768 px in order to match the device screen, where the size of text is 36pt and the size of icon image is 64 * 64px. The perspective is controlled in 0.7 degrees, which is equivalent to reading an icon with the size of 0.5cm X 0.5cm at a distance of 40 cm [6].

1.2. Interface layout

The rate of experimental interface content should not exceed 40% overall screen [11] to aviod anxiety and psychological burden, and the rate of screen coverage also can not be too low, because it will lead to the user's attention rate dispersion. In order to maintain the appropriate ratio, graphic symbols were evenly distributed in line pixel grids on the background picture in AI (Adobe Illustrator) [12]. The location and the stimulus elements are exactly the same, three interfaces were designed as 1 * 1, 2 * 1 and 2 * 4, which are applied into two experiments.

1.3. colors affection

Colors will affect the results of experiments, so the color of background is black(HSB color system indicates 0° 0% 0%), the color of icon is white(HSB color system indicates 0° 0% 100%) or gray(HSB color system indicates 0° 0% 60%) and the color of font also is white(HSB color system indicates 0° 0% 100%) in the experiment, these made the experiment without color tendency interfered [13].

2. Methodology

2.1. Experimental equipment and Materials

There are three experimental phases in this study **I**: An eye-tracking experiment (using Tobii X2-30 Eye-tracking Device) where genric symbons are used; **II**: Depending on the eye-tracking results, the corresponding icons were designed (You could re-phrase this, so it could be consisten with the previous point. For esmaploe Icons were designs, depending on the eye-tracking results previosuly obtained; **III**: A behavioral experiment conducted in order to test the designed itcons (unsing E-Prime software).

In the Experimental task **I**, icons are selected based on expert scores and Likert scale. Some of them have semantics similarity, whereas others have different semantic indicators. So that the experimental materials have comparison of similar semantic symbols and also include no correlation semantic symbols [14-15].

2.2. Subjects

Twenty students, whose ages are between 20~35 years old, 14 males and 6 females, are chosen as subjects. Among those, 15 are with related background knowledge whose major are computer sciense and 5 are not familiar with the field. During the experiment, subjects are asked to keep their eyes 550~600 mm away from the screen and both horizontal and vertical perspective is controlled in 2.3 degrees [16].

3. Experimental procedures and Results Analysis

3.1. Experimental task I

3.1.1. Eye-tracking experiment

The experimental process is as follows. Phase I: a white cross appears in the center of the screen and lasts for 1000ms after which it disappears. Phase II: a word appears in the center of the screen and lasts for 2000ms. In this phase, subjects are asked attend and memorize the word. Phase III: a 1000 ms blank screen. Phase IV: eight symbols appear on the screen at the same time. Subjects are asked to conduct a visual search task to find the semantic symbol which can matched with the word presented in Phase II. After that, the subject is asked to press any key to proceed to next trial. The interfaces are shown in Fig. 1.

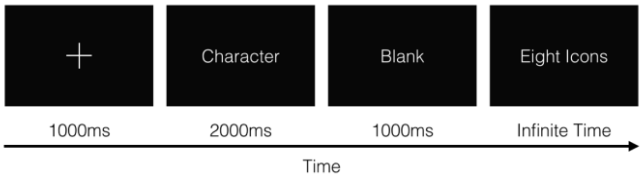


Figure 1. Procedure of eye-tracking experiment.

The Reaction Time and the recognition symbol were explored. Three types of time data were respectively recorded in this experiment. Time for the First Fixation (seconds) referred to as TFF: the average length of time of the first time to enter the interest area. The Duration of the First Fixation (seconds) referred to as FFD: average length of time in the area of interest for the first time. The longer the time, the greater the salience of the region. Fixation Duration (seconds) referred to as FD: the total average length of time in the interest area. The longer the period, the greater the salience of the region. Three standard comparison are used to study the accuracy of the semantic expression of the icon.

3.1.2 Eye-tracking data analysis

Fixation time data analysis

Eight symbolic data curves are more complex and messy, we compare the data of two symbols which have the top-two shortest fixation time.

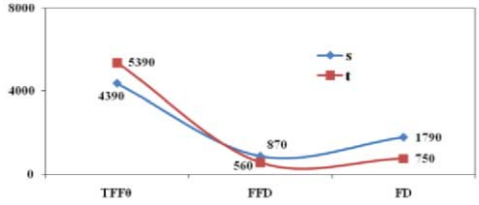


Figure 2. Fixation time of the "time" symbol.

Figure 2 shows the results of the "time" symbol. The blue line represents the symbol "s" and the red line represents the symbol "t" (The time unit is ms). TFFθ of symbol "t" is faster than the symbol "s", but FFD of symbol "s" is slightly faster than the symbol "t", and FD of symbol "s" is faster than "t". The results proves that "s" is more suitable than "t" as a symbol for calculating time function - its universal property is higher than the symbol "t".

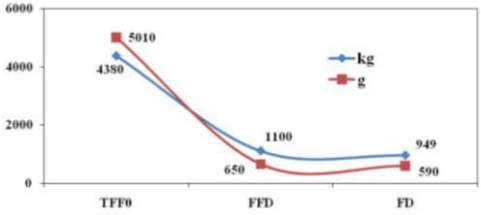


Figure 3. Fixation time of the " weight " symbol.

Figure 3 shows the results of the "weight" symbol. The blue line represents the symbol "kg" and the red line represents the symbol "g" (The time unit is ms). TFFθ of symbol "g" is faster than the symbol "Kg", FFD of symbol "Kg" is slightly faster than

the symbol "g", and FD of symbol "Kg" is faster than "g". The results proves that "kg" is more suitable than "g" as a symbol for calculating weight function - its universal property is higher than the symbol "g".

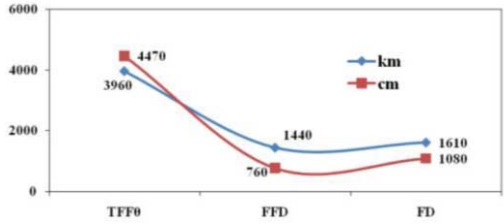


Figure 4. Fixation time of the " distance " symbol.

Figure 4 shows the results of the "distance" symbol. The blue line represents the symbol "km" and the red line represents the symbol " cm " (The time unit is ms). TFFθ of symbol "cm" is faster than the symbol "km", FFD of symbol "km" is slightly faster than the symbol "cm", and FD of symbol "km" is faster than "cm". The results proved that "km" is more suitable than "cm" as a symbol for calculating distance function - its universal property is higher than the symbol "cm".

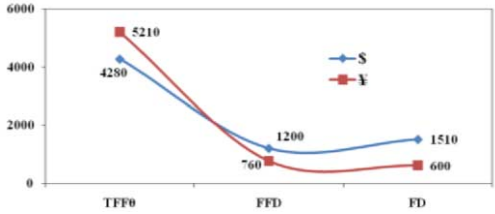


Figure 5. Fixation time of the " money " symbol.

Figure 5 shows the results of the "money" symbol. The blue line represents the symbol "$" and the red line represents the symbol "¥" (The time unit is ms). TFFθ of symbol "¥" is faster than the symbol "$", but FFD of symbol "$" is slightly faster than the symbol "¥", and FD of symbol "$" is faster than "¥". The results proves that "$" is more suitable than "¥" as a symbol for calculating money function - its universal property is higher than the symbol "¥".

Heat Map

Studying the user's attention area and attention distribution through the heat map helps us intuitively find some unqualified experimental data and explore the effectiveness of the task's implementation, which can ensure the accuracy of the experiment.

As shown in Fig. 6, all subjects completed the assigned task. The results indicated that the best universal property symbol of calculating distance function is "km", the best universal property symbol of calculating time function icon is "s", the best universal property symbol of calculating money function is "$", and the best universal property symbol of calculating weight function is "kg".

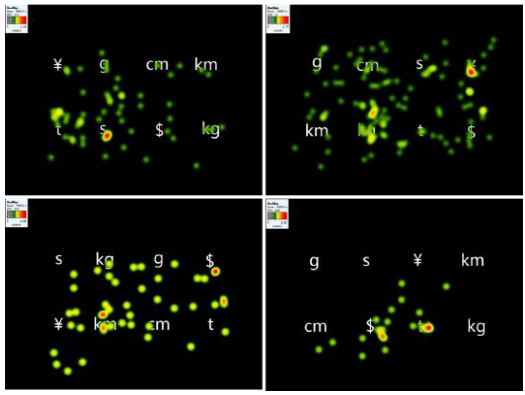


Figure 6. Heat Map.

3.2. Experimental task II

We use AI (Adobe IIlustrator) to design the icons according to the results of eye-tracking experiment. The results of task1 are the elected symbols-"S","Kg", "km", "$", which are the best universal symbols to representative separately "Time","Weight","Distance","Money". These universal symbols are used to design the object-metaphor icon, In order to verify if this method is effectively, we need to compare semantics-metaphor icon with other kinds of metaphor icon. We choose object-metaphor icon, because semantics-metaphor icon is an abstraction image and object-metaphor icon is an object image on the contrary [9-10]. Experimental task II need to design object-metaphor icon and semantics-metaphor icon, which are completed by a designer, icons are shown in Fig 7, the top is semantics-metaphor icon and the bottom is object-metaphor icon. After that the grid line was made horizontal and vertical staggered, and the icons are insert into the desired location in different pages, as is shown in Fig 8, the left icon is semantics-metaphor icon of "Distance", and the right is object-semantics-metaphor icon of "Distance". Many factors have explainted in the “experimental factors” of this paper.

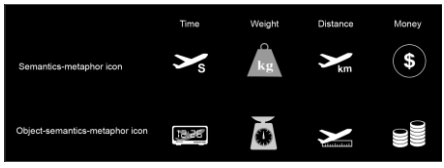


Figure 7. Expermental task II.

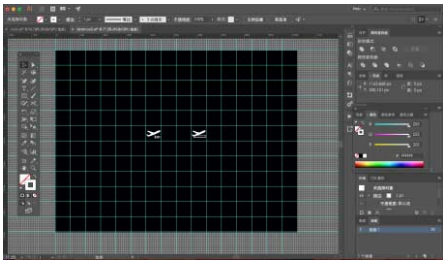


Figure 8. Interface of AI.

3.3. Experimental task III

3.3.1. E-prime experimental

In experiment III, in order to verify the design method scientifically. The icons which are designed in experimental task II are used as the materials, and the user's efficiency (response time and accuracy) of the icon recognition is analyzed by E-prime software. Experimental procedure is as follows: The instructions are displayed on the screen without time limit, the subject reads the instructions carefully, after that the subject is asked to press any key to proceed into the experiment. There are 4 trials in experimental III and each icon "Time", "Distance", "Weight", "Money" will show up in sequence. Each trial covers two icons, one is semantic-metaphor icon and the other is object-metaphor icon. There are four phases in each trial, Phase I: a white cross appears in the center of the screen with the background being black, which lasts for 1000ms then disappears; Phase II: text appears in the center of the screen and lasts for 2000ms then disappeared. In this phase, subjects are asked to remember and understand the text; Phase III: blank appeares and continuously lasted for 1000ms then disappeared. This phase is to eliminate visual persistence; Phase IV: two icons appear in the center of the screen and the subject is asked to decide which one's semantics match the text in Phase II. Then the subject is asked to press key 'A' to choose the left icon and press key 'K' to choose the right icon. After that the subject proceeds into the next trial.

3.3.2. E-prime experimental data analysis

E-prime experimental data include the accuracy rate and reaction time.

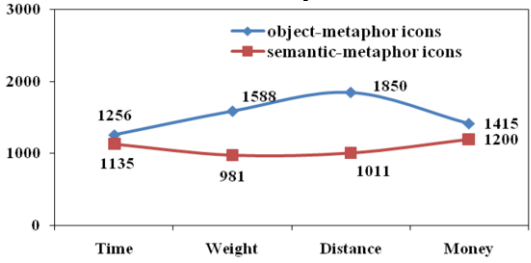


Figure 9. Reaction time to different icons.

Figure 9 shows the reaction time of semantic-metaphor icons and object-metaphor icons, it can be concluded that the time of the subjects identifying the object-metaphor icons are longer than the semantic-metaphor icons.

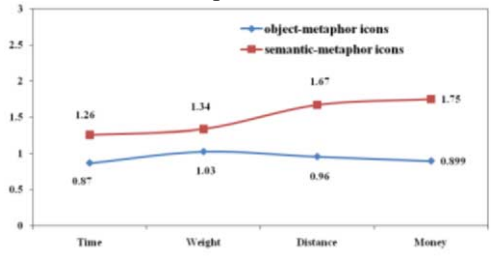


Figure 10. Accuracy rate of icon recognition.

Figure 10 shows the accuracy rate of recognizing semantic-metaphor icons and object-metaphor icons. It can be concluded that the accuracy rate of the semantic-metaphor icon is higher than the object-metaphor icon.

4. Conclusions

This paper studies the universal property of symbols. The corresponding icons are designed according to the results of eye-tracking experiments, in addition to we explored which kind of icon is identified faster and more accurate between the semantic-metaphor icon and object-metaphor icon. The quantitative analysis of the semantics of symbols and icons are carried out, the semantic-metaphor icons with the higher universal property, obtain higher cognitive accuracy and lower cognitive load than the object-metaphor icon. We find that the universal symbol is well used to design an icon, this is an useful design method for the semantic-metaphor icon.

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Benchmark Pre-Production Practice in Manufacturing Engineering

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Abstract. Prototyping stage is a very important phase of new product development, where many decisions need to be taken to get high quality, zero defect products at the right time with minimum cost. Therefore, any value added improvements or best practices in the prototyping stage will support competitiveness of manufacturing companies. This research aims to benchmark the best practices in prototype part manufacture to support early stages of product introduction. A set of of best practices in the prototype component manufacture, along with validated four step prototyping strategy model and best practice prototype journey path model were developed. Research findings provide insight about prototyping trends, best practices and optimum ways of doing prototyping in the manufacturing companies around the globe. Manufacturing companies can use the developed models and best practices to make better prototype strategy in their new product introduction system to achieve their business objectives.

Keywords. New product introduction, prototype, pre-production, benchmark

Introduction

Due to the presence of international competition and market globalisation, manufacturing companies have to compete effectively by reducing product development cost and time, while assuring zero defect products. Therefore new products must be more quickly and cheaply developed, manufactured and introduced to the market [1]. This can be achieved by improving prototyping stage which is most important phase in the new product development (NPD) process. Prototyping (pre-production) phase is a very important stage where many decisions need to be taken to manufacture high quality product at the right time [2]. Therefore, any value added improvements or best practices in the prototyping phase at early stage of product introduction (PI) will support the company in the long range. This research has been carried out with an industrial partner, with aim of finding best practices in prototype part manufacture in the manufacturing companies.

The most important process for many companies will be the New Product Development (NPD). NPD aims in finding an opportunity in the market, converting that opportunity into product and finally launching it successfully in the market [3]. NPD is a huge field dealing with the design, prototyping, actual production and marketing of new products. Fang and Ou stated that the continuous development and

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market introduction of new products can be an important determinant of sustained company performance [4].

Manufacturing companies' success mainly depends upon its ability to introduce new products successfully into the marketplace. According to Sethi et al. [5]; Wang [6]; Buganza and Verganti [7]; Huang et al. [8] and Arastehfar et al. [9], many companies face more and more uncertain environment as changes in technology accelerate, customer expectations and global competition. To overcome these challenges, Ali et al. [10] stated that evolution of the market has necessitated the reduction of time-to-market. This is mainly because the product life cycle is shorter and also very important to proceed more rapidly from an initial conception to a mass production. Leading companies worldwide are discovering that Rapid Product Development (RPD) is a huge and relatively untapped source of competitive gain, especially for new products that have not appeared previously. If a particular product can be introduced early, it gains more customers and is able to maintain their loyalty due to the cost of switching to another product.

Camburn et al. describes that the prototyping is an important tool to identify challenges, reduce risk or prove a hypothesis and should be used wisely [11]. If prototyping is not handled properly, whole PD cycle will face the problem. With prototypes and feedbacks, design teams can effectively explore the ideas versus functional requirements [12]. Prototype in the NPD is the reference point from which the value of future improvements can be assessed as PD progresses. Therefore, a major tool for detecting all the problems is the prototype.

Physical prototypes are information channels carrying information richness, and enable one to cope with uncertainty. Marion and Simpson argues that for successful release of a new product physical prototype iteration is the key driver [13]. Bennett and Gibson et al. believes that both physical and virtual prototype techniques should be used simultaneously in the NPD process to develop complex products [14][15]. Both these techniques have similar goals, which is reduction of time and cost and to get more flexibility in the PD.

Zhang and Liu states that Rapid Prototyping (RP) is a new kind of manufacturing technology and it provides an effective measure for rapid manufacturing (RM) of products and dies to meet the demands for market competition and attracts more attention from corporations day by day [16]. Xiong et al. shows that direct metal prototyping methods like 3D welding Selective Laser Sintering (SLS), Shape Deposition Manufacturing (SDM), shaping welding, Electron Beam Melting (EBM), Laser Engineering Net Shaping (LENS) etc developed to fulfil the requirements for metallic prototypes and tools [17].

The literature explains the different prototyping methods. Most of the works mainly concentrate on either prototypes for software development or rapid product development. There is little information available about proper guidelines for building better physical prototype in PD. It is always not possible to improve reduction in development time by procuring new rapid prototyping machines or using digital prototype method. Instead, proper guideline should be evaluated for better physical prototyping in a PD cycle. To fulfill this gap in the research, benchmarking approach to find out best practice in physical prototype part manufacture, in the manufacturing companies around the world was planned to carry out.

1. Prototype Part Production Requirements

However, industrial partner are already having a New Product Introduction (NPI) roadmap for their new product. They are looking to incorporate latest best practices in prototype part manufacture from successful engineering organisation around the globe. By improving prototype part production phase in NPI system and using this improved system company looks forward to deliver high quality, zero defect new products to its customer with shortest lead time so that it can form a strong platform in the global market.

Some of the key issues like speed of making prototyping, technical integrity of the part and dimension stability, accuracy and finish of the parts are very important to be considered while benchmarking outside companies. When considering all these requirements individually, even small improvements in these requirements will make the organisation grow exponentially.

2. Benchmarking: Data Collection and Analysis

One of the best ways to compare the practices in prototype part production in a company is to compare their process, strategies and requirements with external companies' best practices. To achieve this objective a benchmark study is carried out to get the exact trends in prototype part manufacture in different companies around the world. This approach is allowed comparing the best practices from external companies of different manufacturing sectors with the industrial partners' requirements. This activity enables in getting better idea of what was happening in prototype part production activity around the world.

The main tool used in benchmarking process is on-line survey questionnaire. Survey questions were developed based on the knowledge from the literature review on the chosen research topic and converting industrial partner requirements. Apart from the on-line survey, five different sector companies interviewed face-to-face to get more information about best practice in their prototype part manufacture. These company names were mentioned by letter A, B, C etc.

For the benchmarking purpose, companies form different manufacturing sectors around the world were identified. These sectors belongs to aerospace, automotive, consumer goods, medical and electronic equipments, software, process industries etc.

3. Benchmarking: Data Analysis

To check the quality of data received from the survey an analysis on the experience of the respondent in the field of prototyping was done. It was found that 80 % of respondent have 5-25 years of experience in the prototyping field. This shows that the valuable data used for benchmarking purpose coming from the most experience people of the respective company and these data can be considered as the most authentic.

3.1. Factors for physical prototyping

For building better physical prototype for any new product in the NPD phase, number of factors should be considered. The factors mentioned in the Figure 1 were either from the literature review or from the requirements and same is used for benchmarking purpose. Based on these factors companies designer can think of selecting suitable type of prototyping method for their company new product.

Companies were asked to rate these factors from values 1 to 5 (1= never important and 5= extremely important). It is interesting to see that on an average all the factors are between important to extremely important as shown in the Figure 1 even though these scoring changes when analysing each sector separately.

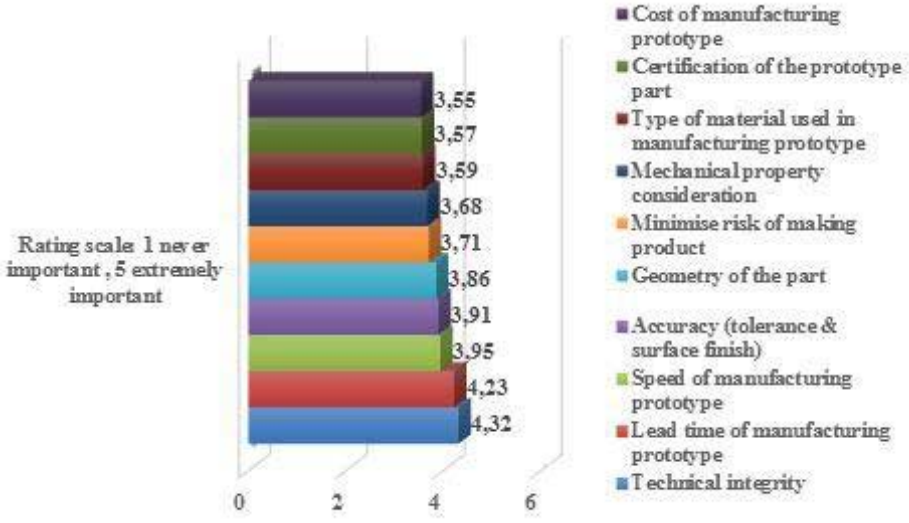


Figure 1. Important factors for building physical prototype.

Based on the result shown in the Figure 1, it is clearly visible that irrespective of the sector technical integrity factor (scores 4.32) is extremely important to consider while building prototype. However for one of the fast consumer goods company this factor is never important. Lead time, speed of manufacturing the prototype, geometry of the prototype and accuracy (tolerance and surface finish) of prototype parts these factors is also other more important factors. Therefore PD team of the company should consider these five important factors seriously before building any prototype to get success quickly.

3.2. Prototyping strategy

Survey results shows that nearly 90% of the company built their product physical prototype within six months depends upon the criticality of the product. Within that 35% of the respondent company confirms that their lead time for making physical prototype is about 6 months. Industrial partner average lead time for building prototype is one year. Survey gives hope that industrial partner still has the opportunity to reduce the lead time of building prototype from one year to six months by using novel methods.

Concerning the number of prototype build, 70% of the responded company built less than 15 numbers of prototypes for their new product in the PD phase. In which 30 % of the company built only 5 prototypes. Process industry will get the optimum benefit by building only one prototype to verify their design where as automotive industry will get the optimum benefit by building 50 prototypes before validating the design. Again these numbers depend upon company requirements and based on the level of benefit they need from these prototypes. It is interesting to see that considering overall results this number will not cross more than 50 numbers. The industrial partner on an average built nearly 20 prototypes before series production. When trend is like this it is better to make careful plan of building these low volume prototypes for success in the PD phase.

Even though selected companies are from various sectors, nearly 40% will manufacture the physical prototype in-house using separate prototype facility rather than making them with the existing production facility. Most of the aerospace companies are using this approach for manufacturing their prototype parts. By seeing this result it is hard to conclude that this approach is best practice, because nearly 30 % companies manufacture their product prototype in in-house using existing production facility. And nearly 20% make all their prototype parts from outside vendors. The industrial partner is using all these methods for manufacturing its product prototype parts depending on many criteria. Since each one is having its own pros and cons, each strategy should be analysed in depth before choosing the best one. Even then survey shows the trends of making prototype parts towards in-house using separate prototype cell.

Most of the companies around the world build prototype in their NPD for many reasons. Since prototype will be used during early pre-production stage of the PD, survey shows that nearly 72% of the company uses their prototype for validation purpose and nearly 67 % company uses for proof-of-concept purpose. Thus prototypes used mostly for three purposes i.e. for proof-of-concept, validation and test an idea quickly. Therefore these best practices should be used during building prototype stage in the PD.

3.3. Methods of prototype

Survey results reveal that the most of the company always built physical comprehensive prototypes which is fully operational version of the product. This prototype will be given to customers in order to identify any remaining design flaws before committing to production. Survey also shows that most of the companies always use extensively an analytical-focused prototype i.e. 3D CAD model to solve most of the problems before building physical prototype. It is always better idea to use the combination of these two categories of prototype methods to solve many hidden problem in the product before ready for final production. Again any one type of prototype method is not suitable for all the manufacturing sectors.

4. Prototype Part Manufacture: Best Practice

This reseach approach provides a set of best practice models whithin which company has to work out its own strategy to get the maximum benefit out of the models.

4.1. Best practice solutions from benchmark study

Benchmarking study analysis and literature knowledge gives some of the best practice solutions. These solutions were already used by the successful companies. However, the following good practice solutions in NPI roadmap to reduce the lead time of making zero defect products have been reported by companies:

1. Use 3D CAD modelling, CAE and FEA techniques maximum before starting to build the physical model. Most of the cases full scale physical prototype can be eliminated.
2. Use reverse engineering techniques for developing new parts.
3. Use more non-destructive test rather than destructive tests.
4. Use concurrent engineered dedicated prototype shop and prototype quality department for prototype development.
5. Use real supply chain and the production vendor for developing prototype parts.
6. Use prototype as learning and communication tool. Capture these learnings in a better data base.
7. Use analytical prototype to narrow the range of feasible parameters and use physical prototype to fine tune the design.
8. Use rapid prototyping technology extensively in PD, but accuracy, build-time, strength and fabrication efficiency aspect should be considered carefully before choosing this method.
9. Addition of a short prototyping phase may allow a subsequent activity to be completed more quickly than if the prototype were not built.
10. Involving customer through out the PD stage. This is possible by building physical prototype in the PD process.

4.2. Best practice model for prototype part production

There is a need to understand a set of models which will help companies to find the optimum solution for verifying engineering design. These models were developed based on the knowledge form the combination of benchmarking result analysis and the literature study as shown in the Figure 2 and Figure 3. Most of the literature says that, use of prototype weather it is analytical or physical will help the PD team to verify their design quickly and with less time and cost. Benchmarking analysis is also proved this theory. Four steps prototype strategy model has been developed as shown in Figure 2.

It is always better to start the prototype journey in virtual environment in the whole product level. By adopting this strategy most of the design unknowns can be identified and solved with lower cost and time. Better example for this case is use of simulation and mathematical model. Once the major problem solved, remaining problems should be solved by building focused prototype in virtual environment like CAD model and FEA analysis. Both these steps are time and cost saving.

To solve unanticipated problem which may occur during service of the product can be solved by building prototypes in physical environment. This prototype should be in detail level and should be focused to solve specific problem like strength test, rig test etc. Finally for integration and milestone purpose alpha, beta and pre-production

prototype should be built before starting series production. Which will be in whole product level and this prototype can be sell to the customer.

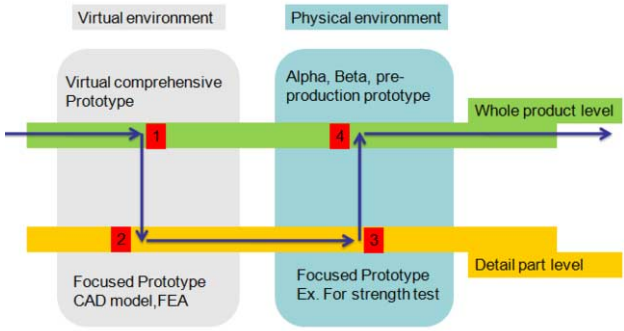


Figure 2. Four step prototype strategy model.

Best practice prototype journey path model developed as shown in Figure 3, using the knowledge from the literature reading and from the benchmark study analysis. This model is consist of 10 steps activity from concept stage to series production in any prototype part manufacture in a PD phase. These 10 steps should be carried out in sequence with eliminating one or two steps based on the company requirement.

Using this model company can able to improve its prototype part manufacture activity in better way and it can introduce its zero defect highly performed new product to the market with lowest possible time and with optimum cost.

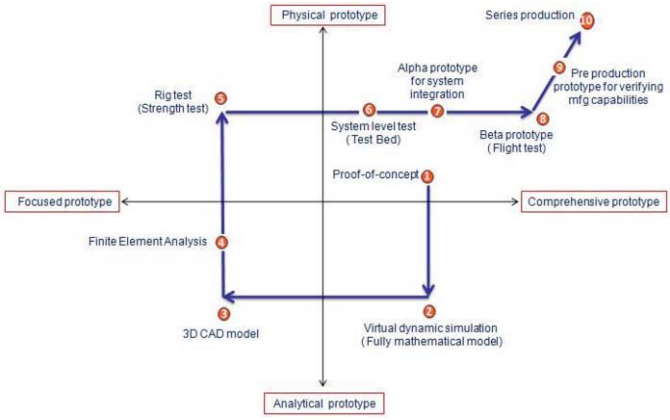


Figure 3. Best practice prototype journey path model.

4.3. Validation of best practice model

Both the models have been generated from the literature review knowledge and from the benchmarking results. Therefore before implementing this concept in the company it should be validated by experts in the NPI area. These models were presented in front of both industrial and academic experts' and discussed about its advantages and area for improvements. Finally both the models were validated with minor modification. However these models can be used as guiding tool while making strategy in prototype part manufacturing in NPI and can be modified and customised according to the company requirements.

5. Conclusion

Benchmarking prototyping strategies in industrial organisations were carried out with the use of effective research tools such as survey and face-to-face interview. Best practices have been developed based on the analysis of benchmarking results. A 4 steps prototyping strategy model and best practice prototype journey path model have been created and validated through industrial and academic experts which can be used by different companies irrespective of their sector for better prototyping effort in NPD.

Prototype may reduce the risk of costly iterations but the anticipated benefits of a prototype in reducing risk must be weighted against the time and money required to build and evaluate the prototype. Therefore research efforts should be made on this issue.

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Part 7

Decision Supporting Tools and Methods

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Transdisciplinary Engineering: A Paradigm Shift
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Age-Based Maintenance Scheduling with Multiple Maintenance Modes Concern

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Abstract. In practical production system, the equipment may shift randomly from working state to the failure state with age deterioration. As the effect of aging on the deterioration rate of most repairable equipment cannot be ignored, and preventive maintenance (PM) activities can only be able to restore part of the performance and corrective maintenance (CM) is performed after failure, efforts should be devoted to combination of PM and CM under age-based policies. This paper considers maintenance scheduling problem with multiple maintenance modes. The objective of this paper is to determine the proper maintenance sequences while minimizing the total cost under equipment age deterioration. This paper develops a model to solve the problem described and uses a yard crane maintenance case to discuss the impact of reliability range parameter.

Keywords. Maintenance Mode, age, scheduling, preventive maintenance

Introduction

During their lifetime, equipment products suffer from inevitable failure due to workload wear-out or age degradation which requires maintenance or repair actions with time moves on. Otherwise unexpected failures may result in severe consequences, such as operation downtime, repair cost, and environmental issues [1].

As equipment products deteriorate over time due to many issues, like aging, wear-out, fatigue, corrosion, we uses age to represent these deteriorating effects. Moreover, the deteriorating can be detected and its failure trend can be simulated by the lifetime statistical data. A variety of research efforts have contributed to age-based maintenance models within broad application areas, e.g. manufacturing industry [2-4], energy industry [5-6], and transportation industry [7-9]. For instance, reference [3]'s preventive maintenance scheduling model is used to determine the optimal number of production run so as to minimize the long term average cost.

Commonly, the maintenance service provided to make sure the equipment operates smoothly consists of preventive maintenance (PM) and corrective mainteance (CM). PM activity is aimed to reduce the failure rate or to extend the operation lifetime before breakdown, while CM is performed to identify, isolate, and rectify a fault so as to restore the equipment to an operational condition. Furthermore, different from condition-based maintenance or predictive maintenance that using real-time data to prioritize and optimize maintenance resources, PM relies on average or expected life statistics to predict when maintenance will be required. A variety of maintenance

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models have been intensively developed which introduced and compared different applications of PM [10-13].

However, in reality, PM is assumed to be imperfect [14] and it inevitably leads to the increase of the failure frequency with aging of equipment[15]. Certain attention has been paid on CM modelling when frequent failure happens. The work proposed a human-machine integrated simulation mothod to evaluate the effect of CM strategies on motor-cycle engine cells [16]. In their proposed model, worker behaviors, which including dynamic and cooperative behaviors, in the CM process is integrated by using agent. Reference [17] conducted a comparative evluation for two CM policies where simulation model is used to predict inventory cost and delivery performance of CM policies while econmoc analysis is used to determine the economic value of althernative CM policies. Therefore, in order to prevent the fast increase of the number of failures, most of the existing efforts deriving the maintenance plan need to make a trade-off between PM and CM under the equipment deterioration condition. A thorough account of PM and CM is developed by reference [18]. In the context of their proposed model, both PM and CM polices are incorporated into the production process which is subjected to process determination and trade credit so as to minimize total cost. Numerical experiments confirmed the cost saving if the PM decision is considered. Therefore, it is essential to incorporate PM and CM into the maintenance modes to enrich the maintenance alternatives.

This paper tries to extend the work presented in source [18] and proposed an age-based maintenance plan with multiple maintenance modes. The alternative maintenance modes include PM and CM. To be specific, there are two types of PM, i.e. imperfect repair (better-than-old): type 1 without replacement and type 2 with replacement, and another two types of CM: minimal repair (as-good-as-old), and perfect repair (as-good-as-new). The proposed maintenance model is built based on aged reduction method. As PM activities are performed as long as the reliability of equipment falls within certain threshold, the PM intervals is different. The optimal maintenance scheme needs to decide which kind of maintenance mode is chosen which fulfills the operation requirement as well as minimizes the total maintenance cost.

1. Problem Statement

The notations in Table 1 are used to describe the problem associated with age-based maintenance scheduling with multiple maintenance modes.

Table 1. Notations of the parameters and decision variables.

Notation	
$\boldsymbol{X = [x_1, x_2, \ldots x_n]}$	Index of job sequence
$\boldsymbol{i}$	$i = 1, 2, \ldots, n$
$\boldsymbol{j}$	$j = 1, 2, \ldots, k$
$\mathbf{Z}$	Total maintenance cost
$\boldsymbol{k}$	Number of failure for the i^{th} job
$\boldsymbol{[l, u]}$	The range of the accepted reliability of equipment
$\boldsymbol{n}$	The number of maintenance tasks
$\mathbf{c}_p$	PM cost without replacement
$\mathbf{c}_{r1}$	PM cost with replacement
$\mathbf{c}_m$	Minimal repair cost
$\mathbf{c}_{r2}$	Perfect repair cost
Decision variables	

x_i	=1, PM without replacement before the i^{th}task =0, PM with replacement before the i^{th}task
y_{ij}	=2, minimal repair before the i^{th}task =1, perfect repair before the i^{th}task =0, others

We consider a single-unit system where regular operation of equipment is known. There are n jobs to be proceeded for the same procedure with same operation time. s_i is the starting time of i^{th} job, p_i is the processing time and q_i is its derived weight which is related to the given workload. It is assumed that the equipment is in the perfect condition at the beginning of the operation and its reliability decreases with time moves on. Whenever the reliability decreased to certain threshold range at $[l, u]$, different maintenance modes are implemented to avoid the unnecessary breakdown. For instance, when the reliability rate $R(t)$ of the equipment is less than l , CM action (minimal repair or perfect repaire) is acted to restore the equipment to the normal condition; if the reliability rate is larger than the upper threshold u, PM type 1 is used to improve the equipment; otherwise, PM type 2 is executed. Therefore, it can be referred that the PM type 2 is much expensive than PM type 1 and cheaper than CM. As the executed maintenance mode impact the upcoming maintenance time and frequency, the objective is to minimize the total maintenance cost as well as satisfy the operation requirements.

In this paper, Weibull distribution is adopted to describe the lifetime of the equipment. Therefore, the failure rate is set as

$$\lambda(t) = \frac{\beta}{\eta}(\frac{t}{\eta})^{\beta-1} \quad (1)$$

where t is the time, β is shape parameter, and η is the scale parameter.

The equipment reliability in the normal circumstance is calculated as

$$R(t) = e^{-\int_0^t \lambda(t)dt} = e^{-(\frac{t}{\eta})^{\beta}} \quad (2)$$

Under the scenario of different maintenance modes, the equipment would have different reliability rate. We adapted the constant age deterioration factor a from reference [19] and maintenance improvement factor b from reference [20] and formulated the failure rate as

$$\lambda_{i+1}(t) = b\lambda_i(t + aT_i), \text{where } t \in (0, T_{i+1}) \quad (3)$$

As mentioned before, there are four types of maintenance mode and each will restore the equipment to different performance. It is assumed that perfect repair action would restore the equipment to the perfect condition with reliability rate equals to one. In addition, the reliability rates of minimal repair and PM depend on maintenance mode of last time which can be derived by mean value theorem for integrals [21] as

$$\int_0^{T_x} \lambda_{i+1}(t)dt = \bar{\lambda}_{i+1} * T_x \quad (4)$$

$$T_x = -\frac{\ln(R_{i+1}^0)}{\bar{\lambda}_{i+1}} \quad (5)$$

where $\bar{\lambda}_{i+1}$ and R_{i+1}^0 are the mean fault rate and reliability rate of the $(i+1)^{th}$ maintenance respectively, and T_x represents the required time to reach the set reliability when its fault rate is λ_{i+1} .Therefore, the reliability rate of equipment after the $(i+1)^{th}$ maintenance can be obtained by

$$R'_{i+1}(t) = R_i * e^{-\int_0^{T_x} \lambda_{i+1}(t)dt} \quad (6)$$

$$\text{Min Z} = \sum_{i=1}^{n}\{[c_p * (x_i - 1) + c_{r2} * (2 - x_i)] + \sum_{j=1}^{k}[c_m * \left(2 - y_{ij}\right) + \frac{1}{2} * c_{ri} * (y_{ij} - 1)] * y_{ij}\} \quad (7)$$

Equation (7) is the objective function that considering multiple maintenance modes with an aim to minimize the total maintenance cost, which is the sum of PM cost (PM cost with and without replacement) and CM cost (minimal repair cost and perfect repair cost).

2. Numerical Example

A numerical example is used to illustrate the feasibility of applying age-based maintenance model for yard crane in the port. As yard crane is used to loading and unloading containers, appropriate maintenance would prolong its lifetime and improve the operation in the yard. In addition, each yard crane has different workload and failure history, the selected maintenance mode could impact the upcoming failure odds and cost given the constrained maintenance resources. In the following experiments, the reliability range $[l, u]$is set at [*0.3, 0.6*], and shape parameter β and scale parameter η are set as 2 and 1000 respectively according to reference [22]. The age deterioration factor a and maintenance improvement factor b are given as 0.15 and 1.15. Because various container lifting workloads are assigned to yard cranes, it is assumed that these workloads follow discrete random distribution of [*100, 599*] per day. The yard crane failure time follows discrete random distribution of [*200, 699*] which is used to generate the failure rate. The PM without replacement costs RMB 1000 per time, and PM with replacement costs RMB 3000 per time. Under the minimal repair mode, the part replacement cost RMB 6000 per time while it costs RMB 10000 per time under the perfect repair alternative. Table 2 demonstrated the experimental results under different maintenance tasks scenarios using exact method. The experiments stopped at the scale of 11 maintenance tasks because the computational time has exceeded 24 hours which is beyond the practical application. It is found that with workload increases, maintenance tasks and the corresponding total maintenance cost increase. The reason of cost increase mostly lies on the increased frequency of the replacement under the failure condition. Therefore, we can conclude that concerning the maintenance mode can greatly reduce the maintenance cost.

Table 2. Summary of maintenance cost concerning different maintenance modes.

Maintenance task number n	Total workload per day	Maintenance cost Z_{min}	The selected maintenance mode under the optimal maintenance cost			
			PM without replacement	Minimal repair	PM with replacement	Perfect repair
5	1907	8000	2	0	0	1
5	1907	12000	2	1	0	--
6	2343	11000	2	0	1	1
6	2343	15000	2	1	1	--
7	3341	11000	2	0	1	1
7	3341	16000	3	1	1	--
8	2955	12000	3	0	1	1
8	2955	16000	3	1	1	--
9	3715	18000	3	0	1	2
9	3715	27000	4	2	1	--

Table 3 showed the sensitivity analysis of the reliability range $[l, u]$ on the maintenance cost. Column 4 to Column 9 represent the time that maintenance happens. Because intense range would bring in frequent maintenance while loose range may cause equipment overuse. The selected experiment scale (i.e. maintenance tasks) is set at 7 where the workload for each yard crane is 507, 552, 163, 556, 416, 14, and 239. The lower threshold l of the reliability is set at $[0.5,0.9)$ and the upper threshold u is set at the range of 0 and 0.5. It is found that as long as the upper threshold is larger than 0.8, the total maintenance cost will increase sharply. The reason lies in the higher upper threshold means higher chance to conduct the replacement action instead of PM. Take comparison of experiment index 4 and 5 as an example, in the arrangement of index 5, the PM has been postponed which allowed the facility to work with inferior condition. The accumulated wear-out requires a throughout replacement action to restore the facility into healthy condition, which brings in the booming maintenance cost. Therefore, we can conclude that a proper setting of reliability range would assist to control the maintenance cost.

Table 3. Effect of reliability range on the total maintenance cost.

#	The lower threshold l	The upper threshold u	The 1st maintenance time	The 2nd maintenance	The 3rd maintenance	The 4th maintenance	The 5th maintenance	The 6th maintenance	Z_{min}, unit: thousand RMB
1	0.3	0.5	1059	1371	1787	2582	--	--	1.2
2	0.3	0.6	1059	1371	1787	2582	--	--	1.2
3	0.3	0.7	1059	1615	1927	2528	--	--	1.2
4	0.3	0.8	312	1107	1659	2528	--	--	1.2
5	0.3	0.9	715	1131	1687	2343	2582	--	1.3
6	0.2	0.5	1059	1638	2194	2582	--	--	1.2
7	0.2	0.6	1059	1638	2194	2582	--	--	1.2
8	0.2	0.7	670	1375	1791	2582	--	--	1.2
9	0.2	0.8	312	1107	1659	2582	--	--	1.2
10	0.2	0.9	715	1222	1778	2343	2582	--	1.3
11	0.1	0.5	1059	1778	2194	2582	--	--	1.2
12	0.1	0.6	1059	1778	2194	2582	--	--	1.2
13	0.1	0.7	670	1465	2017	2582	--	--	1.2
14	0.1	0.8	312	1107	1659	2582	--	--	1.2
15	0.1	0.9	715	1222	1778	2343	2582	--	1.3
16	0.4	0.5	1059	1371	1787	2582	--	--	1.2
17	0.4	0.6	1059	1371	1787	2582	--	--	1.2
18	0.4	0.7	1059	1615	1927	2582	--	--	1.2
19	0.4	0.8	715	954	1103	1659	2582	--	1.3
20	0.4	0.9	507	670	1086	1642	2343	2582	1.4

3. Conclusions

This paper considers the maintenance scheduling decisions for an imperfect operation system with equipment age deterioration. This study assumes multiple maintenance modes where PM is conducted to restore part of the function and CM is implemented after failure. The proposed method considers the effect of maintenance mode on the equipment condition. A numerical example of yard crane maintenance is used to demonstrate the proposed model and sensitivity analysis of equipment reliability range is tested. The results show that cost saving can be obtained for proper arrangement of maintenance mode and maintenance time.

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PI – Definition, Principles, Methodology and Application

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Abstract. PI – Definition, Principle, Methodology and Application " clearly tells about the contents of paper, which defines meaningful product identity for corporate with concrete project which followed theoretical and practical preparation on PI building. PI project is composed mainly of three phases: informing, modelling and Transformation. Informing phase collects and analyses inputs, Modelling phase builds a pattern using keywords system reflecting a defined CI, while Transformation phase translates the working model into entities applicable to product features, which lead to a set of guidelines. Conclusion: we can build our product identity model on three levels: atmospheric, categorical and characterizing; And PI guidelines can benefit both in-house designers and project leader to orientate confidently and acquire efficiently their wished results representing definite corporate culture.

Keywords. PI (Product Identity), Identity model of 3 levels, Semiotics, PI Project

Introduction

Product Identity or PI was the object of my professional life for many years. During my project and managing work around the year 2000 at Huawei Technologies I promoted and pushed for a PI project there. By 2002 I had received support from the Bureau of Foreign Expertise of Shenzhen City and started an independent project called "Study and Application of Identity System for Technical Products". The resulting knowledge was applied to the Project "PI Planning and Design for HUAWEI Network Product Lines", which began in January 2005

1. Definition

PI is an abbreviation, and it may have different meanings. Let us first verify what is meant here. "P" may stand for several words, which all make sense. Only one is meant here, it is product. "I" stands here for Identity, meaning 1. state of being identical, absolute sameness, exact likeness. 2. who somebody is, what something is. [1] Then, there is Product Identity.The above explanation is to clarify our subject. I shall add that our subject is confined within the domain of products, about their identification, and identity; the products should be confined within the category of man-made products, not including architecture, but otherwise including all industrially produced objects.

Here is my observation of product context and its cultural relations inside a corporation.

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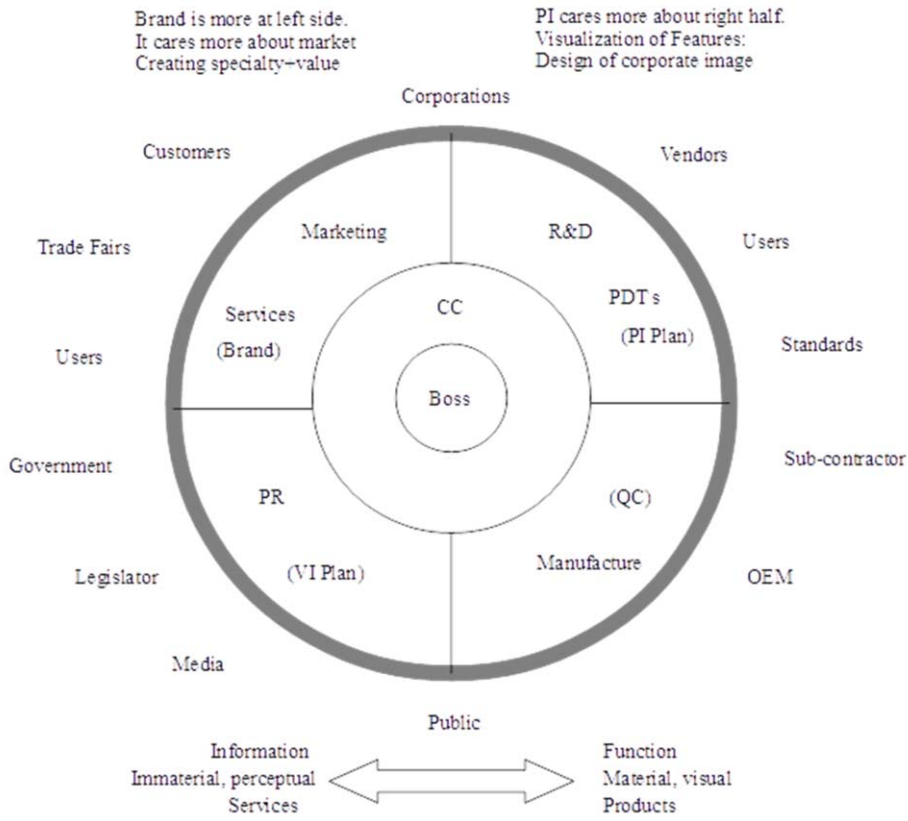


Figure 1. CC and Product Environment / PI in a Production System.

PI means the image of all products of a corporation; CI means the image a corporation builds purposely towards the public; and CC means the corporate culture, the common ideology of a corporation.

We can see from the above diagram Fig.1 that the production happens on the right half of the sphere, including R&D, and the Production Department. Among big companies, there are many where there is no identity-related design requirement, despite their IPD methods. Many a company are buying a lot of expensive foreign expertise, only to result in unidentified styles and product contradiction. The reason for this is simple: they have no clear definition of their own culture and no sense of a consistent design orientation for product teams to follow.

Since 1998 I have been aware of the problem and have been learning how to establish product characters in the process of design. The aim is to find a way to establish product identity as well as a pilot assistant in the design process. Leading a design team in Huawei, I studied the experiences of Philips, Samsung, and Sony, among others. The only thing very close to our objective was from LG: its CIPD, corporate identity through product design, for which we could only find a vague report. The conclusion was, we need to create our own tools and go along our own way. Now our task is clear: PI means building identity of a product group with corporate culture through design.

2. Principles

My objective was to effectively carry out a PI project within a major manufacturer. The expected results should include a process, the PI project, that will create the wanted product identity through planning, and that may be repeated successfully for different companies. By doing so we can finalize a set of product guidelines, helping designers do their work. There we need a method which will turn the metaphysics and concepts into material, forming a product media and thus communicating with the recipient. This set of rules will also help designers to orientate and find their product language quickly. In order to reach this goal, I developed my first concept to carry out the work.

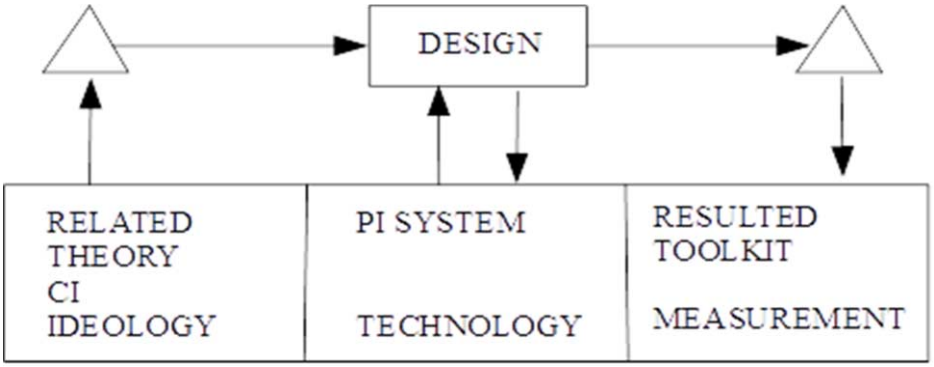


Figure 2. Concept of the PI project – how the PI system works with design.

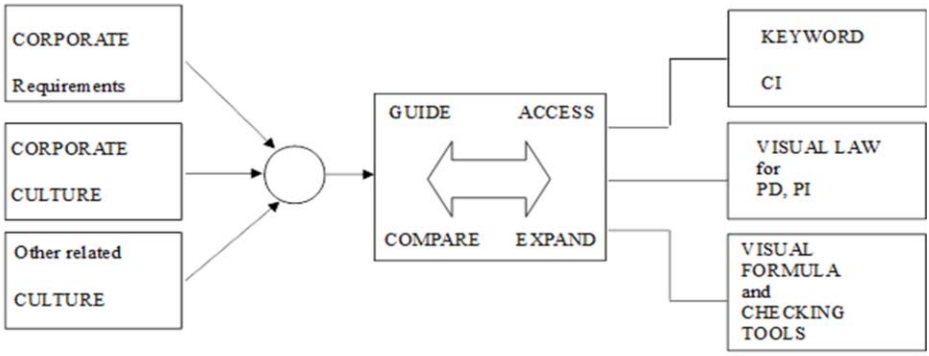


Figure 3. Concept of PI project – What the PI project will produce.

This diagram shows how the PI project works. The frame in the middle is a grey box which processes the inputs like corporate requirements and culture, and expands them to produce three things: a) a CI keyword model, b) a visual design guide, and c) visual regulations and tools for assessment. These three things serve individually at the beginning, middle and end phases of product design as a design tool kit. They also reflect the ideology, technology and checking function of a PI system.

In other words, the above two charts explain how the PI system enables design to create within the guidelines of corporate culture, together with the IPD management practice.

Here I need to mention that product-related visual communication existed long ago in product design, [2] but it was mainly restricted to functional expressions, creating functional product features related to their categories.

What we are doing is about the corporate culture and its expression via products. Here we treat the products as media or quiet symbols reflecting the culture of their mother corporation.

Based on human experience, perception is a process to learn about an object amidst a certain environment. Cognitive observation and psychological experiences tell me that there are three phases to go through, namely: 1. environmental atmosphere, 2. categorical recognition, 3. feature emergence. I explain as follows:

- Atmosphere: it is the first phase when we see a thing of which we do not yet have an impression in our mind. We see it from a distance, receiving information like darkness/brightness, colour range, rough contour; when amidst bright surroundings we see colour first, otherwise the contour or contrast is first. Regardless of whether it is bright or not, movement will catch our eyes immediately.

- Category: when an observer has gotten a first impression, he will look for a visual type that fits a category in his memory. This process can be short or long, depending on person and object. As for design objects it depends on how close the design is from its typical prototype in the category.

- Characters: this is where products excel or exaggerate in their visual language. These are the innovation points of visual designs and are difficult to master. Many designs lose sight of their objective in an attempt to be striking or exceptional. Here we absolutely need the characters of our client, not of designers.

According to perceptional theory [3] we know the short term memory of a human being is weak. (We can keep in mind about only 5 pieces of information after 30 seconds!) That is perhaps why our memory of atmosphere is longer: since this information came to us first and occupied the memory quickly. And for the human sensitivity to colour and movement, we should thank our ancestors for their abilities to react to natural signals and to avoid acute dangers.

After comparison of perceptional psychology and semiotic theory [4][5]I have determined the following relationships:

- Icons have visual directness and can be used to denote characters and visual excellence.

- Index signs can better organize objects into categories and build order.

- Symbols can represent atmosphere and letters are able to describe all situations.

Back to the identity of industrially made products, we verify their semiotic tasks as follows:

A. to represent a comprehensive image of corporate culture and ideology, conforming to given descriptions;

B. to express the visual language telling about product function and system purposes correctly and clearly;

C. to display visually added features of the product lines related to the given product strategy properly.

At last, we have the principle of our PI project. Our task is to import information about corporate culture and product identity into a processor, where PI intelligence leads a process to calculate and work out a set of rules. This set of rules is a series of guidelines, including direction, definitions, and visual references.

3. Methodology

The major challenge of this project is that there are no existing methods to follow. After I did preparatory studies and created the diagrams, my goals became clearer. They are:

a) to understand the corporate culture, and find its definitions

To do this we need our client, sometimes higher level officials in the company to be involved. Without support from all levels, the PI project can never begin. Not all bosses and managers will support it, although they might all agree to the importance of R&D. My recipe for success is to persist in proposing, and improve my proposals.

b) to operate sign transformation, keeping the definition complete and true

Semiotic theory is difficult to explain and apply. For PI purposes, our model of three levels is very helpful: 1 - atmosphere, 2 - category, 3 - characters.

In the perceptional process we move from image to meanings, but in design the process is reversed.

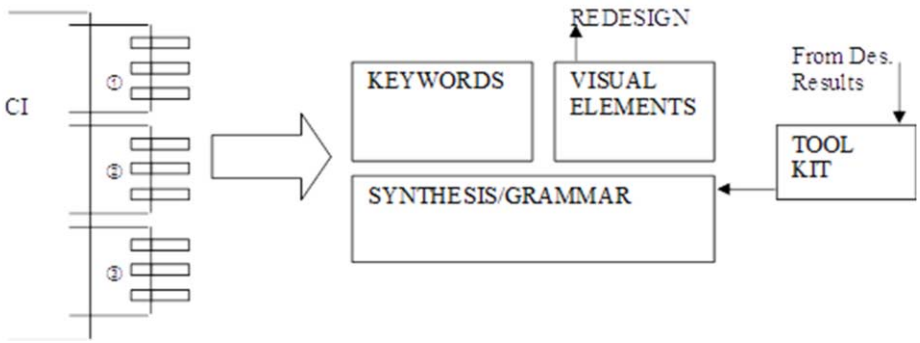


Figure 4. Developing technology for PI project – how does the grey box work.

The above diagram makes it clear. The grey box is composed of three modules: keyword module, visual element module are static, representing input and output of the design process, while the synthesis/grammar module is dynamic and a linking part.

This model is ideal, but it is not a design process, for design decisions can be irrational and are not made automatically by rules. The function of the modules is to give effective suggestions through pairing concept, element and situations.

c) c) to work out an executable plan to persuade future client to accept the project proposal. This is the most helpful thing in a proposal: to let the client know the process in detail. I have made many proposals, and this period lasted a few years before our first PI project finally was allowed to proceed.

3.1. Conceptual Project Procedure

Phase 1 – Ideals

- Researching: CC, CI, CP, related information
- Reflecting: Design requirements, Ideology expression

- Briefing: design policy, ideology recognition
- Follow-up: ideology analysis, semantic organization, re-expression, keywords

Phase 2 – Technology

- Resuming: conclusions, focus allocation
- Developing: semantic method, keyword structure, form-implication method
- Studying: product structure, product line definition, product composition, feature construction, product relationship map, semantic evaluation method

Phase 3 – Tools

- Developing: design pilot, keyword-imaging, 3-level semantic method
- Applying: typical design series, evaluating, modification, finalizing
- Presentation: final approval/end of project

4. Application

The research project "Study and Application of Identity System for Technical Products" was mainly aimed at the company Huawei Technologies, which was my closest partner and client. The relationship dates back to 1997 when I first visited its design department, and by 1998 I had started my work there leading a project.

The preparation of the PI project has been in progress for a long time. I began the idea when I was working on training the Huawei design team and learning international management experiences, together with the young in-house designers.

Inside the company, designers' consciousness to identity was rising. By mid-2000 there was a report by a designer on the product images of the existing products of Huawei with an analysis.

However, I spent over four years proposing, beginning in 2000.

The Huawei PI project was the project with the longest preparation time in my life. This also explains why we made it in two parts and not three phases as initially planned, as the phase one job was largely done before the project started.

Here is the project plan (simplified):

4.1. Part I PREPARATION – DEFINITION – JUDGEMENT

- Phase 1: Project research and information preparation (partly finished);
- Phase 2: Ideology, reality and identity modelling, in keyword/structure;
- Phase 3: Product system analysis/Industrial design re-orientation;

The output of part I was the description of Huawei culture, model of keyword-structure, etc. This part was done successfully by the end of 2005.

4.2. Part II PLANNING – CONCEPTION – APPLICATION

- Phase 4: PI method developing, Keyword model transformation;
- Phase 5: Conception design of typical products, using PI model, guidelines;
- Phase 6: Project output, assessment meeting, and approval.

This was mainly a transformation process where the model in words was turned into visual languages. This was a process full of assessment meetings and starting all over again. Guided by our model and methods our team developed several sets of product concepts.

The Huawei PI project, after almost 3 years hard work, was successfully handed over to the client by our team. The final output: typical concept design (as a 1:1 model), and PI Design Handbook / Guidelines (paper + digital).

The project was handed over to Huawei System Engineering in November 2007. The feedback of the PI results came to me much later. In fact, product design has since then been following the direction and criteria set by PI. The work design was greatly facilitated and time saved. The identity definition was shared by all product lines of the company without exception until 2014 when a new product line was introduced. Ultimately, the success of PI owed considerably to the timing of introduction. Huawei was already influential in technology and management during that period.

At the final presentation I concluded my keywords to Three Layers of Information in Design as follows,

- Layer 1: basic tone / orientating / perceptual
- Layer 2: category / semantic / rational
- Layer 3: characters / semiotic / dual (perceptual and rational)

Throughout our project, PI covers all three layers of information; but CI related guidelines only involve layer 1 and 3, the basic tone and characters. Category is given in our PI as network equipment and solved in a functional semantic way.

Acknowledgement

My thanks go to Prof. Yanta Lam and Benny Leong, who very kindly joined us in 2005 and contributed greatly in building the Keyword model for Huawei Identity. I also thank Mr. Yang, Zhiyan and Ms. Lu, Wenying, who took part in part one of the PI project and supported me. Last but not least I owe thanks to my team members in and outside Rand Development Shenzhen, who worked hard for our goal and proved their talents and loyalty. Thank you!

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Transdisciplinary Engineering: A Paradigm Shift
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A Mathematical Model to Evaluate and Improve Lean Management of Healthcare System: A Case Study of Health Examination Center

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Abstract. Healthcare system plays an important role in our daily life. A well operated healthcare system not only can save lives but also provide good work environment to medical staffs. However, most of the healthcare systems suffer from high workload of medical staff and low customer satisfaction. In addition, the stochastic nature of healthcare services is hard to evaluate the performance. Therefore, this study aims to implement lean management in the healthcare system with lean techniques and a stochastic model to achieve both customer satisfaction and waste reduction simultaneously. The first step is analysis of the current process and collect data to clarify the current status by quality management practices and lean tools. Further, a stochastic mathematical programming model is developed to optimize the performance of this healthcare system. Simulation results show that the efficiency of process flow after leveling is improved about 19.97%, idle ratio of work station is improved about 41.64% and 22.47% and the average flow time is improved about 4 minutes. A health examination center case is applied to demonstrate the benefit of the proposed method. This study might be the first study which implement lean and stochastic characteristics of healthcare system in a mathematical model. This model can serve as a decision support system and can be apply to other service system in lean improvement.

Keywords. Lean management, Mathematical programming model, Simulation, Healthcare

Introduction

Healthcare system plays an important role in our daily life since more and more people become paid attention to health management and regular inspection. Institute of Medicine (IOM) emphasizes that the organization has a good patient safety culture. It needs to focus on systems and processes, re-engineering the work environment, adjusting the system, simplifying unnecessary processes, and proactively avoiding possible harm or adverse events in process [1,2,3].

Lean management is adopted from Toyota Production System [4] and the development of lean management is as Figure 1 [5]. Lean thinking is composed of five principles which is value, value stream, flow, pull, and perfection [6]. Seven wastes are

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transportation, inventory, motion, waiting, overproduction, overprocessing and correction and some examples in healthcare on Table 1 [7]. Use it to find the wastes on the process in hospital and eliminate waste and then upgrade the efficiency and quality in process and provide patients the safety and satisfactory healthcare environment [8].

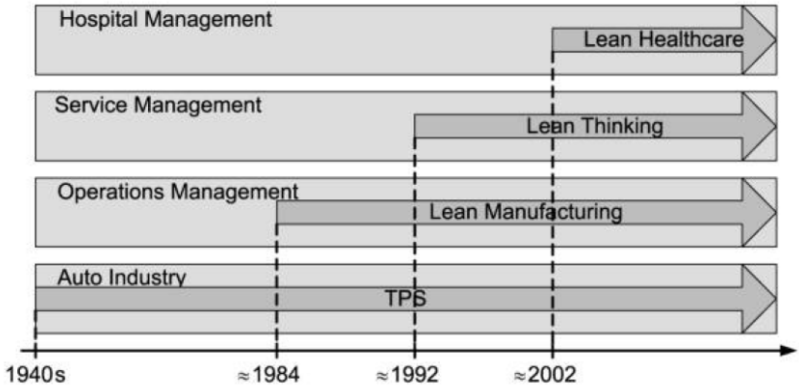


Figure 1. The development of lean management.

Table 1. Seven wastes and some examples in healthcare.

Wastes	Some examples in healthcare
transportation	• staff walking to the other end of a ward to pick up notes • central equipment stores for commonly used items instead of items located where they are used
inventory	• excess stock in storerooms that is not being used • patients waiting to be discharged • waiting lists
motion	• unnecessary staff movement looking for paperwork, eg drug sheets not put back in the correct place • storing syringes and needles at opposite ends of the room • not having basic equipment in every examination room
waiting	waiting for: – patients – theatre staff – results, prescriptions and medicines – doctors to discharge patients
overproduction	• requesting unnecessary tests from pathology • keeping investigation slots 'just in case'
overprocessing	• duplication of information • asking for patients' details several times • repeated clerking of patients
correction	• readmission because of failed discharge • adverse drug reactions • repeating tests because correct information was not provided

However, the high workload of medical staffs and low customer satisfaction become key issues in most healthcare systems. These issues lead us to implement lean management. In addition, a few healthcare systems can measure the performance of customer satisfaction after implementing lean management.

Therefore, the aim of this study is to implement lean management in the healthcare systems with lean techniques and create a stochastic mathematical programming model to achieve both customer satisfaction and waste reduction

simultaneously. Furthermore, this model can serve as a decision support system and can be apply to other service system in lean improvement.

This study is organized as follows. Section 1 discusses lean management in healthcare systems and the stochastic programming model. We identify the problem and create a stochastic programming model (section 2). The case study and the simulation results is presented in Section 3 and the conclusion is discussed in Section 4.

1. Literature Review

Lean management is implemented in both manufacturing industry and service industry. We widely apply lean management to the healthcare systems in our daily life. Use value stream mapping to redesign patient flow to decrease waiting time and eliminate overcrowding [9]. Use Kaizen, standard work and single minute exchange of die to minimize waste, reduce turnover time, and decrease physician and patient waiting time [10]. Apply standard work, 5S, and visual management to reduce cycle time and eliminate waste [11]. Increase patient satisfaction and staff morale by implementing value stream mapping and 5S [12]. Improve patient flow and patient satisfaction by implementing value stream mapping and Kaizen [13]. Therefore, we apply lean techniques to improve both customer satisfaction and waste in the healthcare systems.

Optimization is to maximum utility or minimum lose on the conditions of limited resources. How to use the limited resources to maximum utility is an important issue in healthcare system. A model was formulated to simulate for scheduling on operating room [14]. A queuing model for ICU Griffiths was created and use simulation to solve [15]. A stochastic mathematical overbooking model was proposed to maximize the total expected profits in the healthcare systems by determining the optimal number of appointments to be scheduled [16]. A new stochastic general repair model was developed and it is better than the existing models because of giving faster, more accurate estimation results without relying on time-consuming Monte Carlo simulations [17]. A stochastic multilevel model was created and it can capture cost variations at different kinds of hospitals [18]. Thus, we can create a stochastic programming model in the healthcare systems to maximum customer satisfaction and use simulation to find the optimal or approximate optimal solution.

By literature review, both lean management and optimization can improve the customer satisfaction in the healthcare systems. In this study, we will implement lean management in the healthcare systems and use it to formulate a stochastic programming model to simulate and find the optimal solution, and then apply on Health Examination Center.

2. Methodology

In this section, we introduce the lean tools applied in the healthcare systems and a stochastic programming model.

Value stream mapping (VSM) is to describe the material and information flow in the process. It can help us know the operation is value-added or not in the healthcare systems. Different operations can separate into three types which are value-added, necessary waste and unnecessary waste. The target of drawing VSM is to eliminate unnecessary waste and reduce necessary waste. The following is the steps of

implementing VSM. First, draw a current VSM and find the improvement points, and then propose the improvement actions and draw a future VSM for expected results.

Leveling is to eliminate, merge, simplify and rearrange the steps of the process and help the process more smooth. Use the equation (1) to determine cycle time and then do leveling.

$$\text{cycle time} = \frac{\text{working time}}{\text{service people}} \tag{1}$$

1. Problem definition

The goal is to maximize the efficiency of the process. In this section, we will introduce random variables and notations and build the corresponding stochastic programming model.

2. Define the random variables and notations (Table 2)

Table 2. Random variables and notations.

No.	Random variables and notations.	Definition
1	CT	Cycle time of the process
2	N	Number of the work stations
3	t_i , i = 1,2,…,9	Operation time which follows an unknown distribution
4	$X_{ij} = \begin{cases} 1, \\ 0, \end{cases}$ i = 1,2,…,9 , j = 1,2,…,N	Operation i in work station j Otherwise
5	$Y_j = \begin{cases} 1, \\ 0, \end{cases}$ j = 1,2,…,N	Work station j has operation Otherwise

3. Stochastic programming model

$$\max \frac{E_\xi(\sum_{i=1}^{k} t_i)}{N*CT} \tag{2}$$

Such that

$$\sum_{j=1}^{N} X_{ij} = 1 \ , \mathrm{i} = 1,2, \ldots . \mathrm{k} \tag{3}$$

$$E_\xi(\sum_{i=1}^{9} t_i \times X_{ij}) \ \leq CT \ , j = 1,2, \ldots , N \tag{4}$$

$$\mathrm{N} = \ \sum_{j=1}^{N} Y_j \tag{5}$$

$$\sum_{j=1}^{N} j \times X_{ij} \geq \ \sum_{j=1}^{N} j \times X_{1j} \ , i = 2,3, \ldots , k \ , j = 1,2, \ldots , N \tag{6}$$

$$\sum_{j=1}^{N} j \times X_{8j} \geq \ \sum_{j=1}^{N} j \times X_{ij} \ , i = 1,2, \ldots , k-2, j = 1,2, \ldots , N \tag{7}$$

$$\sum_{j=1}^{N} j \times X_{9j} \geq \ \sum_{j=1}^{N} j \times X_{ij} \ , i = 1,3, \ldots , k-1 \ , j = 1,2, \ldots , N \tag{8}$$

$$X_{ij} \ , Y_j \in \{0,1\} \ , \ i = 1,2, \ldots , k \ , \ j = 1,2, \ldots , N \tag{9}$$

The equations (2) ~ (8) represent a stochastic programming model. Equation (2) is the objective function which maximizes the efficiency of the process. Equations (3) ~ (8) are the constraints. Equation (3) means that any operations can only in a work station. Equation (4) means that the operation time of any work station have to be less than the cycle time of the process. Equation (5) means the number of the work station. Equation (6) means that operation 1 is the first operation in the process. Equation (7) means that operation 8 is the 8th operation in the process. Equation (8) means that operation 9 is the last operation in the process. Equation (9) means that X_{ij}, Y_j are 0-1 variables when i equals to 1 to 9 and j is equal to 1 to N.

3. Case Study

The case is conducted in a health examination center. First, we construct a current VSM. Second, we analyze the problem which is that the customer's waiting time is too long. Third, we use the simulation to find a better solution to operations configuration. Finally, we apply the simulation result to future VSM and then implement the improvements. VSM of health examination center is as Figure 2. We only consider one of the health examination sets which is general.

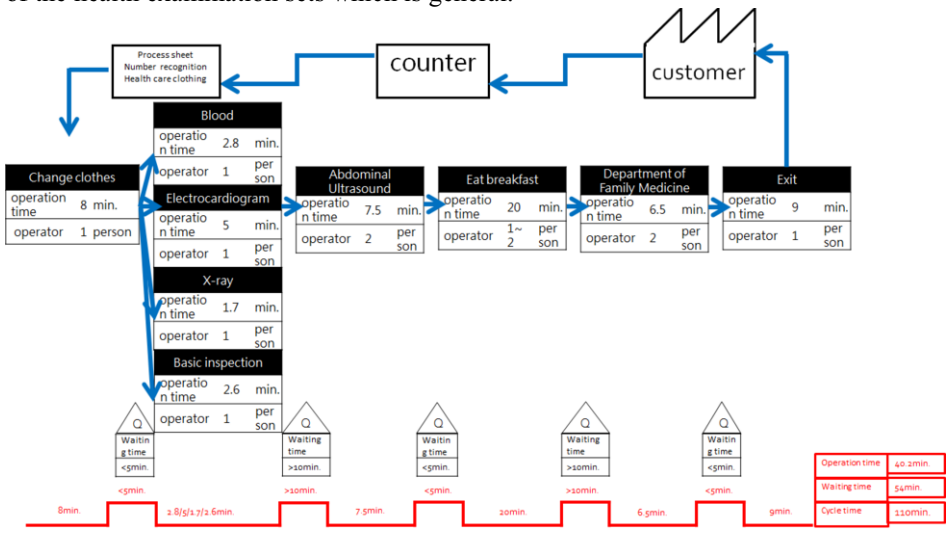


Figure 2. current VSM of health examination center.

After we observe several times in the health inspection center, we can find that the way that medical staffs manage the customers and the relative position of the clinics affect customer's waiting time. The analysis of the problem which is that the customer's waiting time is too long is as Figure 3.

After leveling, we combine Electrocardiogram and Blood to work station 2 and combine X-ray and Basic inspection to work station 3 and work station 1 is Change clothes, work station 4 is Abdominal Ultrasound, work station 5 is Department of Family Medicine and work station 6 is Exit. Then, we use ARENA to simulate the result of the process before and after leveling. The models are created as Figure 4 and Figure 5. The comparison between process flow before leveling and after leveling which contain process time is as Table 3.

We assume that three scenarios of customer arrival time follow exponential distributions which parameters are one person per 7, 8, 9 minutes (i.e. exp(7)). After simulating the model which are process flow before leveling and after leveling, we can summery the average three scenarios results of the efficiency of process flow, idle ratio of work station, throughput and the average flow time as Table 4 and show the difference as Figure 6 and Figure 7.

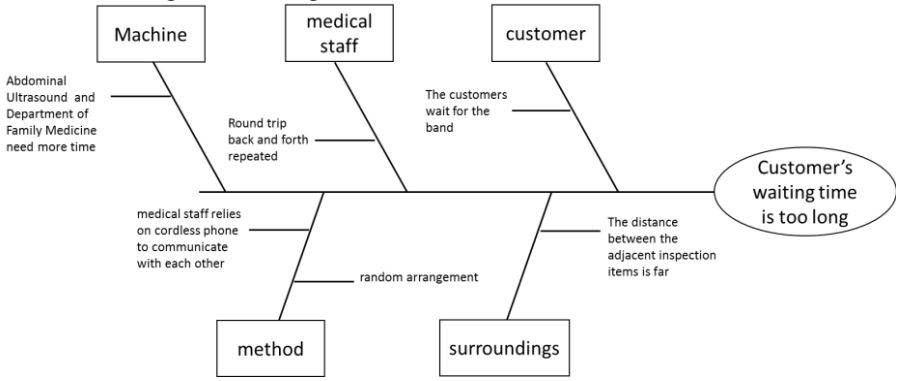


Figure 3. Fishbone diagram analysis of customer's waiting time

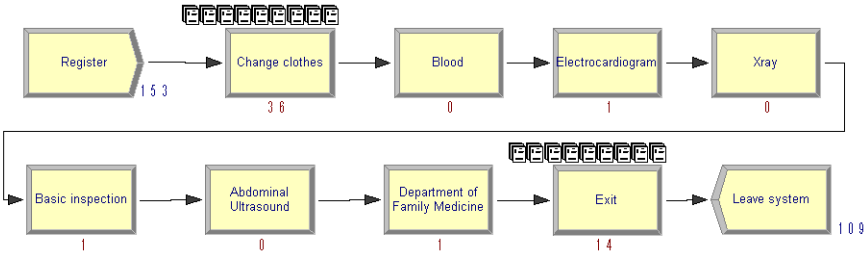


Figure 4. Process flow before levelling.

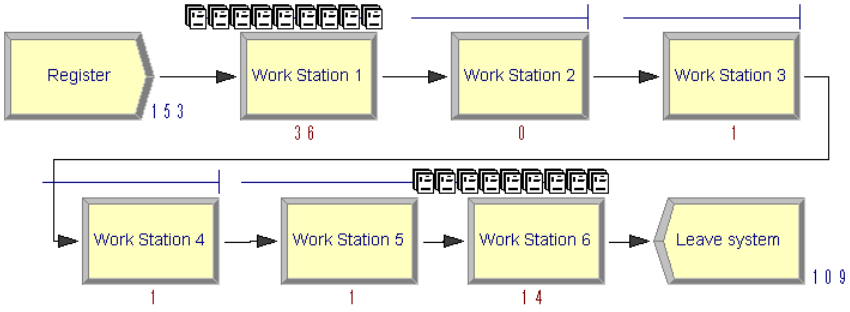


Figure 5. Process flow after levelling.

According to simulation results, the efficiency of process flow after leveling is improved about 19.97%, idle ratio of work station is improved about 41.64% and 22.47% and the average flow time is improved about 4 minutes. They imply that work efficiency is raised and maybe serve more people. But throughput is the same. The

possible reason of that throughput is the same is enter parameter of simulation model is close to cycle time. Thus, we can know that leveling applied to the health examination center is better. The limitation is that use leveling results to do simulation. On the next stage, we will break this limitation.

Table 3. Comparison between before and after leveling.

Work station	Inspect item before leveling	Time(min.)	Inspect item after leveling	Time(min.)
1	Change clothes	8	Change clothes	8
2	Blood	2.8	Electrocardiogram Blood	7.8
3	Electrocardiogram	5	X-ray Basic inspection	4.3
4	X-ray	1.7	Abdominal Ultrasound	7.5
5	Basic inspection	2.6	Department of Family Medicine	6.5
6	Abdominal Ultrasound	7.5	Exit	9
7	Department of Family Medicine	6.5		
8	Exit	9		

Table 4. Results.

Item	Process flow before leveling	Process flow after leveling	Difference
the efficiency of process flow	59.86%	79.83%	19.97%
Idle ratio of work station	Electrocardiogram :46.53% Blood : 69.9%	work station 2 : 16.58%	-41.64%
	X-ray :81.82% Basic inspection : 71.38%	work station 3 : 54.13%	-22.47%
the average flow time	101.51 min.	97.51 min.	4 min.
throughput	122	122	0

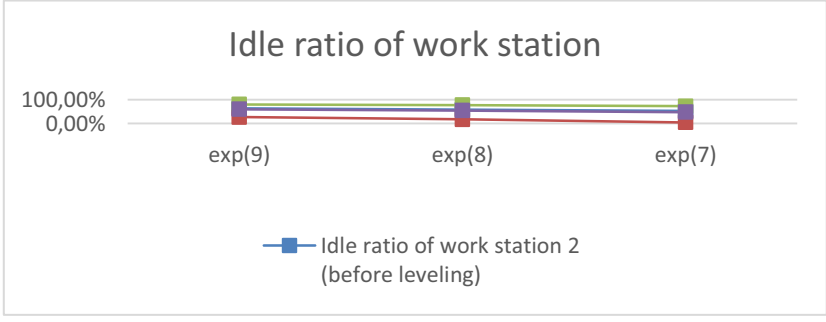


Figure 6. Comparison of idle ratio of work station.

4. Conclusions

We have formulated a stochastic programming model which can balance the process flow of health examination center and use simulation to solve it. From the result, we can know that the efficiency of process and customer's waiting time after leveling are better. Otherwise, this study might be the first study which implement lean and stochastic characteristics of healthcare system in a mathematical model. For future

research, we add some variables and constraints to the stochastic programming model and solve it to find the approximate optimal solution to apply to the health examination center. Otherwise, we need to find a method to verify it is correct.

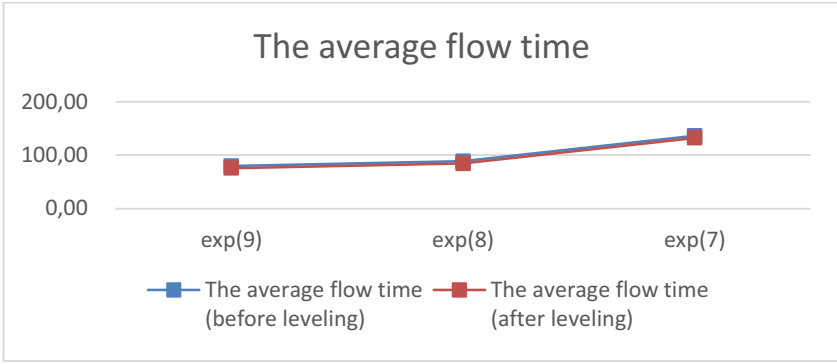


Figure 7. Comparison of the average flow time.

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Influence on Brand Equity from Brand Identification Within the Environment of Social Media − The Mediating Effect of User-Generated Content

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Abstract. Brand is generated when cognitive connection, value evaluation and emotional engagement are done by customers and introduce the brand into their personal self-concepts. As the development of social media platforms, customers interact with brand enterprises, communicate with other customers as well as release their evaluation of the brands through those platforms, which leads to the generation of a large amount of user-generated contents (UGC). Previous studies have proved that customers' interaction and communication on social media platforms have a positive influence on brand equity. In this paper, the author collates, analyzes and summarizes previous studies, constructs an integrated framework based on the constitution of brand equity in an environment with abundant social media platforms and systematically discusses the structure of brand identification as well as its influence on brand equity. Using an empirical research approach, the study shows the mediating effect UGC has on brand equity.

Keywords. User-generated content; Brand equity; Brand identity

Introduction

As the popularizing of Web 2.0 and developing of social media, customers now could influence the marketing result of a brand or enterprise by sharing users' experience and suggestions. This reflects the importance of a new concept "User-generated Content (UGC)", i.e. the content created by users and shared online with other users. The impact of UGC on a customer-based brand equity is larger than marketer-generated contents. An increasing number of scholars agree UGC influence customer-based brand equity [1][2][3][4]. Bruhn, for example, believes UGC is beneficial to promoting the brand image [5]. Other issues include brand attitude [6][7], brand relationship [8], etc.

Besides, strong brand equity is achieved when customers have favorable brand identification [9]. Studies show that brand identification affects brand loyalty [10][11] and thus has the greatest impact on brand equity [11][12]. Therefore, both brand identification and UGC affects brand equity.

In this paper, the author try to explore: (1) whether brand identification affects brand equity directly or through the mediating effect of UGC; (2) which effect has

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greater influence if both of them exist simultaneously. The author will collate and conclude the current literature, construct the integrated framework of customer-based brand equity in the social media environment, systematically discuss the framework of brand recognition as well as its impact on brand equity, and, by doing empirical research, show the intermediate function of UGC's influence on brand equity.

1. Conceptual development

1.1. User-generated Content

UGC, firstly proposed in 2005, refers generally to text, image, music, video, etc. that are created and posted in any forms online by users [13]. In this paper, the definition and features of UGC mainly come from the research of Christodoulides et al. [4], which defines UGC as content: a) generated in social media platform that are accessible for the public, e.g. the internet; b) shows certain degree of creativity of the customers; and c) created in ways that are unprofessional and free of charge.

As a newly-occurred and fast-developing concept that could affect brands, UGC develops in multiple perspectives of different fields, especially marketing. Studies about the category, features, formative reasons and influence on brands of UGC have all been done. O'Hern et al. divide UGC into four categories, namely, informing, pioneering, co-communicating and co-creating [14]. Baxter & Olesen [15] suggest that five motives drive people to interact with brands on social media platforms and co-creation, empowerment, brand community and self-recognition will form UGC and positively impact customers-brand interaction (ibid). Afterwards, scholars constantly study the practical significance of UGC [7][16][17].

In 2010, Burmann noticed the emergence of Brand-related User-generated Content (UGB) and introduced UGC as a tool to promote brand [18]. When studying the relationship between UGC and brand equity, researchers measure UGC for more specific results with definitions and dimensions of UGB. Hence, this paper will take research results of UGB as a reference to make research assumptions of UGC. In 2012, Smith et al. proposed a content framework for user-generated brand comparison [19]. It consists of six dimensions: self-presentation, brand centrality, interactivity, authenticity, the reaction to marketing campaign, and brand emotion, which would be used in this paper to measure UGB.

1.2. Brand Identification

Customers make purchase decisions due to brand identification [20]. So the key to build customers-brand relationship and create brand value is to gain identification from customers and produce strong resonance between brand and customers [21]. Aaker believes brand identification is a status customers approve and support the value, lifestyles, social status of brand users and brand personalities [22]. Schouten states that it is easier for customers to resonate with the brand and develop brand identification when brand personalities are closer to those they admired [23]. In terms of social ideology theory, brand identification is a psychological status, under which customers perceive, feel and evaluate their sense of belongings given by the brand.

Scholars study brand identification individually and socially from different customer self-defined drives. Rio et al. [24] divides brand identification into individual

brand identification and social brand identification. The former originates from the perception of the similarity degree between specific brand personalities and customers' while the latter from the characteristics of the brand that present customers' social status or that of a specific group (or the one they admired). Jin finds in an empirical study both individual and social brand identification significantly impact attitude loyalty and action loyalty [12]. Hence, the paper will take both kinds of brand identification into account.

1.3. Customer-based Brand Equity (CBBE)

Brand equity is always regarded as an important factor of marketing success. Aaker defines brand equity as a group of brand assets and liabilities being related to the name and sign of a brand [22]. It could increase or reduce the value brought to customers or companies via products and services. In the field of branding and marketing, researchers have studied the effect of different issues on brand equity, such as public relation [25], business social responsibility, advertising [26]. Also, people mainly based the definition of brand equity on customers. In 1993, Keller [9] formally proposed the concept of CBBE, defining it as customers' different reactions towards brand marketing caused by different brand knowledge. CBBE drives the improvement of finance-based brand equity [27]. Besides, CBBE is a reaction to direct performance of company marketing activities [28]. Researchers also measure the specific brand equity based on respects of customers [29]. It could reveal the relevant process of company marketing actions affecting customers' psychology (ibid).

Plenty of studies have been done on the component dimensions of CBBE and provided different measurable dimensions. Say, Keller has set up a brand pyramid model, defining brand equity from four dimensions: brand recognition,brand reflection, brand connotation as well as brand relationship. The research of Aaker constructed a model with component dimensions including brand awareness, brand association, perceived quality and brand loyalty etc.; Yoo et al. brought forward brand equity models on the basis of Aaker's research. Brand awareness, brand association, brand loyalty and perceived quality are four dimensions used most frequently in present brand equity model studies and become four general dimensions accepted by scholars [30]. Thus, the author chooses three of them (brand association, brand loyalty and brand perceived quality) to measure brand equity.

1.4. Brand Identification, Brand Equity(CBBE) & UGC

Firstly, brand recognition influence UGC. Individual and social brand identification of customers will largely influence their brand behavioral loyalty as well as attitude loyalty in a positive way [12]. In the social media environment, brand loyalty means active communication around the brand (e.g. public praise) rather than merely regarding the brand as the first choice when purchasing. Sundaram et al. studies that customers generate positive and negative information relevant to the brand owing to different motives [31]. While brand recognition urging customers to have different motives, it is more likely for customers to generate positive information about the brand if they are identified with it. For eWOM, defined as "any positive or negative opinions on the product or company that are produced by previous, existing or potential customers and accessible for different people or organization", is relevant to UGC [32].

Hence it could be inferred from conclusion above that brand identification would produced positive UGC on social media platforms.

Secondly, brand recognition would influence brand equity. Gaining identification from customers and realizing the resonance between customers and the brand is crucial for constructing customers-brand relationship as well as creating brand value [21]; individual and social brand identification would greatly impact customers' attitude and actions such as purchasing intention, recommending intention and the willingness to pay high price [24]; brand recognition would attract customers, generate public praise and influence the dimensions of brand equity such as brand perceived quality and brand association [33]; customers identified with a brand would keep a good attitude towards the brand even if they see negative information about it [34]. Therefore, customers' identification of a brand would affect their attitude towards the brand and their behavioral and purchasing intention. In general, as customer-based brand equity emphasizes not only the brand recognition but the attitude, behavioral intention and purchasing intention of customers, it could be inferred that brand recognition of customers greatly and positively impacts brand equity.

Thirdly, UGC is more influential on brand equity than company-created content. Company-created communication lacks interaction with customers on social media platforms [2]. Company communication, compared with communication among customers on social media platforms, could hardly impact any dimension of brand equity [35]. The influence from customers on brands is decided by customers' participation degree in brand interaction [36], value co-creation [37] and brand communication [38]. High interactivity brand information delivering is the key for business to successfully spread brand in the online brand community [39]. On social media platforms, customers play a leading role in both ways of communication (among customers; between customers and brands) and affect brand awareness, brand association and brand loyalty [2]. Thus, it could be assumed that UGC, as a communicative way between customers and brands, has an impact on brand equity.

2. Research Methodology

2.1. Research Design

This research uses a quantitative model (Figure 1). From all the conceptual theories the author get from collating, analyzing and summarizing previous studies, from each issue, the author mainly come up with an assumption. By doing online questionnaire survey and SPSS analysis, the author is trying to investigate the following assumptions:

a1) brand identification have positive effect on UGC
b1) UGC has effect on brand equity
c1) brand identification has direct effect on brand equity
c2) brand identification affects brand equity via UGC, UGC has the mediating effect

The testing methodology of this paper follows the test theory raised by Baron et al. [40], taking brand identification as the independent variable, UGC as the mediating variable, brand equity as the dependent variable to test if UGC's mediating effect reach the high significant level. The test will includes four stages of regression analysis to test the mediator model: a) brand identification must be a significant predictor of

dependent variable, i.e., brand identification should be of high significance; b) brand identification must be a significant predictor of UGC, i.e., brand identification should be of high significance; c) UGC must be a significant predictor of brand equity, i.e., UGC should be of high significance; d) taking brand identification and UGC into account, mediating variable should be of high significance, R2-values should largely increase. With the precondition that mediating variable is of high significance, if independent variable is statistically significant, then part of the mediating effect works, if independent variable lacks significance, then full mediating effect works.

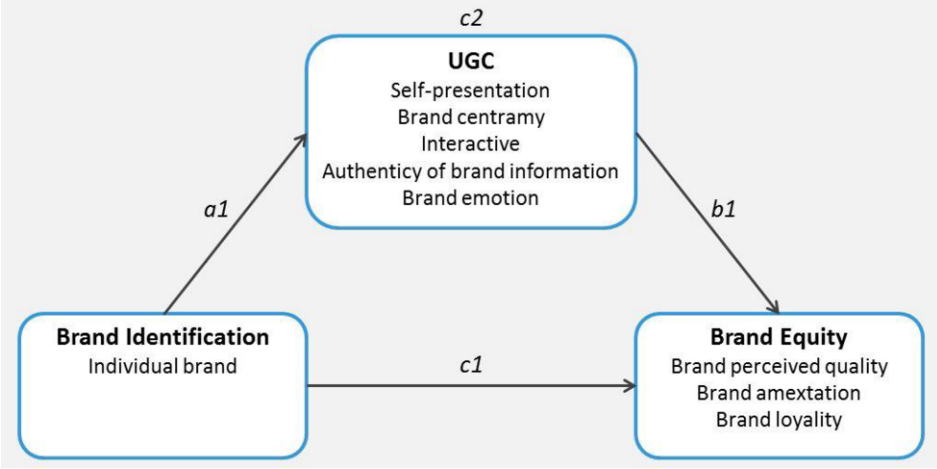


Figure 1. The model of brand identification, UGC and brand equity.

2.2. Sampling and data collection

The samples are collected by an online questionnaire including respondents from all ages without district restriction. The author choose the online questionnaire because the link of questionnaire can be shared by social media platform, which can be effective to help author to focus on respondents who use social media often. To get samples, two screening questions are set to judge whether or not respondents pay attention to specific brand and UGC in social media platforms. After two weeks, 400 questionnaires are collected. Excluding invalid ones, there are 265 effective copies. The response rate is 66.25%.

2.3. Measurement

The variables in this paper are mainly obtained on the basis of literature review, research objectives and mature scales. The items put in the questionnaire all come from previous studies, having been proved by scholars to be effective on evaluating all the variables. In line with the brand UGC hypothetical model, this paper firstly defines brand UGC from six dimensions, which is based on Smith's research for UGC(2012) [19]. Since the author chooses three of four most general dimension accepted by scholars (brand association, brand loyalty and brand perceived quality) to measure brand equity. Therefore, there are 9 questions in total corresponds to three dimensions: 3 for brand loyalty, 3 for brand association and 3 for brand perceived quality [41]. The items studying brand recognition are adapted from of Rio' s research [24]. That is,

measuring individual brand recognition through the consistency degree of the brand image perceived by customers with customers' "self-image, value as well as lifestyle" and social brand recognition by checking whether the brand individuality image reflects "social status, respects and distinction among social groups".

3. Data analysis

3.1. Factor Analysis and Reliability Analysis

The data shows the validity and reliability of the questionnaire (Table 1). The total variance explained of brand identification, brand equity and UGC are 75.892%, 78.134% and 52.033% respectively, all being over 50%, meeting the standard. The last column of the table reflects the reliability test result of this paper. The Cronbach's alpha of every factor is above 0.8 (that of brand equity is even over 0.9), confirming the validity and reliability of the questionnaire and the data collected by this method.

3.2. Regression Analysis

With SIG of 0.000 and F-value ranging between 57.551 -73.175, the regression path shows high significance of all the seven models. The R^2-values (0.180-0.330) confirms the overall effect of the models. The result of the independent variable in parameter test shows all the B-values are over 1%, reaching the level of high significance. All being positive numbers, the 3 B-values indicates that the effects of all the factors are positive. This brings the results that a1, b1 and c1 are all supported.

Table 1. Regression analysis of brand identification,brand equity,UGC.

Model Path	B	R Square	t	F	SIG
Brand identification-UGC	0.494**	0.218	8.554	73.175	0.000
Brand identification-Brand equity	0.511**	0.330	11.378	129.456	0.000
UGC-Brand equity	0.356**	0.180	7.586	57.551	0.000

3.3. Meditating Test

The mediator model is about brand identification, UGC and brand equity (Table 2). The F-values of the 4 models are, respectively, 129.456, 73.175, 57.551 and 73.967, all being significant at the level of 0.01. So all the 4 models are, overall speaking, effective. The R2-values range from 0.180 to 0.361, being within the normal range. Observing the results of the parameter tests of all the models, it could be found that the independent and the mediating variable reach the significant level, meaning that both variables are of statistic significance. Therefore, part of the mediating effect is evident in the model.

Table 2. Mediating test of brand identification,brand equity and UGC.

Model Path	Model 1		Model 2		Model 3		Model 4	
	Brand equity		UGC		Brand equity		Brand equity	
	B Value	T Value	B Value	T Value	B Value	T Value	B Value	T Value
Predictors								
Brand identification	0.511**	11.378**	0.494**	8.554**	0.511**		11.378**	0.494**
Mediator								
UGC					0.180**	7.586**		
F Value	129.456**		73.175**		57.551**		73.967**	
R Square Value	0.330		0.218		0.180		0.361	

**p<0.01…*p<0.05

4. Conclusion and Suggestion

The study finds :1) Brand identification are positively related to brand equity. The higher brand identification customers have, the higher brand perceived quality and brand loyalty are and more positive brand associations is; 2) Brand identification affects UGC in a positive way. Customers identifying the brand are more willing to produce positive UGC on social media platforms; 3) UGC affects brand equity in terms of brand association, brand loyalty and brand perceived quality; 4) UGC acts as a mediator between brand identification and brand equity. Compared with the direct effect on brand equity from brand identification, the mediating effect of brand identification on brand equity via UGC has a greater influence.

The study suggests that brand business should integrate UGC into brand management and brand marketing. First of all, compared to traditional marketing communication, using UGC is a much effective and less costly way of communication. It's necessary to encourage UGC on social media and initiatively interact with customers for customers will help spread brand information when creating their comments and content. A good example way is organizing online activities on social media platform to encourage customers to share their own purchasing experience. Secondly, brand information delivered by UGC is more convincing and influential among customers. So company should also build brand communities established on social media to enhance communication between customers and the brand as well as that among customers, which could reinforce customers' brand recognition. During the process of strengthening the sense of belonging and self-concept, the brand and customers would be mutually connected and get into a process of co-creation. Thirdly, integrating UGC into brand management, companies can also improve competitive edge by embracing a competitive strategy: customer intimacy. Because UGC is an effective two-way communication tool, for companies, it is useful to collect customers' attitude towards brands, much easier to know customers' demands than before, and help to have greater adaptation of products. For customers, UGC can be used to reflect

their comments to brands and this also require companies to perfect internal mechanism like setting up specific department to create highly tailored problem solving capabilities. What's more, since customers with brand identification are more willingness to create positive UGC for companies, for customers, companies should allocate investment on brand management to set up more unique and valuable products, brand culture, brand symbols etc.

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A Study on Comprehensive Evaluation of Deep-Sea HOV Cockpit Console Based on Fuzzy Gravity Center

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Abstract. The cockpit console is an important part in the deep-sea human occupied vehicle (HOV). The comprehensive evaluation of HOV cockpit console is a multi-target and multi-hierarchical decision-making process. In this paper, a multi-level fuzzy comprehensive evaluation model based on gravity center is proposed which can improve the accuracy of the evaluation. Firstly, the ergonomics evaluation index system of HOV cockpit console is established according to the characteristics of HOV console. Secondly, the combination weight of index is calculated by expert subjective weighting method and standard deviation method, meanwhile, the appraisal matrix is constructed based on the theory of fuzzy gravity center, then the comprehensive evaluation result can be obtained. Finally, an experiment is given to illustrate the implementation process of the proposed method, and the experiment result verified the feasibility and rationality of the method.

Keywords. HOV cockpit, comprehensive evaluation, fuzzy gravity center, combination weight

Introduction

The cockpit is an important part of the deep-sea human occupied vehicle (HOV), it is the main work and active region for HOV operators and researchers. The diameter of HOV cockpit is generally 2 meters around [1-3], and all equipment are arranged in the limited space, console will function as nerve centers in HOV, there are all kinds of control and display devices which are playing important role in the work process of HOV. Thus, it puts forward high requirements for the layout design and ergonomics design of HOV cockpit console. Actually, the designer usually places all kinds of devices in a certain position to meet its functional requirements according to specific design criterion and experience. Because of the diversity and fuzziness of the evaluation index in HOV console, it is difficult to evaluate the design scheme with the precise data, most of the time, the evaluation is obtained based on designer's experience and intuition. Therefore, it is of practical significance to design a reasonable and reliable evaluation method for HOV console.

There is no research on the ergonomics layout evaluation on deep-sea HOV console so far. The existing researches mainly focus on the evaluation of HOV cockpit layout. D.F Han [4] put forward analytic hierarchy process to evaluate the overall layout of HOV cockpit; l. C. Zong [5] proposed artificial fish swarm algorithm to evaluate the personnel layout of HOV cockpit. However, they have no concern on the ergonomics evaluation of HOV cockpit console. In addition to the evaluation of HOV

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cockpit, domestic research on such branch is largely confined to the comprehensive evaluation research of the aircraft cockpit, for example, J.X. Chen [6] introduced the different types of uncertain linguistic multiple attribute combination decision making (DTULDM) method in the aircraft cockpit layout evaluation process, this approach has a certain innovation, however, there is no much help for the evaluation of the cockpit console. There are a large number of scholars using the physiological evaluation method for layout evaluation, but it is only for the single factor evaluation.

In view of the above problems and combined with current researches, we will establish the evaluation index system of deep-sea HOV cockpit console and multi-level fuzzy synthetic evaluation model based on fuzzy gravity, and the evaluation result will provide guidance for deep-sea HOV cockpit ergonomic design and optimization. Compared with other comprehensive evaluation method [7-8], the method in this paper introduce language value scale, the experts could give a fuzzy score for each index of evaluation based on language value scale, thus, it is more intuitive and more accurate to reflect the actual situation of evaluation object [9]. Besides, the evaluation method can give a final comprehensive evaluation result of the whole object as well as the evaluation result of all indexes [10], it is very important and convenient to optimize the design object according to the evaluation result.

1. Evaluation system

1.1. Ergonomics evaluation index system of deep-sea HOV cockpit console

Ergonomic evaluation of HOV cockpit console is made mainly from two aspects: controllability and information feedback. The controllability is the convenience and acceptance in the process of operator's action input. The evaluation mainly for the button switch, control handle and other operation equipment. The information feedback is aimed at evaluating the accuracy and rationality of the operator's feedback to HOV cockpit console, mainly for the indicator lights, instruments and monitors. The specific evaluation index system is shown in table 1:

Table 1. Evaluation system facing to HOV cockpit console ergonomic layout.

Main attribute	Primary attribute	Secondary attribute
Controllability	Button switch	Function rationality, Position rationality, size rationality, color coding, shape coding, maximum force, Design of blocking against misoperation, and so forth.
	Control handle	Surface morphology, grip diameter, handle length, inclination angle, handle height, thrust and pressure, backward/ forward distance, left/right distance, and so forth.
	Console	Console depth, console height, console width, panel angle, the minimum knees space, chair-height, adjustment range of seat height, the minimum thigh space, the minimum foot well, and so forth.
Information feedback	Indicator lights	Position rationality, color coding rationality, anti-jam capabilities,visibility, and so forth.
	Instruments	Reading accuracy, range reading accuracy, fluctuation reading accuracy, reading accuracy of multi-instruments, and so forth. Aspect ratio, clarity, readable, Luminance comfort, and so forth.
	Monitors	Aspect ratio, clarity, readable, Luminance comfortableness, and so forth.

1.2. Evaluation model

The evaluation system of HOV cockpit console is complicated and fuzzy, besides, qualitative and quantitative indexes are mixed together. In view of that, we proposed an effective multi-target decision method on HOV console based on fuzzy gravity center and fuzzy hierarchy method. The flow chart of detailed evaluation method is shown below in Figure 1.

After establishing the evaluation index system of HOV cockpit console, all evaluation indexes are divided into two types: quantitative index and qualitative index. The qualitative index will be quantified with the method of language value scale by expert scoring. Then the normalization processing is carried out for all indexes. We will build the evaluation matrix with the normalized index data based on fuzzy gravity center. For the weight of index, the combination weight will be calculated by index subjective weight and objective weight. Finally, we can get the evaluation result of all schemes combining the evaluation matrix and index combination weight.

2. Evaluation method

2.1 The definition of fuzzy gravity center

Similarly to the concept of gravity center in mechanics, if we assume that $\mu_{\tilde{A}(x)}$ is the weight of index in position x , then the fuzzy gravity center of $\tilde{A}$ is defined as follows:

$$G(\tilde{A}) = \int_U \mu_{\tilde{A}(x)} x dx \Big/ \int_U \mu_{\tilde{A}(x)} dx \quad , \int_U \mu_{\tilde{A}(x)} dx \neq 0 \tag{1}$$

U is a boundary and measured set in real set.

Especially, if $U = \{x_1, x_2, \cdots, x_n\} \in R$, the gravity center is defined as follows:

$$G(\tilde{A}) = \sum_{i=1}^{n} \mu_{\tilde{A}(x_i)} x_i \Big/ \sum_{i=1}^{n} \mu_{\tilde{A}(x_i)} \quad , \sum_{i=1}^{n} \mu_{\tilde{A}(x_i)} \neq 0 \tag{2}$$

Generally, $\mu_{\tilde{A}(x)}$ is a convex function, so $G(\tilde{A})$ will be located at the point where $\mu_{\tilde{A}(x)}$ can get the maximum value [11-12]. Thus, the value of $G(\tilde{A})$ is bigger, the evaluation result of index is better. For the multiple indexes comprehensive evaluation, the general gravity center of all indexes will be calculated to evaluate the whole scheme.

2.2 The determination of index weight

The normalization of index is a necessary step before determining the index weight. It is difficult to analyze and compare indexes because there is no uniform measurement standard. Different kinds of membership functions will be built to normalize indexes in the range of 0 and 1 [13].

In this paper, the combination weight is calculated by subjective weight and objective weight. The objective weight is obtained by standard deviation method [14]:

$$\mu_i = \sigma_i \Big/ \sum_{i=1}^{m} \sigma_i \tag{3}$$

The objective weight set is: $\mu_i = (\mu_1, \mu_2, \cdots, \mu_k, \cdots, \mu_m)$,the subjective weight is obtained by expert subjective weighting method, and the subjective weight set is:

$\rho_i = (\rho_1, \rho_2, \cdots, \rho_k, \cdots, \rho_m)$. ω_k is the combination weight of evaluation index, and ω_k can be expressed as linear combination of μ_k and $\rho_k (k = 1,2,\cdots m)$:

$$\omega_k = T\mu_k + (1-T)\rho_k \tag{4}$$

T is the proportion of objective weight in the combination weight.

The objective function is established as follows:

$$\min Z = \sum_{i=1}^{m}\left[(\omega_k - \mu_k)^2 + (\omega_k - \rho_k)^2\right] \tag{5}$$

Differentiate the objective function, and assign the result is 0, we can get T =0.5, that is $\omega_k = 0.5\mu_k + 0.5\rho_k$. The result indicates that the optimal combination weight distribution is that the objective weight and subjective weight have equal weighting. It means that subjectivity and objectivity play the same important role in the process of index weight determination.

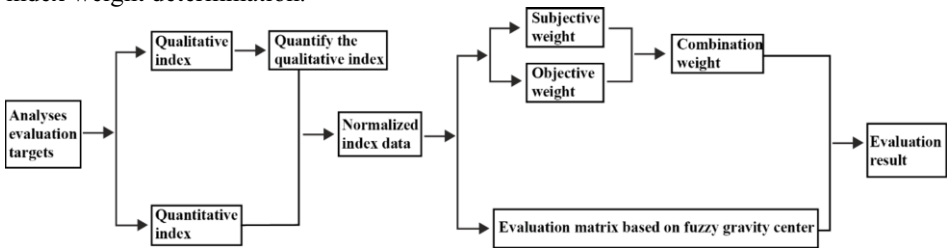


Figure 1. The flow chart of detail evaluation method

2.3 Multi-grade fuzzy comprehensive evaluation based on gravity center

Supposing there are N experts participate in evaluation: $E = (e_1, e_2, \cdots, e_n)$, and the weight of N experts are assigned as $WE = (we_1, we_2, \cdots, we_n)$.

Assuming that the first layer index set is $U = (u_1, u_2, \cdots, u_i, \cdots, u_m)$, for every u_i, the second layer index set is $U_i = \{u_{i1}, u_{i2}, \cdots u_{in}\}$,the third layer index set is $U_{ij} = \{u_{ij1}, u_{ij2}, \cdots u_{ijk}\}$, if necessary, we can continue to divide the index. In order to evaluate conveniently, the language value scale is applied to score the index by experts [15]. The mark format as Figure 2, seven evaluations are placed in a continuous language value scale, and assume that every evaluation is one-unit length, which permit experts to evaluate indexes with fuzzy interval mark. It is helpful to improve the accuracy of the evaluation.

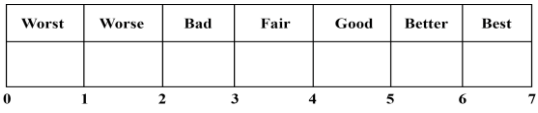


Figure 2. Language value scale.

if expert e_i graded the index u_{ijk} is: $P_{ijk}^i = \left(P_{ijk1}^i, P_{ijk2}^i, \cdots, P_{ijk7}^i\right)$, then we can obtain expert group N score for the index u_{ijk} : $P_{ijk} = \left(p_{ijk1}, p_{ijk2}, \cdots, p_{ijk7}\right)$.

$$p_{ijkn} = \sum_{i=1}^{n} we_i \cdot p_{ijkn}^i, n = 1,2,\cdots 7 \tag{6}$$

Similarly, other indexes will be scored by expert group. Thus, the score matrix of each index is obtained as follows:

$$R_{ij} = \begin{bmatrix} p_{ij1} \\ p_{ij2} \\ \vdots \\ p_{ijk} \end{bmatrix} = \begin{bmatrix} p_{ij11}\, p_{ij12} \cdots p_{ij17} \\ p_{ij21} p_{ij22} \cdots p_{ij27} \\ \vdots \quad \vdots \quad \cdots \quad \vdots \\ p_{ijk1}\, p_{ijk2} \cdots p_{ijk7} \end{bmatrix} \tag{7}$$

And the index weight set $W_{ij} = \left(w_{ij1}, w_{ij2} \cdots w_{ijk}\right)$ is obtained with the method in part 2.2, then we can get the comprehensive score as follows:

$$P_{ij} = W_{ij} * R_{ij} = \left(p_{ij1}, p_{ij2}, \cdots p_{ij7}\right) \tag{8}$$

The score p_{ijk} of the factor u_{ijk} can be expressed by the fuzzy gravity center set in figure 3.

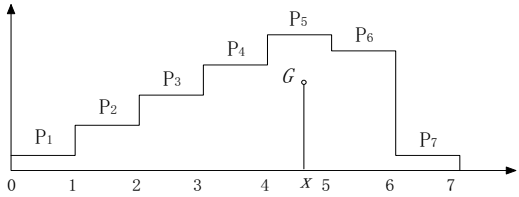


Figure 3. Gravity center of Fuzzy sets.

The gravity center of the fuzzy set as follows:

$$\begin{aligned} G_{ijk} &= \int_0^7 p_{ijk(x)} \Big/ \int_0^7 p_{ijk(x)} dx \\ &= \frac{0.5\, p_{ijk1} + 1.5\, p_{ijk2} + 2.5\, p_{ijk3} + 3.5\, p_{ijk4} + 4.5\, p_{ijk5} + 5.5\, p_{ijk6} + 6.5\, p_{ijk7}}{p_{ijk1} + p_{ijk2} + p_{ijk3} + p_{ijk4} + p_{ijk5} + p_{ijk6} + p_{ijk7}} \end{aligned} \tag{9}$$

Similarly, the gravity center of other indexes can be obtained, and then the vector of each index is obtained: $G_{ij} = \left(G_{ij1}, G_{ij2}, \ldots, G_{ijk}\right)$,with the same method, we can get the gravity center set of the whole scheme: $G = \left(G_1, G_2, \ldots, G_m\right)$.

Fuzzy set's gravity center G will be calculated by the formula (9), the range of G is 0<G<7, referring to language value scale, we can get the evaluation result based on the value of G. Meanwhile, we can find out the index which has low score according to the gravity center vector, continue to track that index gravity center vector, we will discover the element which influence the whole scheme score, then to improve the scheme.

3. Verified Experiment

In this section, we make the comprehensive evaluation of HOV cockpit console, it is an example to demonstrate the effectiveness of fuzzy gravity center evaluation model. And the evaluation index system of deep-sea HOV cockpit console is established in part 1.1, the detail evaluation process is shown blown.

(1) The determination of index weight

The index subjective weight ρ and objective weight μ are obtained by the method in part 2.2, and the index combination weight ω is the average of ρ and μ , the index weight in every layer are shown in Table 2:

Table 2. The combination weight of all index in HOV cockpit console.

	μ_1			μ_2		
ρ_i	0.59			0.41		
μ_i	0.52			0.48		
ω_i	0.56			0.44		
	μ_{11}	μ_{12}	μ_{13}	μ_{21}	μ_{22}	μ_{23}
ρ_{ij}	0.35	0.43	0.22	0.52	0.21	0.27
μ_{ij}	0.43	0.41	0.16	0.46	0.15	0.39
ω_{ij}	0.39	0.42	0.19	0.49	0.18	0.33

	μ_{111}	μ_{112}	μ_{113}	μ_{114}	μ_{115}	μ_{116}	μ_{117}	μ_{118}	μ_{119}	μ_{121}	μ_{122}	μ_{123}	μ_{124}	μ_{125}	μ_{126}	μ_{131}	μ_{132}	μ_{133}	μ_{134}	μ_{135}	μ_{136}	μ_{137}	μ_{211}	μ_{212}	μ_{213}	μ_{214}	μ_{221}	μ_{222}	μ_{223}	μ_{231}	μ_{232}	μ_{233}	μ_{234}
ρ_{ijk}	0.18	0.13	0.07	0.06	0.11	0.03	0.21	0.05	0.16	0.32	0.04	0.11	0.16	0.22	0.15	0.09	0.33	0.07	0.03	0.16	0.21	0.11	0.41	0.17	0.26	0.16	0.21	0.55	0.24	0.07	0.23	0.11	0.59
μ_{ijk}	0.09	0.11	0.15	0.02	0.25	0.07	0.23	0.02	0.06	0.23	0.11	0.20	0.19	0.18	0.09	0.13	0.26	0.02	0.10	0.09	0.32	0.08	0.39	0.22	0.33	0.06	0.16	0.45	0.39	0.15	0.36	0.25	0.24
ω_{ijk}	0.14	0.12	0.11	0.04	0.18	0.05	0.22	0.03	0.11	0.28	0.07	0.16	0.17	0.20	0.12	0.11	0.30	0.04	0.07	0.12	0.27	0.09	0.40	0.20	0.29	0.11	0.18	0.50	0.32	0.11	0.29	0.18	0.42

(2) Experts score the index attribution with language value scale.

The process of experts scoring is arranged with the deep-sea HOV cockpit console ergonomics evaluation list which is shown in Figure 4, which including expert weight distribution, language value scale and index reference value.

Evaluation system facing to HOV cockpit console ergonomic layout	Main attribute			Primary attribute			Secondary attribute			Eigen-value		Language value scale							Descr
	i	μ_i	a_i	j	μ_{ij}	a_{ij}	k	$\mu_{ij,k}$		$a_{ij,k}$		Worst 1	Worse 2	Bad 3	Fair 4	Good 5	Better 6	Best 7	Reference value
	1	Controllability		1	Console		1	Console depth											Standing / Sitting:40cm
							2	Console height											Standing / Sitting:91cm;Sitting:65-91cm;Standing:91cm
							3	Console width											Standing / Sitting: <91cm;Sitting:<91cm;Standing:<91cm
							4	Panel angle											Eye level within more than 10° to 45°; Panel angle of 20°
							5	The minimumKnees space											Standing / Sitting:45cm;Sitting:45cm;Standing:45cm
							6	Chair height											Standing / Sitting:72cm;Sitting:45-72cm
							7	Adjustment range of seat height											Standing / Sitting:10cm;Sitting:10cm;Standing:10cm
							8	The minimum thigh space											Standing / Sitting:>16.5cm;Sitting:>16.5cm;Standing:>16.5cm
							9	The minimum foot well											Standing / Sitting:>10cm;Sitting:>10cm;Standing:>10cm
				2	handle Control		1	Surface morphology											1.Tactile recognition; 2.Avoid the palm and interphalangeal force
							2	Grip diameter											Finger grip:d=2.0cm, Hand grip:d=3.0cm-4.0cm
							3	Handle length											Close to or above the hand length
							4	Inclination angle											Ensure that the arm is in a straight state
							5	Handle height											Avoid shoulder force
							6	backward/ forward angle											<45degree,refer to control ratio
				3	switch Button		1	Function rationality											Avoid redundancy and absence
							2	Position rationality											The main button in the main position
							3	Size rationality											The size is suitable
							4	Color coding											To distinguish the different functions with different colors
							5	Shape coding											To distinguish the different functions with different shapes
							6	Maximum force											Operating force can be kept in the comfort range
							7	Design of blocking against misoperation											Blocking against misoperation
	2	Information feedback		4	Monitors		1	Aspect ratio											Aspect ratio is suitable for visual habits
							2	Clarity											Text and image are clearly displayed
							3	Readable											Text and image can be recognized
							4	Luminance comfort											Eliminating eyes exhaustion caused by luminance
				5	Instruments		1	Reading accurate											Precise readings
							2	Range reading accurate											The accuracy of reading range
							3	Reading accuracy of multi-instruments											Collaborative visualization
				6	lights Indicator		1	Position rationality											The important information in the main position
							2	Color coding rationality											To distinguish the different information with different colors
							3	Anti-jam capabilities											Visibility in vibration environment
							4	Visibility											Conspicuous
NO._							Expert number										Sign		
							Expert weight										Date		

Figure 4. Deep-sea HOV cockpit console ergonomics evaluation list.

(3) Calculating fuzzy gravity center.

Given the limited space available, we use surface morphology u_{121} as an example for calculating fuzzy gravity center. The weight distribution of five experts is $WE=(0.1,0.2,0.3,0.2,0.2)$. Five experts scored the u_{121} with the language value scale are:

$$P_{121}^{1}=(0,0,0,1,0.9,0.8,0),$$
$$P_{121}^{2}=(0,0,1,1,1,0,0),$$
$$P_{121}^{3}=(0,0,0,1,1,0.8,0),$$
$$P_{121}^{4}=(0,0,0,0.9,0.8,0.8,0),$$
$$P_{121}^{5}=(0,0,0,0,0.9,0.8,0). \tag{10}$$

According to formula (6), we can get the expert group scored: $P_{121}=(0,0,0.2,0.78,0.93,0.64,0)$, similarly, we can get the score matrix which including all index score:

$$R_{ij}=\begin{bmatrix} 0.00 & 0.00 & 0.20 & 0.78 & 0.93 & 0.64 & 0.00 \\ 0.34 & 0.44 & 1.00 & 0.77 & 0.16 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.57 & 0.85 & 0.98 & 0.89 & 0.38 \\ 0.00 & 0.00 & 0.62 & 0.96 & 0.94 & 0.46 & 0.07 \\ 0.39 & 0.66 & 0.90 & 0.64 & 0.45 & 0.18 & 0.00 \\ 0.00 & 0.00 & 0.22 & 0.96 & 0.51 & 0.33 & 0.25 \end{bmatrix} \tag{11}$$

From the table 2, we know the weight of u_{12}:

$$W_{ij}=(0.28,0.07,0.16,0.17,0.20,0.12).$$

Then refer to formula (8), we can obtain the comprehensive score of u_{12}:

$$P_{12}=(0.10,0.16,0.37,0.81,0.74,0.48,0.10).$$

Furthermore, we can get the fuzzy gravity center of u_{12} based on formula (9):

$$G_{12}=\frac{0.5\times0.10+1.5\times0.16+2.5\times0.37+3.5\times0.81+4.5\times0.74+5.5\times0.48+6.5\times0.10}{0.10+0.16+0.37+0.81+0.74+0.48+0.10}=3.87 \tag{12}$$

With the same method, other index fuzzy gravity center set will be obtained: $G_{11}=4.67$, $G_{13}=6.31$, $G_{14}=3.20$, $G_{15}=2.88$, $G_{16}=5.95$.

Repeat the step (3), we can get $G_1=4.93$ $G_2=5.62$. Finally, we will obtain $G=5.27$.

(4) Analysis evaluation result.

From the result of fuzzy gravity center G, 5<5.27<6, from the language value scale established in Figure 2, we can get the conclusion: the comprehensive evaluation for the whole scheme of HOV cockpit console is better.

And we can track the evaluation process from low layer to the upper layer to find out the low score of the index, that is the impact of HOV cockpit console needed to be improved.

4. Conclusion

The comprehensive evaluation of deep-sea human occupied vehicle cockpit console is a multi-target and multi-hierarchical decision-making process. Through building a corresponding cockpit man-machine layout evaluation system, we put forward a multi-level fuzzy comprehensive evaluation model based on gravity center and verified the method by a real case experiment. The research method in this study can quantificationally evaluate the cockpit ergonomic layout case, avoid the experts' evaluation deviation, and provide a reference for related field ergonomics evaluation.

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Developing a Cost Model for Aerospace Laser Beam Welding Technology

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Abstract. A significant proportion of the total unit cost of the product is authorized at the early stage of design phase. Therefore, integrating the capabilities of the manufacturing process into a cost model will lead to optimizing the product design, estimating its cost and attaining a cost reduction from it. Due to the advantages of low cost and greater productivity, Laser Beam Welding (LBW) has been employed as a key process in aerospace industry to manufacture components of gas turbine. This study aims to develop a manufacturing process cost model by collecting and analysing the LBW manufacturing data. The developed model will aid the aerospace industry to estimate the cost of product during early design stage. Detailed statistical analysis of past data was done to develop the LBW cost model which was further validated with several weld inspections to assure the conformity of total unit time and unit cost estimation. LBW cost model will guide the designers to make suitable design at the early design stage which will also be useful in reducing the manufacturing cost of the product and consequently, provide a competitive advantage to aerospace industry.

Keywords. Laser beam welding, aerospace industry, cost model, manufacturing process capability, design parameters

Introduction

Aerospace industry is being recently challenged by the development of advanced manufacturing processes. In order to overcome the intense competition in the changing market of today, most aircraft manufacturing companies struggle to apply innovative methods, technologies and systems to achieve a competitive unit cost from design to manufacturing stages.

Most of the product cost is determined at the design stages during aircraft development. Leading aircraft companies have a necessity to develop methods and tools to integrate and estimate cost in the design phase in order to ensure that advanced manufacturing processes can meet the expected specifications. Hence, modelling cost of manufacturing processes will lead to optimise product design at early stages providing decision support regarding cost and manufacturing process capabilities.

Welding Technology is a key for the manufacturing process of gas turbine components. Aerospace industry is emphasising the development of cost estimation methods as an on-going practice to predict costs aiding complex business decisions at early design stages of product development. Due to its recent application to the aerospace sector and its broad range of manufacturing capabilities involved in the

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process, there is a lack of cost modelling in LBW. Therefore, the main motivation for this research is to bridge the existing gap between design and production phase by integrating manufacturing process capabilities required for the application of LBW into a cost model.

As a matter of fact, being able to model the total unit cost of a product welded by LBW will contribute to achieve process optimization and a reduction of the total cost of the aircraft engine. Moreover, a cost model for LBW would be used to guide product development from design to manufacturing stages. Especially considering that in the aircraft industry, 70% of the production cost of a product is determined during the design phase [1]. Therefore, this project aims to develop knowledge about LBW between the design and manufacturing phases of gas turbine components.

1. Background

Laser beam welding (LBW) is a fusion welding technique which is used to join multiple parts by the application of a concentrated beam of light into the material surface. That interaction produces heat which is sufficient to melt or even vaporize the material and join it from the component being melted [2]. LBW provides operation cost savings due to reduced mass of material used for creating the weld, high grade of automation and reduced manufacturing steps such as preheat or post weld heat treatment which may be eliminated [3]. Moreover, there is a corrosion resistance improvement in this technique due to elimination of risk from rivet holes and absence of gaps with this sort of weld [4].

Comparing with other welding techniques, laser beam welding process obtains more advantages from high power density and welding speed. Small Heat Affected Zone (HAZ) and low distortion are both advantages since the volume occupied by the weld is much smaller than for other techniques producing very narrow, deep penetration welds [5]. In that regard, high joint strength and high production rate are achieved with this technique due to the good accessibility and high process flexibility.

On the other hand, laser beam welding process has barriers and disadvantages when it is implemented in the industry. It has a high capital cost due to the technology used. Hence, there is need to develop a model to evaluate the cost of this process so that necessary measures can be made to control the cost of welded products. Cost modelling systems are cost estimation systems which are capable of optimising the manufacturing cost [6].

Shehab and Abdalla [7] explain cost estimation as a methodology that forecasts the cost related to activities before their physically execution. In the nutshell, cost estimation will be understood as an approach that forecasts and quantifies the manufacturing cost of a product before the production phase. Niazi et al. [8] categorised the cost estimation methods into qualitative and quantitative methods. Qualitative methods are applicable at the early stage of product design and for a rough estimate since a limited amount of data is available in this stage, whereas quantitative methods are suitable for detailed estimation because of the large amount of data available. According to Masmouidi et al. [9], the welding manufacturing process is suited for parametric cost estimation technique. On the other hand, Chayoukhi et al. [10] have considered analytical cost estimation technique such as feature-based approach, the suited technique to estimate the manufacturing cost of the process.

It is observed that little or no effort has been found regarding any cost model or cost estimation technique for this LBW manufacturing process. Hence, a necessity to calculate its cost on a welded product is required in order to achieve competitiveness in today's aerospace market.

2. Research Methodology

Research methodology consists of five phases as shown in Figure 1. The starting point of this project is to understand and define properly the project aim, objectives and scope. Afterwards, the "Literature Review" stage comprehended a deep research in different fields (laser beam welding, cost engineering). The third stage is the identification of the design and manufacturing variables. This could enable the researcher to identify the most relevant variables for the model which potentially was the deliverable of this stage. The fourth and fifth phases will be iterative creating a loop of model building and validation until results are aligned with the intended stakeholders' requirements. "Cost Model Development" phase commenced with the creation of a high level process or model structure map to extract and utilize capability information. Afterwards, the statistical cost model selection will depend on the data analysis of the previous phase of it. Finally the cost model will be implemented into Vanguard Studio. Finally during the fifth phase called "Validation", model output data will be analysed and compared with the expected results.

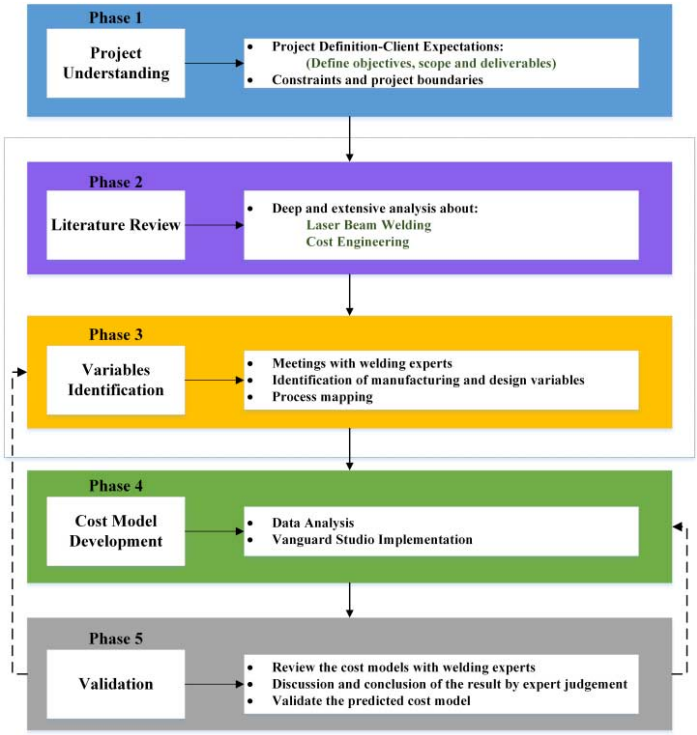


Figure 1. Research methodology.

3. Cost Model Development

LBW cost model has been developed using geometric weld features as inputs and key cost drivers for this manufacturing process. It enables calculation of process operation times and costs for different depth penetrations. Moreover, this model considers two operating modes: Continuous and Pulsed mode. Continuous mode, or also named Continuous wave (CW), stands for continuous wavelength, which means the laser emits a steady beam over a period of time, whilst pulsed mode is when the laser is pumped with short bursts to generate short controlled laser pulses. Generally speaking there are on and off periods to the pulsed laser beam. In that regard, continuous mode is applicable to a broad range of depths of penetration but the pulsed mode is just applicable to depths of penetration smaller than 3 mm.

3.1. Variables Identification

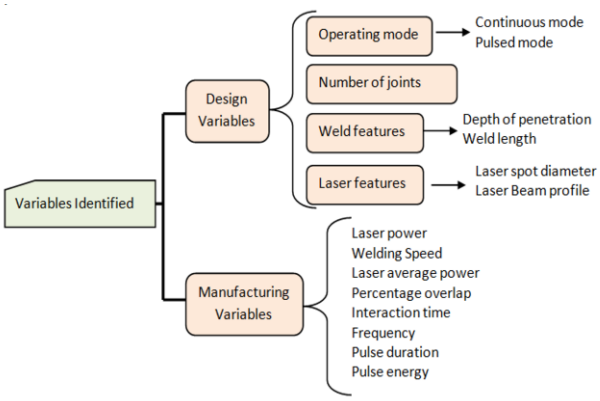


Figure 2. Variables Selected.

The variables involved in LBW process cost model can be divided into two main categories, manufacturing variables, also known as key process variables, and geometry variables or design variables (see Figure 2). The former are related to all the manufacturing parameters such as welding speed, laser power, interaction time, wavelength among other machining parameters. The latter are weld design variables such as depth of penetration, weld quality, type of joint among others, but also the type of operating mode used and number of laser welds on the product. Thus, these geometry variables are closely related with the design stage of the product, in this study High Pressure Intermediate case.

It is understood through literature review that a stable LBW process depends on defining and controlling the process parameters which have a relevant influence on process stability to reliably produce high quality welds at high welding speeds [11]. Hence, the LBW manufacturing parameters and their effects on quality welds have been widely studied during the last years. The suitable parameters were selected by doing a deep research about LBW parameters and relationships among them as well as interviewing welding experts from the industry.

3.2. LBW Process Map

After identifying the main variables, which have an impact on time and cost in the LBW process, an understanding about the essential stages for the LBW process is

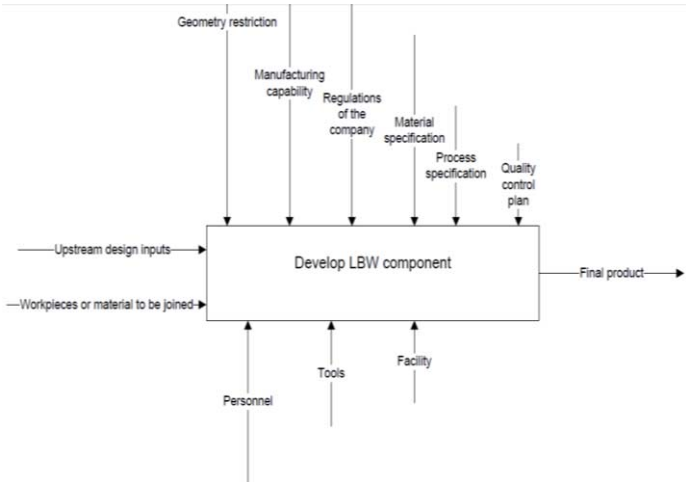


Figure 3. Process map of LBW procedure.

required to take into account every activity in the process and to ease the accuracy estimating the operation process time.

The process map of LBW procedure is shown in Figure 3. According to the process map, a clearer understanding of the LBW procedure was obtained as inputs, outputs, mechanics and controls have been illustrated in the process map. This process map gathers all the information and activities from the design phase to the manufacturing stage.

The main inputs of LBW process include upstream design variables, which have been define previously, and the type of material to be joined but in this case, it will be always titanium since High Pressure Intercases are made of it. The final output will be the welded product.

This procedure is controlled by several restrictions about the manufacturability of the combination of weld design variables in the current production capability and regulation which the aircraft industry follows as well as quality controls. On the other hand, the main mechanisms used are personnel including structure designers, process engineers and welding operators, tools such as computer or design software and facility such as LBW equipment.

3.3. LBW Cost Model

In order to develop the cost estimating tool, Vanguard Studio software was utilised. This software is a numerical modelling tool that uses equations in a similar manner to Microsoft Excel. Hence, Vanguard Studio is a comprehensive business solution to improve reliability on the cost model activities throughout the entire aerospace organisation. This software presents equations as linked boxes called nodes rather than rows and columns of data and it eorks with a hierarchial tree interface. Vanguard studio automatically constructs a visual diagram which is aligned with the logical formulae introduced. Therefore, it is beneficial to tackle complex manufacturing processes as LBW process and that is main reason why this software has been used.

The developed cost model is built up by two main branches, as shown in Figure 4. According to which operating mode is chosen, continuous or pulsed mode, one of those branches will calculate the outputs for the selected operating mode. Both branches follows the same structure to obtain the outputs in terms of cost and time but the inputs

which need to be filled in are different because of the dissimilar manufacturing parameters utilised in each operating mode.

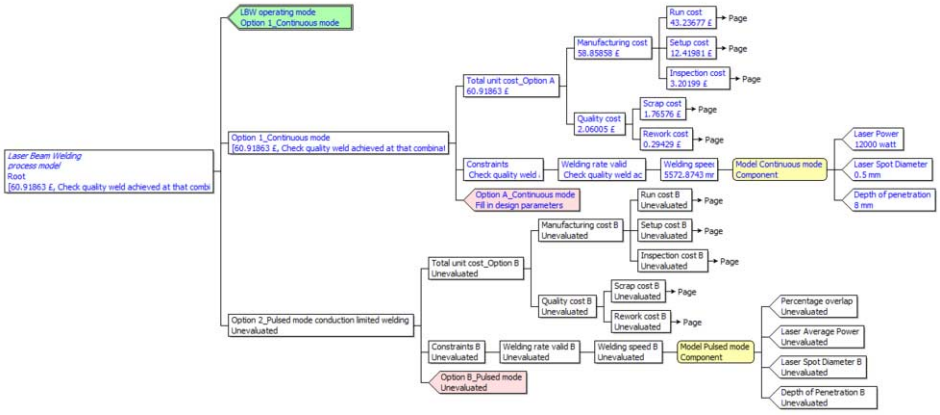


Figure 4. LBW cost model in vanguard studio.

3.3.1. LBW Continuous Cost Model

This model uses data of weld trials as a basis to calculate the welding speed. These weld trials were carried out in order to achieve different depth of penetrations. Due to the data confidentiality, penetration depth have been omitted. This data is illustrated in Table 1.

Table 1. Gathered data of weld trials.

Depth of penetration A		Depth of penetration B		Depth of penetration C	
Interaction time (ms)	**Power Factor (MW/m)**	**Interaction time(ms)**	**Power Factor (MW/m)**	**Interaction time(ms)**	**Power Factor (MW/m)**
10	5.946129	10	12.89326	10	23.1593
15	4.974555	15	10.78655	15	19.37516
20	4.383098	20	9.504072	20	17.07152
30	3.666916	30	7.951143	30	14.2821
40	3.230933	40	7.00578	40	12.58401
50	2.928785	50	6.35062	50	11.40719
60	2.703011	60	5.861062	60	10.52783
70	2.525755	70	5.47671	70	9.837443
80	2.381633	80	5.164203	80	9.276108
90	2.261349	90	4.903387	90	8.807622
100	2.158909	100	4.681262	100	8.408632
110	2.070244	110	4.489005	110	8.063296
120	1.992483	120	4.320392	120	7.760427

In order to obtain an estimation of the welding speed required for performing the weld with the design features introduced by the user, a graphical representation of both parameters for these three depth of penetrations is depicted in Figure 5 in order to show the relations between interaction time and power factor.

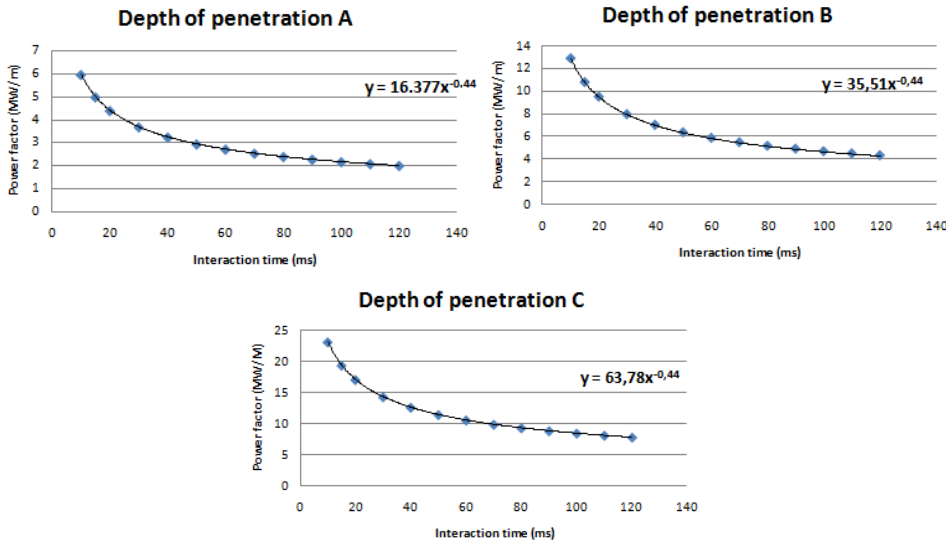


Figure 5. Graphical representation of power factor vs interaction time.

In order to obtain the welding speed for the continuous welding mode, the power factor for the combination of parameters introduced by the user is going to be calculated using Equation 1. Once the power factor (MW/m) is ascertained mathematically, the interaction time for these three depths of penetrations can be obtained using Equation 2.

$$PowerFactor = PowerDensity \times LaserBeamDiameter = \frac{LaserPower}{LaserBeamDiameter} \quad (1)$$

$$InterationTime = \frac{LaserBeamDiameter}{WeldingSpeed} \quad (2)$$

However, the way to proceed will be different since the power factor is the known data and the interaction time is the data the continuous mode model needs to estimate the welding speed. To do so, these equations will be used but interaction time will be the dependent variable also called "y" and the power factor will be the independent also named "x". Hence, the equations used for each depth of penetration have the next expression:

$$y = \frac{x}{\frac{A}{B}^{\frac{-1}{C}}} \quad (3)$$

These equations will provide the interaction time for these three different penetration depths and as welding speed is defined as laser spot diameter divided by interaction time, three values of welding speed will be obtained and a new relationship between welding speed and depth of penetration can be displayed. This relationship will provide an equation which independent variable will be the welding speed and the depth of penetration as dependent variable. Any depth of penetration can be used as an

input and an estimation of welding speed will be calculated applying potential regression to that equation.

3.3.2. LBW Pulsed Mode Cost Model

This model uses four inputs from the LBW cost model which are Laser average power, Laser spot diameter, Depth of penetration and Percentage of overlap in order to obtain the appropriate manufacturing parameters such as the welding speed for that combination of parameters. The outputs displayed will be Welding speed in pulsed mode, Frequency which can be defined as the pulse repetition rate, Pulse energy which is the energy produced in each pulse and Pulse duration which is the time duration of each pulse.

In order to obtain the Pulse energy, the model uses a rule of thumb which is considered as relevant and accurate estimation when the depth of penetration is small. It consists in each millimetre of penetration depth requires a joule of energy. The Frequency is estimated by dividing the Laser average power by the Pulse energy obtained previously by using the rule of thumb stated. Additionally, the pulse duration is the inverse of the Frequency. Finally, the Welding speed for the pulsed mode is ascertained mathematically by the following equation:

$$WeldingSpeed = LaserSpotDiamter \times (1 - PercentageofOverlap) \times Frequency \quad (4)$$

4. Validation

The validation of this LBW Cost Model was done mainly by expert judgement. After every result was completed, a validation was carried out in order to meet collaborator company requirements and fit the cost model for purpose. The process followed is illustrated in Figure 6.

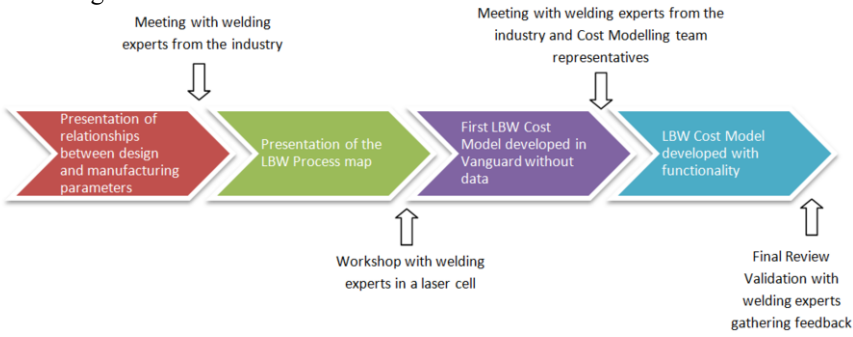


Figure 6. Validation Process.

From the feedback obtained through the different stages in the validation process, these are the main points which should be highlighted as the main strengths of the results achieved:

1. This study will guide designers to understand the feasibility of their combinations of parameters for developing the weld on the product and it will help to achieve a better performance between design and production stages.
2. The process mapping of this process can be used and follow in the aircraft industry since it can be stated as a common practice. It gathers the most

common activities required to manufacture a weld on any product in the aerospace sector.

3. The developed cost model provide an accurate result from early design stage according to the data provided by the collaborator company to build it.

5. Conclusions

In conclusion, this research promotes LBW application in the aerospace industry which is starting to expand its utilisation. Therefore, its application will bring an accurate and high speed process as well as cost reduction to manufacture aircraft engine components. Developed cost model will potentially improve the performance and the interaction between manufacturing and design departments allowing to the designers of the weld features on the product know the weld quality and feasibility of each combination of parameters specified. Hence, this cost model can be used as a basis to help the designing team of the aerospace company to determine the weld features.

The proposed cost model is limited to titanium as material to be joined and some process variables such as beam profile, incident angle and the shielding gas used were assumed and considered constant during the development of the proposed cost model. In future, cost model can be developed for different materials by integrating aforementioned process variables.

Acknowledgements

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Part 8

Concurrent Engineering

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Transdisciplinary Engineering: A Paradigm Shift
C. Chen et al. (Eds.)

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Globalisation of Concurrent Engineering Activities: Transferring-, Translating- and Transforming Approach

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Abstract. The paper analyses the consequences of using a one-size-fits-all concurrent engineering (CE) approach. Six CE projects are studied; each addresses a company located in a high-wage area and one of two abroad facilities located in low-wage areas. The analysis reveals; the companies neglect the consequences of a higher perceived newness and interdependence than anticipated from the outset; habitually, practitioners' understanding draw on existing solutions; because the sub-stance of the handed-over information differs, the one-size-fits-all approach is inappropriate. Three approaches to gain a convergent understanding are suggested: 1) transferring approach, 2) translating approach, 3) transforming approach.

Keywords. Concurrent engineering, globalisation, one-size-fits-all, learning

Introduction

A geographical dispersion of concurrent engineering (CE) activities makes it difficult to achieve a convergent understanding among the practitioners. To achieve a convergent understanding some researchers advocate knowledge sharing across boundaries [1], while other researchers focus on managerial issues [2] adapted to CE principles [3]. In general, these models advocate a one-size-fits-all best practice approach. Ahmad et al. [4] and Cooper [5] question this one-size-fits-all approach and suggest the use of contextual-based models. These models however, do not address the consequences of a geographical dispersion of the CE activities. Likewise, as CE involves different professional disciplines [6] practitioners operate in various working practices [1]; [7] meaning that knowledge is embedded in practice [8] and is continuously modified [9]. This contextual knowledge implies that the use of a "knowledge-transfer best practice" approach is problematic. Hence, to achieve a convergent understanding within and across working practices calls for either a "transfer, translate or transforming approach" [10].

To the best of the author's knowledge, researchers have paid little attention to handle CE in a global context where part of the activities are located in high-wage areas while other activities are located in low-wage areas. This paper aims at revealing the consequences of applying a "one-size-fits-all" approach and by combining these findings with practice-based theories to suggest a method to manage CE in global set-ups.

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The paper subscribes to a practice-based viewpoint of learning [11], appreciating that more information does not always facilitate a convergent understanding [12] among interdependent practitioners operating in different practices [10]. Hence, the achievement of a convergent understanding depends on the degree of newness in terms of the development and the degree of interdependence among the practitioners.

The empirical material illustrates a company located in a high-wage area (Global-Company) and two captured facilities, one located in Eastern Europe (Facility-Europe) and one in Far East (Facility-Asia). The CE of six products is presented and analysed.

The findings are; degree of newness and interdependence among interacting working practices are not a subject upstream the development; habitually, the practitioners' understanding draws on well-known solutions and they do not question the one-size-fits-all approach; as the substance of handed-over information differs, the one-size-fits-all approach proves to be inappropriate. The paper suggests that practitioners should be proactive in terms of degree of newness and interdependences. Three approaches to gain convergent understanding are suggested: 1) transferring, 2) translating, 3) transforming.

1. Theory

CE has received considerable attention [6]. In relation to this paper, academia suggests a best practice for managing development and a best practice for sharing knowledge.

The best practice for managing development addresses the use of guidelines as for instance stage/gate models [2], product-industrial V-model [13], set-based CE [3] using iterative front loading [14] and guidelines facilitating manufacturability [15]. In this stream of research, a large number of guidelines have seen the light of day; Dombrowski et al. [16] reveal 181 guidelines, while Anderson [15] suggests 142 guidelines.

The best practice highlighting the role of sharing knowledge questions the deterministic effect of guidelines; rather, the enabler for CE is a combination of guidelines and lessons learned from past CE activities [17]. In other words, CE draws on the creation of and utilisation of knowledge embedded in different practices [18]. As a means to handle this embedded and continuously modified knowledge researchers suggest the use of a representational guideline model [19]. Indeed, Dekkers et al. [20] suggest that managerial structures and guidelines can have a negative influence on practitioners' experience, judgement and thereby the creation of useful knowledge. Likewise, front-loading of functionality and manufacturability guidelines might paralyse the practitioners [21] and often these requirements and guidelines are conflicting [22]. Hence, it can be called in question whether the involved practitioners have the ability to handle all these guidelines or they are overloaded with information; overload occurs if the information-processing requirement exceeds the information-processing capacity [12] entailing inappropriate decision-making processes [23]. In addition, as knowledge can have differt semantic [1], a one-size-fits-all approach to share knowledge within and across working practices is inappropriate. This is elaborated below.

"Practice and knowledge creation" unfold when handling a CE activity. Referring to Dewey's [11, p. 32] "*every organic function is an interaction of intra-organic and extra-organic energies*". A practitioner's embodied experience constitutes the former, while artefacts and technical matters make up the latter. The two group of matters

evolves in tandem, which entails that experience is embodied and embedded within practice.

The handling of an activity is a five-phased inquiring process [11] that commences when an individual strives to understand what is going on [24] and gradually handles this indeterminacy by ensuring a "*controlled transformation of an indeterminate situation into a determinately unified one*" [11, p. 121]. A successfully controlled inquiring process paves the way for knowledge creation, while an unsuccessfully controlled process results in the inquiring goes astray and consequently no creation of knowledge.

Before elaborating the approach to facilitate knowledge creation within and across working practice the understanding of newness and interdependence are presented.

Newness means that the practitioner(s) can draw neither on their experience nor on existing solutions to handle a CE activity. At the particular point in time of handling the CE activity, something is unknown within the working practice and to find a solution it is necessary to gain access to new knowledge. Newness arises due to new knowledge is or has been created outside the working practice in question.

Interdependence means whether or not the handling of a specific activity in a situated practice influences or is influenced by the handling of activities in other working practices; it embraces activities handled in the past, present activities and the future dimension of activities. Interdependence emerges because of coordinative issues.

"Knowledge-transfer" is pivotal for achieving a convergent understanding. As knowledge is contextual [11] a generic approach to "transfer knowledge" is questionable. In the following, Hutchins [25] account of landing a commercial airliner is used to clarify the *transferring*, *translating* and *transforming* approaches. Hutchins explicates the pilots' actions and use of manuals and instruments during descent and touchdown. The landing manual and technical instruments are the outcome of past development activities in which specialist engineers have written text into the manual and created the instruments.

Transferring: The pilots have lots of experience with landing the airliner and they are well-versed about the landing manual and technical instruments; the manual and instruments enable the pilots to conclusively determine the descent and landing speed. As the pilots are familiar with the manual/instruments syntax, knowledge is transferable.

Translating: If randomly taking one of the passengers from the airliner this person is most likely incapable of doing the landing. However, if the passenger in question is a pilot trained in another type of airliner, he/she might be capable of doing the landing. Despite this passenger is not familiar with the specific syntax in the manual and instruments he/she might be able to use his/her experience from landing other airplanes to translate the information and thereby calculate the descent and landing speed. Thus, the pilot faces semantic knowledge, see [1]; this calls for a translation approach [10].

Transformation: If, for some reason, the manual for landing has to be updated, the specialist engineers need to understand all the codes, indexes and symbols displayed in the manual. In addition, they have to take into consideration information from pilots, various logbooks from the airliners and information on changes/updates conducted on the airliner in question. Referring to Carlile [10], this kind of knowledge is "localised, embedded and invested in a situated practice"; it is pragmatic. This means that something is at stake when handling this knowledge, which requires a transformation approach.

2. Method

Observations are conducted at Global-Company in a five-month period three days in average per week and a visit at Facility-Asia lasting one month. Planned on-location observation at Facility-Europe is replaced by video-, skype- and phone meetings. 15 meetings are observed; lasting from 30–60 minutes. 8 unstructured and 12 semi-structured interviews are conducted, each lasts on average one hour.

Global-Company, founded in the early eighties, is doing business in the consumer goods industry; The company has 350 employees at Headquarters. In 2005, Global-Company acquired Facility-Asia; Facility-Asia has 500 employees. Global-Company acquired full ownership of Facility-Europe in 2008; Facility-Europe has 320 employees.

A stage/gate approach for managing the development is applied; a "business-as-usual" approach. The first stage focuses on creating a design proposal, followed by the preparation of a "concept-plan". The selected facility receives the approved concept-plan and the practitioners gradually clarify the detailed specifications and create a prototype. Finally, the mainstream manufacturing-/supply chain specifications are created.

Table 1 presents how Global-Company, in collaboration with either Facility-Asia or Facility-Europe, develops the six products. The left column shows the labelled project name and duration of the project. The right column illustrates the number of iterations, the project outcome as well as the anticipated/perceived newness and interdependence.

Table 1. The six development projects.

Project	Newness and interdependence
F-Asia 1 Three months.	1 minor iteration and successful outcome. *Global-Company*: Anticipated and perceived newness are low. Capable of creating functional specifications without involving external actors. *Facility-Asia*: Anticipated and perceived newness are low. Capable of creating detailed specification and workable prototype without involving external actors
F-Asia 2 So far, eight months.	3 costly iteration and still awaiting final approval. *Global-Company*: Anticipated newness and perceived newness are low. Functional specifications created in a rush without involving external actors. *Facility-Asia*: Anticipated newness is low; perceived newness is higher than expected. Received information is an upscaling of existing product; struggles to grasp the information to create detailed specifications and a workable prototype; some knowledge interchanges with Global-Company.
F-Asia 3 Seven months.	2 minor and 3 costly iteration. Successful outcome, yet supply chain is inefficient. *Global-Company*: Anticipated newness is low; perceived newness is higher than expected. Specifications do not address product architecture issues; limited knowledge interchanges with Facility-Asia; involves external designer. *Facility-Asia*: Anticipated newness is low; perceived newness is higher than expected. Struggles to achieve understanding of interface issues; collaborates with Global-Company to handle this. Neither manufacturing nor supply chain influence the development.
F-Euro 1 Three months.	1 minor iteration and successful outcome. *Global-Company*: Anticipated and perceived newness are low. Collaborates with Facility-Europa to gain knowledge about manufacturing/supply chain issues prior to drawing up functional specifications. *Facility-Europa*: Anticipated and perceived newness are low. Capable of utilising functional specifications to create detailed specifications.

Project	Newness and interdependence
F-Euro 2 Three months.	1 minor and 3 costly iteration and successful outcome. *Global-Company*: Anticipated newness is low; perceived newness is much higher than expected. Functional specifications do not address product architecture issues; involves an external designer. *Facility-Europa*: Low anticipated newness; perceived newness is much higher than expected. Received information is insufficient to create specifications and a workable prototype; intense collaboration with Global-Company; an external specialist suggests a redesign of the product architecture.
F-Euro 3 Seven months.	5 costly iteration. Termination of the project after 7 months. *Global-Company*: Anticipated newness is low; perceived newness is much higher than expected. Collaborates with external designer to draw up functional specifications; does not realise that this customisable product requires modularised architecture or issues related to manufacturing/supply chain. *Facility-Europa*: Low anticipated newness; perceived newness much higher than expected. Shortly after starting-up detailed design, Facility-Europa realises that the development differs radical from current knowledge; do not understand specifications despite collaboration with Global-Company.

3. Empirical findings and analysis of the six CE projects

Facility-Europe accomplishes the CE activities more systematically and acts as the preferred collaborator; if the objectives of the development is to break new ground Global-Company goes for a collaboration with Facility-Europa. Due to the relative short distance it is more affordable for the practitioners to regularly visit the European facility to evaluate the development activities. However, despite the different conditions, culture heterogeneity and the facts that the practitioners accomplishing the CE activities in Facility-Asia/Europe have different educational background and experience, the application of the "business-as-usual" approach causes to a remarkable homogeneity among the six projects being studied. The findings reveal that the "business-as-usual" approach has a profound influence on the accomplishment of the CE activity. One could claim that it explicates a deterministic effect of managerial guidelines. On the other hand, it can be argued that the business-as-usual approach is too successfully implemented, which constrains the understanding of potential drawbacks upstream the development; in other words the practitioners' do not question the one-size-fits-all approach. Habitually, all practitioners anticipate low degree of newness and thus it makes sense for them to draw on existing knowledge and solutions. In four of the six projects, the perceived newness is higher than expected, which results in costly iteration and in one situation a termination of the development. Indeed, only when the practitioners conducted the iteration the interdependence for sharing knowledge was realised.

The use of the "one-size-fits-all" approach results in a gap between anticipated and perceived newness; please see table 1. The perceived newness of F-Asia 1 and F-Euro 1 is as anticipated low. This is also the situation for F-Asia 2, but during the preparation of the detailed specifications, Facility-Asia faces higher degree of newness than anticipated. As for F-Asia 3, perceived newness turns out to be higher than anticipated by both companies. Finally, perceived newness of F-Euro 2 and F-Euro 3 is much higher than anticipated. The two projects characterised by low degree of newness are completed successfully and only minor iteration occurs. The analysis of these two project reveals that the involved companies mainly do their part of the development on their own; thus, the degree of interdependence is low. The remaining four project,

having higher degree of newness than anticipated, are characterised by costly iteration. These four project have in common that the practitioners at the abroad facility gradually realise an insufficient understanding. The analysis of F-Asia-2, F-Asia-3 and F-Euro-3 demonstrates an interdependence between Global-Company and the abroad facility, while the F-Euro-2 reveals a triadic interdependence among Global-Company, Facility-Europa and an external specialist in product modularisation. However, this interdependence is not a subject matter during the stages of the development where Global-Company has the lead; the interdependence is gradually acknowledge after the abroad facility has taken the lead entailing that the iteration occurs late in the development.

F-Asia 2 is considered as a straightforward development meaning that the functional clarification is accomplished in a rush without involving Facility-Asia. It appears that Facility-Asia is incapable of achieving a sufficient understanding of the handed over information to handle a smooth transition between the functional clarification and the creation of a workable prototype. Likewise, the F-Asia 3 and F-Euro 2, which strictly follow the standardised approach, reveals a similar problematic transition between the functional clarification and the commencement of specifying a workable prototype.

The problematic transitions result in the abroad facility struggles to comply with the functional requirement. The analysis reveals that the accomplished iteration occurs be-cause the practitioners do not address pros and cons in relation to the chosen product architecture; by habit, an integral architecture is chosen. It seems to be a challenge for the practitioners to gain sufficient understanding of the interfaces among subsystems to create a workable prototype. In the same vein, Global-Company does only gain an under-standing of the existing manufacturing-/supply chain set-up upstream the development in one of the six projects; the F-Euro 1. Nevertheless, costly iteration and the realisation of interdependence enable the practitioners to modify the chosen product architecture to the existing manufacturing-/supply chain set-up and thereby achieving an acceptable manufacturability in F-Asia 2 and F-Euro 2. This is not the case in F-Asia 3; despite the practitioners acknowledge the interdependence, it is too complicated at present time to modify the chosen product architecture to the supply chain set-up.

As for F-Euro 3, Global-Company and Facility-Europe realise a high level of inter-dependence shortly after commencing the creation of detailed specifications. Despite intense collaboration during this stage of the development, the practitioners are incapable of creating a workable prototype. Three contributing factors to the termination are identified. First, upstream the development the practitioners employed at Global-Company determine the functional specifications on their own; they are not aware of F-Euro 3 differs radical from the current understanding and existing solutions; they do neither address issues related to the product architecture nor to the manufacturing and supply chain set-up. Second after handing over the functional specifications, the practitioners employed at Global-Company and Facility-Europe do not achieve a convergent understanding in terms of how the “specified customisation options” influences the choice of product architecture and likewise the consequences in relation to the manufacturing-/supply chain architecture; the manufacturing and supply chain are tailored to fulfil current sales variety/volume and not to customisable products. Third, even though the interdependence becomes acknowledge when creating the prototype the practitioners do neither gain an understanding of the interfaces at subsystem level nor how to manufacturing these subsystems. Contrary to F-Euro 2 development, the

practitioners do not involve an external specialist in an attempt to gain access to the necessary knowledge.

4. Discussion and conclusion

The rightmost part of Figure 1 summarises the analysis of the six projects, while the figure to the left suggests three different approaches to gain access to and utilise practice-embedded knowledge depending on degree of newness and degree of interdependence.

The "time axis" in the rightmost figure illustrates the stage/gate approach; in accor-dance with the business-as-usual approach Global-Company has the lead upstream the "point of transition", while the abroad facility takes the lead downstream this point. Newness and interdependence are depicted at the other two axes.

As it appears from the figure, at the outset of the CE the anticipate newness and interdependence are low in all six projects. The arrows alongside the time axis, starting and ending at the grey squares (F-Asia 1 and F-Euro 1), grey triangles (F-Asia 2 and F-Asia 3), grey circles (F-Euro 2) and grey rhombus (F-Euro 3), illustrate how the perceived newness and interdependence unfold during the six projects. The grey square arrow demonstrates CE where practitioners are familiar with the development and thus the handed over information. The *transferred* information enables the practitioners to accomplish the development on their own. The grey triangle arrow illustrates an example where the transferred information is insufficient meaning that the abroad practitioners are incapable of accomplishing the development on their own. A higher degree of newness and interdependence becomes apparent and it is acknowledged that the abroad practitioners need support to *translate* the handed over information; in other words, costly iterations are necessary to bring the two projects back on track. The grey circle and grey rhombus arrows show that the handed over information is obscure for the abroad facility and despite the acknowledgement of a high interdependence the two interacting companies are incapable of gaining a convergent understanding. The analysis demonstrates that something is a stake in terms of the chosen product architecture as well as in the existing manufacturing/supply set-up. The involvement of an external specialist enables a *transformation* of the information handed over in F-Euro 2 (grey circle arrow), which is not the case in the F-Euro 3 (grey rhombus arrow); the high degree of interdependence is not acknowledge and at the end the project is terminated. Hence, at the point of transition the one-size-fits-all knowledge transfer approach is habitually applied. Likewise, the consequences of the actual degree of newness and interdependence are not acknowledged before the abroad facility throws in the towel. This reactive approach results in the practitioners are incapable of handling the information; in the words of Galbraith [12], the practitioners are overloaded with information, which results in costly iteration and a termination of one of the project.

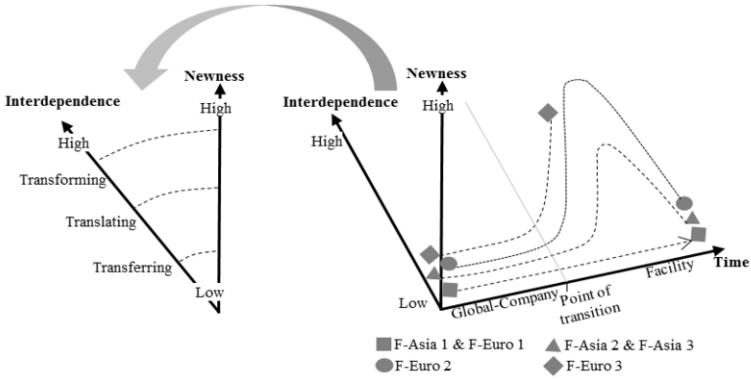


Figure 1. Newness and Interdependence, and three approaches.

This paper suggests a proactive and ongoing reflective assessment of the anticipated degree of newness and degree of interdependence. Obviously, an unambiguous clarification of newness and interdependence is not possible prior to doing the development, but the assessment should be precise enough to understand how difficult it will be for the practitioners to gain access to and utilise the practice-embedded knowledge. The leftmost part of the above figure 1 is a mirror image of the newness and interdependence axes in the rightmost part of figure 1. Based on an assessment of newness and interdependence an approach to handle practice-embedded knowledge is decided. Three approaches are suggested; transfer, translate and transform.

A low degree of newness and interdependence means that the practitioners are on safe ground and thus can draw on well-known solutions (see the analysis of F-Asia 1 and F-Euro 1). As the practitioners are familiar with the development and they know how to understand the handed over knowledge the transferred approach is suitable.

A medium degree of newness and interdependence entails that the practitioners are unfamiliar with and therefore do not offhand understand the handed over knowledge, which is needed to accomplish the CE activities. To gain a convergent understanding the practitioners have to do a translation of the accessible practice-embedded knowledge; in the analysis of F-Asia 2 and F-Asia 3, we witness how practitioners having different organisational affiliation gradually translated the handed over specifications.

A high degree of newness and interdependence means that the received knowledge misfits the current technical solutions and/or manufacturing/supply chain set-ups and thus the prevailing understanding within the specific working practice; as demonstrated in the analysis of F-Euro 2 and F-Euro 3, something is at stake. The achievement of a convergent understanding depends on whether it is possible to transform the practice-embedded knowledge, either within one or among all involved working practices.

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Advanced Manufacturing for Dental Prosthesis Prototypes Development: A Conceptual Model

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Abstract. The quantity of research being done in the oral health has grown significantly in the last decades, acquiring a more interdisciplinary characteristic. As consequence, there has been a large amount of engineering applications developed to this knowledge area. Oral health is directed linked to the well-being and can aid in the prevention of several severe diseases. The more recurrent cases of deteriorated oral health are related to the loss of teeth during the patient's life. Oral dental implants are the solution to this problem; however, they present high complexity development processes and in consequence almost all the work is done handcrafted which entails problems with the precision and comfort of the prosthesis. Therefore, the objective of this research is the development of a conceptual model for the use of additive manufacture and rapid prototyping integrated to CAD/CAM systems to aid the development of an oral prosthesis in an integrated product development process environment. To reach this objective, at first was made a literature review of the relevant subjects. Afterwards the advanced manufacture conceptual model is developed to ensure standardization and formalization of the manufacture and development processes of the oral implant. The conceptual model is then applied in the development of an oral prosthesis in a computational environment. This conceptual model aids the surgeon-dentist to develop and manufacture the oral dental implants more rapidly ensuring the products quality, through the standardization of the manufacture and development processes the conceptual model also reduces the cost and waste of resources of the development and manufacture of an oral implant.

Keywords. Dental Implants, Advanced Manufacturing, Transdisciplinary Engineering, Integrated Product Development.

Introduction

In past decades, dental implants have had their cost reduced and an increase on demand with the crescent use of computational tools and the development of new materials. In spite of this increasing use of technology, most of the implant manufacture continues almost handcrafted and made to attend patients in a case-by-case basis, which

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culminates in low standardisation along the process. The consequence of that problem is an increase in time and costs to the development and to the patient [1].

Computational environments, such as the CAD/CAM environments, associateded with advanced manufacture sistems, e.g. additive manufacture systems and rapid prototyping systems, are able to increase volume and speed in production, reducing the time and costs by adding an standard procedure to the dental implants development and manufacture.

The objective of this research is to develop a conceptual model that uses computational tools integrated to advanced manufacturing systems in an integrated product development environment, defining, by that, an standard methodology that will aid the development and manufacture of a dental implant.

1. Research Methodology

This research has an applied nature, using as technical procedure an experimental case. It has a qualitative approach, since a subjective comprehension of a topic is desired by studying its context [2]. The emergent nature of the concepts analysed classifies the scientific objective as exploratory.

The purpose of this research is to develop an advanced manufacturing conceptual model for dental implants, which aims to improve standardisation during the prosthesis development stages. The methodology for this research is mainly divided in four stages, as shown in Figure 1.

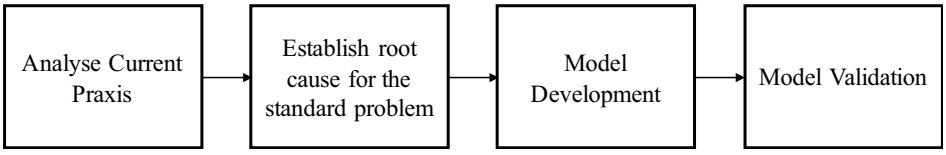


Figure 1. Methodological Procedures.

2. Research Background

This section approaches the research's background through a literature review, which allows a deeper understanding of the concepts approached. This background reviews the concepts of: Dental Implants and Osseointegration, Integrated Product Development Process (IPDP); Computer Aided Design and Manufacture(CAD/CAM); Design for Manufacture and Assembly (DFMA); Advanced Manufacture.

2.1. Dental Implants and Osseointegration

Dental implants arose significantly as a research topic and praxis in past decades, achieving more than one million procedures every year [3]. The implants work as a solution for esthetical issues, problems in the chewing process and phonetic functions of patients.

The process of osseointegration (also called the Bränemark system) is largely adopted by surgeon dentists in latest decades as means to perform the implant. The osseointegration works as a connection, in structure and function levels, of the living

tissue and the implant structure, subject to functional tensions [4]. Osseointegration mainly adopt implants consisting in two parts. The base (placed inside the organism) is commonly known as “pin”, which consists in a conical structure made of titanium (for its biocompatibility and mechanical properties) ; and the external part is commonly known as “crown”, which consists in a polymer exterior, and a metallic inner structure [5]. The crown still presents issues in its manufacturing, as its development is still done mostly by hand and with no standardisation.

As of procedure, the Bränemark system gathers two stages: the first is the Surgical phase, in which the titanium pin is inserted; and the second is the Prosthetic phase, in which the prosthesis (crown) is connected to the pin [6].

2.2. Integrated Product Development Process

The competitive industrial environment is characterized by atending the needs of the consumers for inovative products. The product development oriented to the client aids in the achievement of a competitive advantage and indicates important factors to the success of the product [7].

The product development process has become one of the main factors in the competitiveness in the industrial world. In consequence, a demand to integrate the phases of this process has become vital, as it reduces the development costs and enables the conception of products with higher quality. Therefore, methods were created to aid in this integration, composing the methodology of Integrated Product Development Process [8][9][10][11].

This methodology might bring significant improvements to de the dental implant area, as IPDP is an approach for integrated and parallel development in which are considered the life cycle processes, manufacturing processes alongside the products thecnical requirements [12]. In dental prosthesis development, these three planning factors are key to an optimized result.

2.3. Computer Aided Design and Manufacture (CAD/CAM)

The use of computer software to assist in the product design and manufacture is a practice in expansion and aids remarkably in the stages of product development. Through the use of CAD and CAM software during the development of the project, it is possible to carry out simulations in virtual prototypes which gives greater reliability to the product and reduces the cost of the development process [13].

The use of computational systems in the product development process is not restricted to the manufacturing industries. In recent years, the use of CAD/CAM systems for the development and manufacture of dental implants, especially zirconia and ceramic crowns, has emerged as a popular treatment alternative [14] [15].

Improvements in CAD/CAM technology have changed the way dental implants are placed and fabricated. The use of computational environments and a process planning model, based on prosthesis treatment, enables more precision to the procedure, implying less discomfort for the patient and issues to the surgeon [16].

2.4. Design for Manufacture and Assembly

The Design for Manufacture and Assembly (DFMA) is a method for supporting the product development, aiding the sincronicity of design and planning stages. DFMA considers the product's manufacturing and assembly process during its conceptual development [17]. One of the methodology's big differentials is its capacity to analyse each component and system of the product, regarding necessity and function, as well as manufacturing capacity and methods to simplify the assembly of the final product [18].

In an integrated product development environment, DFMA aims to product design and manufacture planning take place simultaneously. The methodology helps to adapt the product to the productive characteristics of the company, reducing costs and production time while increasing product quality [19].

In dental implants, the most important to consider during manufacturing and assembly is the surface. To achieve that, original requirements of a product development project should be rethought during the application of DFMA to establish new quality requirements, considering: simplicity, materials, standard components, releasing tolerances and reducing secondary operations [20]. In this context, the DFMA methodology considered might bring new thoughts regarding the mentioned requirements associated with the surface of the prosthesis [21].

2.5. Advanced Manufacture

Advanced manufacturing systems are systems that use mechanical, electronic and computational subsystems to operate and control production, encompassing a large set of machines that execute, monitor and connect production processes [22].

The adoption of advanced manufacturing technologies is a key condition for maintaining the company's competitiveness in the long run [23]. However, many advanced manufacturing implementation projects fail to be more significant in small and medium-sized enterprises, as the managers of these companies trust their instinct and base the information from similar companies instead of creating an specific model [24].

Currently, dentists are tending to use advanced manufacturing techniques more often. The applications vary from prosthesis manufacturing, patient's analysis and diagnosis to the creation of study materials and manufacturing of aiding tools [25].

3. Conceptual Proposal of an Advanced Manufacturing for Dental Prosthesis Prototypes Development

This research proposes a conceptual model, in order to adress the lack of standardisation and to approach the new tecniques used in dental implants procedures. The development of the model considered the root cause for the issue with standards, which consists in little or no defined methodology. Commonly, a patient has its information collected and the dentist starts the creation of the model right afterward. This method implies in a trial and error situation based on the skill of the professional, in which to create the prostheis, he must design and manufacture a number of prosthesis until one presents the correct characteristics.

The conceptual model proposes a method to reduce the uncertainty and depend less on the skill of the dentist and seeks to standardise the stages of development and manufacturing of dental implants.

Firstly, it was defined that information should be digitalized so it becomes easier to communicate each step of the model. To scan and generate a 3D model, the DICOM (Digital Imaging and Communications in Medicine) was used, as it is the standard method used in medical applications [26].

The conceptual model consists of 7 steps that range from the collection of patient information to the manufacture of the dental implant to the processes of additive manufacturing and rapid prototyping (Figure 2).

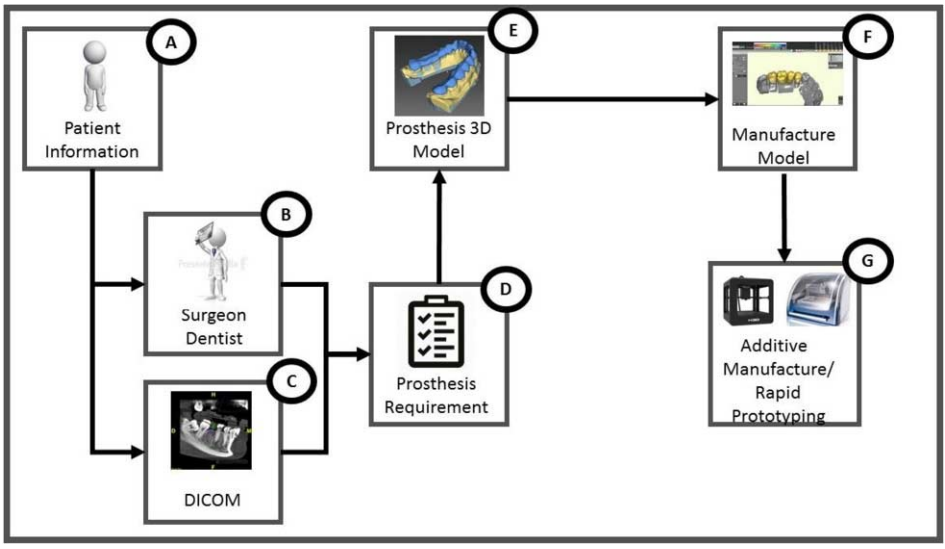


Figure 2. Dental Prosthesis Development Model.

Detail A of Figure 2 refers to the set of patient information necessary for the development of the implant, information such as bone density, teeth to be placed, etc. This information is translated to implant technology information through the observations of the dentist and DICOM (Details B and C of Figure 2). The dentist is responsible for translating patient information into pin specifications, procedure to be performed, etc. While the DICOM method translates the location information, size and shape of the implant.

Detail D of Figure 2 is the compilation and conversion of patient information that has been translated into details B and C of Figure 2 into design requirements, e.g. patient information creates constraints that the dental surgeon will have to follow during the development and manufacture of the dental prosthesis. This step is the main difference from the traditional method, as before modelling, all constraints are considered in order to provide an optimization in the modelling process.

The detail E of Figure 2 is the development of a three-dimensional model in a virutal environment (CAD) of the dental implant, based on the scan using DICOM and respecting the requirements created in the previous step. This model is then converted to the creation of the model of manufacture, also in virutal environment (CAM) (Detail F of Figure 2). The manufacturing model is then used for the manufacture of the

prosthesis through additive manufacturing processes or rapid prototyping (Detail G of Figure 2).

4. Experimental Case

The experimental case proposed compares the average time of the prosthesis developmet using the conventional method and the proposed by the conceptual model. The conventional method, which is the most used currently, consists in the dentist creating 3D models to rough manufacture and finishing by hand a number of times depending on his skill, with little or no standardisation in the process. The proposed model consists in capture and standardise information, creating a 3D model, a virtual manufacturing model and further 3D printing, reducing it to one or two iterations, regardless the skill of the professional.

For this case, the fictional patient is considered to be completely edentulous (no teeth), so the prosthesis development must rely on patient's information and developed from scratch. This particular case was selected so that no teeth can be used as a basis to start, as in partially edentulous patients the development is based on simetry.

The experiment used the work of Joda and Brägger [27] as the reference time to the traditional model. The time was measured using a chronometer during the development of the prosthesis. The results are shown in Table 1.

Table 1. Method Comparision.

Procedures	Proposed Model
Patient Information	21 min
Surgeon Dentist	6 min
DICOM	9 min
Prosthesis Requirement	20 min
Prosthesis 3D Model	26 min
Manufacture Model	33 min
Manufacturing	43 min
Total Time of the Proposed Model	**Approx. 158 ± 6 min**
Total Time of the Traditional Model	**Approx. 185.4 ± 17.9 min**

As demonstrated, the model offers a time reduction in the process. The standardisation provided by the model and the requirement step made easier to define the parameters to move between each stage. This validates the hypothesis that the conceptual model proposed could reduce time in comparision with the traditional model.

5. Results of the Experimental Cases

The experimental case has shown a remarkable reduction in time using the conceptual model, in comparision with the traditional method, almost 15% less time. The manufacture of the dental prosthesis in the case considered a set of standardised information and of easy manipulation, which saved time during the design and

manufacturing planning of the product. Each stage was submitted to scrutiny after its completion, so there was no misinterpretation or redundance passed onwards.

It is possible to imply that the created model was cheaper than the traditional one, as very few adjustments were necessary to achieve a final product. The prosthesis presented a satisfatory finishing visually, which shows that its complex geometry can be achieved through advanced manufacturing process.

The printed crown fits in with the pin, but its assembly in a human subject still must be tested. Also, for this research, the crown wasn't tested regarding its tension limits and different possible materials, which might be analysed in further research.

The conceptual model proposed has shown a simplified way to standardise the manufacture of a dental prosthesis, this way improving communication, sincronicity and reducing time in development. Also, the information in the process is now traceable, so when there is a problem it becomes easier to find.

6. Conclusion

The proposed conceptual model was able to standardise the phases of the dental prosthesis design and manufacturing process, reducing the time and cost of the project without reducing the final quality of the product in many aspects. This standardisation, coupled with the use of advanced manufacturing processes such as manufacturing and fast prototyping, integrated into CAD/CAM computing environments, guarantees the geometric and dimensional characteristics of the implants, as well as providing the flexibility for the development and manufacture of several implants according to the need of the surgeon.

This research provided a formalisation for the process of prosthesis development, improving this way the communication and information sharing. The model integrates new technology and validated procedures to improve the current status of dental implant, this way optimizing the method and possibly the surgical procedure as well.

For further works, it is suggested that research shine light to different materials to explore, tensions in the printed product and testing in human subjects. Other possible works relate to the exploration of this model as basis to develop a formal informational base, to develop knowledge and explore an automated system alternative.

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A Concurrent Design Architecture for Electronic Product Design and Test

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Abstract. Concurrent Design (CD) has been applied in space missions and systems designs since the European Space Agency (ESA) evaluating the benefits of CD towards assessment studies as part of the definition for future space missions. In 1998, the European Space Research & Technology Centre (ESTEC) Concurrent Design Facility (CDF) was established to perform concurrent assessments of space missions. CDF approach is an alternative to the traditional design methods due to its abilities to address deficiencies such as, lack of synergy among design teams, inefficient design cycle, lack of systems-level perspective and developing a completely consistent design process. Research institutions, industries and universities using CDF/CE have reported better results than traditional methods for end-to-end space missions and space systems design projects. But, over the past 20 years, CDF/CEF has focused mainly in aerospace system design when compared with automotive and electronic products designs sectors. These commercial product design/manufacturing sectors are important to our global economy too, so CDF/CEF methods should also be widely expanded into these sectors. This should helps meet market windows, lower product costs with improved quality and reliability. In this respect, more engineers are required to be trained in CDF focusing in automotive and electronic products designs for production. This paper provides high level description of early CDF architecture, electronic volume production line architecture, and integrate the relevant parts of both to derive an enhance CD architecture. Next, the working principles of the main testing platform to capture production defects will be presented in order to show the benefits of incorporating design-for-testability (DFT) especially in the early CDF design phase, before providing an adaptation of this enhance CD version [1], suitable for education. This aims at familising students in the process of application of specific domain disciplines including design-for-manufacturability (DFM) and design-for-testability (DFT) for volume production.

Keywords. Concurrent Design Facility, Aerospace design education, Space missions and systems, Automotive engineering and Electronic Product Designs.

Introduction

Concurrent Design (CD) approaches have been applied in space missions and systems designs since the European Space Agency (ESA) evaluated the benefits of CD for future space missions [2]. The ESA Concurrent Design Facility (CDF) was established in 1998 to perform space missions assessments. The CDF approach is an alternative to the traditional design methods due to its abilities to address deficiencies such as, lack of synergy among design teams, inefficient design cycles, lack of systems-level perspective and developing a completely consistent design is difficult [3]. Research

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institutions, industries and universities using CDF have reported better results than the traditional methods for end-to-end space missions and space systems design projects.

This paper provides a high level description of the early CDF architecture and electronic production line architecture in Section 1 and 2 respectively. In Section 3, the working principle of a test platform to capture production defects is described in order to show the benefits of incorporating design-for-testability (DFT) especially in the early CDF design phase within the enhance CDF architecture (Figure 7). Section 4 provides an adaptation of the enhance CDF environment mainly for consumer electronic product and automative product design (target for volume production), which is also suitable for education. This is to familiarise students in the process of application of specific domain disciplines including design-for-manufacturability (DFM) and design-for-testability (DFT) for volume production.

1. Early CDF/CEF framework workflows

The CDF concept was first introduced by ESA for space mission design [2, 4, 5]. It started operation in early 2000, located in Noordwijk in the Netherlands. Its use to date has recorded a factor of 4 reduction in design time and a factor of 2 reduction in cost. increased no. of studies per year, quality improvement to provide quick, consistent and complete mission design, technical reports as part of specifications for industrial activities & capitalisation of corporate knowledge for further reusability [5, 6].

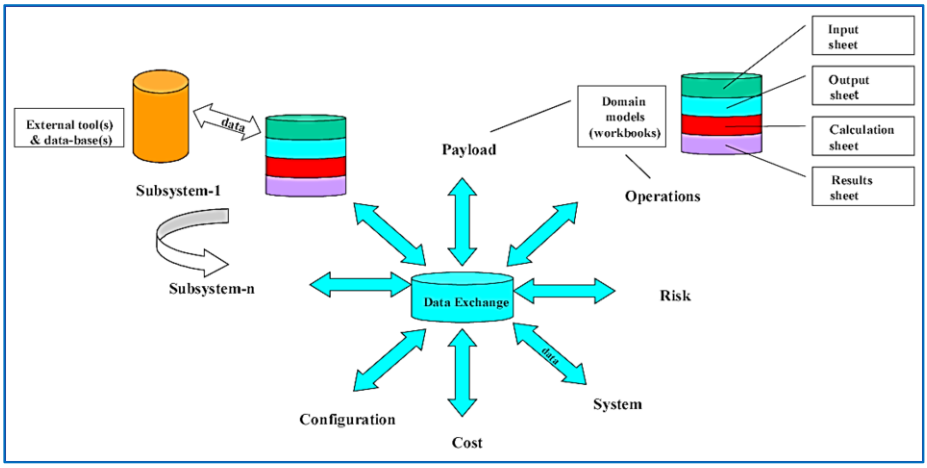


Figure 1. ESA/ESTEC CDF Architecture of Software Model [2].

The CDF process includes conducting model driven, highly co-operative and interactive design, which includes mission requirement analysis, mission analysis, subsystem design, designs verification, risk assessment and cost analysis, with design options comparison and trade-offs [5, 6]. The ESA CDF architecture is shown in Figure 1 [2].

2. Electronic Volume Production Line Architecture (PLA)

A typical electronic volume PLA is shown in Figure 2, which may consist of 8 main production stages. Production stage 2 and 3 may further consist of 3 sub-stages [1]. In general, a unit under production may consists of one or more Printed Circuit Board Assemblies (PCBA) housed in its associated chassis. Such PCBAs may typically use mixed technology, e.g. with topside Surface Mount Technlogy (SMT) and Plated Through Hole (PTH) components. After completing the main production stage 3 (Hand Load), the UUP will be transferred to the stage 4 (Test 1) to capture as much defects as possible. This is the In-Circuit-Test (ICT) platform, which determine the measured value against its set limit, one component at a time.

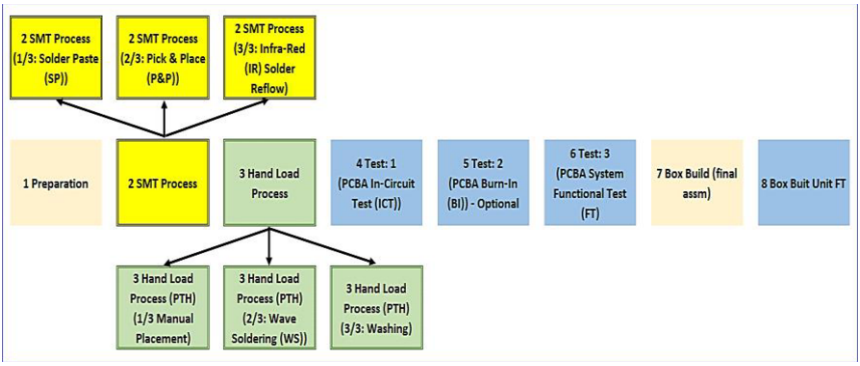


Figure 2. Volume Production Line Architecture (PLA) [1].

If the meaured value is outside the set limit, it is considered an ICT test reject. Subsequently, a team of engineers/technicians will debug the rejected PCBA to determine whether the reject was manufacturing/test equipment or process, or product design related. The ICT passed PCBAs are transferred to stage 5 for Burn-In (reliability test – optional). After that, the PCBA System Functional "black box" Test (SFT) commences at stage 6. After passing this stage, the PCBAs are assembled into their associated chassis manually.

3. Working Principles to Capture Production Defects

In volume production environments, it is critical that every completed PCBA is free of defect. In reality, this is a challenging task to accomplish due to 'land and estate' limitation versus the need to pack as many features as possible into the smallest PCBA size. Therefore, this is likely to impact the manufacturability and testability of the PCBA, and limits the ICT and SFT "black box" test platforms to capture production defects. Consequently, the producton lead time is longer, cost is higher with lower quality and reliability. This section describes the working principles of the ICT and SFT platforms for determining the values and limitations for capturing production defects from poorly designed PCBAs. These descriptions provide a generally good reference point for consideration when proposing an CDF architecture for education. The aim is to familiarise students with what needs to be considered when designing a product for volume production.

3.1. Working Principles of In-Circuit Test (ICT) Platform

This section describes the basic working principles of ICT test system measurements of SMT components bonded to a PCBA, its limitations and work-arounds relating to DFT. This highlights the importance to include a production test supporting domain discipline, amongst others production related disciplines, within the initial design phase. Only analog SMT component testing is described here. After the PCBA has been in-line washed, it is transferred into the ICT area for production stage 4 (ICT Test 1) to capture as many production process/equipment and/or design related defects as possible. Such defects may include open/short circuits, missing/wrong/reversed polarity/faulty components. The ICT test system measures each component at a time, while isolating surrounding components. For example, in Figure 3, the ICT measurement unit applies a known voltage and measures the current through R_{Ref} in feedback loop to determine the unknown resistance R_M. This is often called "apply voltage, measure current." [7]. R_M measured is accurate because there are no other components connected in parallel to R_M.

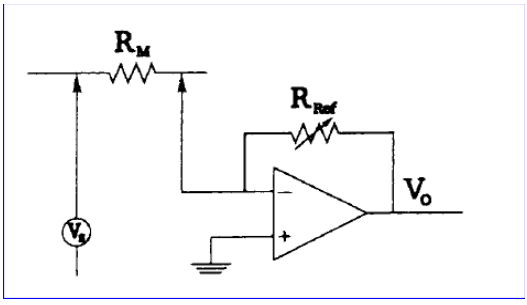


Figure 3. The "apply voltage, measure current" in-circuit measurement technique [7].

However, in many circuitries, parallel networks, such as those in Figure 4, are commonly used. So, the equivalent ICT measured value between X and Y using Eq. 1 is 6.67 kΩ though R1, R2 and R3 is 10 kΩ each. Under such conditions, the ICT test system is unable to measure the expected value of R1 accurately if the measurement point is only through a two-terminal X and Y nodes. In other words, it is unknown whether a 10 kΩ has actually been inserted/bonded or whether the 10 kΩ resistor is faulty.

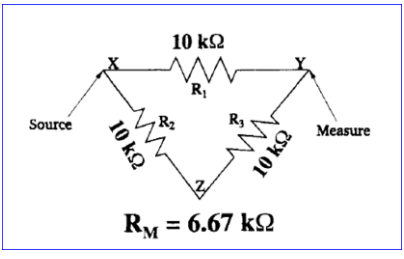


Figure 4. A measured value between X and Y of 6.67 kΩ is correct, while R1 is a 10 kΩ device [7].

$$\frac{1}{R_M} = \frac{1}{R_1} + \frac{1}{R_2 + R_3} \quad (1)$$

In such a scenario there are still two possible options available to determine that the 3 resistors are correct. Option 1 is to measure R1 accurately at 10 kΩ value. This is possible only if the ICT test system is able to assess node Z, i.e. via a hole used as test point on the bottle side of the PCBA – e.g. VIA hole is in Figure 6 (B)). If a Z node is available, the test engineer can include a guard point in the test programming instructions (Figure 5). The ICT test system is connected a ground node Z before measuring R1. In theory, there is no current flowing through resistor R2 or R3 because the Measurement point Y is at virtual ground and Z is at guard node ground, which is also at 0 V. Without voltage at the measure Y and guard node Z, there is no current flowing through both R2 and R3. This guarding at Z has effectively broken the parallel path and is said to have isolated the surrounding R2 and R3 from R1. All the source current from the known voltage source flows through R1 for an accurate measurement.

Option 2 measures R1, R2 and R3 together as a Block Circuit if the Z node is not assessible by the ICT test system on the bottom side of the PCBA. An example is shown in Figure 6 (C). The ICT measured value is 6.67 kΩ through point X and Y only. If this test fails, the debug technicians/engineers has to analyise all three components on the PCBA to determine the reject status. This takes longer than option 1, where only one component is analysed. It is important that the ICT test engineer collaborates with the PCB design engineer and circuit design engineer in the early design phase to optimise the block circuits test approach to assign test points.

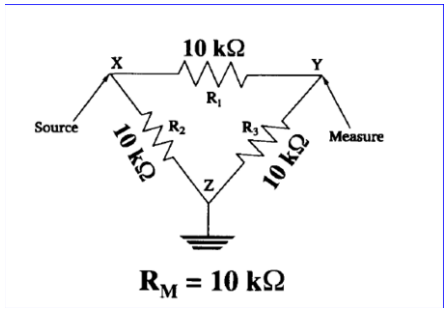


Figure 5. Grounds node Z before measuring R1. No current flows through resistors R2 or R3 [7].

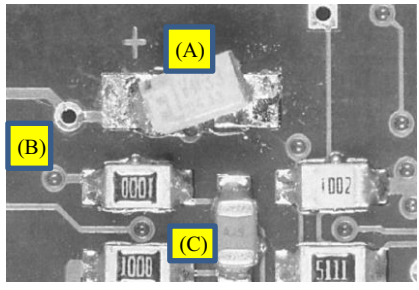


Figure 6. (A) An off-registration or off-pad component, (B) VIA holes linked to SMT pad/components allowing ICT test system to assess the SMT components for measurements and (C) notices that 2 SMT component pads is linked together without any visible VIA holes for use as test node [7].

The aforementioned ICT test principles and their limitations show the importance of facilitate testing in the design process. Poor ICT test coverage may result in the PCBA failing the System Functional Test (SFT). Such failure is generally more difficult to detect as SFT generally does identify a specific component failure. A PCB design engineer should always work closely with a circuit design engineer to optimise the test approach for circuitries that have little space on the PCB to assign VIA holes. Other considerations are VIA hole sizes and spacing. If a VIA hole size is too small, there may be contact problems due to mechanical accuracy. Large probes require a 1.0 mm hole and 2.5 mm spacing; it is able to reliably contact a 1.0 mm test pad for at least 10,000 connections. A smaller probe needs a 0.5 mm hole and 1.3 mm spacing. It is not as strong and is considered reliable for only 2,500 connections to a 0.5 mm pad [8].

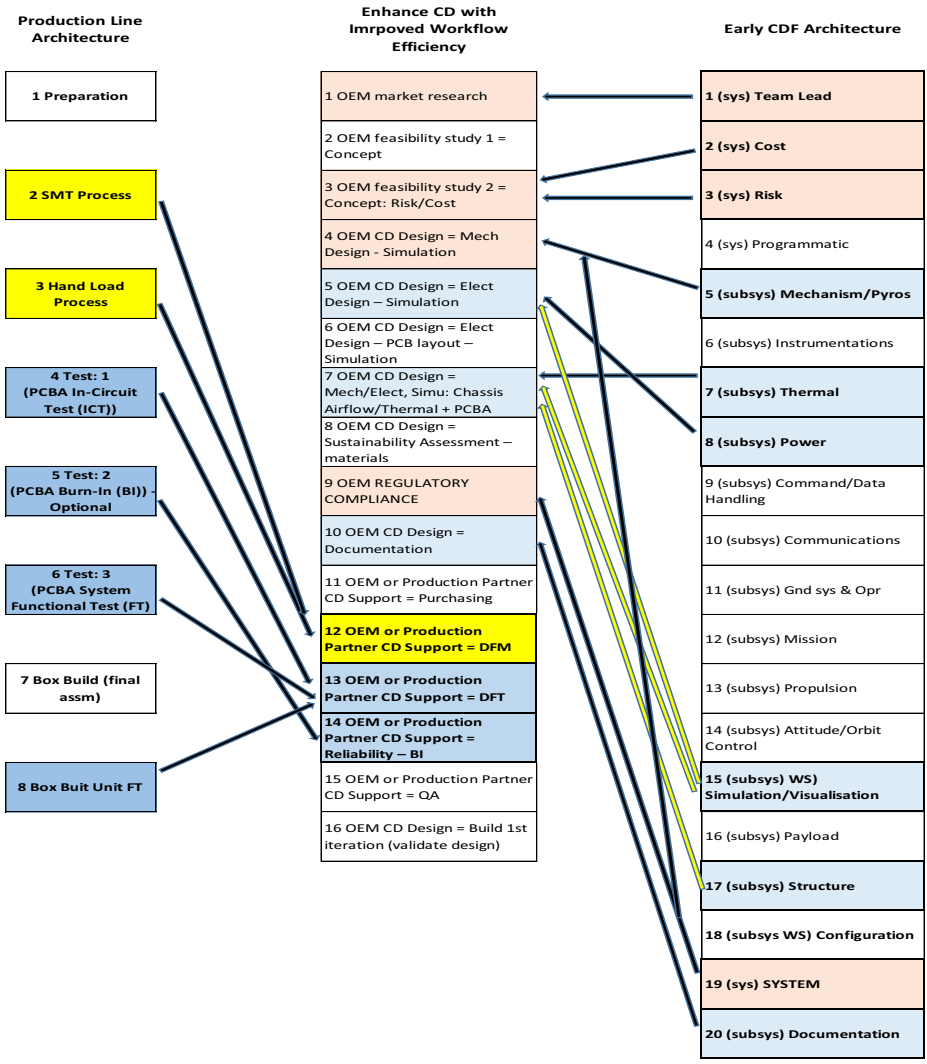


Figure 7. A CDF Architecture derived from a Production Line Architecture using relevant domain disciplines.

A CDF environment for electronic product design/manufacturing, e.g. consumer computer and automative audio/video/navigation with 16 domain disciplinesfor full product design cycle is shown in Figure 7. This new CDF environment includes production support in early design phase (middle column workflow) , derived from the relevant parts of Production Line Architecture (left column workflow) and early CDF Architecture (right column workflow). The advantages of this approach, which creates a new CDF environment with improved workflow efficiency is that, the first iteration design is unlikely to require further iterations re-design because potential manufacturing/test related defects were identified and resolved early in the 1st iteration design phase by production support specialists at almost real-time basis to the PCB design and other related design specialists. This is likely to provide better consistency in overall designed product performance, leadtime and lower production costs [1].

However, this approach is only workable if the selected supporting specialists are fully familiar with the complete specific capital production/test equipment operational limits and process limits which the targeted product is to be produced within it. The idea is to 'wrap' the product design around a specific production line environment, where each supporting specialist determines what the design configuration/limits are or are not workable within the targeted/selected specific production line process and equipment. Therefore, information required to determine manufacturability and testability comes from the extensive hands-on experience of each supporting domain specialist aligned to specific production processes. Such experience is also non-product specific, but mainly capital production/test equipment and process specific [1].

4. Adaptation of the enhance CDF Environment for Education

For educational purpose, smaller student team is more manageable and better suited [5]. The 16 domain disciplines can be reduced to 10 domain disciplines as in Figure 8. This effectively remove disciplines from Figure 7 considered less essential for familiarising students with CDF setting and process of application of specific domain discipline such as market research, sustainability assessment, materials, regulatory compliance, purchasing, QA and Build 1st (validate design) prototype. Common design software is to be used so that all stations could peer review almost realtime and provide quick feedback. Collaboration is by Email, MS Office, Skype video conference, realtime messaging and Cloud. Data/design models backup is by data exchange server and consolidation of sub-system and system level results is by spreadsheets and in-session discussions is by a large media wall and smart board.

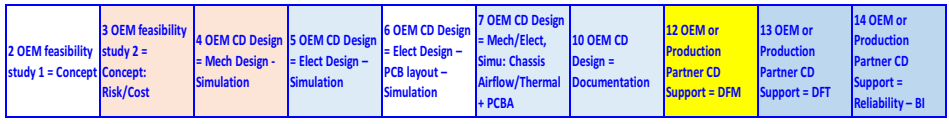


Figure 8. 10 Domain Disciplines in a CDF Architecture for Education.

Our approach, which adopt our proposed CDF integrated design environment (IDE), similar CDF layout and considerations of other CDF best practises/challenges described in detail in [5], do also have similarities to the approach adopted by [9], which is lesser, i.e. 10 essential study/domain discilines, is considered sufficient for educational purposes as the focus is mainly on familiarising students with the process

of applications of specific domain descriplines and not on actual continuous product developments. In this light, limitations described in section 3 is therefore not as critical for education (i.e. this approach only works if selected support specialists are fully familiar with the complete specific capital production/test equipment operational limits and process limits which the targeted product is to be produced.) Students are likely to acquire richer experiences in in-session design, almost-realtime collaborations internally [10], externally with other institutions, working together with every team members on the same pages, improving efficiency and completing the design projects with higher quality, shorter leadtime and less likely for re-design mainly due to DFM/DFT problems as presented in section 3.

5. Conclusions

In section 3, we have demonstrated that integrated production support domain disciplines is an important part in a CDF environment and should be an integral part of the initial design cycle in order to minimise the chances of re-designing due to mainly DFM/DFT problems. In section 3, we have also presented an enhanced CDF architecture derived from PLA and early CDF architecture, and proposed a CDF architecture in section 4, by adapting the enhance CDF architecture, with a reduced number of domain disciplines to accommodate smaller student teams. This is considered sufficient for education purposes as the aim is to familiarise students with the process of applying specific domain disciplines in a CDF environment with focus in consumer electronic product and automotive product design. This adaptation of a CDF environment is beneficial to students and the general electronic product and automotive industries as more such students are trained, and has the potential to become an invaluable tool for education.

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Product Data Management with Solid Transactional Guarantees

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Abstract. This paper presents an innovative software platform PDMhub intended to build concurrent engineering environments and to conduct multidisciplinary projects in various industrial domains. The platform provides advanced intelligent services for managing semantically complex engineering data, a formal model of which is specified in EXPRESS language. The platform enables model-driven engineering data to be shared concurrently among project stakeholders under different collaboration modes corresponding to varied levels of data availability and consistency trade-offs. Partial attention in the paper is paid to unique features of the platform and its key distinctions from existing solutions. Basically, these features are: versatility to handle different product model data and applicability in various domains, compliance with the STEP standard, vertical and horizontal scalability, availability of uniform interfaces to access and analyze engineering information as well as solid ACID/BASE guarantees for the supported transactions. The paper also briefly summarizes the preliminary employment results in the domain of architecture, engineering and construction and outdraws the perspectives of the platform in other industry domains.

Keywords. Concurrent engineering, STEP, DBMS, ACID, BASE

Introduction

In recent decades, concurrent engineering environments are widely used to conduct complex multidisciplinary projects in such industrial domains as aerospace, defence, automotive industry, shipbuilding, and construction [1, 2]. The drivers motivating their use are well-known. These are reduction of new product time-to market, improved profitability, raised sales and profits from downstream production, reduction of human and capital costs, increasing product quality, leveraging knowledge and experience, close integration between departments and promotion of team spirit [3].

While concurrent engineering is generally recognized as a practice allowing teams of designers to remotely communicate on a network and share engineering information in a common database, there are fundamental factors preventing the creation and deployment of concurrent engineering environments, namely:

- participation of small, medium and large enterprises having heterogeneous information infrastructures corresponding to their specific business profiles and practices,
- involvement of a large number of individuals and teams with own roles, responsibilities, expertise, skills and tools to solve particular problems,

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- semantic complexity of the engineering information circulated among project stakeholders,
- large volumes of diverse data to be managed and processed correctly and efficiently.

As the cornerstone of concurrent engineering is information sharing where designers freely exchange product and process information through an integrated computing environment, product data management (PDM) and product lifecycle management (PLM) systems like ProjectWise, Windchill, Team center, Enovia have got a certain popularity [4, 5]. Being developed to manage and control the volume of engineering data created by CAD/CAM/CAE software (spreadsheets, 2D drawings, solid models, documents, bill of material, images, design geometry, project plans, parts files, NC machine tools programs, analysis results, correspondence and reports), PDM systems are primarily intended to manage documents rather than entire datasets driven by formal information models.

The data integrity within documents is basically ensured by third-party applications, and PDM systems provide users with the ability to control the consistency between documents through reviews and simple check-in/check-out operations. These operations hinder real-time collaboration while particular documents are locked for reading or writing by individual users. However, some concurrency of design and engineering processes is reachable if the users proceed with different documents and the documents can be reviewed and reconciled with little effort.

The abovementioned PDM systems are succesfull for such use cases, however become quite limited and even useless if product data are represented as entire datasets driven by semantically complex information models like ISO 10303 STEP application protocols, ISO 13584 P-LIB, CIS/2, ISO 15926 POSC/CAESAR, ISO 18629 PSL, and ISO 16739 IFC [6, 7]. Being written in EXPRESS, the dedicated formal language developed within the STEP standard, these models define hundreds of interrelated data types and semantic rules.

For example, the IFC (Industry Foundation Classes) is an object-oriented data model intended to facilitate interoperability in the architecture, engineering, and construction (AEC). It is a commonly used to exchange and share information among BIM applications such as CAD systems, HVAC design systems, electrical design systems, formwork design and scheduling systems, structural analysis systems, energy simulation systems, quantity take-off systems, cost estimation systems, production scheduling systems, clash-detection systems, product information providers, steel and timber frame construction systems, prefab systems, stand-alone visualization tools.

Embracing multiple disciplines and providing interoperability among BIM applications, recent IFC 4 model defines 766 object data types, 391 simple data types, and 668 local and global rules [8]. These rules being applied to real product data induce millions of algebraic constraints which must be satisfied the product data be applicable in further sessions. Any constraint violation makes the dataset useless as the data cannot be uniquely interpreted even while ensuring application interoperability. Controling and maintaining the data integrity are non-trivial problems which cannot be effectively resolved by available PDM systems because of the fragmented document-based representations of product data.

Sharing product data among users is another critical problem. Being represented as an entire database or as a single file in full accordance with the SPFF format [6], product data have to be locked to avoid transaction anomalies. But it prevents the data

availability and results in the concurrency degradation. Therefore, emerging PDM systems should provide effective multi-access to the shared product data while preserving all the transaction principles.

The paper presents an innovative software platform PDMhub intended to build concurrent engineering environments and to conduct multidisciplinary projects in various industrial domains. The platform provides advanced intelligent services for managing semantically complex data, a formal model of which is specified in EXPRESS. The platform enables model-driven data to be shared concurrently among project stakeholders under different collaboration modes corresponding to varied levels of data availability and consistency trade-offs. The paper also briefly summarizes the preliminary results of the platform validation in the domain of architecture, engineering and construction and outdraws the perspectives of its employment in other industrial domains.

1. Transactional principles

In computer science, ACID (*Atomicity*, *Consistency*, *Isolation*, and *Durability*) is a set of principles that guarantee database transactions are processed correctly. Although the abbreviation was first introduced in 1983 [9], recently the ACID principles are commonly recommended for any traditional DBMS. PDM systems, being special DBMSs, should follow these principles too.

Atomicity implies that either all the operations in a transaction must happen, or none of them. The transaction must be completed if successful or rolled back if it fails. This principle works well for short transactions but it is unlikely to be productive for long transactions peculiar to concurrent engineering sessions. The results of long-term individual works should be taken and consolidated to the greatest extent even if some of the operations have been unsuccessful or conflicting.

Consistency assumes that any transaction brings the data from one valid state to another. Although this term is broad in scope, generally, it means both integrity and logical coherence of data. The data integrity is a critically important requirement as any violated semantic rule may result in the data corruption and uselessness for further transactions. The data coherence is a property that allows the attenuation caused by pending updates of partitioned or replicated data.

Isolation avoids any interference of simultaneous transactions with each other. Intermediate results within a transaction must remain invisible to other transactions. Often this property is defined as the ability to serialize concurrently executed transactions and to bring the results in a data state that would be obtained if the transactions were executed serially, one after the other. Insufficient isolation may result in anomalous phenomena such as dirty writes, dirty reads, non-repeatable reads, lost update, phantoms, skew reads, and skew writes [10]. This principle seems to be a strong requirement for concurrent engineering environments as the results of individual sessions should be deterministic and predictable even if they are arranged in parallel.

Durability assumes that results of completed transactions cannot be discarded. They must persist even in the event of power loss, system crashes or errors. To defend against these events, the transaction results need to be stored permanently in a non-volatile memory, e.g. hard disks. This principle is meaningful for the discussed applications due to the requirement to keep all valuable revisions of product data.

Strictly following the ACID principles, it is difficult to reach a compromise between data availability and consistency within concurrent engineering sessions. Usually, being written in EXPRESS, product model specifications contain hundreds of interrelated data types and semantic rules. For brevity, we omit consideration of specific structures pecular to this declarative object-oriented modeling language and draw attention to the fact that semantic rules are usually defined for both simple data types, object data types and object type extents. These rules may limit the values of the individual object attributes, may interrelate the states of different objects linked through associations as well as may constrain the states of entire object type collections.

Complex product models prevent effective multi-access to instantiated data which have to be locked entirely to avoid semantic violations. Indeed, a few ambiguous operations or uncoordinated transactions can disturb product data integrity because of the deep semantic relationships among data elements. Shared access to the product data in read mode and exclusive access to the product data in write mode seem to be the only way to isolate transactions safely. After a transaction has obtained an exclusive lock, the data becomes entirely unavailable for all other transactions which have to be blocked until the transaction commits or rolls back. A transaction that needs data access and requires an exclusive lock cannot start until there are no active transactions. High level isolation prevents all sorts of anomalies and guarantees the product data remains consistent, certainly, on the condition that individual software clients update it concordantly. This, so-called pessimistic transaction model is well suited to downstream design and engineering workflows allowing serial execution of works. However, it is quite onerous for the activities performed concurrently within large work packages by teams under strict time deadlines. As typical transactions in engineering applications are quite long, such isolation may result in the unproductivity of teams.

This contradiction between data availability and consistency is a consequence of a more general “CAP theorem” [11]. In practice, many DBMS allow selective relaxation of these properties for better performance and scalability. For example, NoSQL systems such as Amazon’s Dynamo, Google’s BigTable, HBase, Hypertable, Cassandra, SimpleDB generally do not provide ACID transactional properties, but follow to BASE (*Basically Available*, *Soft state*, *Eventually consistent*) principles [12]. As opposed to immediate consistency, eventual consistency means that fetched data is not guaranteed to be up-to-date, but updates are guaranteed to be propagated to all replicas eventually. This allows them to replicate and partition data over many servers and support extremely high loads of simple operations. With the advent of the web sites where thousands and millions of users may both read and write electronic mail, personal profiles, web postings, wikis, and many other kinds of data, scalability and performance have become a more important requirement than permanent consistency.

BASE principles are widely deployed in distributed DBMS, often under the moniker of optimistic replication. In contrast to pessimistic transactions restricting concurrent access to shared data, optimistic replication avoids blocking data elements and provides immediate access to data entirely without any preliminary locking. But the advantages in concurrency are realized due to weakening permanent consistency. Different diverged replicas must be periodically converged using syntactic or semantic reconciliation, which might then prove difficult or even insoluble. By this reason, BASE is sometimes criticized as increasing the complexity of distributed software applications [13]. However, sacrificing ACID in favor of BASE, optimistic replication technologies are widely used in such domains as collaborative environments, software configuration solutions, mobile databases, distributed services [14].

2. PDMhub platform

PDMhub is a software platform intended to build concurrent engineering environments and to conduct multidisciplinary projects in various industrial domains [15]. The platform provides an advanced set of intelligent services and functions for managing product data with solid ACID/BASE guarantees. Within PDMhub platform the product data are interpreted and processed in strong correspondence with underlying models formally specified in EXPRESS. Basic datasets can be supplemented by all sorts of documentation, and they are considered as optional secondary data. In the process of engineering and design activities, both basic data and secondary documents are subject to revisions, so the platform provides and leverages both product data management, document management and revision management.

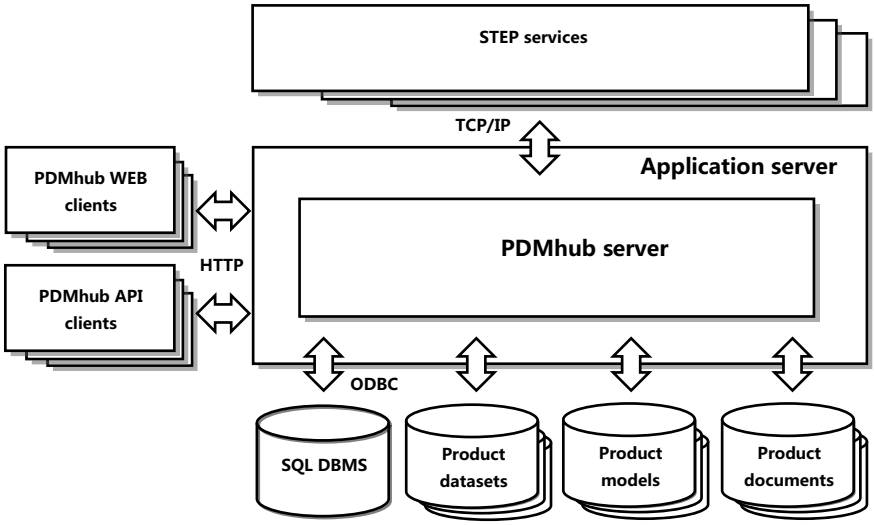


Figure 1. Typical configuration of concurrent engineering environment based on the PDMhub platform.

The platform comprises an PDMhub server running under Tomcat application server, general-purpose PostgreSQL DBMS used mainly for administration purposes as well as STEP computational services intended to process product data (to check the compliance with the underlying model, to compare and merge revisions, to evaluate queries, to generate reports, etc.). Although both product data and product models are internally stored as binary indexed files, they are available as SPFF files and EXPRESS files correspondingly. Figure 1 presents a typical configuration of the deployed concurrent engineering environment. PDMhub server, DBMS, computational services and clients can run on different computers providing the best scalability and performance. Hosting PDMhub server, DBMS and single STEP service on the same computer is also admitted.

The platform supports both vertical and horizontal scaling. The platform capacity can be increased (vertical scaled) by adding more resources, e.g. updating multi-core CPU, extending RAM, adding extra or larger hard drives to the existing computer network. The platform can be scaled up horizontally. It is accomplished by adding more commodity hardware nodes to the PDMhub cluster and running more STEP services there. Running on top of a computer cluster the PDMhub server balances load

of STEP services taking into account available resources of each individual node and computational tasks to be carried out.

PDMhub provides a straightforward JSON-based API through HTTP. That separates clients from the server so that clients are not concerned with data storage and processing, and the server is not concerned with the user interfaces and client functionalities. PDMhub API is logically organised as function sets intended to administrate projects, to query product data, to manipulate data and to analyse data. PDMhub API is uniform in the sense that it allows clients to access projects, product revisions, objects, attributes, collections in a uniform way independently of a particular product model. For brevity, we omit the technical details and focus on the supported transaction models.

3. Product data management with solid ACID/BASE guarantees

PDMhub server provides both pessimistic and optimistic transactions. In combination they support multimodal collaboration sessions corresponding to varied levels of concurrency and consistency trade-offs. Every supported transaction model strongly obeys either ACID or BASE principles. Ensuring these principles can be holistically satisfied using the presented revision management facilities.

PDMhub server processes client transactions which may be either read or write. A new revision appears whenever the client commits a succesful write transaction or checks in a new SPFF file. Read-only transactions do not produce revisions. Existing revisions can never be changed. Therefore, the full transaction history is represented as a product data revision tree with the root corresponding to the initial dataset and leaves — to its terminal representations.

The root revision is assigned the number 1.1. The next revision takes the number 1.2, the next succeeding — 1.3 and so on. Thus formed branch is called main branch (see Figure 2 to understand the applied revision indexing policy). New minor branches are created by committing write transactions on non-terminal revisions. New branches can be created intentionally to maintain alternative configurations of the same product. New branches can be created occasionally as a result of committing concurrent transactions proceeding on the same revision. Concurrent engineering environments must provide opportunities to both individuals and groups to work in parallel with a recent product revision. If all the transactions are successful, the first committed transaction produces a new revision on the original revision branch, and other committed transactions produce revisions on minor branches.

To reduce the entropy of occasionally produced revisions and to consolidate results of individual efforts and groupwork, the revisions merged using so-called three-way technique. A common ancestor is determined and deltas for the merged revisions are computed beginning from the ancestor revision. Then, deltas are analysed against potential conflicts and if no conflicts are detected the deltas are consolidated into a resulting one, which being applied to the ancestor produces a new final revision.

Delta calculus is applied in the platform by another reason. Storing all revisions is ineffective from the standpoint of hard disk space consumption. PDMhub server manages changes and stores only partial deltas between nearest revisions instead of full representations. Taking into account large size of product data and relatively low percent of changes between sequential revisions, the total space saving can be significant.

Because every successful transaction leads to a new revision, and unsuccessful — roll back to a previous one, atomicity property is ensured. Durability property is guaranteed as a result of saving key revisions and all subsequent deltas on disk. Any revision can be recovered using a key revision and delta calculus.

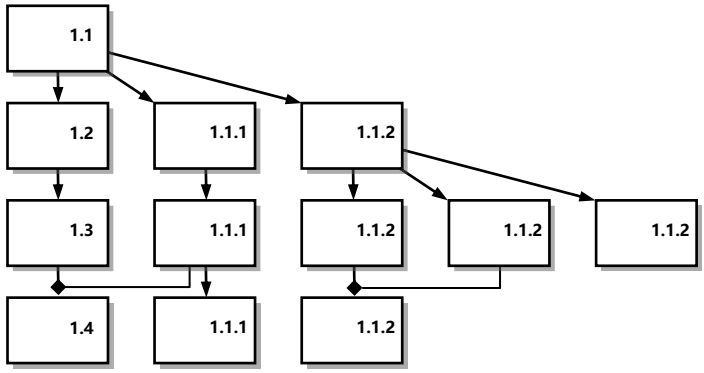


Figure 2. Managing product data revisions.

The isolation of pessimistic transactions and the ability for them to be serialized is provided by locking product revisions entirely. Locks at other granularity levels, i.e. at object and attribute levels, are not supported due to risks to disturb data integrity. Any revision can be locked exclusively for a single write transaction. Locking a revision entirely provides full isolation, avoids anomalies and eliminates semantic violations that could occur because of concurrent writes.

The isolation of optimistic transactions is naturally supported due to the fact that each transaction proceeds with its own revision and thus does not affect the other concurrent transactions. When necessary, the results of individual transactions can be merged. Risks of detecting conflicts and rolling back one of the concurrent transactions remain, however the number of such incidents can be minimized by proper organization of workflows.

Data integrity and consistency are not trivial requirements especially in the case of semantically complex product models. However, these requirements can be also ensured by PDMhub server within the adopted pessimistic and optimistic transaction models. The server provides functions to check the compliance of a product data with the underlying model. These functions enable to control not only separate revisions, but also every committed transaction and thereby to guarantee the integrity and consistency of the entire product data. Control of committed transactions, including those transactions which have been obtained my means of merging operations, is accomplished through incremental semantic checks. Such checks can be carried out much more quickly than a full validation of the produced revisions. Indeed, short transactions usually contain a relatively small number of operations which have local impact on related data. Therefore, typically there is no need to subject the entire revision to all checks. Only data related to committed transaction operations which may violate a semantic rule should be subject. Assuming that the initial revision and all transactions were validated, it can be argued that the entire product data representation is correct.

Thus, PDMhub platform allows effective management of model-driven product data with solid ACID/BASE transactional guarantees.

4. Conclusions

The innovative software platform PDMhub has been presented. Being developed for building concurrent engineering environments in various industrial domains, the platform has been successfully validated in the AEC domain [16]. The building process has been reduced to the assignment of the IFC as an underlying product data model and to the customization of a visual cross-platform web client intended to administrate the built environments and to perform some end-user activities by working with SPFF files interactively. The key inherited features such as compliance with the IFC standard, vertical and horizontal scalability, solid ACID/BASE transactional guarantees resulted in competative advantages over similar environments based on existing BIM servers.

Successful introduction in the AEC industry as well as versatility to handle different product model data give some prospects for the platform employment for those industries in which product data models can be formalized and specified in EXPRESS language or have been already formalized and accepted as industrial standards.

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Part 9

Knowledge-Based Engineering

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Transdisciplinary Engineering: A Paradigm Shift
C. Chen et al. (Eds.)

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CAD System Basic Operations Semantic Generalization to the Designed Product Construction Conformity

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Abstract. This article is devoted the approach to the product 3D-model maximal information content achievement. The proposed method is based on the accordance between the designed products actual construction and 3D-models creation tree in the CAD-system, comprising a basic operations set. Under the proposed approach, the 3D-model creation tree is a designed product functional elements formation semantic macrofunctions hierarchical set, which combination displays its construct structure.

Keywords. 3D-model, design process automation, informational content, design data integration, product subject area, CAD-systems, 3D-geometry, solid modeling, CAx-technologies, bijection, design knowledge, product functional structure, design solution generalization, CAD-system basic operation.

Introduction

CAx-systems become the main engineer design tool [1]. This is due to the constant enterprises desire to improve the products quality. So come to the forefront the problem of preservation and storage of design data received in CAD-systems for its modification and reuse [2]. A key aspect is the preservation of the design data in the form of electronic informational models – ***3D-models*** that can clearly be perceived semantically correct [3].

One solution to this problem – *Knowledge-based Engineering* ***(KBE)*** Technology [4, 5]. Knowledge-based design is the use of systems based on knowledge (*Knowledge-based Systems,* ***KBS***) – programs that use the knowledge base on the basis of cause-effect relationships to solve complex problems in the field of design and production [6].

Geometric models in the CAx-systems lineup are used to solve many different problems: from visualization, modeling and analysis to optimization and development of control programs for CNC equipment, etc. However, primarily the geometric models (3D-models) are used **to store** design data about the design product and **for processing** this data in a convenient form for CAD-system and engineers. CAD-systems is precisely product *"construction"* systems.

Designed product 3D-models is already fully its depict in the manufacturing process at the enterprise. Modern CAE/CAD-systems development reinforcing the 3D-

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models position in product lifecycle, especially at the stage of **R&D** [7], making the relevance of the *product* ***digital mockup*** [8].

1. Digital Mockup as the Primary Design Product Information Source

Within the concept of *digital manufacturing* consisting in the widespread and continuous use of three-dimensional informational images (**3D-models**) during the production systems design and exploitation, designed product is fully described by a set of design documentation in the form of a digital mockup. That is, the digital mockup is designed products injective mapping in the CAD-system:

$$CAD: Mod^{3D} \rightarrow Prod. \quad \textbf{(1)}$$

However, digital mockup the most informative and useful in complex design process achieved by displaying the designed product construct structure. Let's start in order, and first of all look at the structure of the digital mock.

1.1. Digital mockup structure

Product digital mockup is standardized as a direct geometric model, which describes its attributes set and a specifications set that shown in Figure 1. It is an analogue of the traditional *"paper"* design documentation, is defined as a document containing a design data clearly perceived right for reading and products producing.

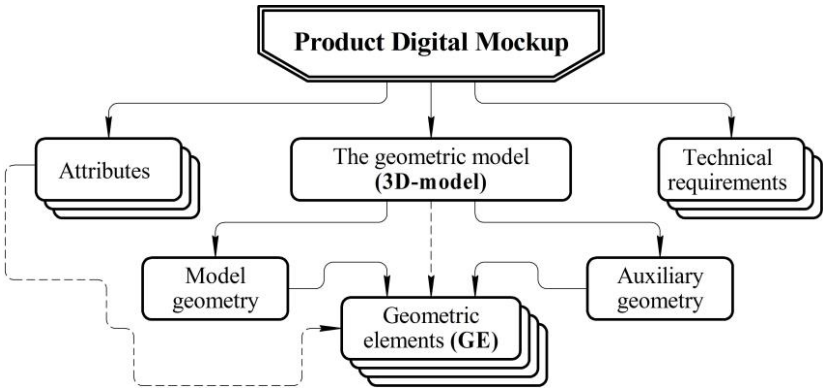


Figure 1. Product digital mockup structure

The core of the digital mockup is the product geometric solid model or a 3D-model – digital model describing the geometric structure, shape, size and other properties of the designed product (depending on its structure, shape and size).

Considering the digital mockup as ***the system*** stand out its main components:

● *Model geometry* ***(MG)*** – a geometric elements set that are components of the product geometric model .

● *Auxiliary geometry* ***(AG)*** – a geometric elements set, which are used in the product geometric model creating process, but are not elements of the model *(for example, center line, anchor points of the spline, plane forming the surface lines, etc.).*

● *Geometric element* ***(GE)*** – identified geometric object that used in the data set *(for example, point, plane surface, geometric shape, geometric body, etc.)*. Geometric elements included in the model and construction geometries: $GE \in (MG \cup AG)$.

● *Model attributes* ***(Att)*** – different dimensions, tolerances, text or symbol required to determine the product geometry and its characteristics.

1.2. 3D-model creation process

The product 3D-model – its electronic model that represents the geometric shape as a result of the composition given set of geometric elements within the *Constructive Solid Geometry* ***(CSG)*** *Technology* – with the use of Boolean operations to them. Geometric elements – the output of the *basic operations* ***(BO)*** CAD-systems. Thus, the product resulting 3D-model structure provided by hierarchical sequence perform basic operations, is presented in Figure 2.

As an example of the designed product presented **sleeve nut** from the coaxial radio frequency (RF) connector.

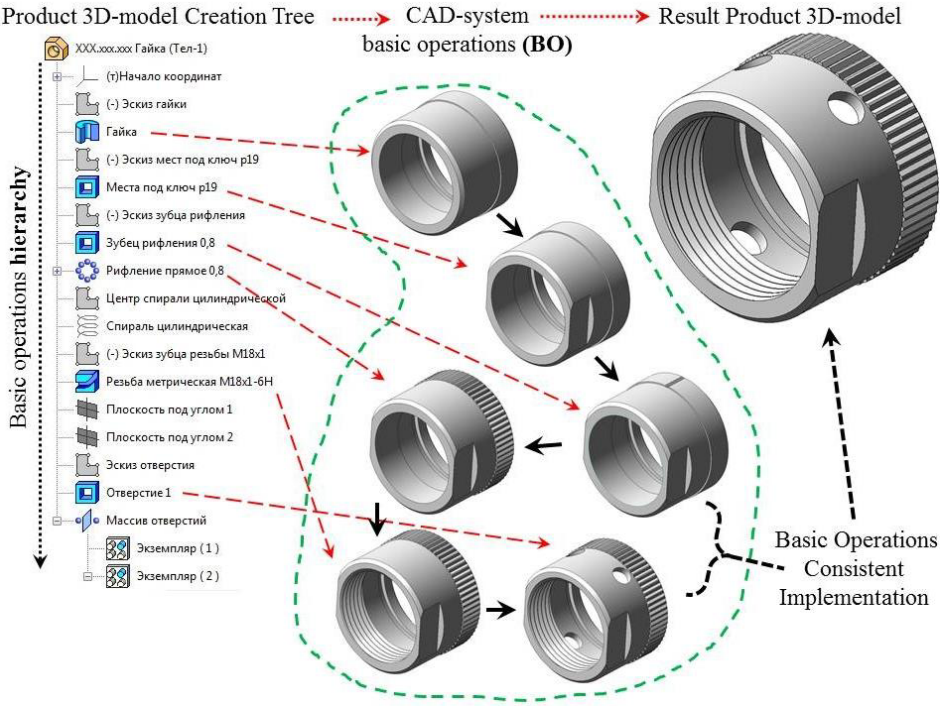


Figure 2. Product 3D-model creation process by CAD-system basic operation

Figure 2 shows that each GE sequentially complicates the resulting 3D-model, bringing it closer to the designed product step by step.

Product 3D-model thereby fully determined by the process of its formation in CAD-system and as a complete an ordered basic operations set, and consequently [9]:

$$Mod\ {}^{3D}_{Prod.} = \bigcup_{i=1}^{n} GE_i \qquad \textbf{(2)}$$

where the symbol «∪» denotes not directly under the addition of Boolean operations, as just a contribution to the resulting 3D-geometry formation.

Consider a in more detail the CAD-system basic operation as the mechanism of the GE formation.

1.3. CAD-system basic operation

Each BO is defined *identifier* ***(ID)*** within the CAD-systems. Base operation ID ***(IDBO)*** – a unique character-numeric designation assigned to each BO ensuring its uniqueness and difference from other BO included in the functional use CAD-systems.

IDBO is the basic operation main attribute, as it defines it as an instance of a class of all available in the CAD-system BO; a an instance BO, in turn, describes the unique internal implementation algorithms that determine a parameters set to be provided for their values to the engineer:

$$M_{CAD}^{BO} = \{\ BO_i < ID, Name,\ M^{par.}, M^{GE}, Alg.^{CAD} > \ \}, \ i = \overline{1,n}. \qquad \textbf{(3)}$$

where M_{CAD}^{BO} – a set of BO, incorporated in of CAD-systems; ***ID*** – identifier of the i[th] BO (BO_i), ***Name*** – BO name displayed for its engineer recognition; M^{par} – a set of the BO perform input data *(design parameters)*, M^{GE} – a set of the BO output data *(Geometric element)*, $Alg.^{CAD}$ – BO implementation algorithm: a sequence of project actions, performed in CAD-systems, comprising a set of abstract rules and conditions.

According to the formula (3), BO can be present as process within the the functional modeling methodology **IDEF0** as it presented in Figure 3.

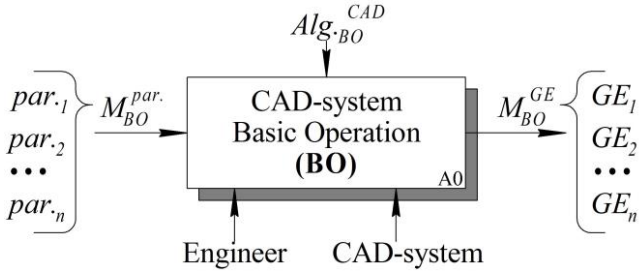


Figure 3. CAD-system basic operation process diagram in IDEF0 notation

As seen in Figure 3, the BO implementation mechanism is CAD-systems. It converts the input data values are specified by engineer to the output data as a set of GE, in according to a predetermined algorithm CAD-system *($Alg.^{CAD}$)*.

BO is the lower level of abstraction, as its semantic content is relevant only in the methods by used CAD-systems, and the GE, formed as a result of its implementation, is informative only for the relationship to a higher-level product geometry model [10]. Thus, to perform the BO, user needs, primarily working with knowledge of the principles used by the CAD-system.

2. The Designed Products Structural & Functional Representation

The *system classical definition* involves a set of any objects and relationships between them. The product, as a design object on the stage of development work, the **system** can be represented in terms of its design, as it is shown on Figure 4, and therefore:

$$Mod_{Prod.}^{3D} = < PFE_i, Constr.>, \ i = \overline{1,n}\ , \qquad \textbf{(4)}$$

where ***PFE*** – the product functional elements, which has a fixed meaning in the subject field of the designed product and specific functions perform in its design; ***Constr.*** – designed product construction (an instance the product materialization in the form of inter-related in a certain way PFE).

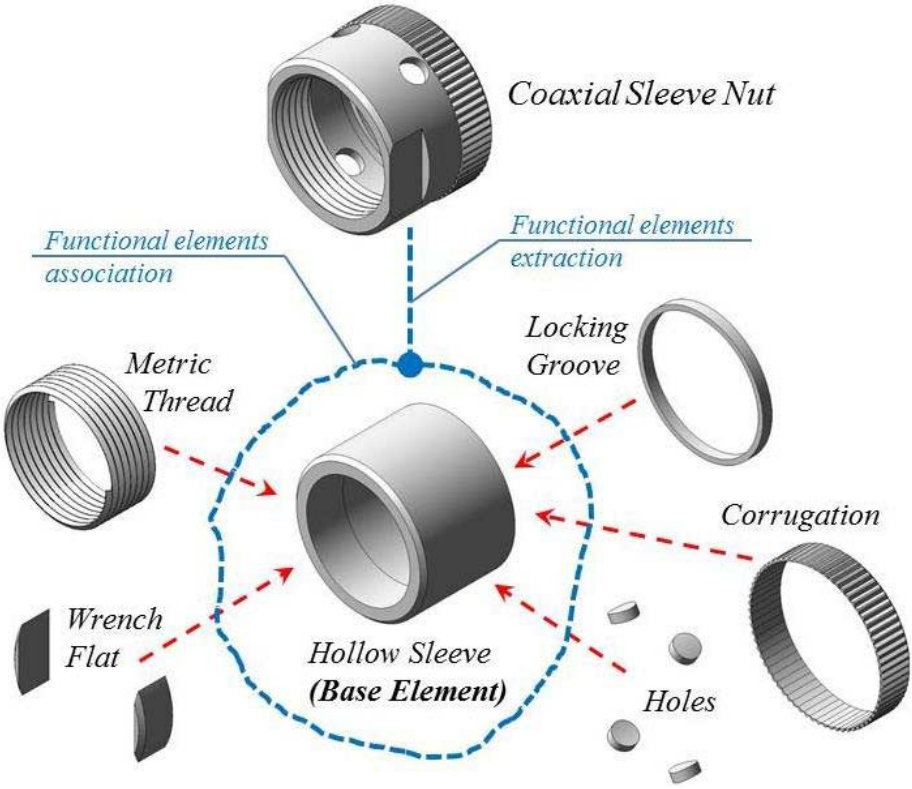


Figure 4. Product functional elements extraction

The functional structure is given in a terms of reference for products development as is its *"essence"*. The PFE relationship set provided by product design – the result of a construction engineering stage.

3. Design Product Information Imagingt in the CAD-system

The result of the construct phase of designing is the product construction formed, presented in a CAD- system by 3D-model as:

$$Mod\ {}^{3D}_{Prod.} = \{\ GE_i\ \},\ i = \overline{1,n}. \qquad \textbf{(5)}$$

in this case, as a rule, accordance of the form *GE→PFE* is not realized because of the high intellectual load on the engineer, as well as the long time for 3D-model creation and the requirements of the product internal device knowledge [11].

However, the ability to design data reuse is not at the level of the product, but at its PFE – this is a **significant** step towards the formation of the enterprise knowledge and opportunity to it accumulations and generalizations, as well as design knowledge reuse.

The classic method of PFE construction – by BO set, each of which – according to Figure 4. Such BO do not carry specific information about the object of construction (its semantic fullness): this relationship is necessary to think out their own engineer.

4. The Structural & Functional Product 3D-model Construction Method

4.1. The proposed approach essence

The proposed approach of the designed product informative imaging in terms of its structure within the 3D-model creation tree of CAD-systems is based on set of BO accurate accordance to PFE according with Figure 5.

This approach is based on the the next ***critical positions couple***:

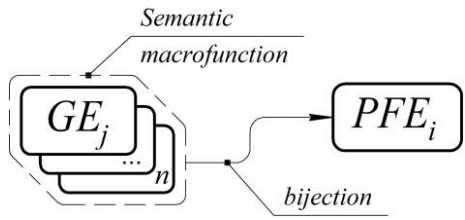


Figure 5. Semantic macrofunction and product functional element conformity

► Basic operations generalized to the level of the *semantic macrofunction* ***(SMkF)***, providing the design parameters totality for its definition and the intermediate data inaccessibility. *Macrofunction* – it is the PFE formation *indivisible element*.

► Formed a informative macrofunction attributes set by establishing formular, tabular and conditional dependencies between BO design attributes (parameters). This set of attributes *is not an abstract* carries meaning only within the CAD-system, and completely determines the appearance of the respective PFE.

PFE creation semantic macrofunction IDEF0-model is shown in Figure 6.

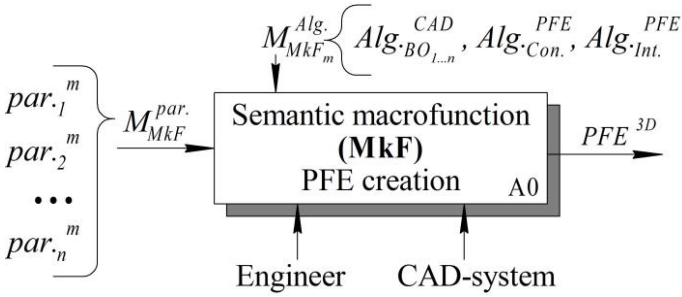


Figure 6. Semantic macrofunction process diagram in IDEF0 notation

According to Figure 6, the semantic macrofunction – an object with clearly defined behavior, regimented algorithm of its implementation, which displays all of the dependencies between the original data and the result of its implementation, as well as a clear data structure – can not be obtained as the result of its performance object does not fit, or violates the original inherent physical meaning.

The main purpose of this method, as has been noted, is design decisions reuse providing. As a rule, any new technical development based on some already known results, and therefore much easier (as in construction, technological and economical terms) used the already implemented product basis and modify it, changing its structure, geometry for new technical requirements. Such modified design solutions set form the semantic similarity class – products generalized according to their functional *(or purpose)*, is much higher than the classical geometry and structure generalization.

Figure 7 shows the information about the designed products structure – sleeve nut from the coaxial RF connector. As seen, product 3D-model **much more** than simply an abstract *"summation"* of geometric elements *(in CSG technology)*, as stated in the

formula (5) and carries a strict and clearly defined meaning in the designed product subject area in the form of conformity bijective: GE → PFE.

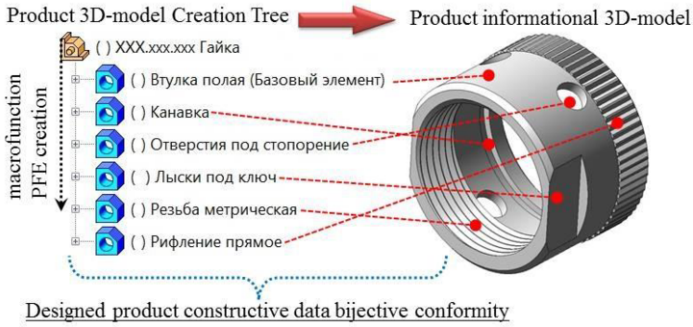


Figure 7. Semantic macrofunction and product functional element conformity in 3D-model creation tree

4.2. Further research

Further research conducted by the authors in this direction associated with a PFE generalization already on their *semantic orientation*. Figure 8 shows an example of sleeve nut semantic generalization. For modification is enough to change the semantic macrofunction attributes to appropriate to get a new design solution that satisfies the specified requirements is already new.

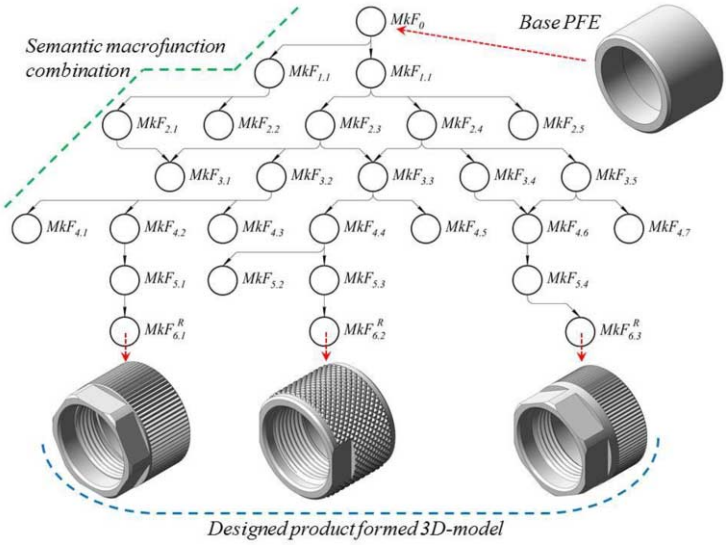


Figure 8. Designed product 3D-model creation (modification) by macrofunctions content

It is important to note that the algorithm of the macrofunction may be adjust – this *is not the enterprise standard*, it is the ***knowledge base*** of sector or department, summarized the content of the subject area. Furthermore, the addition of new macrofunction and the introduction of additional branches the project route is available to all engineers team. Thus formed the knowledge base, which not only takes into account years of hoarding reserve engineering knowledge, but also represents in a readable and reuse form.

5. Conclusion

Proposed by the authors approach to the designed product construct structure imaging in the CAD-system by a 3D-model creation tree posing its main task not simply the CAD-systems basic operation set duplicating. **The aim** – is the formation of their own macrofunctions, taking into account both engineering expertise and manufacturing technology in the enterprise. This method allows a design decisions reuse at the level of product structural elements and the enterprise's knowledge base formation.

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A Knowledge-Based Decision Framework for Merchandise Systemic Risk Management Under Cross-Broader E-Commerce Pattern

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Abstract. Cross-broader e-commerce has been a basic economic pattern of the world economy and an important channel of the world trade. Most merchandises are bought by means of cross-broader e-commerce is high risk products, and it is strongly related to the people's livelihood, such as imported food, cosmetics, health products and electrical products. Since overseas merchandise generally is sent to consumers by parcel express under cross-broader e-commerce pattern, it is difficult to find merchandise's risk by traditional port regulation pattern. Therefore, it is imperative to develop a decision support model for real-time and accurate identifying risk of merchandise by means of cross-broader e-commerce. This paper develops a knowledge-based decision framework for the systemic risk management of merchandise for cross-broader e-commerce trade. Firstly, a knowledge-based decision modeling is proposed, including ontology modeling for knowledge base and reasoning process for the problem solving method of risk identification, assessment and monitoring. Secondly, the corresponding decision support platform of merchandise systemic risk management is performed including decisiong framework, core technology and the structure of the platform. Finally, many typical cases are provided to illustrate how does the proposed knowledge-based decision framework is applied in practice.

Keywords. Cross-broader e-commerce, risk identification, risk assessment, risk management action; knowledge-based decision

Introduction

The economic globalization has brought the rapid development for the global economy and trade, especially with science and technology promotion, cross-border e-commerce has experienced an unprecedented growth in recent years. Take China as an example, the value of general import and export trade reached RMB 24.59 trillion in 2015, and the value of cross-broader e-commerce trade achieved RMB 5.4 trillion, accounting for 22% of the general import and export trade. Furthermore, the cross-broader e-

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commerce trade maintains a growth rate of about 30%, it is well above the development of general trade. Chinese Ministry of Commerce predicts the value of cross-broader e-commerce trade expected to reach RMB 5.4 trillion, and the proportion of cross-broader e-commerce trade will continue to increase in the future. All this shows that cross-border e-commerce has become an important way of economic and trade liberalization in the world.

However, many risk problems are emerging quietly with the rapidly expanding of cross-broader e-commerce, particularly the merchandise importing through online shopping overseas contains a lot of risks. In view of the various import categories, extensive original countries, numerous risk points, diversified data sources and huge information volumes of cross-broader e-commerce trade, the traditional risk supervision model cannot meet the supervision demand of cross-border e-commerce development. Therefore, the construction of risk management platform for cross-border e-commerce trade has become extremely essential and urgent.

This paper presents a decision framework of knowledge-based systemic risk management of merchandise for cross-broader e-commerce trade, this framework can provide risk identification, risk assessment and risk monitoring for cross-broader e-commerce trade in real-time. Firstly, a knowledge-based decision modeling is proposed, including ontology modeling for knowledge base and reasoning process for the problem solving method of risk identification, assessment and monitoring. Secondly, the corresponding decision support platform of systemic merchandise risk management is performed. Finally, many typical cases are provided to illustrate how does the proposed knowledge-based decision framework is applied in practice.

1. Literature Review

As a significant content of SCM (Supply Chain Management), the importance of SCRM (Supply Chain Risk Management) has been increasingly emphasized in recent years, in order to identify, assess, monitor and control the negative effects caused by emerging risks, an enormous of research in the area of SCRM is undertaken in both academia and practitioner circles. Literature reviews of SCRM, Jüttner [1], Tang [2], Rao and Goldsby [3], Tang and Musa [4], Colicchia and Strozzi [5], Sodhi, Son, and Tang [6] and Ho et al. [7], provided a comprehensive introduction to research achievements related to SCRM.

Similarly, cross-broader e-commerce as a new modality of the global supply chain, the study of merchandise risk management under cross-broader e-commerce pattern has also received enough attention. Mauricio and Raymundo [8], Young [9], and Navid [10] concerned on the risk indentification, qualitatively studied the supply risk, demand risk, logistics risk, environmental risk, institutional risk, operational risk and information technology risk of cross-broader e-commerce trade, and proposed the main risk factors and risk dimensions. In the aspect of risk assessment, Pater, Biehl and Smith [11] assessed the cross-broader e-commerce risk based on the exposure grade of risk factors. Jukka [12] from the perspective of the probability and impact of the uncertain event, built a two dimensional eature map of risk. Bogataj and Bogataj [13] proposed the concept of risk cost to measure internal and external risks in a supply chain. With respect to risk control, Christy and Grout [14] classified the risk of cross-broader e-commerce, analyzed the risk source and internal relevance, and they pointed out the risk management should trade-off the cost and benefit of risk reduction.

Although these researches have achieved many accomplishments in SCRM, but there are also some deficiencies in the area of merchandise risk management under cross-broader e-commerce pattern [15]: (1) the proposed methods and models are not flexible enough, it cannot address the supervision need of easy extensive and real-time adaptability under cross-broader e-commerce pattern; (2) most of the papers mentioned above are over-theoretical, the practical operating system support is inadequate. Therefore, a practical decision support platform for merchandise risk management under cross-broader e-commerce pattern is needed [16].

2. Knowledge-based Decision Modeling

The proposed knowledge level model for SCRM in this paper is given in Figure 1, which follows Newell's model [17]. There are two parts are contained in the knowledge level model: ontologies and problem solving model, where ontologies are concerned with the static knowledge needed for problem solving, and problem solving model with the dynamic reasoning process with knowledge [18][19][20].

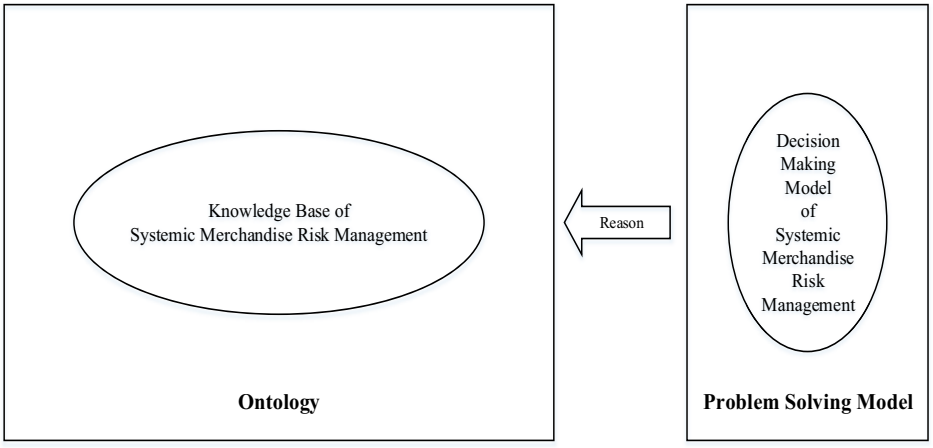


Figure 1. Knowledge level model for SCRM.

2.1. Ontology Modeling

Ontology is the term used to refer to the shared understanding of some domain of interest which may be used as a unifying framework to solve the above problems in the above-described manner [21]. Ontological analysis clarifies the structure of knowledge, and given a domain, its ontology forms the heart of any system of knowledge representation for that domain [22]. As shown in Figure 2, the ontology discussed in this paper include six parts: catalogue of goods prohibited and restricted imported, mandatory national standards, China compulsory certification(CCC), catalogue of products notified by governments, catalogue of products with injury accident report, and media & public opinion.

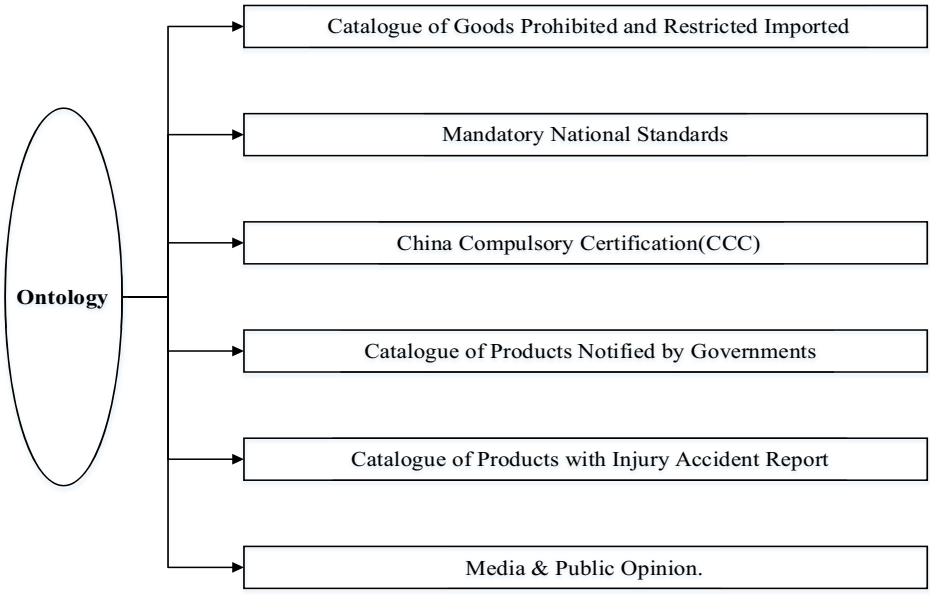


Figure 2. The structure of the proposed ontology.

2.2. Rule Representation and Rule Reasoning

The rule-based knowledge base is used is the SCRM because of the following advantages: (1) the rules and program code is separated, so it has higher flexibility when the rules are changed; (2) an integral theory system it has when redundancy and conflict are emerged. In the construction of rule-based knowledge base (or the rule base), two key issues should be mentioned: rule representation and rule reasoning.

The rule representation applied in this paper is a typical method: if-then rule, since the high degree of operational and the mature reasoning mechanism it has. As for the rule reasoning, an improved rete algorithm is used.

2.3. Problem solving model

The problem solving model represents the reasoning process of the knowledge to solve the focused problem. Based on the model proposed by Simon [23], the problem solving model formulated in this paper defines four different phases: intelligence, design, choice and review, the detailed illustration is shown in Figure 3.

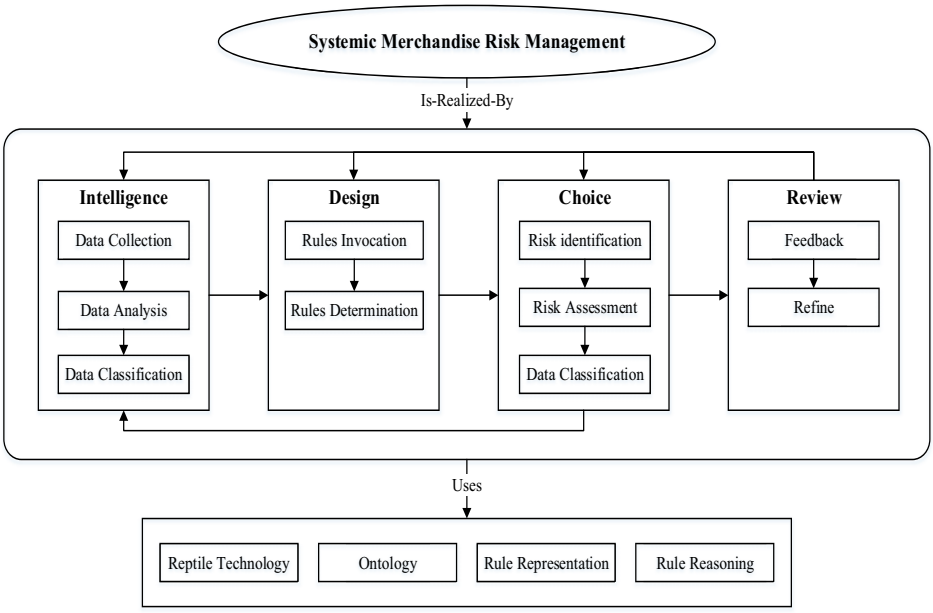


Figure 3. Problem solving model for systemic merchandise risk management.

3. Platform Building of Systemic Merchandise Risk Management

In this section, a platform of systemic merchandise risk management under cross-broader e-commerce pattern is built, which can provide risk identification, risk assessment, and risk monitoring in real time. The platform contains three important parts: the decision framework, the core technology and method, and the structure of the platform.

3.1. Decision Framework

Based on the knowledge-based decision model proposed in the section 2, the decision framework of systemic merchandise risk management is constructed, as shown in Figure 4.

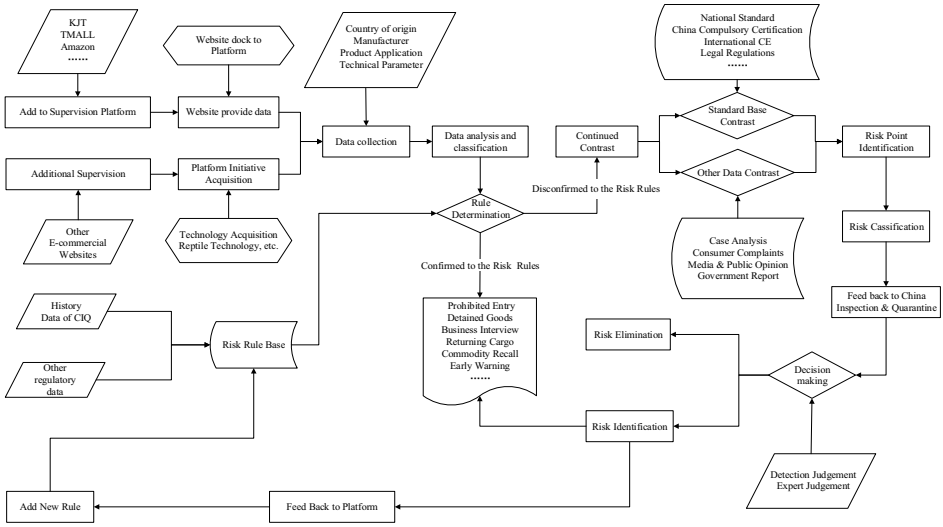


Figure 4. Decision framework of systemic merchandise risk management under cross-broader e-commerce pattern.

3.2. Core Technology and Method

3.2.1. Big Data & Semantic Dictionary

Due to the huge data volume of cross-broader e-commerce, an efficient mechanism for data processing is essential for the systemic merchandise risk management. The combination of big data and semantic dictionary is applied to build an intelligent big data platform.

- Big Data: based on the HDFS (Hadoop Distributioned File System), a large amount of data on cross-border e-commerce trade can be stored, retrieved and operated in the platform, and real-time web crawling is also supported.
- Semantic Dictionary: semantic dictionary includes all the key concepts in the field and links up according to the semantic relation, provides intelligent understanding ability for the platform.

3.2.2. Risk Search Engine in real time

Risk search engine coding of national standards and regulations using the if-then rule, combination parallel scanning based on an improved rate algorithm, the search engine can realize risk identification and assessment in the milliseconds order and continuous risk monitoring.

3.3. Platform Structure

The integrated platform structure of systemic merchandise risk management formulated in this paper is shown in Figure 5, which can be divided in to five different layers: application layer, information setting layer, information processing layer, connectivity layer, and the hardware layer.

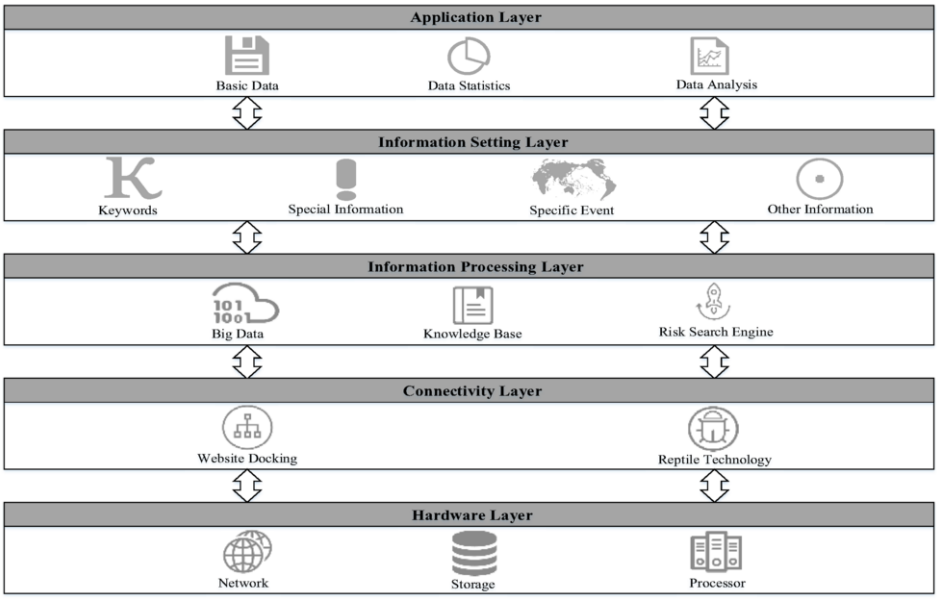


Figure 5. Platform structure of systemic merchandise risk management.

4. Practical Cases Study

Aim to test and verify the efficiency and quality of proposed platform in practical, a series of scenarios are tested, included risk identification, risk assessment and risk monitoring of merchandise under cross-broader e-commerce pattern, the platform interface of systemic merchandise risk management is shown in Figure 6. In this section, three typical cases are provided to illustrate the main results of the proposed framework used in merchandise risk management.



Figure 6. Platform interfaces of systemic merchandise risk management.

Typical Case 1: Risk Identification for Prohibited and Restricted Goods

- Judgement Criterions: Positive List of Cross Border E-commerce and Negative List of Free Trade Zone.
- Judgement Results: using "fresh, eggs, pets, seeds, potted" as the keywords, 17235 goods of online shopping overseas are included, and 6927 goods are identified the risk item by the platform in 2 days.

Typical Case 2: Risk Assessment of Online Shopping Overseas Milk Powder

- Judgement Criterions: "GB 10765-2010, National Food Safety Standard, Infant Formula" and "GB 10767-2010, National Food Safety Standard, Follow-up Infant & Children Formula".
- Judgement Results: 36894 products of infant milk powder are be included in the platform risk identification range, 1433 products are being assessed for potential risk issues by the platform in 2 days, this provides a scientific basis to the government for quality risk assessment of merchandise under cross-broader e-commerce pattern.

Typical Case 3: Risk Monitoring for Products Recall

- Judgement Criterions: information of CPCS, (Consumer Product Safety Commission, www.cpsc.gov) and consumer comments at Amazon (www.amazon.cn).
- Judgement Results: 7000 products which were recalled by CPCS are added in platform searching range, and 12 e-commerce enterprises have been spotted continuing to sell 33 products among these recalled products.

5. Conclusions

In this paper, we study the merchandise risk management problem, a knowledge-based decision framework for the systemic risk management of merchandise for cross-broader e-commerce trade is proposed, includes a knowledge-based decision model and the corresponding decision support platform. Three typical cases are provided to illustrate the main results of the proposed framework used in merchandise risk management.

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Applying Connectivism to Engineering Knowledge to Support the Automated Business

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Abstract. Maintaining products in an automated business includes digitalization and automation of engineering knowledge. When new products are to be developed, and introduced not only has the production processes be automated but also the knowledge regarding how the product should be constituted depending on customer requirements. One big challenge that companies of this kind face is how to make sure that the knowledge automated still can be understood by its stake holders during the development project and after product release and through the whole product life-cycle, which might last for decades.

In this paper, we present a method to navigate and share vast amount of knowledge in businesses with high degree of automated engineering. The method is based on the connectivistic view of knowledge were network formation and filtering are two corner stones which implies the utilization of graph theory together with electronic publishing functionality.

Keywords. Engineering Knowledge, Engineer to order, Knowledge Management, Connectivism

Introduction

Engineering knowledge refers to the knowledge engineers apply when developing products and corresponding production systems. This is a wide definition with emphasis on applying, which means that the knowledge is part of decision making processes and hence excluding curiosities. Engineering knowledge refers to any reason for why, how, when, where, what, by whom something is to be done or be constituted.

Knowledge management and knowledge based engineering have for decades strived to digitalize and automatically utilize this kind of knowledge within product and production development. Knowledge based engineering (KBE) includes tools and methods to digitize and automate engineering knowledge. Even if KBE has gained much attention through the last three decades it is still found hard to industries to develop and even harder to maintain them over time. Here it is suggested to take the connectivistic view on knowledge to see what can be achieved to help industries continuously grow their product knowledge. The paper is organized as follows: first the research method is described, then a frame of reference is given where KBE and connectivism is briefed. Thereafter is the case study described in connection with the

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connectivistic view on knowledge. Finally, a discussion is given followed by conclusions.

1. Research method

This paper reports a research project entitled *Efficient Implementation and Management of Systems for Design and Manufacture of Custom Engineered Products* (IMPACT) that runs 2015 through 2017 aiming at developing tools and methods to make increasing and more effective use of information and knowledge rich systems supporting customization of engineered products. Four large companies are engaged in the research project and serve as testing areas for the ideas. This paper presents suggested working approach for one of the companies.

2. Frame of reference

This paper deals with a KBE system that has been developed for decades and is very mature within the company. The KBE system is in fact a part of the business case and a key factor to the company to stay competitive. In this section, we will shortly review what KBE is and then review a new perspective on knowledge called connectivism and that has served as guidance through the development of the suggested working approach. The connectivistic perspective is described in the context of knowledge and learning in general.

2.1. Knowledge based engineering

La Rocca [1] defines knowledge based engineering as a technology based on the use of dedicated software tools called KBE systems, which are able to capture and systematically reuse product and process engineering knowledge, with the final goal of reducing time and costs of product development by means of 1) automation of repetitive and non-creative design tasks and 2) support of multidisciplinary design optimization in all the phases of the design process.

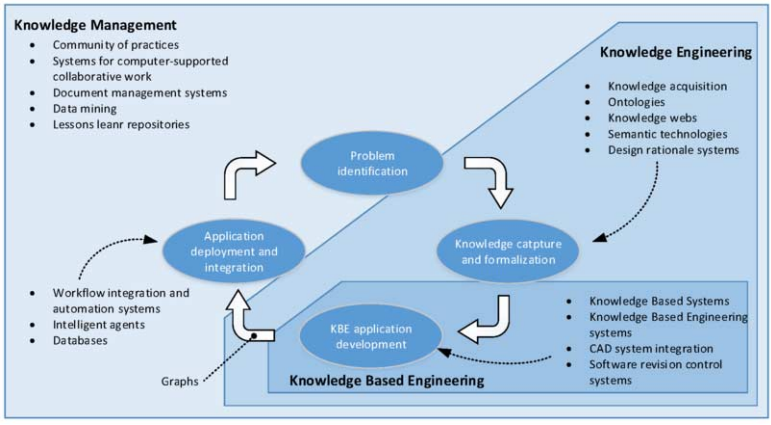


Figure 1: Components of knowledge management. Adapted from [1].

Knowledge based engineering can be said to be the integration between artificial intelligence and computer aided engineering. Artificial intelligence is a set of methods and models from the computer science research field that support flexible modelling of concepts and methods for logical reasoning while computer aided design includes methods and models to model geometry and product structures. La Rocca [1] further puts knowledge base engineering in the context of knowledge management saying that KBE is a subset of knowledge engineering which is a sub set of knowledge management, see Figure 1.

2.2. Connectivism

Connectivism is a philosophy of knowledge described by Siemens [2] which address learning that is located within technology and organizations, a type of learning that KBE ultimately is intended to support. Connectivism is based on nine principles (not numbered in the reference): 1) Learning and knowledge require diversity of opinions to present the whole. 2) Learning is a network formation process of connecting specialized nodes or information sources. 3) Knowledge rests in networks. 4) Knowledge may reside in non-human appliances, and learning is enabled/facilitated by technology. 5) Capacity to know more is more critical than what i s currently known. 6) Learning and knowing are constant, ongoing processes (not end states or products). 7) 8) Ability to see connections and recognize patterns and make sense between fields, ideas, and concepts is the core skill for individuals today. 9) Currency (accurate, up-to-date knowledge) is the intent of all connectivist learning activities. 10) Decision-making is learning and the incoming information is seen through the lens of a shifting reality.

Five components are identified within connectism. Networks is where knowledge resides. Conduit, context and content together shape the meaning of knowledge and individualized filters to help focusing.

Central in the connectivistic view on knowledge is that learning is a network formation process [2]. In the knowledge technologies as seen in Figure 1 this is realized through community of practices, systems for computer-supported collaborative work, ontologies and knowledge webs. Interestingly, these technologies are not considered to be a part of knowledge based engineering system.

Context in the connectivistic view includes elements like emotions, recent experiences, beliefs, and the surrounding environment. Each element possesses attributes, that when considered in a certain light, informs what is possible in the discussion. The object is tied to the nature of the discussion, framework or network of thought. The context-game is the formulation and negotiation of what will be permissible, valued, and the standards to which we will appeal in situations of dispute. The context-game of implementing a new corporate strategy involves individuals, politics, permissible ways of seeing and perceiving, recent events, corporate history, and a multitude of other factors [2]. Context in this broad definition is not normally considered in theories for knowledge management, knowledge engineering and KBE.

Conduits is the medium through which knower (i.e. experts) and seeker (i.e. knowledge consumers) communicate and through which the known entity finds expression [2]. Conduit is the facilities making the knowledge relevant, current, and available.

Siemens [2] briefly reviews the history of how information has been consumed and concludes that we used to go to one source of information to get a thousand points of

information (for instance new papers). Now, we go to a thousand sources of information to create our own view. He continues by saying that we have become the filter, mediator, and the weaver of the networks. A statement that indicates how intervened the concepts in connectivism are.

Since we as humans have a limited possibility to focus our attention (we can only do one or a few things at a time and we only have a limited time per day) and since the amount of information and knowledge is ever increasing there is a great need for filter the content based on individualized filters and current context.

Content is of course of central importance (even if it is told that the capcity of learning is more important than what we already know). Relevance, however, is not only about the nature of content. The process of ensuring currency of content/information is critical to manage knowledge growth and function effectively. Content has to blend together with conduit and context [2].

3. Case study

The studied company is the world's leading supplier of tools, tooling solutions and knowhow to the metalworking industry. The company is active in an internationally very competitive market and needs to constantly cut development lead time by seeking means to improve their processes and system maintenance. The company has a long-standing tradition in automation of quotation and order processes and has adopted an engineer-to-order business model supported by systems for automated design and production preparation of customized product. A request for quotation of a custom engineered product is replied within hours including detailed design drawings and a final price. All the necessary documents and manufacturing programs are automatically generated when the bid is accepted by the customer [3]. On order acceptance, production operations including CNC and CMM routines are sent to the production site. That in turn initiates the automatic trucks or other material handling systems to feed the manufacturing machinery with working material. When the individual product is finally ready it is automatically packed, and shipped to the customer, sometimes just a few hours after order acceptance.

During the first step in the research method two research areas were found important to the company [4]: 1) Models which enables companies to formalize their knowledge to facilitate multidomain utilization. 2) Documentation of relations between produced products specific system versions, used in the products creation, to connect it to the knowledge of which it was derived from. The two areas are targeted with the connectivistic approach.

The company has been working with knowledge based engineering, or rule based design since the mid 1980's and is a very mature company in this area. The fourth generation of their design automation system is based on a domain specific language (DSL) which means they developed a unique programming language to be able to capture all aspects or their products in a way that suites the engineers. The DSL is a text-based programming language that comes with an in-house developed integrated development environment (IDE). The DSL captures not only the concepts and logics of the products but also the geometrical models which makes the DSL a KBE-system as seen in the frame of reference, Figure 1.

The knowledge of the product is captured and digitized as class hierarchies and logical expressions in a format and with terms that are crafted to fit the everyday

terminology of engineers at the company. The IDE is crafted so that product knowledge is stored close to the product geometry, albeit not within the CAD-system. User defined features (UDFs) have served as the baseline to achieve this. UDFs are composite features, i.e. a combination of geometrical elements packed with parameters and references so that they can be used in many parts. The design engineers develop the UDFs necessary to make complete products and the design programmers uses the IDE to write programs in the DSL so that the UDFs are automatically combined into products based on user enquires.

As seen in Figure 1 knowledge management and knowledge engineering includes networking activities, which is in line with the connectivistic principle that learning is a network formation activity. Since KBE systems are results of these activities inherently they will form networks too. To visualize these networks, it is possible to apply graph theory. The visualization and reflection upon such graphs guides the continual refinement and knowledge development as marked in the bottom left arrow in Figure 1.

To try this out a plugin was made to the IDE that scans the knowledge base to connect its various elements and how they are related through logical and structural expressions in the code.

The plugin was applied to a sub-set of the knowledge base for the simplest product at the company with the result as shown in Figure 2. The nodes of the graph represent both geometrical and conceptual components such as parts, UDFs, surfaces, coordinate systems, class declarations, enumerations, and base type parameters. The graph contains both “kind-of” and “part-of” connections.

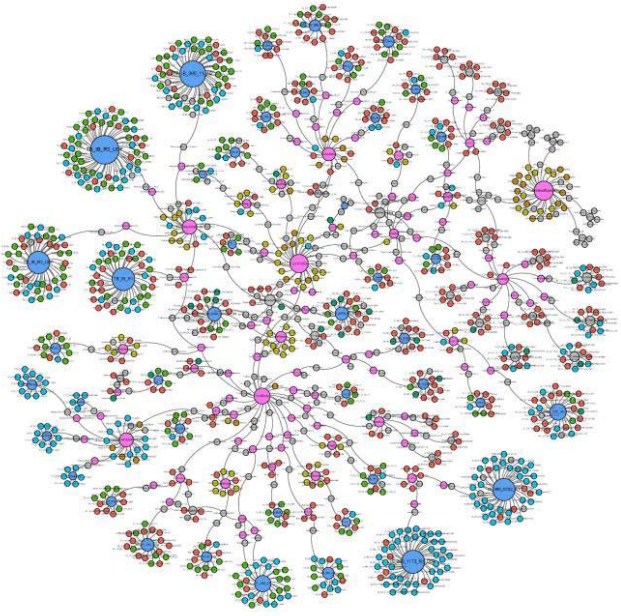


Figure 2. 1366 nodes connected through 1458 edges.

There are many ways of automatically layout graphs. The following methods were tested: Fruchterman-Reingold [5], Force Atlas 2 [6] and Yifan Hu [7]. The graph in Figure 2 is a result of combining the two latter layout methods.

The graph in Figure 2 is hard to grasp, it simply contains too much information to consume at once. Therefore, filters are so important. Filters should make it possible for the engineers, individually and based on their context, to control: What to see (or not to see). When to see. How much to see. In what format to see. It should also be possible for engineers to manipulate and statically store views of the product knowledge.

Another add-in was developed for the IDE that continuously scan the neighbouring context of the code block currently selected to create, layout and broadcast smaller graphs. This gives an instant and focused view of context. The graph creation as aligned with the IDE abstract structure tree so that whenever the programmer changes the code, the graphs are automatically updated within milliseconds.

It is possible to change the levels of neighbouring code block to view at a time, and it is possible to change whether to see kind-of or part-of relations or all together. It is possible to change at what access level to generate the graph (private or public members). It is also possible to tell what types of content to see, parts, UDFs, geometrical elements, classes or base type parameters (if all is shown at once there would be 4620 nodes and 4846 connections in the graph corresponding to Figure 2).

When making this close integration of graph visualization and IDE it was also possible to capture content in forms of code-comments into the graphs. Since the IDE supports the commenting of code blocks in the web-page format (xhtml-fragments that supports rich text and pictures) it was found possible to add the so important content into the programming code in a format that fits the content itself: text and pictures (movies would be possible as well but was not relevant). When hovering the mouse over or right clicking on a node a pop-up window show the comment in web-page format.

According to the connectivism, conduits are the pipes where knowledge continuously flow. It is said that conduits should be blended with content and context. This has been achieved by the integration of graph-visualization and web-page-comments of the code, which forms the conduits to the engineers. Through the connections made by the logics of product knowledge it is possible to navigate the knowledge and through the comments it is possible to change it (code blocks also need to be changed in such case, not just the comment). The dynamically generated graphs were made interactive so that when clicking on a node the IDE focused on that code block

Still there was a need for another type of conduit. That was to provide knowledge to stakeholders that make use of the KBE system after product release. These stakeholders include aftermarket and engineers making special adjustments or modifications of the products. They need to know why the products are constituted the way they are, still they do not need all the information. The information provided to them also should be of the same version as when the product specification (CAD-models and other documents) where generated through the KBE system.

To achieve this, methods were developed to extract the web-page-comments from the code for each executed code block when running the KBE system. These web-page-comments are then compiled into an electronic book (ePub or PDF) containing all the information for that specific instance of the product family, in an interlinked way based on the network. So, that for instance when viewing a page describing a class definition it is possible to click on links to pages describing its members and other classes where it is used.

4. Discussion

To apply the connectivistic view to knowledge based engineering five areas were covered: network, filters, context, content and conduits. Even if connectivism is an abstract philosophy of knowledge this research proves that it is possible to adapt such a mindset to further enhance KBE systems and processes to keep them alive and up-to-date. The methods developed during the research project are far from ready and much work must be done to make them readily available to the engineers in the global company.

When reviewing the nine principles of connectivism it can be concluded that they are, or can be realized at the company by the following (same numbering as in section 2.2): 1) Since the IDE support web-page like comments it is possible to let other than programmers make use of it to encourage an interdisciplinary work setting. Design engineers, production engineers, marketing and programmers would be able to continuously contribute to the knowledge flow. User access functionalities should be added to the IDE for this to be secure though. 2) The KBE system serves as the infrastructure to connect nodes of information sources, to form the network. 3) The digitized knowledge stored in the KBE system inherits its network from processes in knowledge management and knowledge engineering. The visualization of the network makes this more obvious. 4) The KBE system facilitates storage of digitized engineering knowledge. 5) Through the visualization of networks, interactive retrieval and navigation amongst pieces of knowledge and the automated compilation of electronic books the capacity of knowing more has increased. 6) Viewing knowledge development as a continuously ongoing process can be enabled through extensive versioning control of the knowledge. It would change the picture in Figure 1 so that there would be no barriers between knowledge management, knowledge engineering and knowledge based systems, they would be continuously sub processes of the organizational learning. 7) The visualisation of network and context through graphs makes it literally possible to see the connections and patterns of the knowledge. 8) The close integration of geometrical models, concepts, logics and web-page-like comments within a single IDE makes the knowledge content up-to-date. To keep the accuracy a continuous review of the knowledge is important. 9) Viewing decision-making as a learning process is in line with viewing product development as learning, in which engineers indeed find themselves in a very shifting reality. Through the IDE with the visualisation of network and context, interactive navigation of knowledge with easy to add knowledge content an agile KBE development platform is at place supporting the flow of information.

One thing that has emerged from this research is the absence of content, within code comments, but also outside of the IDE. When a product development project is ready and product is released in form of a KBE-system, it lacks comments and the background knowledge used to develop the product still resides in the minds of the engineers. Further work will be put to develop methods to make it more natural to programmers, but more important possible to non-programmers, to add comments into the IDE already at the beginning of product development projects, even before adding code to the KBE. This means that comments will be added first and code thereafter.

The low amount of knowledge re-use at the company is thought to be a result caused by low standardization in the formalization of knowledge created by the design engineers. Report content varies a lot from engineer to engineer and it is not certain that the Company can make use of them in new projects. A more standardized way to

formalize this knowledge could result in a higher re-use of the knowledge which could both save time and ensure quality of the produced products [4].

The broad definition of context within the connectivism was covered at the company through the development of a DSL, the common language suited to the engineers. During that process, it was agreed on basic terminology making up the DSL. Even if released the DSL is general enough to engineers to develop and share their own concepts and models which reflects their own context. When other engineers change these models, it will in turn be from their context point of view. It can further be said that the KBE treats the elements of knowledge stored in the knowledge based on context as well. Sometimes a UDF is treated as a logical element, another time it is viewed as a geometrical element being part of a drawing, and yet another time it is used in a CNC or CMM process. The term polymorphism in computer programming reflects this very technical view of context, even if the connectivistic term is much broader.

5. Conclusion

This paper is a starting point of applying the connectivistic view of knowledge [2] to knowledge based engineering. It was shown that by scanning the elements within a knowledge base in a KBE system it is possible to visualize and navigate its content through graphs. It was also shown that it is necessary to enable individualized and contextualized filtering of the vast amount of information. Not least has the importance of adding content been shown. No matter how good the conduits are and no matter how many nodes and connections the network has, it still useless if there is no content. With the increased ability for the company to learn this challenge can now be well met.

Acknowledgement

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Analysing Engineering Knowledge in CAD-Models and Spread Sheets Using Graph Theory and Filtering

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Abstract. As the era of Knowledge Based Engineering (KBE) and design automation has evolved a big effort has been put to automate CAD-models to quick and accurately respond to changes of customer specifications. The automated knowledge in these KBE-systems is represented as sets of rules, sets that are continuously growing. Parallel to KBE-systems knowledge is also automated in spread sheets (were the cells can be viewed as rules in a KBE-system). These spread sheets also tend to grow in number and complexity. The vision of reusing corporate knowledge through automating it in computer systems are now threaten by the fact that the complexity makes it hard to grasp and manage what was automated. Complexity management and graph theory are scientific fields addressing these types of problems. This paper describes how engineering knowledge stored in CAD-models and spread sheets can be analysed through the application of graph theory, visualization and filtering. Information models of CAD-models and spread sheets are developed and applied to a real industrial case to generate and analyse the content.

Keywords. Knowledge Based Engineering, Knowledge Engineering, Graph Theory, Complexity Management, Graph Visualization

Introduction

In the era of information and knowledge management mass customization has been a strong driving force to automation of engineering processes. Big effort has been put to automate CAD-models to quick and accurately respond to changes of specifications [1]. This change has caused manufacturing companies to not only focus on developing single products but product families with wide and flexible design spaces. The automated knowledge is stored in KBE-systems (Knowledge Based Engineering) and is represented as sets of rules, sets that are growing in size and complexity as the mass customization evolves [2]. We also see that engineering knowledge is automated in spread sheets (the cells can be viewed as rules in a KBE-system). These spread sheets too tend to grow in number and complexity. The vision of reusing corporate knowledge through automating it in computer systems are now threaten by the fact that the complexity makes it hard to grasp and manage what was automated.

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Two other trends during the information era have led to development of theories and tools that can be applied within engineering design and product development. These two trends are social networks and geographic information systems. Along with the development and utilization of these big infrastructures in the society also methods and tools for graph visualization and filtering have emerged that can be utilized by within engineering design with little effort but with big potential [3][4].

Visualization of interdependencies of elements in CAD-models has been target as a research subject. Kozlova et. al. reviewed how graph visualization can be used for CAD-models of architectures [5] they also developed prototypes for interactive graph visualization. The focus of that work was the visualization of the graphs and functions. Tsygankov et. al. [6] studied how to semantically represent the building process of CAD assemblies containing multi-body components. Camba et. al. [7] developed methods to travers CAD-models of components to identify and visualize dependencies between features. Marchenko et.al. [8] developed a tool to represent CAD-models as graphs in CATIA, that work considered how the elements of the CAD-models were connected not only as parent/child relations but also through mathematical formulas.

This paper focus on what types of relations exist within CAD-models (features, components and assemblies) and in spread sheets connected to them. Also, it describes how engineering knowledge stored in CAD-models and spread sheets can be analysed through the application of graph theory, visualization and filtering. The paper is organised as follows: First the information models for CAD-models and spread sheets are introduced and graph theory in connection with these information models is presented. The theory is then applied to a real case which is a CAD-model that was automated using spread sheets as design tables that grew out of control.

1. Dissecting the constituents of engineering knowledge

In this study, we focus on CAD-models that are controlled by spread sheets. The original reason to connect spread sheets to CAD-models was to define family tables, i.e. sets of similar components derived from a single parametric CAD-model. That is an efficient way of handling parametric design of for instance fasteners, washers or other components. Things are getting more complex when adapting such an approach to assemblies of components. The increase in difficulty is due to the introduced combinatorial complexity of the assembled components. To handle the complexity, and for other reasons, it has become common to use the cells in the spread sheet not only to specify the values for each member of the design family but also to add mathematical relations within the spread sheets to change the values in the family table.

We will take a close look at these two types of engineering content, CAD-models and spread sheets, to see how they are constituted and how they are connected to make a foundation to further studies in knowledge and complexity management.

The information model of a CAD-model can be constituted in many ways and differs between CAD-systems (therefore neutral CAD-formats are needed). In Figure 1 a schematic information model is shown where the most fundamental components are drawn. An **assembly**, is as seen in the figure, composed of **instances** of **parts** which can either be **components** or **assemblies** of **instances** (the terminology differs somewhat between what is a part and what is a component, here a component is a piece made from one material, a part can be either one component or a composition of components). **Components** are made up from at least one **feature** while **assemblies**

may contain **features** or not. **Components** and **assemblies** may contain **parameters** which are carriers of base type data such as Booleans, integers, doubles or text values packed with a name. **Assemblies** and **components** may contain **equations**, which are mathematical expressions between **parameters**. The most common type of **feature** in CAD-models is **geometrical features**. **Geometrical features** are composition of **entities** which may be two or three dimensional geometrical elements, such as points, lines, curves, planes, and surfaces. **Geometrical dimension or constraints** are special type of **parameters** that make references to geometrical **entities** to control their definitions.

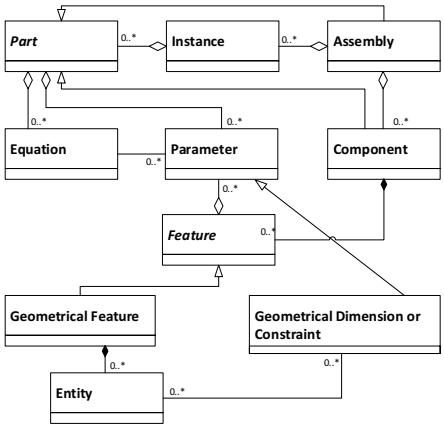


Figure 1. Information model of CAD-model.

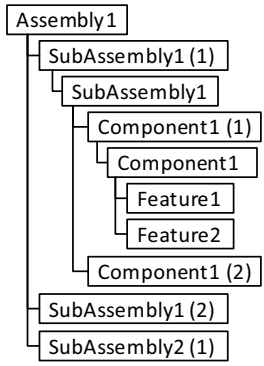


Figure 2. A typical model tree in CAD-systems only shows "part-of" relations.

Table 1. Five types of relations are identified within CAD-models (the two marked by * are the only relation types that are undirected). Connected constituents are defined in Figure 1 and Figure 3.

Relation type	Connected constituents	Realized by
Part-of	Entity → Feature	Feature entities
Part-of	Feature → Component	Component features
Part-of	Component → Assembly	Assembly instances
Part-of	Cell→WorkSheet	WorkSheet
Part-of	WorkSheet→WorkBook	WorkBook
Kind-of	Instance → Part	Instance
Connection	Entity → Feature	References in feature
Mathematical	Parameter → Parameter, Cell → Cell	Expressions in equation, Formula
Connection*	Entity ↔ Entity, Part ↔ Part	Geometrical constraints
Spatial*	Entity ↔ Entity	Location

There are several types of relations in a CAD-model. As seen from Figure 1, components are related to assemblies as "part-of" relations. Features, parameters and equations are also "part-of" components, and entities are "part-of" features. These relations are easy to understand and are often visualized in the CAD-system through a "model tree". A typical model tree is shown in Figure 2 which contains a top assembly (Assembly1) having three instances of parts (2 SubAssembly1 and 1 SubAssembly2). SubAssembly1 in turn is composed of two instances of Component1 which is made up from Feature1 and Feature2 (only few CAD-systems show the instances in the model tree).

There are other relations in the CAD-model than these "part-of" relations, relations not that obvious but interesting to engineers when developing and maintaining the models. One such relation is references between geometrical entities through

geometrical dimension or constraints. For instance, if creating a feature with references to an already existing feature there is an ordering relation, referred to as parent/child relation. Deleting the first feature will cancelling the other one. It is possible in most CAD-systems to add logics to the CAD-model through equations. The equations may refer to geometrical dimensions that in turn change the size or even topology of the geometry of the CAD-model. Such relations are here called mathematical relations (these relations could also be viewed as parent/child relations if they are unary expressions). The relations are modelled as edges in the graphs per Table 1.

Spread sheets are frequently used within engineering design to store and manage information regarding the product and is indeed a part of the product model. Spread sheets may be connected to CAD-models as design tables or as a part of the geometrical build process as an "analysis" features. The reason for adding spread sheets as a part of the product model is the flexibility to model information yet overview the information provided by spread sheet applications. The central concept in spread sheet applications is the cell. In Figure 3 a schematic information model of a spread sheet is draw.

Cells resides, as seen in the figure, in **worksheets** and **worksheets** resides in **workbooks**. A cell may contain a **formula** that refers to other cells. Formulas act as functions with several input cells but with one output only, which is displayed in the cell containing the formula. When connected to a CAD-model we can view these functions as rules in a KBE-system according to the definition of KBE in [9], the inference engine is then realized by the spread sheet application.

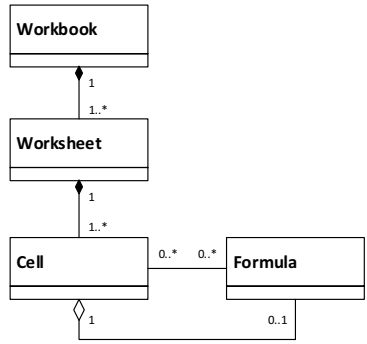


Figure 3. Information model of spread sheet.

A graph G(N, E) is a set of nodes (N) and edges (E). The nodes represent entities of interest and the edges represent how they are connected as tuples of two nodes first one is the source node and last one is the target node [10]. When two nodes are connected through an edge they are said to be neighbours. The nodes represent entities of interest and the edges represent how they are connected as tuples of two nodes first one is the source node and last one is the target node. Edges can be directed or undirected [10]. When two nodes are connected through an edge they are said to be neighbours. The degree of a node is defined as the number of neighbours it has, i.e. how many edges are pointing in and out from it. In-degree refers to how many neighbours a node depends on and out-degree how many neighbours are depending on it.

To add meaning to the graph it is useful to add attributes to nodes and edges. Attributes were added to the nodes and edges in this paper are listed in Table 2. The EdgeType attribute is what separates the graphs presented in the paper from the model-trees in CAD-systems. With this attribute, it is possible to model how the entities are connected. When reviewing the class diagrams in Figure 1 and Figure 3 five different types of couplings are found, these are listed in Table 1. The values in the first column of that table is used as possible values of the EdgeType attribute and as labels for the edges.

To understand huge graphs, it is necessary to filter their vast content and two combinations of filters are suggested here. The first set of filters is the combination of retrieving nodes of types “Geometrical Dimension”, “Parameter” and “Cell” (i.e. nodes representing entities that control the design) and of degree 0. The entities represented by the retrieved nodes of such filter are the entry points for the CAD-model, changing any of their values impacts the design. We call these values design parameters.

With edge filtering, it is possible to filter different structures (or nets) of the CAD-model. Filtering edges on “External connections” yields the interfaces between the CAD-model and design tables. Adding edges of types “Mathematical” gives the entire set of logics for the CAD-model, which is the second suggested set of filters. The nodes resulting from that filter represents the logical part of the product model.

Table 2. Four attributes were added to develop the graphs in this paper.

Name	Applies to	Description
URI	Nodes	Unique Resource Identifier. Includes file path and internal path to the represented entity.
Label	Nodes, Edges	Text to show in graph.
EntityType	Nodes	Type of entity as in Figure 1 and Figure 3
EdgeType	Edges	**Type** of relation as defined in Table 1

2. Putting the parts together

To get a seamless overview of the engineering content CAD-models and design tables as connected spread sheets can be analysed to render graphs using the theory in the previous section. There are two algorithms used to do the analysis, the first one travers the CAD-model and its sub-models to extract the nodes and edges. The second algorithm analyses any spread sheet connected to the CAD-models or referred to in spread sheet to extract nodes and edges within them and in connection to the CAD-model.

We make a simple example to demonstrate the output from these algorithms. Let say we have a CAD-model containing a box with a hole through it. The model-tree is of course simple containing two extruded sketches, one to make the box and one to make the hole. The two sketches are shown in the model tree. The CAD-model is controlled by a design table so that height, width and length are controlled by the cells in in a connected spread sheet. Two configurations (or product instances) are defined. The values for the first configuration is in turn controlled by a cell in another spread sheet.

Applying the algorithms to the simple box-with-hole example yields a graph with 22 nodes and 28 edges. The graph is visualized in Figure 4 with the Yifan Hu layout algorithm [11]. There are seemingly duplicate nodes (for instance two D1) this is because of using short names on the nodes (Label attribute). The nodes are unique with the URI attribute identifying them. It is possible to retrace the URI from the Part-Of connections, we then see that both Sketch1 and Sketch2 have a dimension D1. For cells in spread sheet one must review the URI attribute to see the entity-location.

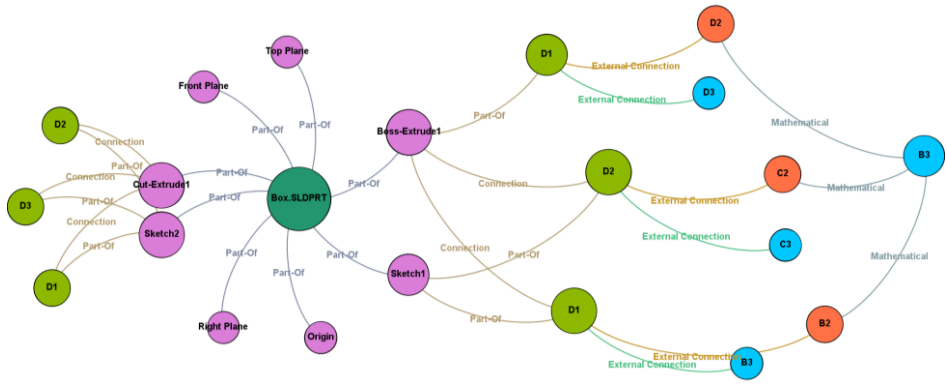


Figure 4. Graph illustrating the relations in the CAD-model, design table and in between. 22 Nodes and 28 relations.

Applying the filters to retrieve design parameters results in 7 design parameters: the nodes D1, D2 and D3 (green) to the left and B1, B2, B3 and the other B3 (blue) to the right in Figure 4. This is interesting as it indicates that every value in a design table indeed is a design parameter. In the box-with-hole example the number of design parameters is reduced by the formulas for the Default configuration controlled by B3 in the other sheet. Applying the filter to retrieve the logics behind the example yields a graph showing how the 7 design parameters are interconnected with mathematical expressions.

3. Real Case Example

To verify the concepts presented in the previous sections a prototype software was developed and applied to a real-life example. The company where the software was tested develops and manufactures heated runner systems for injection moulding of plastic materials and is the same company as described in source [12]. To verify the concepts presented in the previous sections the algorithms applied to a real-life example. The company where the software was tested develops and manufactures heated runner systems for injection moulding of plastic materials and is the same company as described in source [12].

One reason to analyse the CAD-models at the company was that the product is a product suitable for design automation. Every produced hot runner system is unique. Even if unique there are standard procedures to render the final product. This led to the automation of the CAD-models through interconnected spread sheets as design tables. Due to the combinatorial complexity of the product mathematical equations were added as equations in the CAD-models as well as in the spread sheets. This approach made the CAD-system instable so that when adding several instances of the in-gates it eventually crashed after long time (sometimes up to 40 minutes) of crunching. It didn't always crash so the engineers tended to wait and hope for it to go through. The crashing problems were eliminated when reforming the CAD-models as described in source [12], the graph shown at end of the paper may give a clue of why the model became so difficult to handle.

The prototype software took 2 minutes to generate the entire graph as presented in **Figure 5**. The output from the routine is a file containing the graph in Graph Modelling

Language (.GraphML) which is a general, XML-based language, to store graphs in a standardized way [13]. To visualize the graphs several freely available software applications were tested (the pictures in this paper were generated using Gephi [14] with the Yifan Hu [11] and Force Atlas 2 [15] layout routines). The graph contains 3932 nodes (47% formula, 28% geometrical dimension, 17% feature, 2.9% instance, 2.2% cell, 0.7% Component, 0.6% Assembly, 0.2% parameter) connected in 11321 relations.

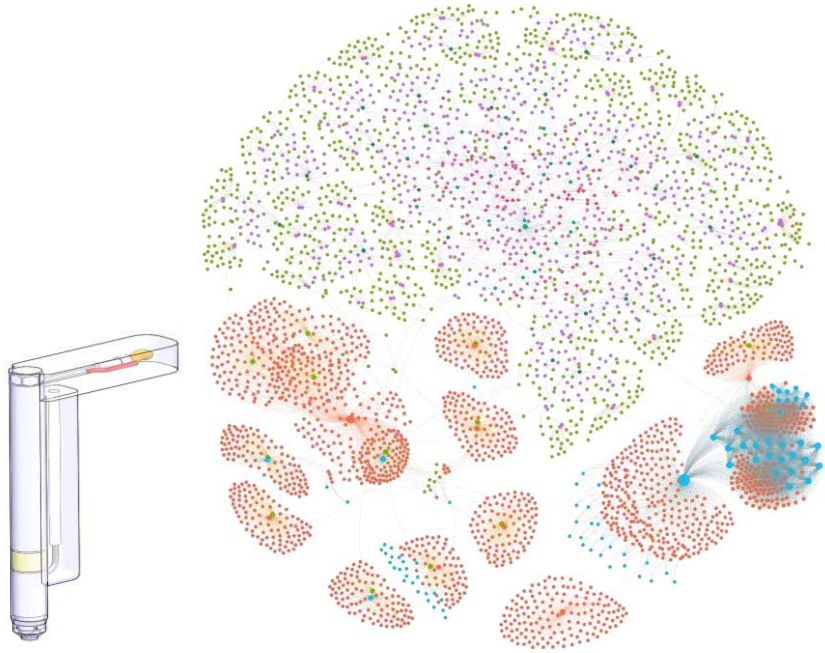


Figure 5. (Left) CAD-model that comes in 17 billion variants. (Right) CAD-model and interconnected spread sheets. 3938 nodes connected in 11321 relations. The firework shapes are from spread sheets, and the top part is from the CAD-model (all nodes are connected).

The CAD-model targeted consists of five sub-parts of which only one is an assembly (which in turn consist of three components). In total, we are talking about 7 components in two assemblies which seems very little to make a CAD-system to collapse. What makes it so difficult is the vast number of variants for each component (stored in the same model). Another problem lays in the application of the product which is to operate in much higher temperature than it is produced which resulted in several temperature configurations for each component. The top-level assembly contained 42 equations controlling features on all levels.

The spread sheets connected to the CAD-model as design tables included all possible combinations of the components. The combinations where added using formulas in the spread sheet so that when changing certain cell values then parts of the design table were changed (this method works for ETO-products). In total the design table contained 1248 cells and there were additionally 46 cells with data and formulas to adjust the values in the design table.

The prototype software took 2 minutes to generate the entire graph as presented in Figure 5. The output from the routine is a file containing the graph in Graph Modelling Language (.GraphML) which is a general, XML-based language, to store graphs in a

standardized way [13]. To visualize the graphs several freely available software applications were tested (the pictures in this paper were generated using Gephi [14] with the Yifan Hu [11] and Force Atlas 2 [15] layout routines). The graph contains 3932 nodes (47% formula, 28% geometrical dimension, 17% feature, 2.9% instance, 2.2% cell, 0.7% component, 0.6% assembly, 0.2% parameter) connected in 11321 relations.

When applying the filters, there are 1165 entry points of which the majority are of Geometrical Dimension type further filtering shows that there are 12 parameters and 86 cells. These entities should be managed and the information regarding them should be made easy to retrieve to engineers. The logical model consists of 1248 external connection and 6990 mathematical connections.

4. Discussion

As seen in this paper it is possible to penetrate CAD-models and spread sheet to extract and visualize graphs. The method is not limited to CAD-models or spread sheet but could be applied to FEA-models, Manufacturing models or other types of models of the product if there are APIs or a deep understanding of the information models. Question is what can be achieved by these graphs?

It was possible to identify how design tables are connected to the CAD-model. Filtering techniques were applied to retrieve all entry points for the CAD-model and to visualize the product structure and the structure of the logical entities.

The combinatorial complexity of products when starting to automate CAD-models is often underestimated, as mentioned in source [12] there are stunningly 17 574 796 800 possible and impossible combinations of components for the in-gate model. The combinatorial complexity of products when starting to automate CAD-models is often underestimated, as mentioned in source [12] there are stunningly 17 574 796 800 possible and impossible combinations of components for the in-gate model. Even if seemingly large that figure is small when talking about combinatorics. Due to this complexity, it is necessary to help engineers to manage the design content and to see what impacts their decisions have in this aspect.

The graphs must be filtered to make sense in the context of the decision to be taken. The two filters mentioned in this paper are general and useful for all models of this kind but the filtering is individual and context based so it is necessary to provide engineers with filtering possibilities rather than fixed filters. Filtering possibility is tightly connected to the attributes added to the nodes and edges, so that more attributes gives more filtering possibilities. A higher granularity of Mathematical relations would make it possible filter in the 6990 connection in the case example. Attributes can be organized in categories.

If making the graph contextual, filtered, and embedded into the CAD-system as a different view of the CAD-model the graphs could be used throughout the entire product life-cycle. In the conceptual phases and in design phase the graphs would serve as visual feed-back to engineers. It would guide them to develop more lean and re-useable models of the product knowledge. If the product is already developed the graphs could be used during modularization project (graph clustering) or in carry over project between product generations. The graphs would in such cases serve as a foundation for recapturing the knowledge. When maintaining the product models the graphs would provide functionality for change propagation analysis.

During the penetration of the product models it would be possible to store comments and formulas (content) as additional attributes to nodes. If doing so the network would conform well with the connectivistic view on what knowledge is [16].

5. Conclusion

This paper is a starting point of applying the connectivistic view of knowledge [16] to knowledge based engineering. It was shown that by scanning the elements within a knowledge base in a KBE system it is possible to visualize and navigate its content through graphs. It was also shown that it is necessary to enable individualized and contextualized filtering of the vast amount of information. We dissected CAD-models and spread sheets to develop information models to serve as a foundation for graph visualization. Five types of relations between the constituents were identified: "Part-Of", "Kind-Of", "Connection", "Mathematical" and "Spatial". Two algorithms were developed to travers CAD-models and spread sheets to retrieve graphs representing the information stored within them. Two filters were used to filter the resulting graphs to identify design parameters and the logical model of the product model at hand. These steps are taken to enable manufacturing companies to master the complexity of their product families.

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Development of Presentation Slide Retrieval System Based on Visual Information

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Abstract. Sharing and reusing knowledge in presentation form is very important because more and more presentations are made and accumulated in many companies. However, most of existing presentation slide retrieval systems are document file unit searches, which deal with only text information. Therefore, it is difficult to search enough reusable slides comprehensively when users don't memorize clear text information about necessary slides. The objective of this research is to develop a slide retrieval system which can comprehensively search slides necessary for presentation creation in a short time. First, Presentations are decomposed into slides. A Uniform Resource Identifier (URI) is assigned for each slide and managed in metadata repository in order to search across databases. Second, relevant slides can be retrieved based on the similarity of text or visual image such as colors and shapes so as to search enough slide candidates for a reusable slide. Third, a retrieval function based on handwritten graphic information is developed in order to search based only on visual memory. In case study, the effectiveness of each function is illustrated. In addition, it is illustrated that this system reduces the time to make a presentation by 19.7%.

Keywords. Presentation Knowledge Sharing, Slide Retrieval, Bag of Visual Words, Bag of Words, Handwritten Graphic Information

Introduction

Sharing and reusing knowledge in presentation form is very important because the more and more proposals and reports in presentation form are accumulated in companies and it takes much more time to make a presentation slide, which includes not only text information but also visual information such as colorful diagrams, graphs and charts in various layouts in order to express the message clearly.

However, there are three problems. First in companies, many presentation slides are accumulated across databases in a presentation file unit. Therefore, unnecessary work occurs such as switching of the database to be searched, opening and closing the presentation file, and browsing extraneous slides in the file. Second, there are many similar slides edited according to the various purposes based on a slide. It is difficult to

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comprehensively check all of them when users search the reusable slide candidates. Third, most of the existing presentation slide retrieval systems deal with only text information. Users cannot obtain appropriate search results adequately when they don't memorize the text information with sufficient amount and accuracy to identify the required slide. Therefore, since it is inevitable to decide which slide to reuse from the limited search results, despite the fact that better slids are accumulated, the slide which is not the best is reused.

The objective of this research is to develop a slide retrieval system which can comprehensively search slides necessary for presentation creation in a short time. Specifically, the slide retrieval system using visual information which can search the slide most similar to the necessary slide based on fragmentary and ambiguous information of the necessary slide imaged in the user's head. First, in order to shorten the opening and closing time of the presentation file, the slide unit search is realized by decomposing the presentation file into slide units and managing them by Uniform Resource Identifier (URI) and metadata. Second, in order to comprehensively and efficiently search reusable slide candidates, the similar slide search function is developed which can search similar slides by using the specified slide itself as a search query. Third, in order to realize slide retrieval based only on visual memory when a user cannot remember the character string as the search query, a retrieval function based on handwritten graphic information is developed.

In case study, the effectiveness of each function is illustrated by comparing each developed function with the full text search function. In addition, it is shown that this system reduces the time to make a presentation by 19.7%.

1. Related work

In this chapter, existing presentation slide retrieval systems are outlined. UPRISE [1] and DocMIR [2] were developed as content retrieval systems for lectures with a slide-based search function. However, these systems only have a full-text search function. In order to improve the accuracy of full-text search, Kushki et al. [3] proposed an indexing method for weighting slides based on structured information expressed in OpenXML and it is demonstrated that the search accuracy and the coverage of the search result are higher than UPRISE.

Liew et al. [4] considered a slide as an image and proposed a slide retrieval system SLIDIR applying image processing technology. SLIDIR gives text labels by machine learning to the area excluding the background from the slide image. A slide search can be performed using text as a search query. However, it is a problem that a large amount of correct training data is required for learning.

Tanaka et al. [5] proposed a slide retrieval method focusing on the shape and arrangement of figures in slide based on analyzing OpenXML included in presentation file and. It is not practical because it is necessary to create a slide as a search query. Sakuragi et al. [6] also analyzed OpenXML and estimated the meaning and the hierarchical structure of the group of figures by analyzing the arrangement and the relationship between the figures, and added metadata for search to each slide. Since this method can be applied only to the OpenXML format, the information such as pictures and images contained in the slide is not utilized for a slide retrieval system. It is difficult for users to convert the characteristics of the necessary slide into the metadata

such as the number of elements of a figure group or the shape of elements of a figure group and so on.

In addition, Sakuragi et al. proposed the similar slide re-search function. However, the similarity calculation method has only one criterion, which is based on hierarchical structure of figures. Therefore, this search function can not fully deal with various similarity measures in user 's memory.

DRIP system [7] was developed as a system with a presentation creation support function. This system is unsuitable for reuse of slides including images and graphic data because only text data can be reused when a presentation is created.

In our research, we will focus on reusing accumulated presentation slides and supporting the creation of new presentations. In order to comprehensively search candidate slides, we develop the function which can search similar slides using the slide itself as a query based on the various criteria: shape, color, and text.When it is difficult to express the search query as a character string, we develop a sketch image search that makes it easy to intuitively search the desired slide based on the handwritten sketch of the slide. Since images in slides and presentation files that are not in OpenXML format such as ppt format are also search targets, our system handles slides as images and text, and does not analyze OpenXML.

2. Proposed presentation slide retrieval system

Figure 1 shows the overview of this system, which consists of one metadata repository and three search functions. The following sections describe the details of each function.

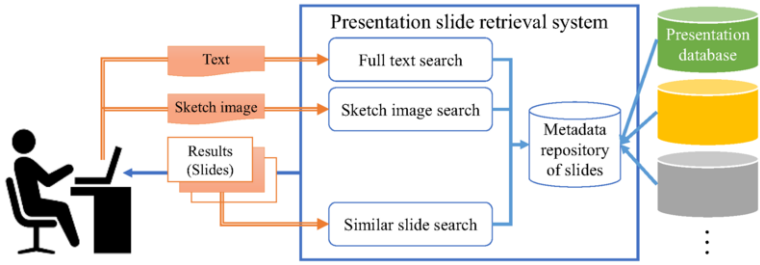


Figure 1. Overview of presentation slide retrieval system.

2.1. Metadata repository of slides

In order to save time opening and closing the presentation files and searching different repository, slide unit search is realized by decomposing the presentation files into slide units. URIs (Uniform Resource Identifier) are assigned to all the slides accumulated in several different presentation databases. URIs and metadata of slides are managed in one metadata repository which is based on RDF (Resource Description Framework).

2.2. Similar slide search

In creating a presentation, it is very important to confirm better candidate slides. This makes it possible for users to select the slide which is more suitable for the purpose, reducing the work of editing and correcting the slide. Therefore, when discovering the slide that the user thinks is beneficial, this system makes it possible to easily search

similar slides. A presentation slide itself can be regarded as an image and most of slides includes character strings. Therefore, the similarity is calculated based on the shape and color derived from the slide image, and the text included in the slide.

2.2.1. Feature vector for shape : Bag of visual words [8]

The slide image is converted into feature vector based on a set of SURF feature quantities which are local feature quantities that are invariant to scale and rotation, robust to light and dark. First, all the SURF feature quantities are extracted from all the slide image set and categorized into K clusters using K-means clustering method. Then, Centrobaric vectors for each cluster (visual words) are obtained. K is set to 500 in this system. Next, SURF features extracted from each slide image are assined to the closest visual words. Finally, 500-dimensional feature vector for each slide image is obtained as a normalized histogram on visual words.

2.2.2. Feature vector for color : Color histogram [9]

In the case of 256 gradations of RGB, 16,777,216 colors can be expressed. However, users can neighter memorize nor identify all the exact color of slide image. Therefore, RGB is reduced to 4 gradations each and the color of the pixel of each slide image is assigned to the reduced colors. 64-dimensional feature vector is obtained as a normalized histogram on colors.

2.2.3. Feature vector for text : Bag of words [10]

The character strings are extracted from each AutoShape included in the slide and unnecessary spaces included for the appearance are removed. All the words are extracted from all the slides using morphological analysis. Among them, the upper 1,000 words with the highest occurrence frequency except for the stop word are selected. The frequency of occurrence of the 1,000 words for each slide is calculated to obtain 1,000-dimensional feature vector as a normalized histogram on text.

2.2.4. Similarity based on Bhattacharyya coefficient [11]

For the two histograms **I** and **M,** the similarity is calculated using the following equation:

$$BC(\boldsymbol{I},\boldsymbol{M}) = \sum_{j=1}^{n} \sqrt{I_j M_j} \tag{1}$$

where n is the number of dimensions of histograms. Threshold values are defined for each of the three features, and the similar slides exceeding the threshold value are associated with each other from in terms of three features: shapes, colors and text.

2.3. Skech image search

2.3.1. Feature quantity of contour line

Contour lines are obtained from a query sketch image and slides by canny edge and contour line tracking. Next, the obtained contour lines are described by P type Fourier descriptor [12], and amplitude spectra are extracted as feature quantities. The P-type

Fourier descriptor is one of methods for expressing a curve line on the plane, and this amplitude spectrum is invariant with regard to the translation, scale, and rotation of the contour line.

2.3.2. Similarity calculation

The Euclidean distances $d(\boldsymbol{x}, \boldsymbol{y})$ between the extracted amplitude spectra are calculated. The contour lines are similar as the distance is smaller [13]. When N amplitude spectra are obtained from sketch image K and M amplitude spectra are obtained from slide image S, their distances are defined by the following equation:

$$Dist(K,S) = \sum_{i=1}^{N} \min_{j=1,2,3,\ldots,M} d(\boldsymbol{a}_i, \boldsymbol{a}_j) \tag{2}$$

where $\boldsymbol{a}_i$ is the amplitude spectrum. The smaller $Dist$ (K, S) is, the more similar the two images are.

2.4. User interface

Figure 2 shows the user interface of presentation slides retrieval system. Users can search slides by entering queries on text forms in the area A. Search results is shown in the area B. When a useful slide is found, you can store the slide in each item of the table of contents of the new presentation prepared in advance in the area C. Finally, we can merge and download the slides stored in the table of contents as a pptx file. Our system has a user interface for sketch image search shown in Figure 3a. Users can draw a sketch as a search query in the sketch area using tablet PC in Figure 3b, and then obtain slides displayed in descending order of similarity in the results area.

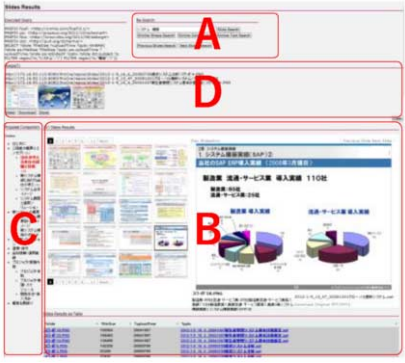


Figure 2. User interface of the slides retrieval system.

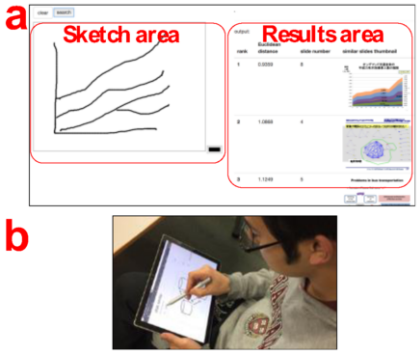


Figure 3. User interface of sketch image search.

3. Case study

3.1. Evaluation of similar slide search

The performance of similar slide search function is evaluated by comparing it with full text search function. The evaluation criterion is the number of search steps until all the search target slides are found from the accumulated slides.

In this evaluation, 17 existing presentation files including a total of 1632 slides are used. The search target slides are six slides including a figure of a V-shaped process which illusrates a system development standard process called SDEM [14] as shown in Figure 4.



Figure 4. Search target slides.

Search results with only full-text search, and search results with full text search and similar slide search are shown in Table 1 and Table 2, respectively.

In order to find all the target slides with full text search function, it was necessary to include a string “development” in the query without a string “standard”. Because search results by full text search depend on the input search query, it takes time to find an appropriate search query. On the other hand, all the target slides could be found with fewer steps by similar slide search based on the slides (Slide ID = 1, 2, 3, 4) obtained by full text search for the query string “SDEM”. Specifically, text similar slide search (Query ID = 3, 6, 12 in Table 2) made it possible to find all the six target slides. In addition, those precisions was larger than the precision of full text search (Query ID = 7 in Table 1), which could find all the search target slides.

Table 1. Search results by fullt text search. Query ID, query string, the number of search results, search target slide IDs contained in the search results, precision, recall , and F value.

ID	Query string	Num of results	Correct slide ID	P	R	F
1	SDEM	9	1,2,3,4	0.44	0.67	0.53
2	"body of standard process"	4	3,4	0.50	0.33	0.40
3	"standard process"	10	3,4	0.20	0.33	0.25
4	standard process	29	1,2,3,4	0.14	0.67	0.23
5	"development standard"	10	2,3	0.20	0.33	0.25
6	"development process"	8	1,2,4,5,6	0.63	0.83	0.71
7	development process	56	1,2,3,4,5,6	0.11	**1.00**	0.19

Table 2. Search results by similar slide search. Query ID, slide ID as search query, type of similalrity, the rest which are the same as those in Table 1.

ID	Query slide ID	Type	Num of results	Correct slide ID	P	R	F
1	1	shape	10	1,6	0.20	0.33	0.25
2	1	color	10	1	0.10	0.17	0.13
3	1	text	23	1,2,3,4,5,6	0.26	**1.00**	0.41
4	2	shape	10	2,4,5	0.30	0.50	0.38
5	2	color	10	2	0.10	0.17	0.13
6	2	text	35	1,2,3,4,5,6	0.17	**1.00**	0.29
7	3	shape	10	3,4	0.20	0.33	0.25
8	3	color	10	3	0.10	0.17	0.13
9	3	text	10	1,2,3,4	0.40	0.67	0.50
10	4	shape	101	2,3,4,5,6	0.05	0.83	0.09
11	4	color	10	4	0.10	0.17	0.13
12	4	text	34	1,2,3,4,5,6	0.18	**1.00**	0.31

3.2. Evaluation of sketch image search

Next experiment verifies that the target slide can be searched by developed sketch image search function. In this experiment, a user watches the target slide and draws a sketch for the target slide. It is evaluated that it is possible to obtain the target slide from the registered 10 slides. Figure 5 shows 10 slides accumulated in the system. Figure 6 shows the sketch image for slide with ID 8 drawn by the user.

Table 3 shows the distances calculated by the equation (2) between the drawn sketch image in Figure 6 and the 10 slides in Figure 5. Result showed that the most similar slide to the input image was the slide with ID 8. Therefore, it was confirmed that sketch image search function works well even for the simpler input image than the original slide image.



Figure 5. Accumulated slides in the slide retrieval system.



Figure 6. Drawn sketch image for the slide ID 8.

Table 3. Distances between sketch image and slide images.

Slide ID	Dist
1	2.80
2	1.97
3	1.97
4	1.09
5	1.13
6	1.35
7	1.97
8	**0.94**
9	1.35
10	1.94

3.3. Evaluation of effectiveness in practical work

In order to evaluate effectiveness in practical work, a draft of presentation material including about 40 slides is created by one user on developed system. This user has 16 yeas of experience in sales. The data set is the same as 3.1, and the time limit is set to 2 hours. We compare the current method using only Windows Explorer and Microsoft PowerPoint and the method of using this system in terms of required time. In order to reduce bias of prior knowledge, the interval between the two experiments is set to one week.

Table 4 shows the difference of creation time. The creation time using this system was 19.7% shorter than the current method because this system reduced time to open and close files, to browse irrelevant slides in the same file, and to reassemble extracted slides. Table 5 shows search efficiency of similar slide search, which was calculated based on the system usage log. From the viewpoint of the number of extracted slides per search, text similar slide search function is more than five times as efficient as full text search function, while the absolute value of the number of slides extracted by full text search function is the largest.

Table 4. Comparison of required time (minutes).

Current method		Using this system	
Preprocess	5	Preprocess	0.5
Search & Extraction	55	Search & Extraction & Reassembly	66
Reassembly	21		
Modification	28	Modification	21
Total	109	Total	87.5

Table 5. Search efficiency of similar slide search.

Type of search		Num of searches	Num of stored slides	Search efficiency
Full Text Search		92	33	0.36
Similar Slide Search	Shape	8	2	0.25
	Color	4	2	0.50
	Text	14	29	2.07

4. Conclustion

In our research, we developed a slide retrieval system which can comprehensively search slides necessary for presentation creation in a short time. Slide unit search is realized by decomposing presentation files into slide units and managing them by URI and metadata in one metadata repository. In order to comprehensively and efficiently search reusable slide candidates, similar slide search function was developed which can search similar slides by using the specified slide itself as a search query. In order to realize slide retrieval based only on visual memory when a user cannot remember the character string as a search query, a retrieval function based on handwritten graphic information was developed.

In case study, the performance of similar slide search and sketch image search was evaluated. The presentation creation time using this slide retrieval sytem was reduced by 19.7% compared with the current method. Through this case study, we found that the search efficiency of text similar slide search was the highest among the search functions.

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The Personal Profile of Lean Leader of Leaders

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Abstract. Today companies worldwide are implementing Lean and hereby make their company more effective. It is our observation, that companies are capable of implementing the various tools and techniques of Lean (VSM, Kaizen, Policy deployment, Performance management and PDCA etc. At the same time, it is our experience that many companies struggle or even fail to develop a CI culture. The authors behind this paper consider a lack of essential mindset and personality traits of the Lean leaders as a major contributor to these struggles. The aim of this paper is to address the question: Which personality traits does Excellent Lean leader of leaders have? As an attempt to answer that question, this paper presents a profile description of an excellent Lean leader of leaders based on an assessment made by a Lean experts panel composed from 26 different Danish companies. The personality profile is divided into 16 traits and furthermore compares the profile to the average Dane..

Keywords. Lean, Leaders of leaders, personal traits

Introduction

The curiosity of this research, derived from a field of practice that still isn't fully explored and therefore raised questions regarding which traits to look for when recruiting and developing Lean managers.

The ambition is to generate and combine knowledge about excellent Lean leaders on different leadership levels and methodology about assessment tools, to clarify which elements that are required to develop a unique assessment tool that specifically targets finding the best qualified Lean manager candidate. This paper its focus to the leadership level, Leader of Leaders [1][2].

Hence, recruiting and developing excellent Lean managers are of the greatest importance as managers, according to Womack, have a pivotal role in setting an example for the employees by addressing the 3Ps (purpose, processes and people) to ensure a sustainable Lean change [3]. It's all about finding the right candidates to fill the shoes as it is not a job for everyone. Key elements for a suitable candidate include the ability to set goals, continually challenge the status quo and raise the target for performance, alongside empowering employees and having the adequate knowledge and tools to operate on an everyday basis [4].

A current trend when recruiting and assessing potential candidates is the use of personality tests that have increased rapidly in recent years, as HR professionals tend to

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use personality tests to predict whether a candidate fits the job profile or not [5]. The reason for this has to be credited to economic and performance related incentives as personality tests can help improve employee fit, help avoid candidate profile misfits and ensure a positive impact on company performance [5].

The reliability of personality tests is a subject of discussion as there are some pitfalls to consider when using personality tests for recruitment and development purposes. Studies have showed that the predictive validity of personality tests are rather low compared to other types of assessment methods, which serves as an indicator that assessment tools can't serve as the sole basis of recruitment, but should be complemented by other methods to ensure a positive outcome [6]. Viewed in isolation, an IQ test has a higher predictive validity since the measurement method is more limited and therefore more accurate [7]. To improve the predictive validity of personality tests, an identification of which personality traits that are desirable in a specific job profile needs to be performed [8]. Using trait theory as a framework for personality tests it is possible to assess whether a candidate is fit for the job or not, given that the desirable traits for the job profile differ significantly from the norm.

1. Research Objective

The aim of this research is to identify specific personality traits that apply for excellent Lean managers on the leadership level: Leader of Leaders. The traits identified in the research are to be used as a target guideline for recruitment and development of Lean managers.

2. Research Design

This paper is based on a research program called The Excellent Lean Leader Profile.

The research program involves different actors from various types of businesses, including 2 universities (Aalborg and Aarhus University), a management consulting firm, and Garuda, the largest supplier of assessment tools for individuals, groups and organizations in Scandinavia. The main focus of this full paper is to showcase the output from an expert panel workshop held in October 2015.

In the selection process Lean managers from 26 medium-sized and large Danish companies were chosen to represent the public, manufacturing and administrative & service sectors. Common ground for all participants was several years of gathered experience and knowledge from working with Lean.

The methodology used during the workshop was inspired by and combined different methods and models, where the socialization, externalization, combination, internalization (SECI) model, the Delphi method and focus group interviews were used in the attempt to extract tacit knowledge from the expert panel through a socialization process (Nonaka & Takeuchi 1995).

During the workshop the 16 personality traits from Garuda's assessment tool, Competence Profile, was used to reach consensus among the participants. The aim was to specify which traits that applies to excellent Lean managers, which led to multiple rounds of group discussions and plenary sessions.

Each group discussion was isolated on choosing between and highlighting the descriptions and texts that gave the best description of the ideal Lean leader. To do so

each group was given a short description of all 16 traits along with a scale for each trait that had five to six sub- divisions, see example in figure 1. It should be taken into account that the expert group weren't able to choose the outer scores (the gray area in the illustration), as the outer scores are found to be irrelevant for any Lean leader. In the process every group had to give a primary and a secondary score within each trait.

After each round the various groups presented their results and the reasoning behind their answers to summarize the trait. The research group anticipated differences in the group assessments, which led to the use of a basic statistical analysis.

The results from the workshop led to a profile description of the ideal lean leader, which afterwards were given to all participants for further review and feedback.

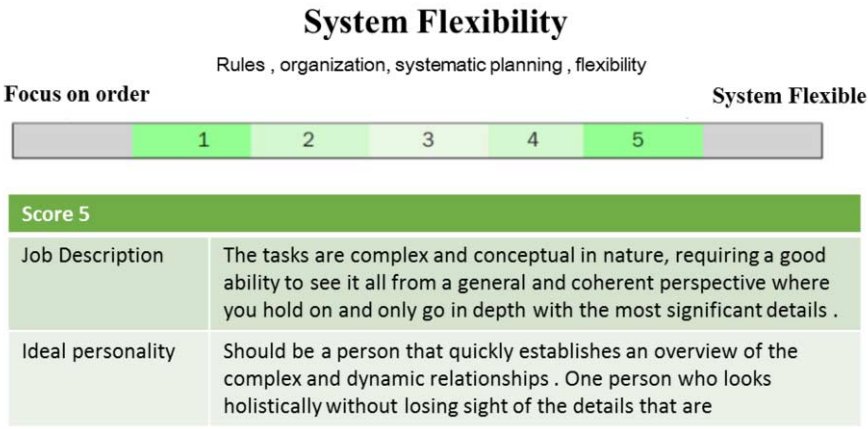


Figure 1. System Flexibility.

3. The Framework of the 16 Traits

The 16 personality traits in the Competence Profile that served as framework for the workshop can be divided further into three categories.

First: In situations where the Lean leaders feel content with them self and can do as they wish how do they process the tasks and problems they face in their daily work? This is the Head work of the Lean Leader. The category covers the traits: System Flexibility, Comprehensiveness, Abstract Thinking, Risk and Impulsive.

Second: In situations where the Lean leaders feel content with them self and in harmony with the people they socialize with in their daily work, how can the relationships with these people be characterized? This is the Heart work of the Lean Leader. This category deals with the areas of: Empathy, Social Contact, Social Flexibility, Support and Confidence.

Third: In situations where the Lean leaders work on solving a problem, how do they go about it and how great an influence do they have or wish to have on the process of solving a specific problem? This is the Leg work of the Lean Leader. This final category handles the traits: Competitiveness, Influence, Self Confidence, Independence, Psychological Strength and Physical Energy.

4. Empirical Result

This section presents the results of our empirical work. It consists of 16 traits that will be introduced separately by picturing a short description of the outer scores for each trait. This allows us to illustrate the Lean leaders' score within the trait – further guidelines for the illustrations are displayed in figure 2. To conclude each trait a job and a personal profile description will be presented.

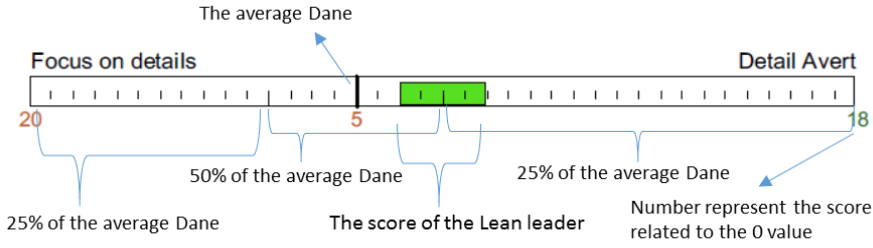


Figure 2. Illustration guideline.

4.1. The Lean Leader related to system flexibility

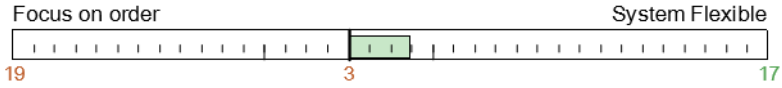


Figure 3. Measure of flexibility.

Job Profile: The task's solution and possible solutions are controlled to some extent by fixed rules, frameworks and systems. Within these, it applies that certain key tasks require independent planning, organization and choice of solution methods and processes.

Ideal personality: Should be able to solve tasks where solutions and possible solutions are not limited by any fixed rules, frames and structures. Must have well organized working habits and emphasis on concrete planning, controlling, and organization.

4.2. The Lean Leader related to Comprehensiveness



Figure 4. Measure of comprehensiveness.

Job Profile: The variety and complexity of the given tasks are fairly large, and the given solutions have great importance for the whole, which is why the most important details require a thorough and independent processing.

Ideal personality: Should have a comprehensive view and general knowledge where the more detail oriented routine tasks are left to others. Should be able to handle complex and dynamic connections with focus only on the most important details.

4.3. The Lean Leader related to Abstract Thinking



Figure 5. Measure of abstract thinking.

Job Profile: The key tasks represent problems that are best solved through an intellectual intervention and using models, theories and abstract concepts.

Ideal personality: Should be a person, who likes to work with tasks calling for a high degree of intellectual thinking. A person, who finds it exciting and challenging to work with new practical, conceptual and strategic features, which demand a more abstract general character where models and theories can be used.

4.4. The Lean Leader related to Risk

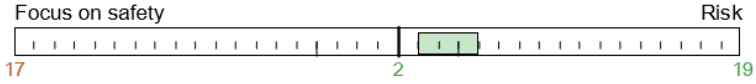


Figure 6. Measure of risk.

Job Profile: The nature of tasks and their content is varied. For key tasks it applies that the premise decisions taken are often fluid and uncertain, and are often made under some time pressure.

Ideal personality: Should be a consistent decision-maker, who likes to make decisions based on as well concrete analysis as estimated valuations of collected data. A person who is also willing to make decisions in areas where the consequences are of vital importance. A person, who purposeful can zigzag his/her way through matters.

4.5. The Lean Leader related to Impulsive

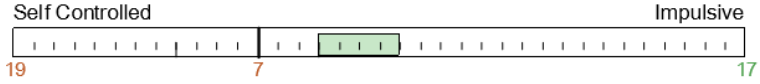


Figure 7. Measure of impulsiveness.

Job Profile: Tasks are solved under conditions where the person responsible, in between, may be under some time pressure or because of the nature of the task. Decisions are, however, made in a reasonably open environment where the more impulsive reaction is accepted.

Ideal personality: Should be a person, who stays calm and keep cool in hectic situations. A person, who does not overreact if the task solving is not working out as planned or if you get unexpected criticism. As co-operation mostly is together with known persons, who get to know each other, is there a certain understanding for the more spontaneous and emotional reaction.

4.6. The Lean Leader related to Empathy



Figure 8. Measure of empathy.

Job Profile: Tasks are solved in cooperation with others, which is dependent on a common understanding and acceptance of the division of tasks and responsibilities, and thus aware of the interdependence.

Ideal personality: Should be a person, who is conscious in his/her efforts of wanting to understand other people's personality, social and professional background for acting as they do. A person, who focuses on other's attitudes, motives and feelings, and who, from this, is good at integrating him/herself in the interaction with others.

4.7. The Lean Leader related to Social Contact



Figure 9. Measure of social contact.

Job Profile: Task solution requires that the person responsible is active in the effort to establish, maintain and deepen contacts with a group of collaborators.

Ideal personality: Should be an active, out-going and contact seeking person, should however, not be governed by a need to be the centre and exposing him/herself. A person, who finds it easy to maintain and widen the contacts to known people.

4.8. The Lean Leader related to Social Flexibility

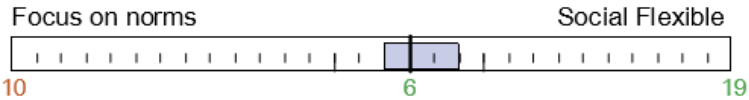


Figure 10. Measure of social flexibility.

Job Profile: Tasks are solved in an environment where there is some acceptance of, but also a limit to the patience and tolerance towards people with an alternative approach to disciplined task-solving and social behavior.

Ideal personality: Should be a person who can function in a work environment where there is some acceptance, but also limits of patience and tolerance towards people with an alternative approach to disciplined problem-solving and social behavior.

4.9. The Lean Leader related to Support

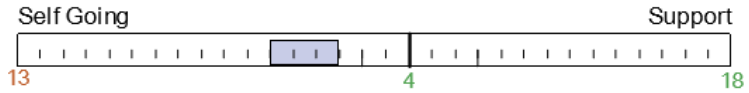


Figure 11. Measure of support.

Job Profile: Tasks are solved under conditions where the task-solver, only in exceptional situations, is dependent on or has to ask for others' acceptance, support and encouragement.

Ideal personality: Should be a person who can provide independent efforts and initiate things in time without the need for support, praise and recognition.

4.10. The Lean Leader related to Confidence

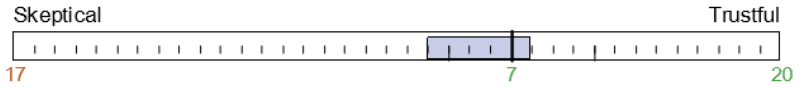


Figure 12. Measure of confidence.

Job Profile: Tasks are solved in an environment where the direct contact to others, in general, is characterized by openness and trust, which is why only situationally there is a need to remain skeptical of others' behavior, ideas and motives.

Ideal personality: Should be a person, who meets other people with a high degree of trust and kindness in his/her daily work, based on the philosophy that confidence and openness meet with confidence and openness. However, he/she must be a person, who can look objectively to others. Must be able to deal with situations where the personal trust not always is shown.

4.11. The Lean Leader related to Competitiveness

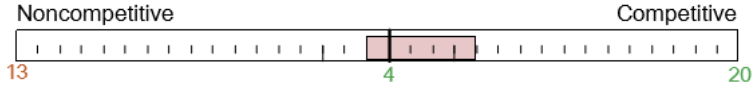


Figure 13. Measure of competitiveness.

Job Profile: Task solution, goal and setting requirements for result creation requires a certain degree of individual involvement and in many areas sets requirements on independent proactive and performance-oriented activities.

Ideal personality: Should be a person, who is always setting new and higher goals. The aim, the ambition to be among the best and improve whatever he/she is doing should be an important source of energy.

4.12. The Lean Leader related to Influence



Figure 14. Measure of influence.

Job Profile: The task's optimal solution requires that the person responsible for the solution takes independent initiatives to initiate and participate in the decision-making process, including, in certain situations, to make authoritative binding decisions.

Ideal personality: Should be a person, who does not keep a low profile in the decision making process. A person, who is constantly making an effort of carrying through his/her ideas and points of view without losing flexibility, neither on the

intellectual nor personal level. A person, who finds it easy to give orders without being dictatorial.

4.13. The Lean Leader related to Self Confidence



Figure 15. Measure of self confidence.

Job Profile: The tasks are of such a nature that in many contexts they place great demands on the task-solver's ability to independently deal with unforeseen and unknown problems and situations in a constructive and proactive manner.

Ideal personality: Should be a person, who keeps his/her self-confidence in the direct confrontation with other people and meanings. A person, who constantly seeks new challenges and new limits for his/her ability.

4.14. The Lean Leader related to Independence

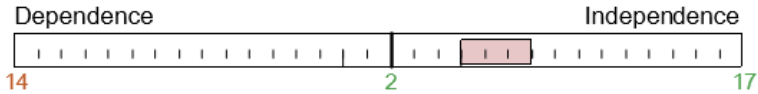


Figure 16. Measure of independence.

Job Profile: The job includes key tasks whose solutions are subject to some established procedures, as well as authoritative given orders, which often call for the jobholder's independent and constructive critical position.

Ideal personality: Should be a person with a basic need for independence. A person, who does not necessarily do what is expected of him, but has a independent and critical point of view and does not mind being in opposition if he/she disagrees. However, the independence must not be larger than the person accepts the superior frames and rules.

4.15. The Lean Leader related to Psychological Strength



Figure 17. Measure of psychological strength.

Job Profile: The task's nature and solution represents many unforeseen difficulties and challenges. The jobholder will, in certain key areas, experience a practical time-related and/or psychological pressure and may also meet resistance and criticism from others.

Ideal personality: Should be a solid and strong person, who does not take criticism, defeat or personal humiliations too seriously. A person, who has the excess energy to consider and evaluate criticism in a constructive way. A person, who does not keep a low profile for fear of difficulties or personal opposition.

4.16. The Lean Leader related to Physical Energy



Figure 18. Measure of psysical energy.

Job Profile: The tasks are of such a nature that they require a fairly high degree of self-initiated physical and/or intellectual activity, the level of which may vary from situation to situation.

Ideal personality: Should be a person who likes to be in motion all the time, both physically and mentally. A person for whom it is important that something happens all the time, and thus a person who keeps things going, does not wait for things to happen, and will impatiently push others in front of them.

5. Discussion

From the assessment it has been concluded, that 5 of the 16 traits are within the 50% quartile of the Dane. Furthermore, it shows that 7 of the scores are represented in both the 50% and 25% quartile. In 4 cases the score is purely within the 25% quartile. Lastly there are 6 cases where the score touches the mark of the average Dane.

Dealing with that many traits it's crucial to outweigh their relative importance to each other. The expert group was subsequently asked to contemplate which 5 traits they deemed more important.

1. Comprehensiveness: The incentive for comprehensiveness is based on the opinion of the expert group, that it is important for a lean leader to know the details of the operations, while maintaining a comprehensive view and control at the same time.
2. Confidence: The incentive for choosing confidence is that respect towards people is a key element in the TMS and therefore it is critical that lean leaders are capable of having faith in and trusting their employees to do their job.
3. Psychological Strength: As Lean is built on the premises of a Learning organization paradigm and a CI mindset, learning from your mistakes and errors is seen as a core element of an improvement culture, thereby making it a necessity that lean leaders are psychologically capable of handling criticism in a constructive manner and hereby developing a constructive feedback culture within the company.
4. System Flexibility: A key part of the foundations in Lean is standardization. CI cannot happen if there are no standards to improve from, therefore making structure an important trait for lean leaders to create and sustain a Lean environment through standardization. On the other hand, the leader must possess a mindset that challenges the status quo and makes him think beyond current standards and fixed rules for new ideas.
5. Empathy: The incentive for this trait derives from research, showing that people who work together in high performance teams tend to create far greater results in a Lean environment. Therefore, the lean leader possesses a critical

role in forming team spirit and one of the traits that promote this behavior is empathy.

6. Conclusion

This paper has presented and discussed the results regarding the research of characteristics of excellent Lean leaders that derive from the assumption that Lean Leaders have a specific profile. The output of the empirical study is a profile consisting of the 16 traits. In addition to this output the expert group chose 5 traits that they believed were most important: Comprehensiveness, Confidence, Psychological Strength, System Flexibility and Empathy. To further strengthen the assumption that Lean leaders have a specific profile further empirical study can be carried out within foreseeable future. At this early stage the current results can be used as a guideline or as a template to compare candidates in recruitment processes. Furthermore, it seems obvious to use the results as a tool for internal organizational development of Lean managers by using gap analysis to enable strategic competence development. Finally, another way to put the results into use is as a self-awareness tool for Lean managers.

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Development of System to Support Knowledge Discovery in Historical Study with Linked Data

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Abstract. In the field of historical study, the system called Digital Archive, which digitizes historical resources and publish them on the web, has been developed. This helps preventing damage of resources and providing them beyond temporal and geographical constraints. On the other hand, practical use of Digital Archive has not been considered, because the primary aim of it is preservation and publishing of them. This prevents from sharing data and knowledge with others and efficient usage of published data such as digitalized images and catalog data. As for this problem, Linked Data has been considered as one of solutions. Linked Data is a term used to describe a practice for sharing and connecting data and knowledge on the web. The objective of this paper is to develop the system to support knowledge discovery in historical study by use of Linked Data. Developed system connects with Digital Archive through Linked Data, and allowed historians to use catalog data on the web and research data, which historians accumulate based on their objectives, integrally. This helps historians to analyze a large amount of historical resources quantitatively, and encourages to discover new knowledge which have not been discovered by qualitative analysis. We apply developed system to the case of historical study, and the effectiveness was verified by finding new characteristics of historical resources.

Keywords. Digital Humanities, Digital Archive, Linked Data, Knowledge Management

Introduction

Recently, the application of information technology to Humanities called Digital Humanities is growing in popularity and necessity. In the field of Historical Study, the system called Digital Archive, which digitizes historical resources and publish them on the web, has been developed. This helps preventing damage and degradation of them, as well as providing them beyond temporal and geographical constraints.

The aim of historical study is for historians to understand history and discovery new knowledge using those resources. Historians collect, arrange and analyze resources based on their objectives. Growth of Digital Archive makes it easy for historians to

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access those resources through the internet. On the other hand, practical use of Digital Archive has not been considered, this is because the primary aim of Digital Archive has been preservation of them. As the result, historians collect resources and arrange them manually, and this prevents from sharing data and knowledge with others and efficient usage of published data such as digitalized resources and catalog data.

As for this problem, Linked Data[1] has been considered as one of solutions. Linked Data is a term used to describe a practice for exposing, sharing, and connecting pieces of data, information, and knowledge on the web. This enables users to access data on the web via the query language called SPARQL, and results are basically returned in machine-readable formats. This makes it easy to handle those data not only manually by human users but also mechanically.

The objective of this study is to develop the system to support knowledge discovery in historical study by use of Linked Data. Developed system connects with Digital Archive through Linked Data, and allowed users to use catalog data on the web and research data, which historians accumulate based on their objectives, integrally. This system enables to analyze a large amount of historical resources quantitatively and encourages to discover new knowledge from those resources. In addition, this system provides the function to visualize the frequency of resources in chronological order and helps historians to analyze them from the point of history transition. We apply developed system to the case of historical study, and the effectiveness was verified by finding new characteristics of historical resources.

1. Related works

Linked Data is a term used to describe a practice for exposing, sharing, and connecting pieces of data, information, and knowledge on the Semantic Web using URIs and RDF. URI (Uniform Resource Identifier) is a string of characters used to identify a resource. Such identification enables interaction with representations of the resource on the web. RDF (Resource Description Framework) is a general method for conceptual description or modeling of information that is implemented in web resources. In addition, the usage of Web API such as SPARQL, which is a query language of RDF, enables third parties to develop applications for wide variety of objectives.

Representative example of utilization of Linked Data in the field of digital humanities is “Europeana” [2]. This is a cross-site search portal that allows access to resources possessed by cultural facilities such as more than 3,000 libraries, museums and archives in 35 European countries. Also, development of standardization of schema for describing catalog data is growing in necessity [3]. For example, OCLC (Online Computer Library Center), which is an organization composed of universities and research institutions around the world centered on the United States, converted the authorized data into Linked Data and publishes them as a service [4].

In addition, application of Digital Archive and Linked Data is getting in popularity for virtual museums recently [5][6]. Kiourt et al. [7] are developing a system called "DynaMus" that enables virtual exhibition in Web space. As one of the information sources of exhibition resources, they use catalog data such as form and size of resources by using Linked Data published by Europeana.

Furthermore, there are some researches for efficient utilization of historical resources by use of Digital Archive [8]. Sato et al [9] developed the system to make annotations on historical resources with several historians for metadata harvesting.

As mentioned above, the application of Linked Data to Digital Archive is getting popular. However, the objective of these applications is mostly focus on development of cross-site search portals or virtual museums. Besides, there are some systems which allow users to annotate metadata of historical resources, but these do not focus on analysis of those resources based on various objectives of historians. This paper aims to improve process of historical study with Digital Archive and Linked Data, and to encourage historians to understand history and discover new knowledge.

2. Developed System

Figure 1 shows overview of developed system.

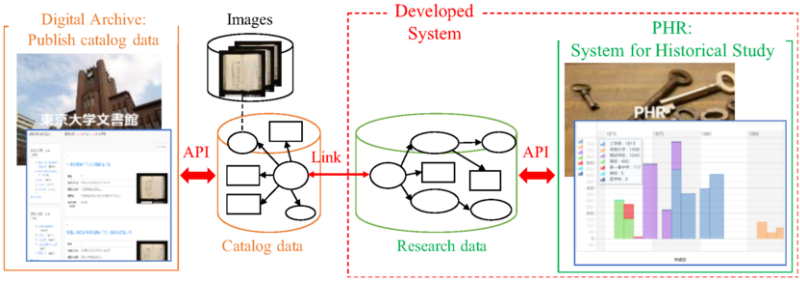


Figure 1. Overview of developed system which relates to Digital Archive with Linked Data.

This system connects with Digital Archive which published catalog data as Linked Data, such as Europeana. Catalog data is basically bibliographic information of historical resources, such as title and created date. Developed system provides database for users, and allows them to accumulate and arrange data which we call "research data". This data can be defined freely based on research objectives of each historian, such as research notes and achievement gained from research. Also, this system provides interface to analyze historical resources based on metadata. Linkage of catalog data and research data allows historians to analyze resources quantitatively with large amount of data.

The details of description of catalog data and research data by RDF and interface of developed system to analyze resources based on metadata are explained below.

2.1. Data description by RDF

Figure 2 shows how to manage catalog data published on Digital Archive and research data which historians accumulate and arrange based on their research objectives. Left part shows example of description of catalog data. RDF requires to assign URI to each resource on the web, and catalog data such as title and created date of them are attached as metadata. These catalog data is basically defined by Dublin Core [10], which is RDF Schema to describe bibliographic information of web resources. Right part shows description of research data. Historians use historical resources with wide variety of research objectives, and it is rare that catalog data fulfills all of their demands. Therefore, this system allows historians to accumulate research data according to their objectives.

For example, metadata about "receivers" in Figure 2 is described with unstructured format, such as "Minami Kou; Higashi Kou; etc…", which is a list of receivers of the

resource. This format is not suitable for analysis of these resources by each receiver. Therefore, research data shows the example which historians converted unstructured data into structured data. These research data are also accumulated as metadata of resources, and this allows historians to analyze them with catalog data and research data together.

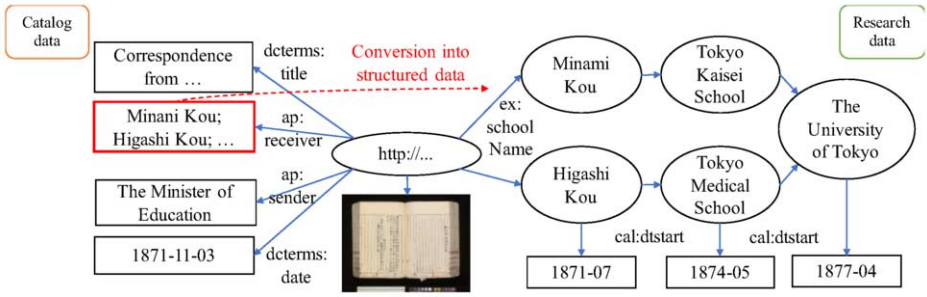


Figure 2. Management of catalog data and research data with RDF format.

2.2. System interface to analyze resources with stored metadata

Figure 3 shows interface to analyze resources with metadata stored in developed system. The bottom part shows frequency of resources extracted based on users' configuration. This system provides configuration interface where users can set criteria of analysis. This allows historians to analyze resources according to their objectives. In this example, historical transition is shown based on created date of resources extracted based on some configuration. In addition, the timeline which corresponds to duration of retrieved resources is shown like upper part. This allows historians to analyze historical transition with events which occurred at the same time.

These functions allow historians to analyze resources quantitatively with large amount of data based on their objectives, and helps them to discover new knowledge and findings.

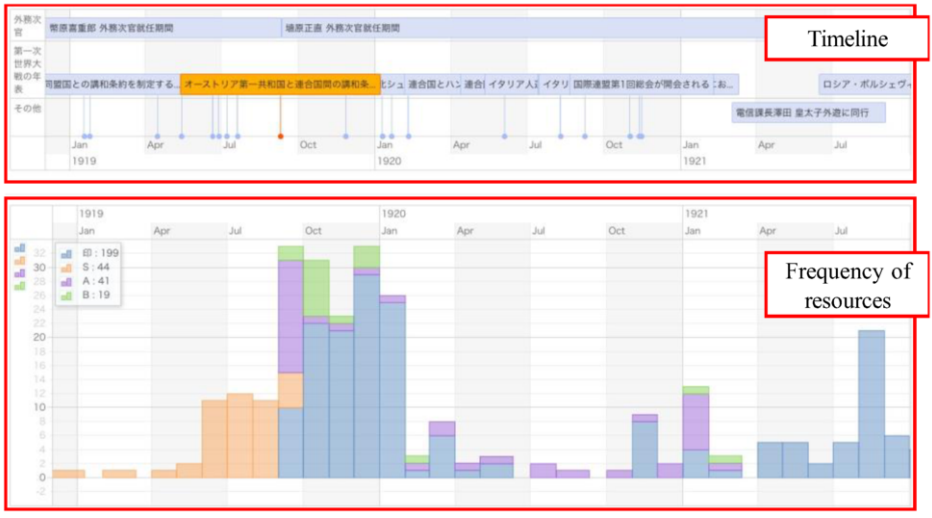


Figure 3. Interface to analyze historical resources with stored metadata.

3. Case Study

3.1. Introduction

From the beginning of Meiji era (Japanese era which extended from October 23, 1868 through July 30, 1912), the University of Tokyo continued to merge with many different schools specializing in various fields, and has experienced a number of name changes over the years.

Figure 4 shows an example of those changes. The merging of Tokyo Kaisei School and Tokyo Medical School created the four Faculties of Law, Science, Letters and Medicine, which came together with a university preparatory school (yobimon; the First Higher School of Japan's predecessor) to form the University of Tokyo.

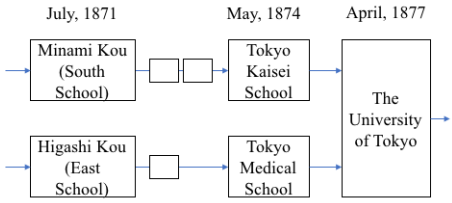


Figure 4. Example of name changes of the University of Tokyo.

"Monbusyo Ofuku" is one of useful historical documents to understand this history. This is official document between the University of Tokyo and the Ministry of Education in Japan, and this is designated as a nationally important cultural property in Japan. 12,000 resources in this document and catalog data of them were digitalized by "The University of Tokyo Archives". Also, we have developed the prototype system of Digital Archive, which manages those catalog data with RDF and publishes them as Linked Data. The example of interface on the prototype system is shown in Figure 5.

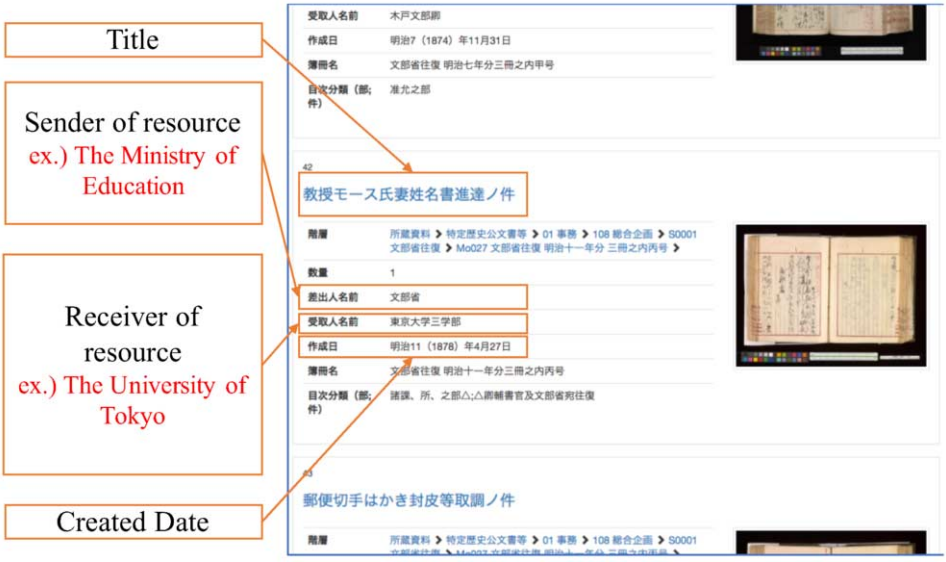


Figure 5. Example of interface on the prototype system of Digital Archive.

Catalog data is composed of two types of data. One is general bibliographic information, such as document title and created date. The other is characteristic information for the correspondence, such as name of sender and receiver of resources.

By taking the advantage of catalog data of "Monbusyo Ofuku" which is digitalized and published as Liked Data, this case study aims to overview the name changes of the university. Specifically, we visualize historical transitions of name changes of the university based on catalog data such as sender and receivers of resources. Furthermore, this aims to discover new characteristics of this document through the quantitative analysis.

3.2. Accumulation and Arrangement

First, we submitted SPARQL query which extracts catalog data such as title, created date, senders and receivers of resources from prototype system mentioned above. As the result, the catalog data about 11,823 resources was extracted, and those were stored in database on PHR. The example of those catalog data is shown in left part of Figure 2.

Next, we arrange catalog data for quantitative analysis like right part of Figure 2. Catalog data such as sender and receiver of resources was described with unstructured format, this is because catalog data basically follows the letters written on resources. Figure 6 shows the process to convert unstructured catalog data into structured research data.

For example, the receiver of resource which were sent to "Minami Kou" and "Higashi Kou" was described like "Minami Kou; Higashi Kou;". Quantitative analysis requires structured data for each name of schools. Therefore, we listed names of the university such as "Minami Kou", "Higashi Kou", "Tokyo Kaisei School", etc..., and stored names extracted from unstructured catalog data as research data into database on PHR.

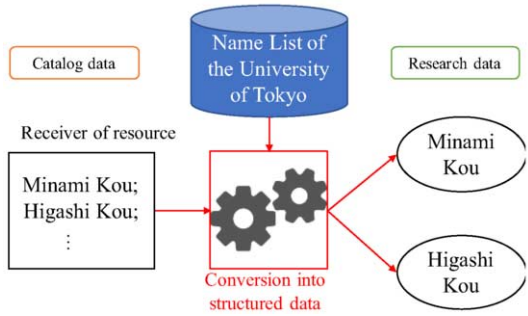


Figure 6. The process to convert unstructured catalog data into structured research data.

3.3. Analysis

Figure 7 shows the result of classifying resources with school names arranged as research data, and visualizing them in chronological order with created date, which is one of catalog data. Name changes of the University of Tokyo can be seen visually. Though detail explanation of these name changes are omitted in this paper, we confirmed with references that this result represented historical transitions of the university correctly.

In addition, the result which is pointed out with red circles shows that, these resources contain correspondences with "Higashi Kou" and "Tokyo Medical School", even the number of them is very limited. This is different knowledge from prior research [11], which mentions "Monbusyo Ofuku" does not have correspondences with schools inherited from "Higashi Kou", such as "Tokyo Medical School". This means that quantitative analysis could discover new characteristics of "Monbusyo Ofuku" in this case study.

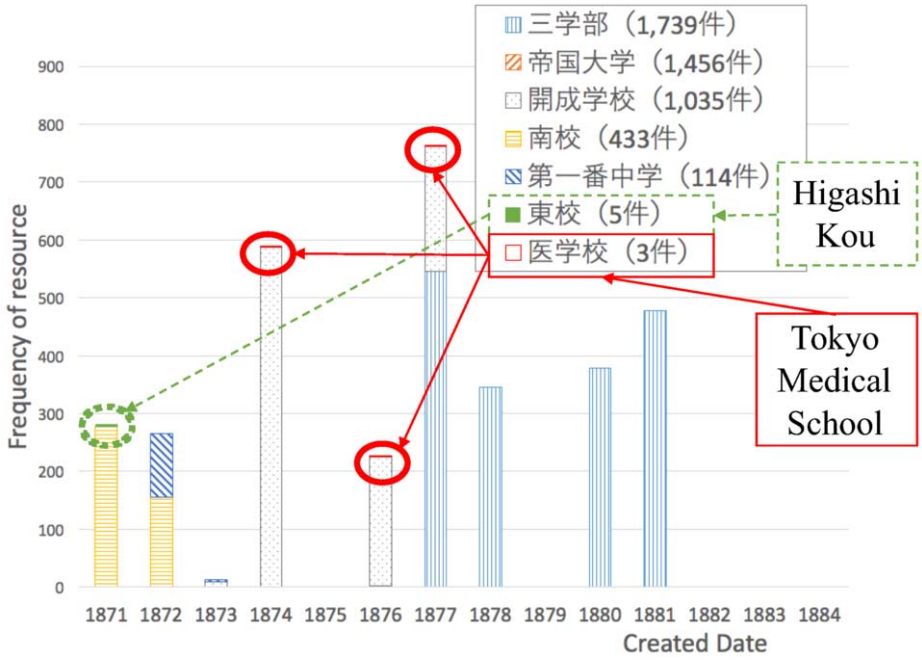


Figure 7. Visualization of history transitions of name changes of the University of Tokyo.

4. Discussion

Here, we evaluate the effectiveness of proposed system based on the interview of co-researchers in the case study above. Co-researchers, who specialize Japanese history, brought up the following problem in the current process of historical study which is mainly relied on qualitative analysis.

"Researchers especially who have high expertise in the research fields tend to unknowingly builds understanding of historical resources."

The experience of many years in specific research makes it difficult to bring new findings from qualitative analysis, which especially comes from minority data. Against this problem, proposed system allows users to analyze history and historical resources objectively and quantitatively by use of the large amount of catalog data and the visualization of frequency of them. In practice, the case of historical study could bring new characteristics of historical resources. Co-researchers highly valued these functions in developed system. This quantitative and objective analysis by use of large amount of research data was brought by the interaction of catalog data in Digital Archive and research data which historians arrange based on their objectives. Regarding this point, we confirmed that proposed system is effective for historians to discover new knowledge in historical study.

On the other hands, qualitative analysis against historical resources is still essential methodology to understand history. Though this article focuses on the utilization of catalog data provided in Digital Archive, we will work on the utilization of contents of digitalized historical resources with information technology such as image-processing technology or text-mining approach in the future.

5. Conclusion

In the field of Historical Study, Digital Archive, which digitizes historical resources and provides them on the web, has been developed. This has brought a lot of merits to historians, such as easy access to historical resources through the internet. On the other hand, practical use of Digital Archive has not been considered. As the result, historians need to collect resources and arrange them manually, and this prevents from efficient usage of published data such as digitalized resources and catalog data provided in Digital Archive.

In this article, the system to support knowledge discovery in historical study by use of Digital Archive and Linked Data was proposed. Developed system allowed users to use catalog data provided in Digital Archive and research data which historians accumulate based on their objectives. This helps users to analyze a large amount of historical resources quantitatively, and encourages to discover new knowledge which has not been discovered by qualitative analysis.

The effectiveness of developed system was verified through the case of historical study which analyze the history of the University of Tokyo by use of "Monbusyo Ofuku", which are official documents between the University of Tokyo and the Ministry of Education. The analysis which visualized the history transition of the name of the University of Tokyo in the early Meiji era with about 12,000 resources helped comprehensive understanding about the history of the university. In addition, this quantitative analysis discovered new characteristic of documents which is different from the result of previous research.

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Integrated Data Management System of Tank Test and CFD Data Considering Hull Form Design Process

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Abstract. The objective of this paper is to propose data management scheme of towing tank test and CFD data considering the reuse in design process, and to develop an integrated data management system based on the scheme. To be concrete, the data scheme is proposed by using Resource Description Framework (RDF), which is one of the technique of Linked Open Data (LOD). Towing tank test and CFD data have many kinds of data type and format including video, measured time-series data, and so on. Various kinds of type and format can be assumed for experiments and CFD softwares. But the defined data scheme enable to manage all the data and every achievement of designers can be shared. Moreover, information about procedure of the hull form design process is modeled in RDF format as well. By connecting the past achievement data to the information about design process, a hull form design assistant system is developed as a web application, on which designers are able to access required information in their required timing. In a case study, a simplified case of the actual design process is assumed, and by applying the developed system to the case, we demonstrate that the developed system can achieve the objective and is useful to make hull form design process more efficient.

Keywords. Ship Design, Data Management, Tank Test, CFD

Introduction

In considering ships' performance, hull form highly affects their performance including propulsive, seakeeping and so on. For improving ships' fuel efficiency and safety, it is important to design their hull form appropriately corresponding to their operating condition, such as speed, loading condtion, and route.

The well-known and general agreed chracterstic of ship design process is that the process takes many loops of trial and error [1]. Moreover, ship design highly depends on experienced naval architects, and the design space was practically explored using the designers' implicit knowledge [2]. When focusing on the process of hull form design, the state is the same. Design process by trial and error depending on designers' intuition and experience needs much cost and cannot guarantee the design's quality.

To overcome this situation of hull form design, many methods of automatic optimization using CFD have been studied [3][4]. In these study, hull form is expressed by some parameters, and by iteration of changing the prameters and evaluation by CFD

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automatically, they tend to find an optimized hull form without human's work and konwledge. However, the application to gemba is limitted because the evaluation of CFD takes too much time, and the iteration process cannot be repeated enough times, or the simulation has several kinds of uncertainties [5]. Of course, CFD is recognized as a strong tool to evaluate ship performance, but the design process of hull form still highly depends on designers' intuition and experience.

Another way to overcome this situation of hull form design process is to utilize past designer's work to cover his or her shortage of experience, or to decide design plan with obvious evidence. Design process based on the clear evidence improves efficiency and quality of hull form design because waste iterations can be eliminated and deviation of the quality can be prevented.

Based on the background mentioned above, this paper develops design process data management system. The role of this data management system is to accumulate designers' work history for utilizing it as evidence in design process. Firstly, we analyze hull form design process and define the system's requierment. And on the basis of the requirements, the data management system is developed using Linked Data technology. In this system, a new approach to accumulate hull form design data is applied, in which not only traditional design data including CAD, tank test and CFD data but also data about design process itself can be accumulated and managed.

In case study section, it is demonstrated that the developed system fulfill the defined requirements by applying it to the simplified case; wave making resistance reduction using CFD. The result shows that by using data retrieved from the developed system, designer can find out new design with better performance which cannot be found from only design data, and the proposed new approach to accumulate both design and process data is more useful to support future design process than the traditional way without process data.

1. Related research

The most traditional way to manage past designed hull form data is to summrized in a chart, such as Yamagata chart or Taylor's chart [6]. These kinds of charts are useful to roughly decide ship's main principles in early stage, so they or those which imitate them are still widely used in recent years. Aguilar et al. [7] developed a parametric hull form design system to support fishing craft design. They also installed past design data summrized in charts as an internal knowledge for decision support of initial principles. However, these kinds of charts are too simple and not enough to investigate hull form in detail and write lines of the hull. Relationship between hull form and the performance is so complicated that for detailed hull form design, much more information is needed.

Hiekata et al. [8] developed ship design workflow management system for the purpose to transfer knowledge about ship design, which is called ShareFast. For management of workflow, ShareFast associates knowledge with design process by Semantic web technology. Through experiments, they show that this methodology is effective for transferring knowledge or education to beginners of ship design. However, in considering hull form design, knowledge about design is not stated explicitly, so design process and knowledge cannot be associated directly as same as their study.

PDM (Product Data Management) system [9] is often used for management of these kinds of design data. While PDM have significantly matured over the past years, analysis of the process should be conducted before the introduction.

The novelty of this research is to propose a new system to manage ship design data associated with design process. Firstly, the target process is analyzed to define system's requirement. Moreover, the target data of management is all the design data including tank test, CFD, CAD data and other documents and this method enables integrated management of all these data.

2. Design and development of a data management system

This section gives how to design and develop of a data management system for hull form design. First subsection provides analysis of current hull form design process and definition of what data should be managed in the system. And then, on the basis of the first subsection and usage context of this system, requirements of the system are defined in 2nd subsection. Last subsection describes how to implement the requirements as an information system.

2.1. Analysis of current design process and definition of system's requirement

Figure 1 shows current process for hull form design written by Object Process Methodolgy(OPM) [10]. The whole process consists of three process, selection of type ship, selection of several design candidates, and selection of conclusive design. Firstly, initial requiments, such as restriction of length, breadth, and draft, displacement, and speed are provided to a hull form designer. The designer selects a type ship, which is the base line of the design from exisiting designs and modify the type ship's hull to fit the provided requirement more. For the performance evaluation of the modified hull form, CFD is utilized in the step to select design candidates. The designer make a lot of modified hull, calculate their performace, and pick up several ships as design candidates on the basis of CFD result. In the third step to select conclusive design, designer conducts a towing tank test of the design candidates and they decide the conclusive one based on the result.

All of the contents on this OPM diagram should be targets of the data management. In this paper, it is defined that design process data consists of design data and process data. The design data is input or output of each process. In OPM, this data is "object" node which is connected to "process" node by consumption/result links. The process data is about process, which is directly described as "process" node in OPM. According to this diagram, design data can be decomposed as 7 data and attributes like Table 1. The attribute means the information is minimum requirement to express the data. For example, CAD data is required to express type ship, and the other information defines the type ship, such as the length, breadth, C_p(Prismatic coefficient), and etc. can be calculated from the CAD data. As well as the design data, process data can be defined 8 kinds of data, searching type ship, hull modification, mesh generation, CFD simulation, decision of design candidates, making model ship, tank test and decision of conclusive design. However, the definition of attributes is more ambiguous than design data because a lot of ways can be assumed for the process. For example, there are many methods for CFD simulation and their requirements are difference. RANS simulation

needs turbulence model, but Rankine source method doesn't need any model. It is obvious and common that all the process needs Input/output design data.

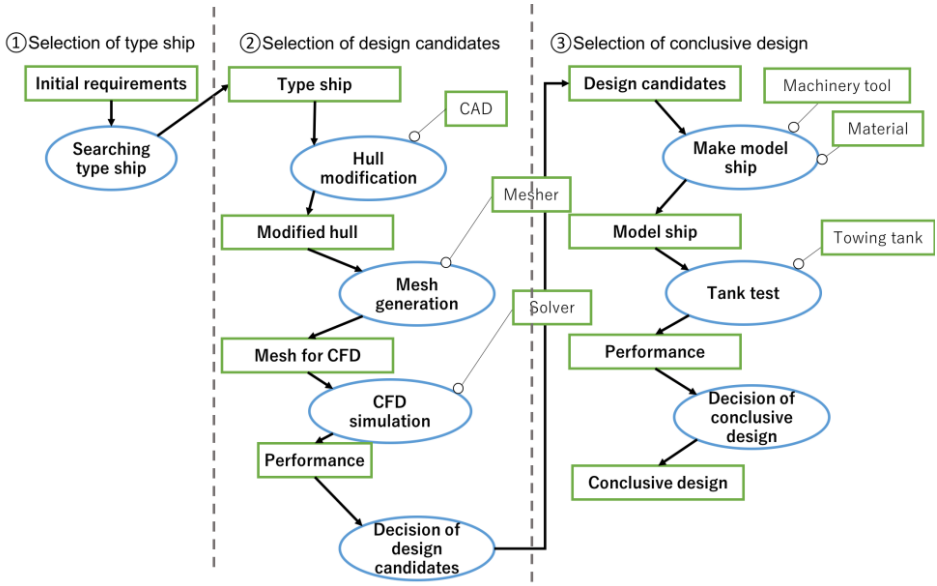


Figure 1. Current hull form design process written by OPM.

Table 1. Data and the attributes of design data.

Design data	**Attribute**
Initial requirements	Length, breadth, draft, displacement and speed
Type ship	CAD data
Modified hull	CAD data
Mesh for CFD	Computational grid data
Hull's Performance from CFD	Simulation result(v, p, etc.) on each mesh
Model ship	Material and size.
Hull's Performance from tank test	Ct, Sinkage, Trim, η_R, η_0, $1-t$, and $1-w$

To define requirements of the data management system, we should also consider the usage context of the system. The system assumes that users retrieve the data as reference according to their design situation. Users search the past design history by ship's speed, size, shape, and type. So, the system should have functions to retrieve the data using these 4 items as query. UI for the retrieving is needed. In this paper, ship's size means L_{pp}(length between perpendiculars), breadth, depth, draft and displacement, ship's shape is expressed by Lcb(longitudal center of buoyancy), mid area, block, prismatic, run and entrance coefficient. For retrieving by these information, type ship or modified hull data should have this information.

In summary, the data management system's requirements are following.

1. System can store 7 kinds of design data and 8 kinds of process data. Design data has each attributes and process data has I/O. The system's database needs all of these contents.

2. System can retrieve stored data according to inputted query. As the inputted query, ship's speed, size, shape, and type should be assumed. These informaton about type ship and modified hull should be added to stored data and UI for the retrieving is needed.

2.2. Development of design data management system

This subsection describes devloped design data management system and how to implement the requirements defined in *2.1*. This system has 2 funtions, data storing and data retrieving, and each function has requirements. This subsection provides explanation about how to implement these functions.

Firstly, we explain the function of data storing. For data storing of design and process data, traditional relational database(RDB) and resource description framework are adopted. Data file such as CAD or mesh data are stored in RDB and by annotating those data file using Resource Discription Framework(RDF) [9], design and process data storing is realized. Figure 2 and 3 show examples in cases of data annotation for design data and process data. Conceptually, RDF expresses data using links and nodes. There are 2 kinds of node, resource(ellipse) and literal(rectangle). In this system, resouce node expresses design and process data or an actual data file such as CAD file, mesh file and so on, and literal means text data. So, Figure 2 shows that draft of design data "Type ship" is "14.0" and the CAD data is "type_ship.igs" file stored in RDB, and Figure 3 shows that input of process "Hull modification" is "Type ship A" and output of the process is "Modified hull". Information annotating to design data is attribute of each, and only to data of type ship and modified hull, ship's speed, shape, size, and type defined in the previous subsection are added. For annotating to process data, this system force users to annotate input, output data, and a document file which is explanation of the process. These annotations are minimum required in this system.

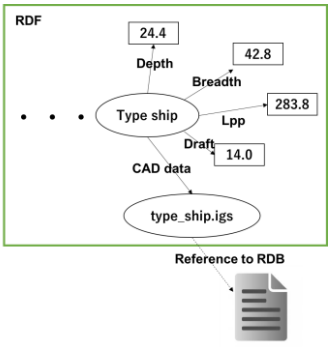


Figure 2. Example of design data on RDF.

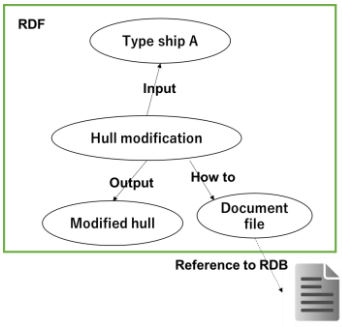


Figure 3. Example of process data on RDF.

In addition to these minimum required annotation, users can add more annotation if they want. Because various kinds of situation are assumed in hull form design, it is not realistic to determine the method to express data uniquely. This system defines the minimum required information to construct database, leaves the other information to users and realizes flexible database. By this flexibility, users can add the information which is likely to be useful in parallel with their work, and the database will be getting richer and richer. Figure 4 shows the UI to input and annotate design and process data. This figure shows the example to input design and process data about hull form, and

hull modification, mesh and CFD simulation. Rectangle expresses the design data and circle expresses process data. As the figure shows, user can add rectangles and circles and define the relationship as they want. In "properties" area, user can edit the information annotated to the data. Moreover, user can upload data files and associate the file to data objects expressed by rectangles or circles. If users want to annotate more information, user can add the key of properties and edit the value flexibly.

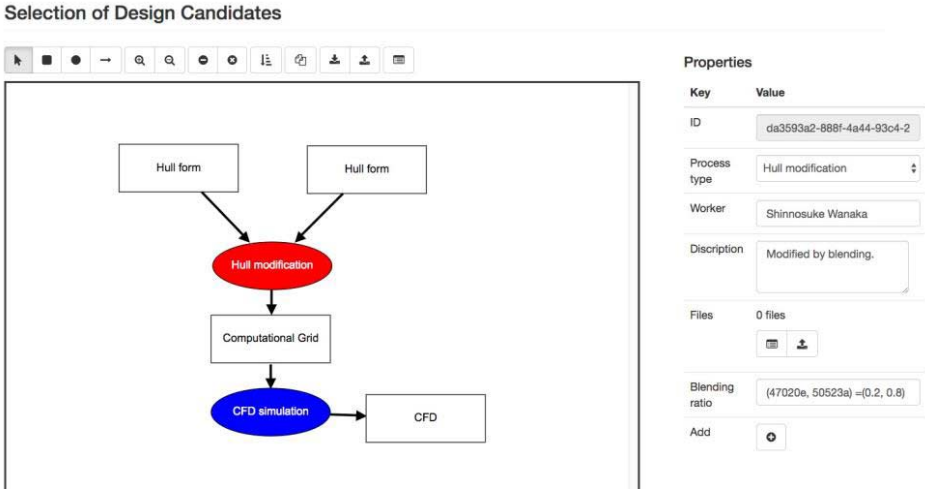


Figure 4. UI to input and annotate design or process data

Lastly, the function of data retrieving is explained. This system assumes that after data retrieving, users analyze and do post-process the reetreived data. So, the system provides the retrieved data in the format of Microsoft Excel, which is used as data anaylsis platform all over the world. Users input query of ship's size, shape, speed and type, and then obtain a list of design process data. By selecting from the list, they can download the data in their local laptop.

3. Case study

This paper proposed design data management with process data. In this case study, the retrieved data from the developed system is more useful for design process than data without process information.

By searching on the proposed system, we retrieve past design data resulted by blending 3 types of hull form. Blending is a method of hull design in wchich new hull form is defined by blending several type ship through blending parameter [11]. For example, when considering to blend 2 hull form, A and B and setting each blending parameter T and $1-T$ (the sum must be 1), the new hull form is defined using control points $\boldsymbol{P_{new}}$ calculated from A's control points P_A and B's control points P_B according Equation.1. In this case study, three blended hull are defined as A, B and C.

$$\boldsymbol{P_{new}} = T\boldsymbol{P_A} + (1-T)\boldsymbol{P_B} \tag{1}$$

In this case study, Lcb and energy of wave making estimated by Rankines sourch method [12] are stored in the system as design data and blending parameters used in

hull blending is stored as process data in addition to the mimum required data defined in Table 1.

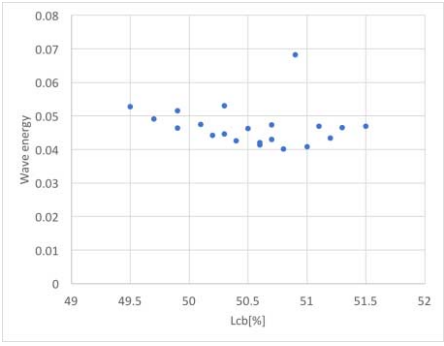


Figure 5. Results of Rankine source method (without process data).

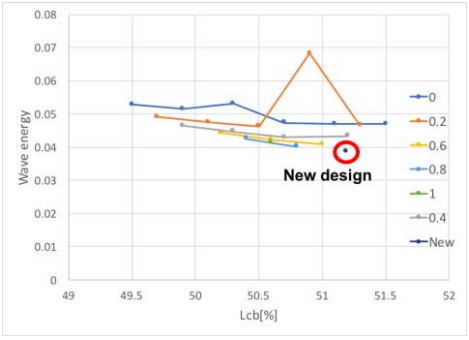


Figure 6. Results of Rankine source method (with process data).

Figure 6 shows the Lcb - energy of wave making graph of the retrieved data. From the graph, designer can obtain that the best hull is the hull whose Lcb is located on 50.8% of the L_{pp}. However, designer cannot obtain information about how to improve the hull form. On the other hand, Figure 6 shows the graph resulted by adding blending parameter data to Figure 5. In Figure 6, the same color is added to every data whose C's blending parameter is the same. From this graph, designer can understand the best hull's blending parameters configuration is (0.2, 0, 0.8), and this configuration is better than (0, 0.2, 0.8). That is, the more A's parameter increases with keeping C's parameter, the more hull's performance is improved. Actually, when blending parameters are set to (0.4, -0.2, 0.8), more improved hull is obtained than the best hull in Figure 5 as showed in Figure 6. This result displays that by managing both design and process data, designer can utilize them as useful information for design more than the situation without process data.

4. Discussion

In the case study, result shows that the retrievd data from the developed system is useful to design. However, it is essential to annotate appropriate information to the design and process data for getting this kinds of good effect from the developed system. Knowledge for hull form design is now tacit, and mostly in designers' intuition and experience. By designing what kind of data should be appropriate to annotate and orgnaizing past design data, this system can be useful to extract formalized knowledge from designers' experience.

CFD is a strong tool for evaluating ships' performance, but it includes some kinds of uncertainty, numerical error, model-based error, and so on. To solve these uncertainties is one of the most important challenge of the future. On the other hand, it is known that tank test is accurate enough to estimate ships' performance. It is necessary to compare CFD to tank test and continue to discuss how to deal with the uncertainties. This system can manage both of tank test and CFD data associated with each other, and enables to search related cases of tank test and CFD quickly. This function can support the comparison process of tank test and CFD, so it can be said that this is another contribution of the developed system.

5. Conclusion

In this paper, a design process data management system is developed. The role of this data management system is to accumulate designers' work history for utilizing as evidence in design process. Firstly, we analyze hull form design process and define the system's requierment. And on the basis of the requirements, the data management system is developed using Linked Data technology, RDF. In this system, a new approach to accumulate hull form design data is applied, in which not only traditional design data including CAD, tank test and CFD data but also data about design process itself can be accumulated and managed.

In case study section, it is demonstrated that the developed system fulfills the defined requirements by applying the developed system to the simplified case; wave making resistance reduction using Rankine source method and hull form blending. The result shows that using data retrieved from the developed system, designer can find out new design with better performance which cannot be found from only design data, and the proposed new approach to accumulate both design and process data is more useful to support future design process than the traditional way without process data.

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Knowledge Based Processes in the Context of Conceptual Design

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Abstract. The paper presents an attempt of real, industrial, engineering knowledge modeling, used in a small company. The authors concentrate on the concept of personal/team knowledge repositories and tools which can support conceptual design. The introduced software solutions allow to perform and acquire key steps which are necessary to achieve the final conceptual goals.

Keywords. Engineering knowledge modelling, conceptual design, case study

Introduction

The paper presents an attempt of real, industrial, engineering knowledge modeling, used in a small enterprise. The authors focus concentrates on the stage of the conceptual design [1][2]. The developed software solutions allow to acquire key steps which are necessary to achieve the final conceptual goals. Both modelled and analysed design processes aim at capturing design steps based on mental as well as formal modeling.

Usually, the performing of engineering design tasks concentrates on two types of activities [3][4][5]:

- activities connected with modelling the reality,
- activities analysing the models of reality and associated decision making actions.

Both types of activities are normally fulfiled and integrated by the designers [6][7][8][9][10]. In doing so, the applied models can be on different levels of complexity, starting from very simple ones, which are based on few formulae to huge systems of equations. Problems of a high degree of complexity are mostly solved in collaboration with other designers [3][4][7][8][9][10]. But both complex problems and simpler ones are first of all "solved" in the engineers' minds and hardly ever recorded in one way or other [5].

All activities mentioned above require engineering knowledge which is the result of education and professional experience [5][11][12].

Although designers' knowledge can be stored in different forms of computer representations it is difficult to express all details connected with a particular set of engineering problems [5][13][14][15][16][17]. Only the designer as the main knowledge source understands everything widely, this means the multi-aspect and multi-context of the problem [5].

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The designer is able to operate actively with his knowledge [5][13][14][11]. The knowledge can be the result of reflection on past tasks which he recalls [19][20][21]. In many cases, especially in conceptual design, this is a kind of evolutionary progress in a selected knowledge development.

In the paper we concentrate on the concept of personal/team knowledge repositories and tools which can support conceptual design. The whole approach was created and verified in a real industrial design office [22].

1. Design knowledge modeling during the conceptual stage of a design process

Each design process is determined by the final function of the respective product [1][2]. For the design knowledge modeling the product function is decomposed on sub-functions [23]. Designers look for suitable and feasible solutions to realize particular sub-functions. Then the alternate combinations of the analyzed solutions are examined and evaluated. The new approach is repeatedly corrected till the final satisfying solution is achieved.

In the literature we find various methodical approaches for conceptual design [1][2][24]. One of the most interesting ideas seems to be the so called systems engineering [25]. This approach bases on the assumption that there are certain components with their attributes and relations, etc. which could be used in formal model building [26]. The complexes of such elements can be used to model the structures and functions of a product for example [27][28][29]. Applying this approach may important characteristics of a product can be preciously captured [30]. The main goal is to shift the development process from a document-centric to a model-centric one [31].

Solutions based on the above concepts offer better quality of knowledge storage. Moreover they represent a better discussion basis for the team members.

On the other hand these approaches require more effort from the designer's side.

To build new versions of the existing systems' engineering models or to create their thematic libraries are tools which may be helpful [32][33].

The concepts developed during conceptual design can first be expresed in the form of the initial paper document. Later evolutions can be moved to the environments with systems' engineering computer models.

More than 20 years ago people started to use multi-media records for knowledge storing [3][4][7][10][34]. Documents/logs of communication between the designers (team members) about the conceptual design stage became a valuable material. The recorded information was not a mere collection of sentences. The recordings contained descriptions, opinions, models and acts of validation. Sometimes even interactions between team members together with their argumentation could be found [19][20][35][36][37].

Looking at the conceptual design from a more general perspective we can observe two kinds of activities [24][38][39][40]:

1) team discussions, interactions between team members,

2) individual work of team members together with their own concepts, models and tools.

These two types of actions are usually performed one after the other. Then the proceedings start again from the beginning and are repeated in a number of cycles. We can try to apply computer tools for both types of actions. With the first type we can

record acts of communication, store argumentation (design rationale), explain decision making processes, etc [41]. With the second type we can store models typical for different domains – for instance those belonging to the systems' engineering category.

The proposed concept of the knowledge storage during conceptual design in a team offers the chance to catch core information associated with the whole process together with its key details, decisions and applied strategies.

Many papers concerning conceptual design are based on design problems which are especially created for the purposes of a certain research [5][18][42][43][44].

In the paper the authors present the analysis of the conceptual phase on the example of steel sheet metal processing machines in a small enterprise [22]. The authors try to provide an architecture of the computer system and attempt to implement a more universal, multi-profile, multi knowledge representation tool that is able to support the designers with solving the problems mentioned above. The results of the analysis of the selected real design processes, their knowledge background with their conceptual design stages are presented in the article [22]. This material is the basis for the solutions shown in this paper. In the next chapters the concepts of the computer environment for conceptual design support are explained.

2. Exemplary environment for conceptual design support

In industrial practice tasks belonging to the considered class of conceptual design problems are usually solved in an iterative way [24][22]. The degree of requirements, and design details increase gradually over time as the result of systematic problems' modeling and collaborative team work.

In the subject company mentioned above the concept creation of a new machine looks like one conceptual design task.

The case study design team consisted of 8 persons. The task referred to the problem of a multi-stage manufacturing process of a steel sheet metal processing machine. The first version was in principle a further development of the existing machine to which new components were added "by hand". The result was approved as a first iteration of the process. The concept was evaluated and validated and its development was accompanied by very detailed and comprehensive discussions. The team members came to the conclusion that several partial concepts and solutions should be improved. The improvement led to a set of new partial solutions. After that the designers started to work individually or in two persons teams. While looking for the partial detailed solutions they used their personal/team models and tools. Additionally series of carefully planned experiments were performed.

The activities described above were treated as one cycle. Although there existed 7 cycles altogether. During this stage different available knowledge resources and the tools associated with them were applied.

For the process structure described above the authors have built a more formal and computer based approach to create a new manufacturing machine. In the proposed approach the specificity of the domain plays a significant role. The problem was structured in the following manner: **production line, system, sub-system, part, knowledge element.** This structure reflects the way the designers look at the whole machine.

The **knowledge elements** of the above approach had the following forms:

- computation modules (different programming tools, different sizes and complexities),
- design recommendations (useful hints, design rules),
- standards (documents),
- past project documentation,
- multimedia recordings from previous projects (discussions, records of collaborative sessions).

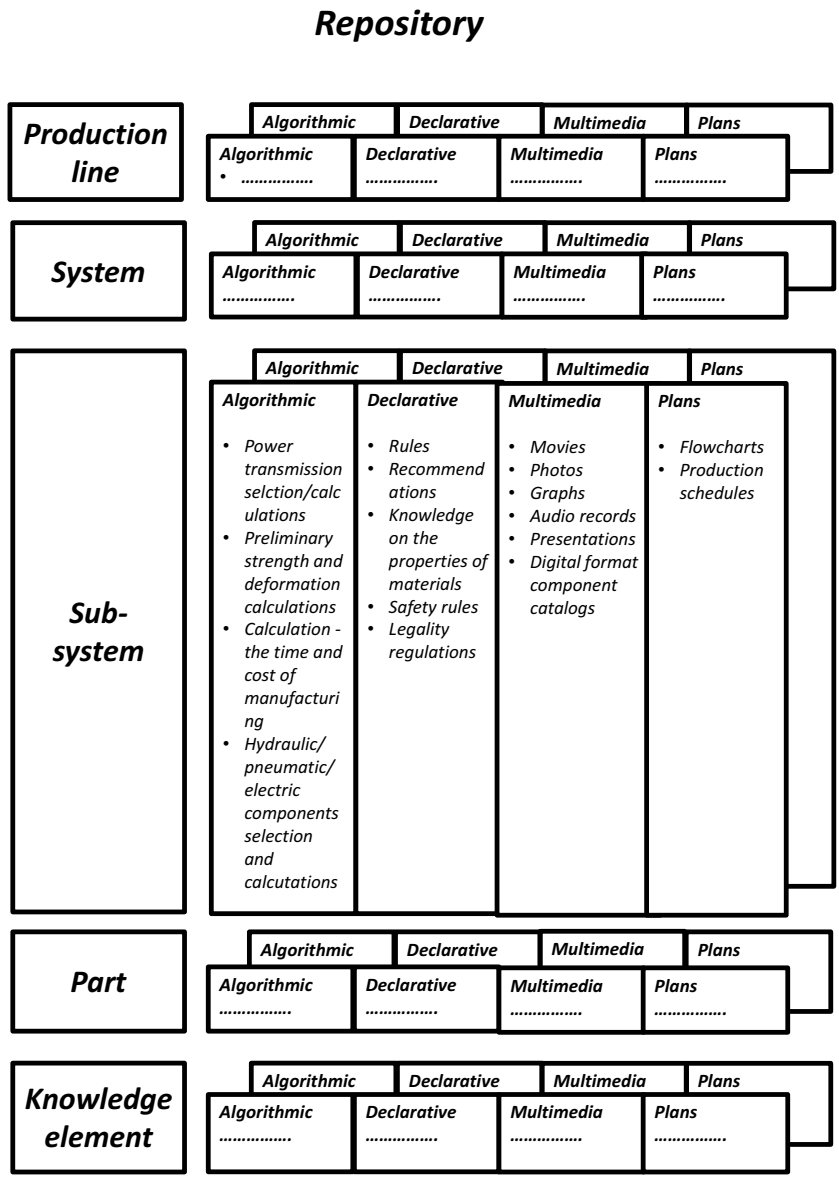


Figure 1. Knowledge repository and its structuring.

The **Parts** contain sets of knowledge elements which are strongly connected with the respective part. The **Sub-systems** store knowledge how to design certain mechanisms, bodies, geometric features of rolls and transmissions, control systems, etc.

The **Systems** and **Sub-systems** store knowledge of the devices which are main parts of the production line. The **Production lines** keep knowledge about requirements and knowledge connected with the manufacturing processes performed on those lines.

An exemplary content of the repository with its structuring is presented in Figure 1.

The problem of the conceptual design for the main structure of the approach, as it was performed in a specific company is shown in Figure 2. The diagram shows the core elements of the conducted processes with their descriptions and visualizations.

Figure 3 shows the structure of the computer environment for the conceptual design support of the new developed approach. The concept of the environment was created after analyzing a number of real-life conceptual design processes. However, the

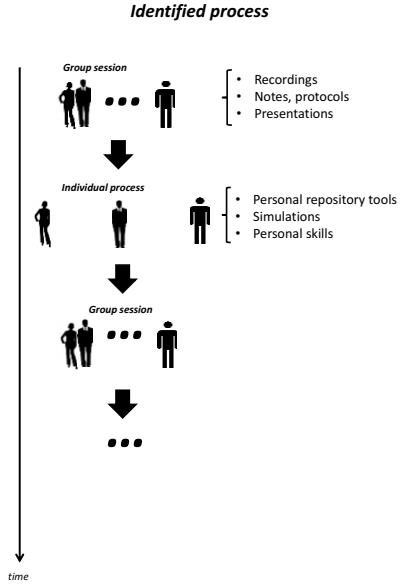


Figure 2. Structure of identified conceptual design process.

concept is not universal. It may only function as an actual iteration of the developed environment. Looking at its software it reminds a toolbox with useful solutions. While operating with the environment the user can exploit resources from the structured repository and build his own structure of activities based on the scheme presented in Figure 3. Figure 4 depicts two scenarios of actions performed during two different projects.

3. Implementation

The authors have also started working on the implementation of the proposed solution. They assumed that the new environment consists of a user interface (similar to the actually developed for smartphone applications) and a tool controlling the functionalities which were realized with the software applications originally used in the company. The concept of the user interface is similar to the ideas shown in Figures 1-4.

The interoperability of the available applications and repositories was ensured by wrapping which is similar to the techniques used in multi-disciplinary optimization. The data integration was solved individually for particular functionalities.

The authors have tried to develop their applications in two versions (using an object oriented approach): 1) strong in reflecting the reality of the mentioned company, 2) using more general and universal solutions.

The newly created system is currently being tested, corrected and verified in the subject company. Sets of the developed modules are used as a support in sub-sequences of actions in exemplary problem solving. Figures 5 and 6 show the computer interface and one of the exemplary problems.

Two of the authors are very deeply involved in the implementation process. Jarosław Pruszyński, apart of the working on the method and software development, is the proffesional leader of the design team (in subject company) which tests and verifies the proposed software solutions. The subject company is involved in the construction and manufacturing of the equipment as well as in the complete customizable production lines according to customer needs. The specificity of the company is that practically every order can be produced in only one copy, hence the problems of designing and starting machines are very well known to him.

Konrad Oleksiński, who also works on the method and software, is responsible for implementing and maintaining software and hardware in a large media company. He also manages the process of creating and implementing new applications used in the company's business.

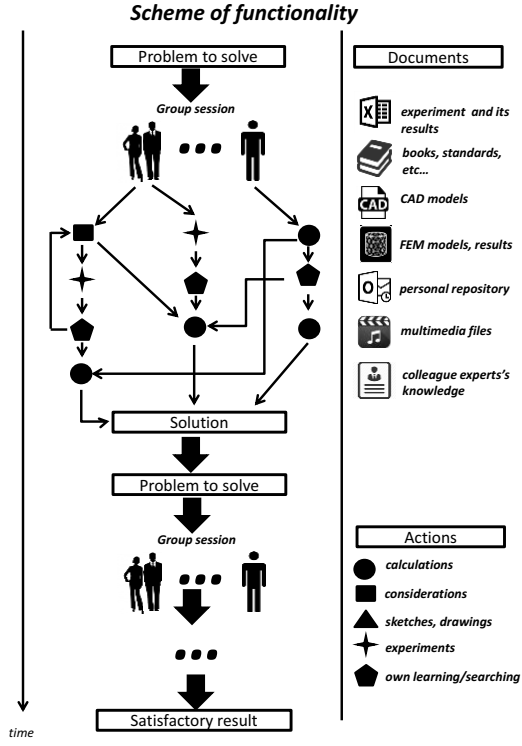


Figure 3. Backbone of modeled conceptual design process.

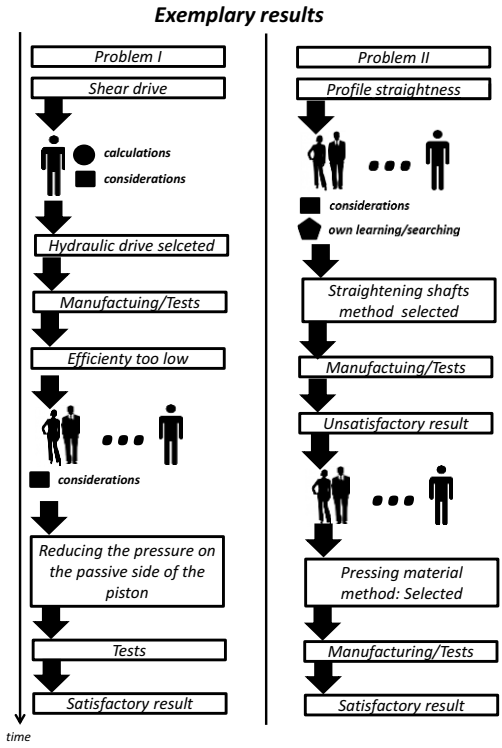


Figure 4. Two exemplary instances of performed conceptual design scenarios.

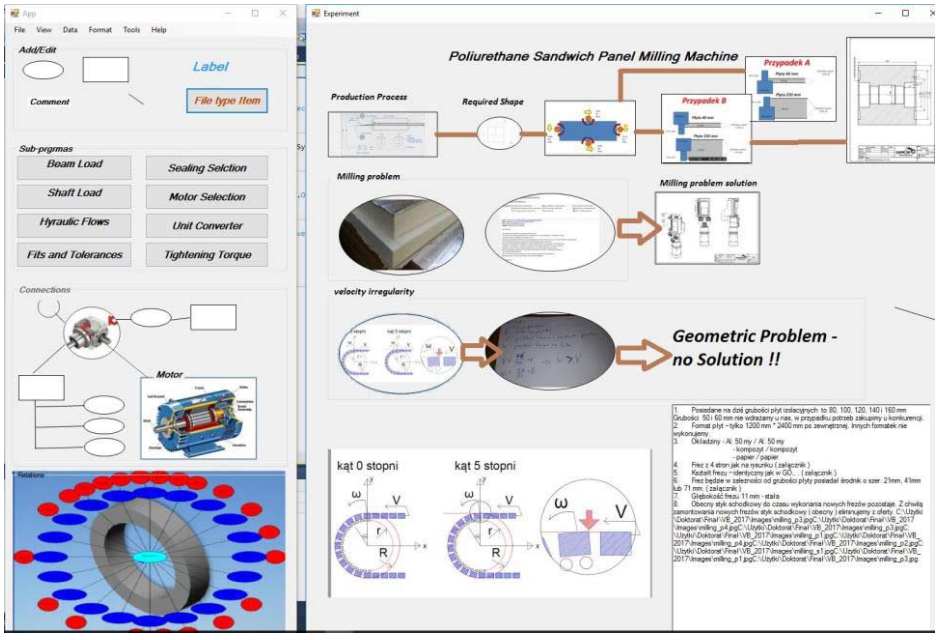


Figure 5. Snapshots of the developed application – searching for analogies (arrows indicate the order of the performed actions).

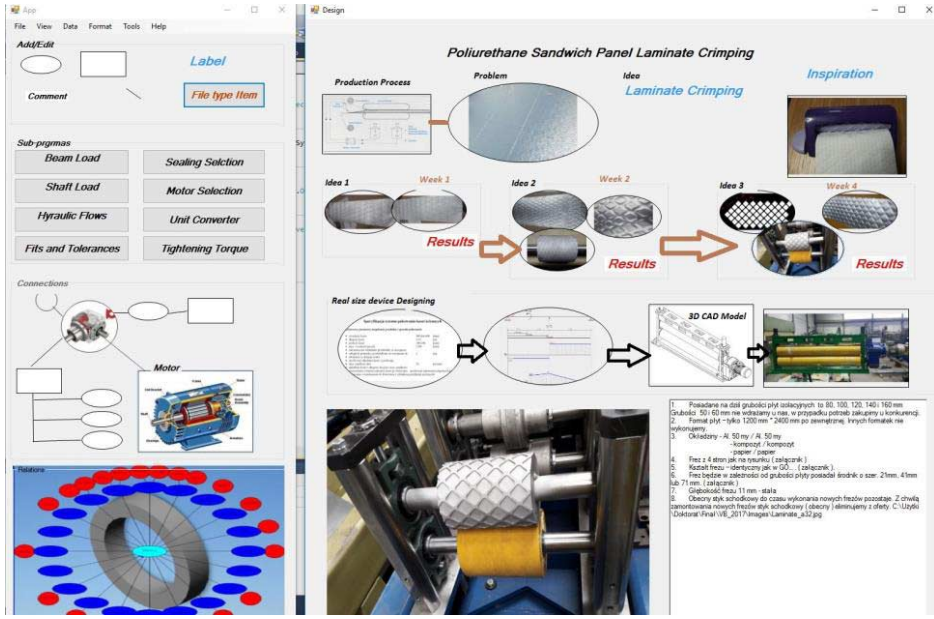


Figure 6. Snapshots of the developed application – succesful solutions (arrows indicate the order of the performed actions).

4. Conclusions

The paper presents a proposal for the computer support in conceptual design. The proposal is based on a real-life case study and it was created with the intention to a high degree of flexibility.

The whole approach is based on many human-computer interactions. The analyzed cases indicate that the considered class of problems needs many knowledge sources and the speed of processing is less important. The open format of data exchange seems to be useful in this case.

The performed research allows to formulate several detailed remarks:

1) During the process of creating the new conceptual solution it was very important to store the following information:

- new ideas, presentation of new concepts, acts of communication, models and their descriptions,
- information about models which had been used earlier and were re-applied in the next design iterations, information how to operate with these models, how to select the values of their parameters and how to make their structural modifications,
- descriptions, characteristics of the sequences of the experiences which were realized and corrected during the concept development (together with elements of qualitative reasoning),
- information about human sessions and their results (also that sessions realized out of the project plan),

- information concerning the solutions of alternative variants which influenced the finally selected ideas,
- information concerning: a) new ideas and their authorship, b) the form in which these new ideas were realized in practice.
- information about the evolution of the concepts during the design process from the personal and team perspective.

2) Each team member had the chance to present his new ideas. In the end all new exposed ideas were stored.
3) Small firms suffer specifically from permanent market pressure. This fact strongly compels entrepreneurs and engineers to develop new conceptual solutions and also requires approaches like the one prepared in this paper.

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Integration of Knowledge Based Approach and Multi-Criteria Optimization in Multi-Disciplinary Machine Design

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Abstract. The approach presented in the paper attempts to integrate the concept of a knowledge based software (knowledge storage/management software) into a multi-criteria optimization applied for a multi-disciplinary problem. The approach focuses on the management issues of a multi-stage solving procedure and its functionalities.

Keywords. Engineering knowledge modelling, multi-criteria optimization, multi-disciplinary design

Introduction

The approach presented in the paper attempts to integrate the concept of a knowledge based software (knowledge storage/management software) into a multi-criteria optimization applied for a multi-disciplinary problem [1][2][3][4][5][6]. The special focus is put on the management issues of a multi-stage solving procedure and its functionalities [3].

The area of multi-disciplinary optimization applications is slowly but continuously extending [1][7]. It is no longer limited to astronautics and aviation. This comment doesn't only concern a research but also an industry.

One unexpected phenomenon which appeared while applying multi-disciplinary optimization in industry was the negative attitude of industrial engineers [1][3][7]. They had objections against the high costs and risks connected with those tools. The high cost and high risk result from the fact that introducing multi-disciplinary optimization to a new domain of application needs developing sets of new software solutions which are necessary to support the engineering activities.

At the initial stage of optimization process it is often difficult to specify and foresee the range and size of the environments which have to be modeled. The labor – intensive analyses become necessary and conclusions have to be formulated concerning the systems, their modules and the tools which shall be integrated. Each made decision is associated with concrete cost and risk.

Multi-disciplinary models are relatively big and are very complex [8][9][10][11][12][13]. They are assemblies of partial models which have their origin in different disciplines. Linkages of partial models reflect the fact that products and problems of their designing are complexes which are homogenous and multi-aspect.

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The merit knowledge of the designers decides which models shall be applied in the certain case [7][14][15]. Usually, the members of a design team are quite familiar the professional capabilities of their colleagues from the same design office or design team [10] [14]. They also know the possibilities of the used tools and methods. Nowadays those capabilities and possibilities play an important role in the design process, even in small firms, because the realised project must meet the requirements of the market. Such knowledge should be acquired, stored and re-used.

In the next chapters multi-disciplinary design problems, aspects of the design knowledge associated with them, concepts of tools for their knowledge management are characterized. It is assumed that the multi-disciplinary optimization approach will be used by a small design office.

1. Characteristics of multi-disciplinary problem modeling

Designers solving machine design problems try to build computer models [13][16] [17][18][19], examine, verify and validate them (Figure 1). Each of the activities in those models has its knowledge sources' background [2][13][16][17]. In most cases this process doesn't end up with one sequence of well selected activities. Designers' work also consists of a series of corrections where each correction gives a new variant (or variants) of the considered model together with its examination and verification [2][3]. Between two corrections (due one last- examined and the one just being created) the designer performs some intellectual work, considering what to do next. Designers perceive the whole path made of separate corrections, together with its mental interruptions, as one reasoning process, which finally leads to one satisfying solution. This process represents a kind of real-life optimization. If this process is handled in a computer environment we speak of knowledge based approach.

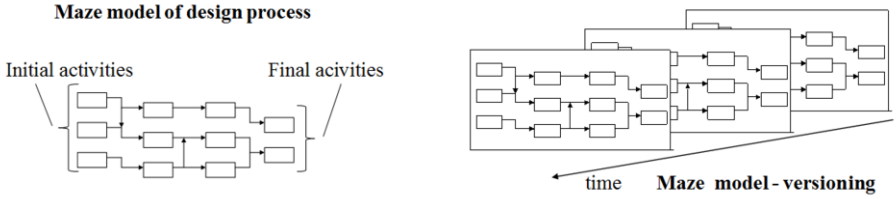


Figure 1. Personal activities and their structuring

On the other hand we shouldn't forget that decision problems solved by designers, in most cases, look like a chain of interconnected single decision problems with loops, iterations, macro-decisions etc. [3][4][5] (Figure 2).

Formal multi-criteria optimization methods (especially based on multi-criteria, multi-level hierarchic approach [2][3][20][22][23]) can support the designer (or the designers in case of collaboration) in his decision making process [20][22][23][24] (Figure 3). However, the multi-stage, knowledge based nature of the decision making process will remain the same.

The designer exploits the results of a certain examined decision problem at the further stages of the design process [2][4][16]. The interactions between the different stages of the design process can be informal or formal (Figure 4). In the first case it is difficult to build a formal integrated approach. In the second case, however, we can

consider interactions between different multi-criteria problems solved by the designer on the realized design process path.

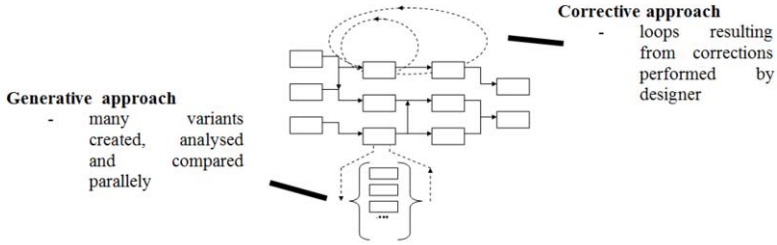


Figure 2. Corrective and generative way of functioning of performed processes.

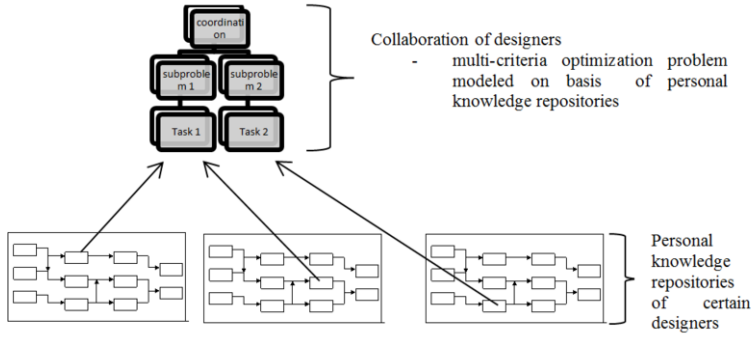


Figure 3. Multi-disciplinary problem modeling on the basis of personal knowledge repositories.

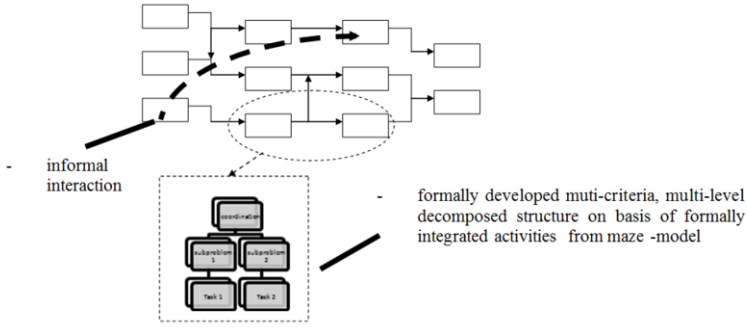


Figure 4. Informal and formal connections between activities.

Our chances of finding new and better results increase when we examine problems which have never been optimized (even without optimization methods) [7][15][20][22]. Such a task is typical for a multi-discipline design approach. Looking at the history of such an approach it seems that the different disciplines evolved separately. But in reality, in the case of real technical objects (from the so called product perspective), disciplines are integrated and overlap [8][9][25].

For a human the abilities to specialize in several disciplines are very limited. Therefore with a complex engineering problem a group of specialists has to cooperate as one team. If each team member optimizes his problem as a sequence of model corrections in a knowledge based approach or uses optimization methods and if all the team members cooperate, then the problem arises who dictates the parameters and makes the necessary decisions [1][4][5][7][9][14][16].

In real-life situations there is always a position of a leader who makes the decisions and shares the resources.

In the case of a multi-person team this means (collaborative design) the leader of the whole complex problem has a plurality of designers and he can therefore compose a path made of problems which are solved by different designers [1][7][10][19].

The development of multi-disciplinary models can also include considerations about mutual linkages (between partial problems) which have been never noticed before. Those linkages may exist between disciplines [14][26] or they can go deeper – noticing situations where disciplines overlap and mentioned problems are not separable [8][9].

2. Computer support of engineering design - example

The chapter presents an example of the dedicated computer environment to support the modeling of multi-criteria optimization problems together with the storage and management of their corresponding engineering knowledge as well as their corresponding data management.

The example deals with the problem of spiral stairs design [27]. External requirements decide about the general structure of the stairs. Because of that only limited changes of the structure are possible (Figure 5).

When setting about a multicriteria optimization, the respective problem (the stair in our case) is formulated with the goal to achieve its most optimal structure and the most optimal values of parameters.

This is the classical way a conceptual design problem is solved. When a conceptual solution has been found, detailed solutions for the whole project can be generated. The second stage of the prosess is deeply integrated with the optimisation models. With the final results the manufacturing process can be provided. The second module cooperates directly with a CAD system.

Similar ways of solving engineering problems can also be found in other areas. For instance: defining the structure of the car [20][22][28][29](Figure 5). For many automotive units exists only limited numbers of variants. In those cases, approaches based on Case Based Reasoning dominate [2]. There are also tasks with numerous variants – for instance: the configuration of the seats layout in a car or bus, or the routing of pipes and cables, etc. For such problems, the optimization approach is the most suitable. The example of the bus is presented further in the section 5.

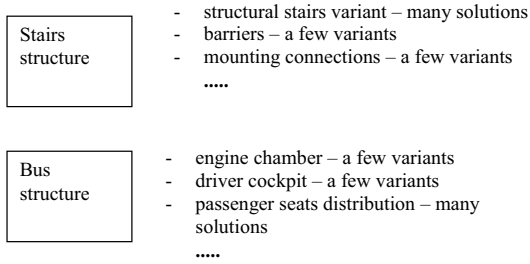


Figure 5. Structure of variants of certain products.

3. Integration of knowledge based approach with multi-criteria optimization in engineering design

Engineering design is a multi-stage process built interactively by designers [2][16]. Design processes realized in industry are characterized by a relatively little repeatability which results from a continuous engineering knowledge development, changing external requirements and a growing complexity practically solved tasks.

The knowledge owned and used by a designer can help to make certain inferences which may yield new elements in the realized design process of a certain product. When working the active designers look for the suitable knowledge, and often acquire that knowledge from many sources [2][16][17]. This is a kind of optimization with predefined goal areas. The fixed goals are achieved by searching for already existing similar solutions and their adaptations (Case Based Reasoning) [2][3] (Figure 6).

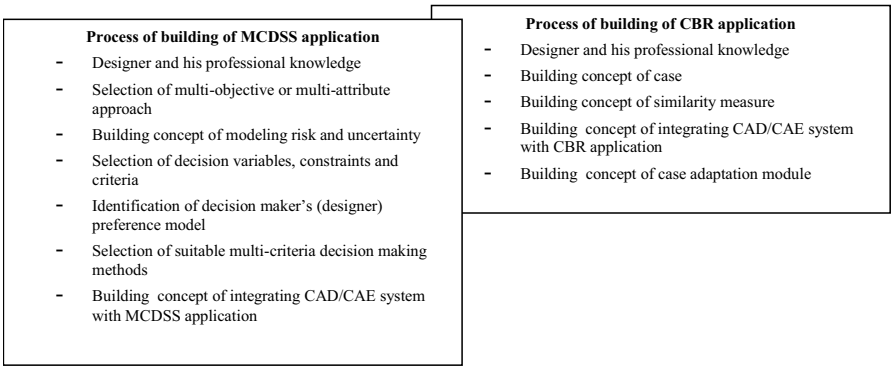


Figure 6. Core processes of building Multi-Criteria Decision Support System/ Case Based Reasoning (MCDSS/CBR) applications.

With many design problems the inferencing actions lead to design problems with numerous number of variants, modeled formally explicitly or implicitly. The selection of the most preferred solution with the help of inferencing approaches often costs a lot of work. In such a situation multi-criteria optimization brings more fruitful results (Figure 6).

Models developed formally as partial problems belonging to different disciplines can be analyzed by many different computer tools. The analysis of the performed partial problem can be done separately or can have common elements: decision variables, state variables, other (coordination) variables, etc. The integrated sets of partial problems can be solved as one large multi-disciplinary optimization problem. As a final result a solution is obtained which may be optimal from a global perspective.

4. Concept of engineering design knowledge modeling

Design processes are permanently modified and improved [10][16][18][2]. Those processes are performed on the basis of the designers' knowledge and cause a growing complexity of the respectve design tasks [24][26] as the applied knowledge concerns large fields of reality. In many cases the conducted design processes are unique.

One of the biggest challenges is the dilemma how to model multi-disciplinary design issues with limited human, hardware, software and financial resources (assumption concerning small company circumstances [3][7][15]). Like always the most optimal result is obtained after many iterations, lots of experiments and extensive consulting and knowledge sharing. Because of that effort any progress achieved that way is worth storing and re-using in the future. The knowledge which stays behind that progress should be stored in special repositories (Figure 7).

A data base is a helpful tool during the process of multi-disciplinary optimization in engineering design modeling [3][30][31][32]. The data base can store the following resources:

1) General description of the multi-disciplinary problem; problem description, list of partial problems, structure, theoretical and formal background; personal data of modeling persons,
2) Detailed description of the partial problems; description of variables, description of resulting variables, the description of methods and tools; the data concerning versions of the applied software,
3) For the partial problems; information concerning test iterations, information concerning model improvements and its decision background,
4) For the multi-disciplinary problem; information about integrated partial problems, information about performed iterations and their results,

The created software can store extensive, complete information about the evolution of the formal problem modeling and the evolution of the formal and informal structured problem's knowledge background - together with its real-life facts and observations, together with its associated hypothesises, mental or mental-formal, partial or complete multi-disciplinary models.

5. Example

In the chapter the example of the computer system supporting the process of the bus structure definition is presented. The example is based on the cooperation with a known bus manufacturer.

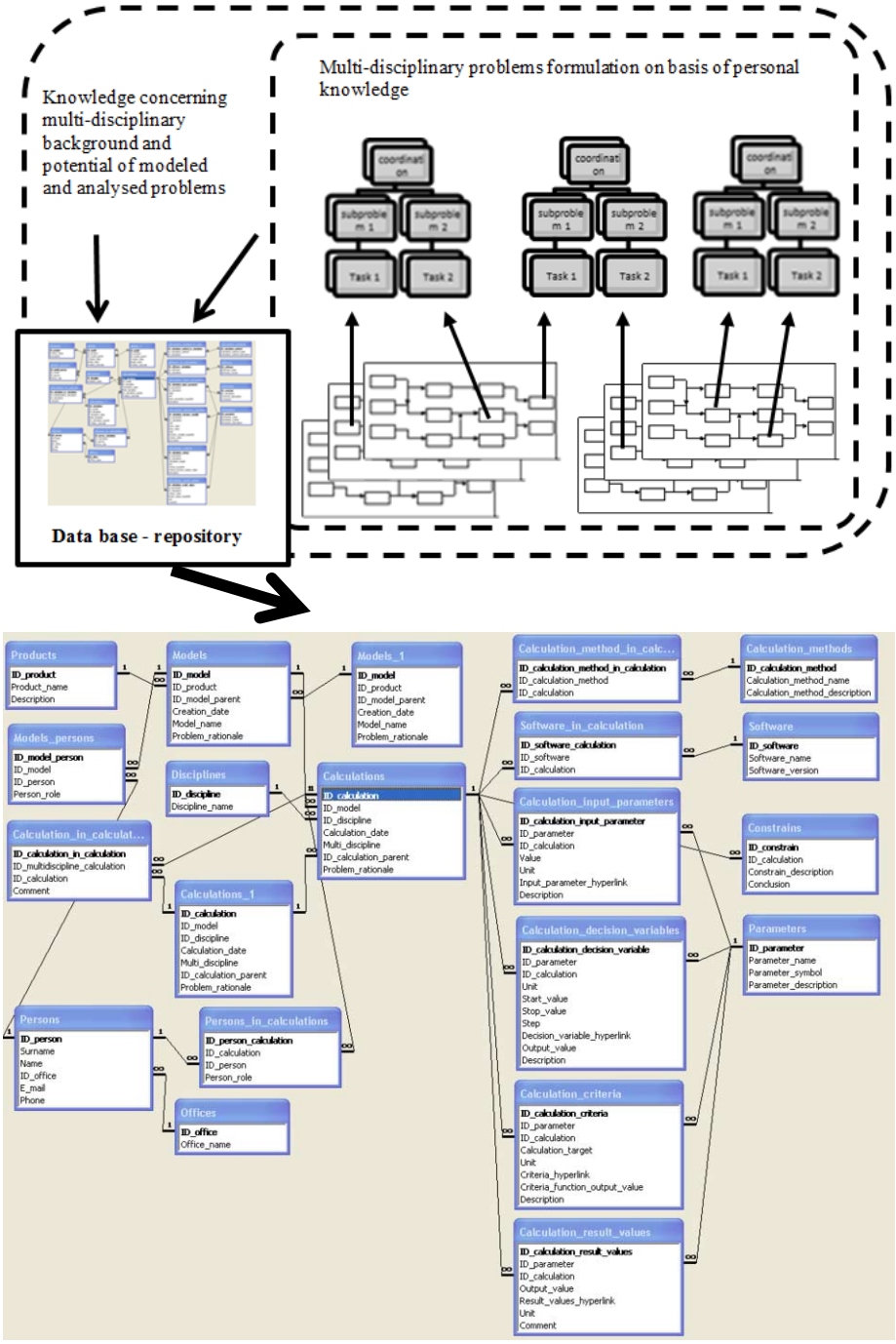


Figure 7. Concept of repository of knowledge concerning formal componets of multisciplinary optimization and its personal formal and informal knowledge background.

It shows modules for the configuration of the whole bus structure (Figure 8) together with its seats layout and attempts of seats layout optimization (Figure 9). The developed system is equipped with tools for the fast presentation of alternative variants.

For many bus modules exist only limited numbers of variants (for instance for the cockpit, the engine chamber, etc.). For those cases, an approach based on Case Based Reasoning is proposed in the system (Figure 10).

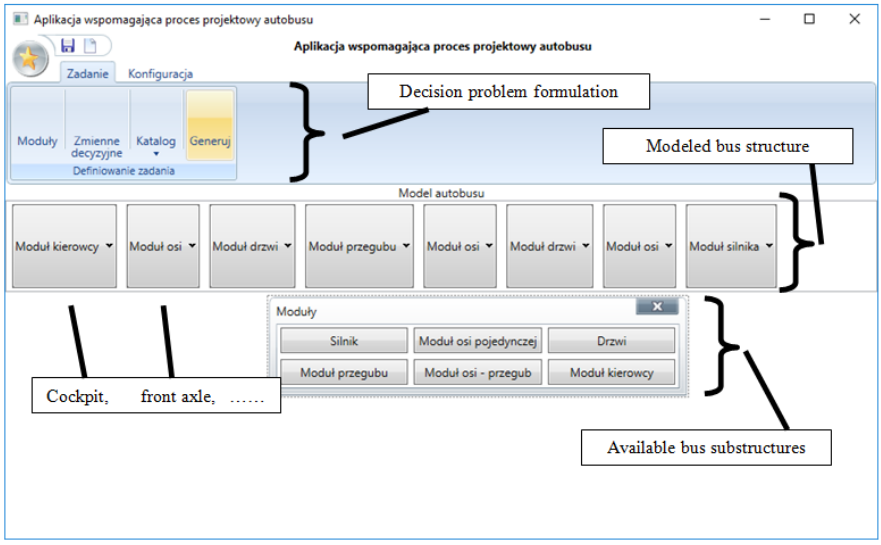


Figure 8. Tools for bus structure definition and decision problem formulation.

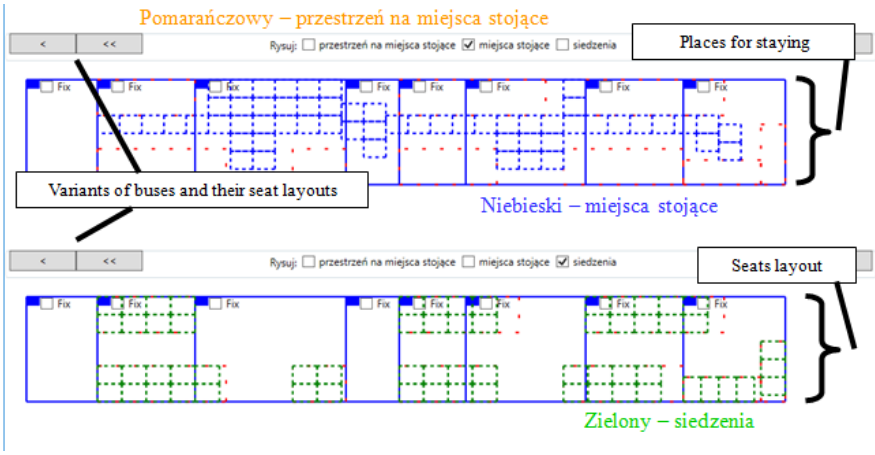


Figure 9. Results of automatic bus structure and seats layout generation.

There are also tasks based on Knowledge Based Engineering (KBE) where the developed system allows to create a sets of data for the prepared dedicated, KBE, problem-oriented 3D models.

The functionalities offered by the developed system can be used in sequences and give some knowledge and practical experience. The results of these processes can be modeled and stored in the environment – the dedicated database is shown in Figure 7.

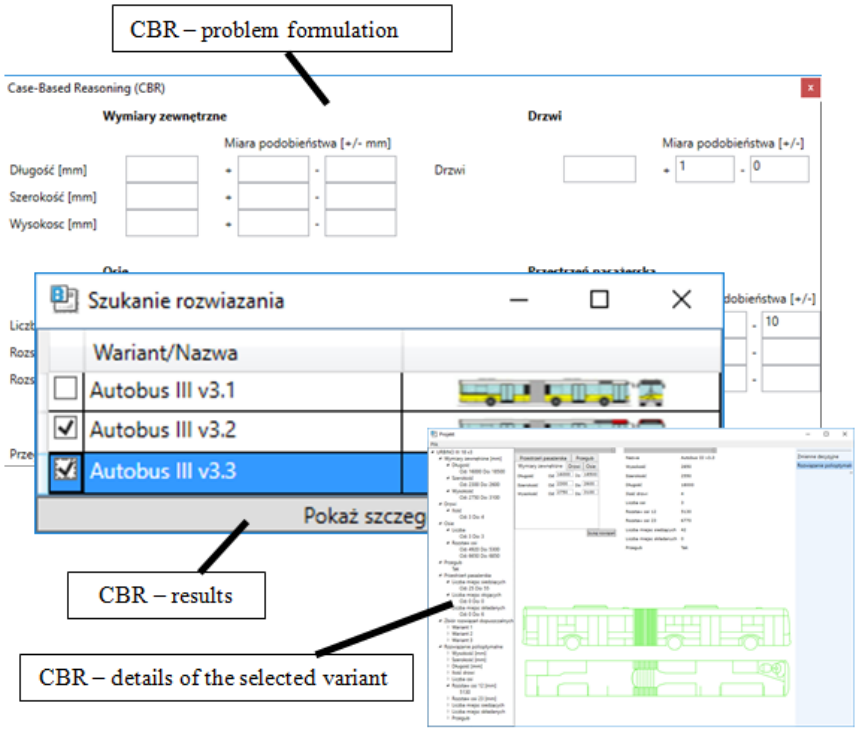


Figure 10. Case Based Reasoning functionality applied in case of the whole bus.

6. Conclusions

The paper presents the concept of a software for supporting the process of engineering knowledge storing in case of multi-disciplinary design tasks modeling and development.

The software is created to store information about the evolution of the problem modeling and the associated knowledge resources.

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A Simulation Study on the Automated Container Storage Yard Cranes System

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Abstract. In this paper, we introduce a configuration of container storage yard, in which lift AGVs and shuttle carrier are used. We address the approach for building one detailed simulation system for this automated container storage yard system. Simulation frame, several control logic and decision making rules are presented. Simulation experiments for scheduling triple RMG cranes are carried out to evaluate the effects of the scheduling strategy. The objective of the study is to maximize the productivity of the system, which might be applied to import containers set and export containers set at the same time.

Keywords. Automated container storage yard system, automated container terminal, lift AGV, Railmounted Gantry Cranes (RMG) Scheduling, simulation

Introduction

In recent years, an increased number of attention has been paid to automated container terminal, which improves operating efficiency and provides better service. Since improving operatring efficiency and service level is not easy, it may be affected by many factors. Generally, scholars focus on the configuration design of automated container terminal, considering it as the main factor. So we can see some container yards of different configurations.

In general, an automated container terminal consists of berth and quay crane, container storage yard, transport vehicles and gate.

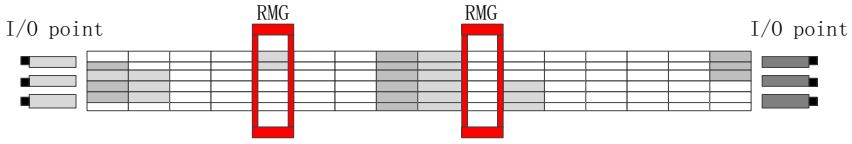


Figure 1. Basic configuration of container storage yard.

Figure 1 is the basic configuration of container storage yard in the automated container terminal. A container block with two input/output (I/O) points has two non-passing Railmounted Gantry Cranes (RMGs), in which one RMG serves one I/O point. In this configuration, two RMGs are unable to pass each other, and automatic guided vehicles or trucks pick up and drop off containers at I/O point.

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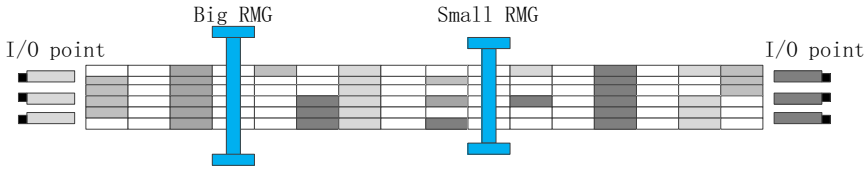


Figure 2. Container storage yard with double different size cranes.

In Figure 2, the container storage yard is using double different size cranes. In this way, big RMG and small RMG are able to serve two I/O points without interfering with each other.

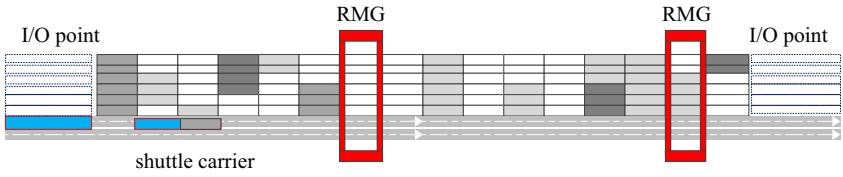


Figure 3. New configuration of container storage yard.

Figure 3 shows a new configuration of container storage yard to be applied the automated container terminal. At I/O point, lift AGV are adopted to pick up and drop off container without waiting for RMG to transit the container. The shuttle carrier can transmit the container to any position in the block to solve the handshake problem between RMGs (RMG cannot pass anther RMG to place the container in the block). Gharehgozli et al. addressed the problem of scheduling twin automated yard crane with the consideration of inter-crane interference [1]. The scheduling problem was modeled as traveling salesman problem with precedence constraints, and solved by a heuristic [2].

However, there is also another factor, which may impact on the operating efficiency and service level, rarely taken into account [3][4]. It's the scheduling control logic of storage yard equipment. We need to compare different control logics to get the better one, which means that different control logics must be realized and compared. Due to the high cost in finance and time, realizing the control logics with real automated container terminals is not a wise choice. This is why simulation needed. By designing models of automated container terminal with simulaiton software instead of building real ones, much time and money will be saved, in addition, we can change the design whenever we want.

1. Literature Review

A brief summary of yard crane scheduling problem follows: Source [5] proposed a mixed integer programming (MIP) model of one yard crane routing problem. Source [6] also studied one yard crane problem to reduce the total amount of delay time. They proposed a Lagrange relaxation-based algorithm to determine the optimal number of cranes to be assigned to each block in one planning period. Source [7] studied the multiple cranes scheduling problem. They proposed a heuristic algorithm to minimize the total loading time without loading sequence requirement. Source [8] also discussed the twin yard crane system for optimal scheduling problem. In the paper, the loading

plan is assumed to be known in advance. Source [9] developed Priority/ACO (Ant Colony Optimization) heuristics to solve multiple cranes scheduling problem. They discussed how crane interference affect make-span and crane utilization. Source [10] studied the yard crane problem as a continuous time MIP model, considering constraints, i.e. crane interference, separation distances, same time storage/retrievals handling tasks. Source [1] addressed the problem of scheduling twin automated yard crane with the consideration of inter-crane interference. The scheduling problem was modeled as a traveling salesman problem (TSP) with precedence constraints, and solved by a heuristic. Source [11] designed a twin automated stacking cranes with a handshake to solve the inter-crane interference As to the double different size cranes system, source [12] studied two RMG system of different height and width, and assumed that there is only type of container to be handled in one yard slot.

2. Simulation model

In this paper, the automated container storage yard employs non-passing RMGs with two shuttle carriers, which can transfer the containers to any position in the yard block. This configuration solves the RMG non-passing constraint and RMG handshake problem to bring the storage container to its final location as shown in Figure. 4. At both ends of the block, lift AGV can pick up and drop off container at platform without the handshake with RMG like Figure 5.

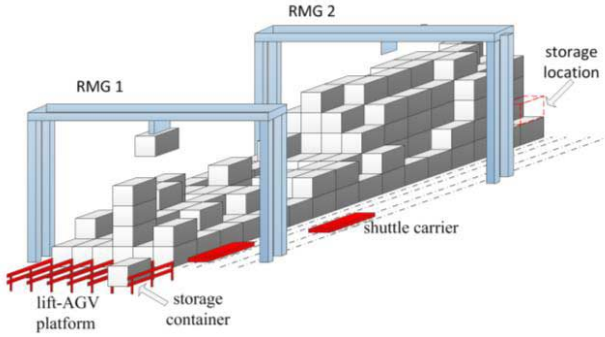


Figure 4. Side view of RMGs with shuttle carriers.



Figure 5. Lift AGV (http://www.konecranes.de/).

Figure 6 shows the frame of the simulation model designed in this paper. The first step is the layout initialization. The layout elements include container, lift AGV platform, vehicle track and control sensors. In the simulation model, the movement of

RMG and shuttle carrier are controlled by the control sensors. So the sensor control logic is created in advance. The number of elements can be customized by the parameters input (see Figure 7). The second step is the handling equipment initialization. Handling equipment includes RMG, shuttle carrier and lift AGV. Handling equipment characteristics define the type and the basic operational procedures of each handling equipment. Handling equipment control logic dictates the motion of the each handling equipment to perform tasks. The number and the setting of handling equipment can also be customized. Lastly, the decision making rules such as task planning rule and task assignment rule are defined in the third step to have a complete simulation model.

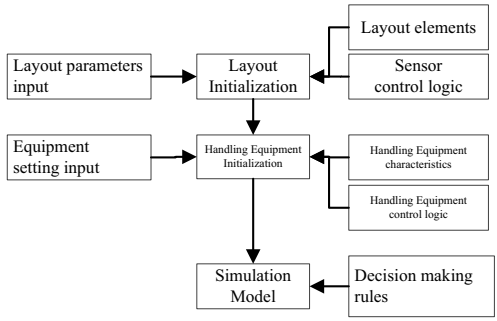


Figure 6. Frame of the simulation model.

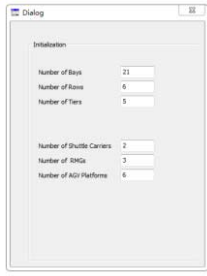


Figure 7. Layout parameters input.

Figure 8 shows the final layout of the simulation model.

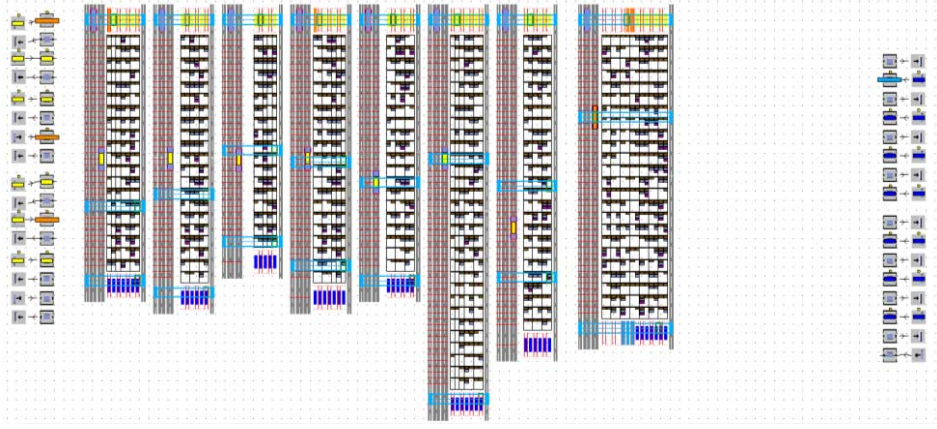


Figure 8. Layout of the simulation model.

3. Control Logic

There are two types of control: "RMG oriented" and "Lift AGV oriented". The following control logics are based on "RMG oriented" scheduling control logic.

3.1. RMG Control Logic

In this paper, there are two type of RMG control logic. One type of control logic is designed for RMG, away from shuttle carrier platform and working with shuttle carrier. The control logic is shown in Figure 9, where RMG needs to waiting for an idle shuttle carrier to do the container handling task. The second control logic of RMG is designed for RMG, next to shuttle carrier platform. This type of RMG can do carry container from or to shuttle carrier platform without handshake with shuttle carrier, and also needs to serve for shuttle carrier to carry container from or to shuttle carrier platform. The control logic is shown in Figure 10. The task type A is container handling task without handshake with shuttle carrier. The task type B is container handling task together with shuttle carrier.

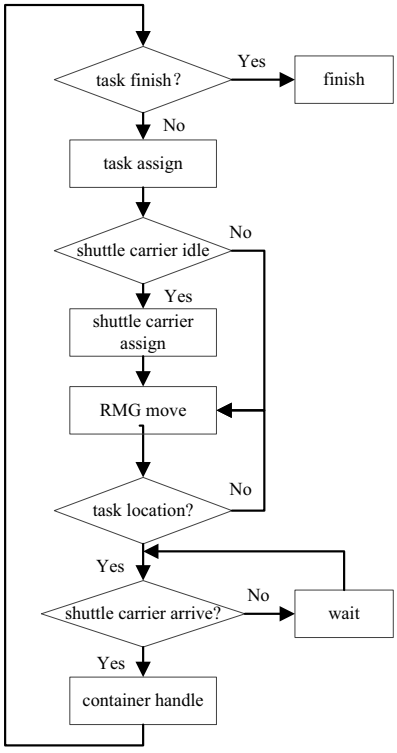


Figure 9. Control logic of RMG together with shuttle carrier.

3.2. Shuttle Carrier Control Logic

The tasks of shuttle carrier are mainly created by the RMG. Once a RMG is assigned a task, which needs to work with shuttle carrier, an idle will be also assigned. Once

shuttle carrier becomes idle, it will check whether it is needed for the task of RMG and will work for it.

3.3. Decision Making Rules

For RMG dispatching problem, each yard block is divided into several parts. Each part will be assigned one RMG to serve the handling tasks. And export container handling tasks to be given higher priority to be handle than inport container. And task sequence is based on task arrive time and updated by the priority.

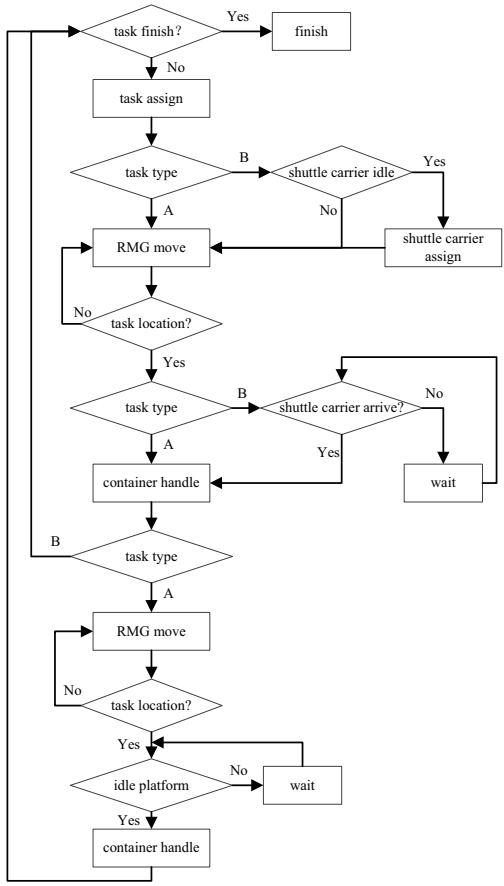


Figure 10. Control logic of RMG.

4. Experiments

4.1. Assumptions

There are some assumptions to be made in the experiments:
(1) All containers are 20 feet standard.
(2) Safety space regulation is not considered.

4.2. Input Data

The input data to be used in the simulation model are provided in Table 1.

Table 1. Equipment Setting.

Equipment		
RMG	Number in one block	3
	Speed	100 m/min
	Avg. handling time	2 min
Shuttle carrier	Number in one block	2
	Speed	200 m/min
Shuttle carrier platform	Number in one block at each end	3

4.3. Results

In Figure 11, the performance (Average makesan of one yard block tasks) of Lift AGV oriented control logic and RMG oriented control logic proves that RMG oriented control logic is better.

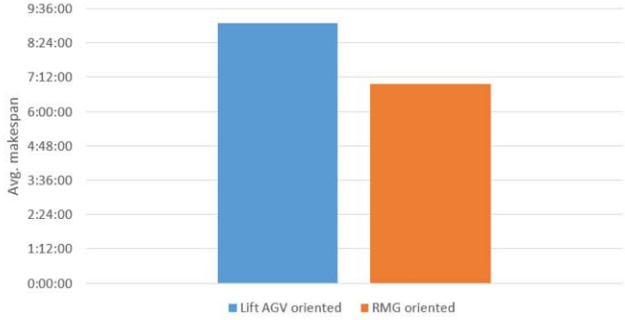


Figure 11. Performance using Lift AGV oriented and RMG oriented control logic.

The performance with different yard block division for RMG assignment is presented in Figure 12. The configuration case 7 (block): 7 (block) : 7 (block) has a minimum makespan of 6 hours 44 miniutes 52 seconds. All the tasks in the block are evenly assigned to each RMG.

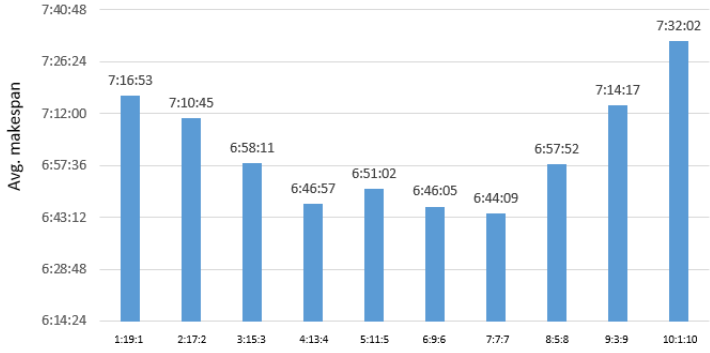


Figure 12. Performance with different yard block division.

5. Conclusions

Firstly, a new designed container storage yard and its simulation model have been described. Lift AGVs and platforms are adopted at I/O point to eliminate the handshake with RMG. And shuttle carriers are used to solve the RMG interference problem. The simulation frame and control logic are presented in detail. The experiments show that the "RMG oriented" scheduling control logic is superior. And the best configuration of block division is 7 (block): 7 (block) : 7 (block).

Acknowledgement

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Part 10

Collaborative Engineering

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Transdisciplinary Engineering: A Paradigm Shift
C. Chen et al. (Eds.)

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Design Platform - A Coherent Model for Management and Use of Mixed Design Assets

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Abstract. For many companies, it is a challenge to balance product variety and cost, i.e. external and internal efficiency. Product platforms has been the dominant solution for a business targeting mass-customization. The main idea is to dived the product into modules that can be shared among different product variants. This has been a success on the consumer market, however, many manufacturing companies are engineer-to-order (ETO) oriented, such as original equipment suppliers (OES). They design a unique solution, often in close collaboration with other companies, based on different product concepts and/or core technologies. For these companies, there is a strategic need for a platform model influenced by the principles of mass-customization, although, not limited to only include modules. In this work, a novel platform model, called Design Platform is described. The model has been developed and applied in cooperation with four companies. The Design Platform provides a coherent environment for management of heterogeneous design assets to be used in product development and supports an improved ability to master fluctuating requirements and systematic introduction of new technologies.

Keywords. Customization, Engineer-to-Order, Design Platform, Product Development, Fluctuating Requirements, Technology Development

Introduction

Export of products account for about 70% of Sweden's exports and represent a significant body of Sweden's prosperity [1]. To maintain and strengthen manufacturing competitiveness and innovation, new methods are needed to meet the requirements of the global market, the changes in customer needs, the technological progress, the introduction of new business models, and new regulations. According to the Swedish Association of Automotive Suppliers [2], the suppliers accounts for 75% of the added value in the automotive industry and they take more and more responsibility for product development. Production at low cost is required and positive volume effects are expected by contracts with several vehicle manufacturers. The supply chain is leading the initiatives and the implementations of new technology in different strategic areas. To offer new technological solutions that increase customer value strengthens both the supplier's and the OEM's competitiveness. A supplier who strategically lead the development in an area must invest in research and development as the

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responsibility, initiative and risk is shifting. New methods and tools are needed to integrate new technologies in new products efficiently and quickly and achieve volume effects. From a vendor perspective, this is a big challenge as requirements and interfaces are highly diverse between different systems that the product will be integrated into, markets the product to be delivered to, the use of the product and the customer's individual preferences. Adapting to adjacent systems are usually necessary to achieve a feasible solution, while effective production must be ensured in order to keep costs low. New technical solutions are need to industrialize the adaptive system that easily can adapt to changing customer requirements. Furthermore, the engineering work in product development, quotation and order processing must be well-organized to allow for a high degree of customization at low cost through efficient production. For many manufacturing companies, customization is required. One strategy is to develop a modular product architecture that enables variant formation by configuration. A higher degree of customization is often required for system suppliers and modularization must be supplemented by parametric models and design methods. Configuration of modular products are the focus of most research, but little has been done regarding more heterogeneous descriptions. Some support exists in Knowledge Based Engineering (KBE) but a holistic approach covering the whole chain between technology development, product development and customization activities is missing.

This paper reports results from a 3-year research project, entitled Challenge Fluctuating and Conflicting Requirements by Set-Based Engineering, that ended in the beginning of 2017. Swedish industry has a long-standing tradition of continuous and systematic investment in technology development in strategic areas. The project was based on the national strategy that this has to be further strengthen, bringing more value to the customers, improving the sustainability of products, and to sustain and increase the industry sectors competitive edge. For supplier, however, customization and proactive technology development are major challenges due to the large differences between the various systems that their products are to be integrated into, the markets the product are intended for, the use of the product and the customer's individual preferences. To reach a feasible solution, adaptation to adjacent systems is necessary while efficient production must be ensured to keep costs low. The overall objectives of the project where to build a better understanding of these challenges and introduce a new method for increased ability to efficiently develop and describe adaptive technology solutions and subsequently adapt these in the product development projects to comply with changing and conflicting requirements. The expected long-term effects of a broader application of the results would be a better and quicker introduction of new technologies in combination with an increased degree of market adaptation and customization, which strengthens competitiveness and innovation capability.

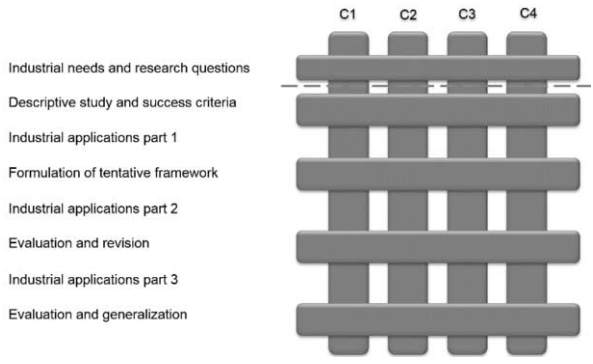


Figure 1. Project set-up.

Four companies participated in the project and joint activities (Figure 1) were combined with focused case studies, development of

demonstrators and cross-case studies. The overall research approach used in this work is based on the one suggested by Blessing and Chakrabarti [3] for development of design support. This work reports the findings and the development of a general method applicable for the four companies. Information about the cases has been gathered from meetings, workshops, demonstration of applications, reviews of documents and in-depth interviews.

1. Is there a need for new platform models?

Customisation refers to the ability and strategy that aims towards design and manufacture of tailored products for an individual customer. Depending on where the actual customization starts, four different business models can be identified: (1) Engineer-to-order, (2) Modify-to-order, (3) Configure-to-order and (4) Select variant [4]. For the latter two, product platforms have gained a lot of success as an enabler for efficient customisation. The definitions of product platform range from a platform consisting of components and modules [5], a group of related products [6], a technology applied to several products [7], to a platform consisting of assets such as knowledge and relationships [8]. This is also reflected among suppliers, as shown in [9], where the company platform description is categorised on four levels of abstraction and compared to their customisation strategy. Platforms are generally described to be of one of either two kinds: (1) The module based (discrete) characterised by sets of components being clustered into interchangeable modules that together form the product. The module-based platform can either be integral, where functions are shared by several modules, or modular, each function is delivered by only one module. (2) The scalable platform that becomes adaptable due to letting some of the design variables vary which leads to a stretching or shrinking of the product instances [10]. The research in the field of product platforms has mainly adopted an artefact oriented approach supported by the evolution in PLM and configuration systems, i.e. the rules have been defined and organized in accordance to a product structure. This approach has been further supported in engineering by the different commercial KBE tools available today for modelling of design knowledge. The process approach, on the other hand, has gained more success in the area of computing, where engineering tasks defined in different applications are connected for the purpose of simulation and optimization.

Many suppliers act in the business-to-business market and are involved in the actual development of the final product in collaboration with their customers; e.g. an OEM, a manufacturing company that needs special production equipment or a service provider that use unique products in the operation. These suppliers have a product concept for a specific application, however, this concept is more or less implicit, i.e. it is not fully described and managed in a structured coherent way, and it includes more assets and resources than pre-defined modules, if any. They frequently respond to different customers' requests for quotation by submitting specific offers and it is vital to respond quickly and with a sufficiently accurate price [11]. If the price is set to high a competitor will get the order, on the other hand, if the price is set to low there might be a financial loss in the long run. If a contract is won, a project is initiated for the final development of the specific solution based on the needs and requirements of the customer. The development project is executed in close collaboration with the customer and can run for years and changes in the requirement specification are frequently faced [9]. Other characteristics of these businesses are low production

volumes and/or high technology change rate which makes it impossible to launch large product platform development projects with a pre-planned number of product derivatives [12]. The product concept evolves with the knowledge and experience gained from executed product development projects. To continuously learn and build corporate knowledge is a core process of Lean Product Development (LPD) called knowledge value stream [13]. The knowledge value stream consists of capturing and reuse of knowledge about markets, customers, technologies, products and manufacturing capabilities. In order to make use of the created knowledge it should be generalised and visualised as far as possible to support a flow across projects and organisations. Another important methodology that falls within LPD is Set-Based Concurrent Engineering (SBCE) that opposed to a traditional point based approach supports the development of solution sets [14]. Each discipline draws a space and the sets of candidate solutions can be found in the intersection of the different disciplines' spaces. The impact of changes in requirements can be evaluated and either is the number of candidate solutions decreased, or new solutions have emerged, or no solution exists. In the latter case, the search for a solution can be supported by untightening the requirements. Positive effects when applying the SBCE-principle has been observed in industry [15] and suppliers would most likely benefit from increased support to systematically learn from executed development projects (knowledge value stream) and building an ability to adapt when requirements are changed (SBCE).

For many ETO industries, a modular platform approach is not applicable due to the specific needs of every customer. Still, there are similarities in the products that are designed, the tasks that are executed and the utilised resources. If the product constructs cannot form a platform, other approaches can be used. However, while many modelling approaches exist for products and processes, very few address the integration of both. In fact, no integrated product and process model exists that gives equal weight to product modelling as to process modelling [16]. A platform approach has been shown to be an enabler for efficient customisation, reuse and production standardization. In source [17], the question is raised if companies even have a choice regarding implementing a platform or not to stay competitive in the future since platforms can exist on several levels making them useful to all kinds of products. However, the common platform definition that builds upon pre-defined modules and components has been shown to be insufficient for companies working with an ETO business approach [18].

2. Supporting platform based development at systems suppliers

Four companies participated in the project, (see Table 1).

Table 1. Main characteristics of the four companies.

Company	Business area	Nr employees at site	Nr employees total
C1	Automotive	300	3 000
C2	Product and production system	70	150
C3	Aerospace	2 000	44 000
C4	Automotive	600	10 000

C1. The company develops and manufactures its own products for and international market and is also a system supplier for the global automotive industry. Roof rack is one of the products and being able to quickly launch a roof rack

considered very important as a roof rack with accessories are often acquired in the purchase of a new car. The requirements for roof racks are changing as car bodies are different, but also contradictory as they must be clamped tightly while the bodywork do not get damaged. The company needed a general method that facilitates the engineering work to adapt to fluctuating requirement and verify the solution.

C2 offers its customers complete product and production solutions. The company is also software vendor and developer of specific software applications. The company sees opportunities to partially re-use solutions in new projects and to smoothly introduce new technology into the re-use solutions but lack structured methods for this.

C3 is a global actor in the development, production, service and maintenance of components for aircraft, rocket and gas turbine engines with high technology content. Performance requirements, system change during the lifetime of the product and conflicting requirements concerning, e.g.. performance, weight, strength, heat resistance and production, must be balanced. The company has extensive experience in the automation of design and production preparation for quick adjustment to changing requirements specifications. The company was in need of improved methods to efficiently develop and describe new technical production solutions that can be quickly adapted to the varying requirements.

C4 develops and manufactures its own products and is a system suppliers to the global automotive industry. All vehicle manufacturers have different specifications and requirements has to be assessed and balanced continuous throughout the joint development projects. The company needed a general method to develop and describe new innovative technical solutions enabling efficient customization.

2.1. Re-modelling the product realisation process

Difficulties in using the linear models designed to describe a product's life cycle was identified early in the project. The companies also described a situation where they want to use some kind of a platform description except a truly modular one. The two most common ways to provide customized product is to either develop a set of specific products that customers can choose from, or develop a modular platform that is used for sales to configure a variant that the customer is satisfied with. The individual customer enters the process late the actual time of the purchase and do not have any impact on the development of the product. The customer interaction is different for system suppliers. The customer is not a consumer but a different organization, e.g. a final manufacturer (OEM), the requirements are unique and require different degrees of special solutions, and product development is done in a dialogue for a period of time when the requirement specification all too often changes. These companies do not have the opportunity to invest in large platform development projects and it is not considered appropriate when the requirement changes are difficult to predict and rapidly technology development occurs in some essential areas. New support to continuously build up an archive of good solutions, components, methods and knowledge and create effective methods for using these engineering assets at the scoping, the quotation design and the final development of unique solutions are needed. Companies also need to develop an ability to cope with difference in requirements from different customers and changes during the development work. In Figure 2, a common product life cycle model (top) and the model introduced in the project to provide a comprehensive picture of the development content and the need for a system supplier (bottom).

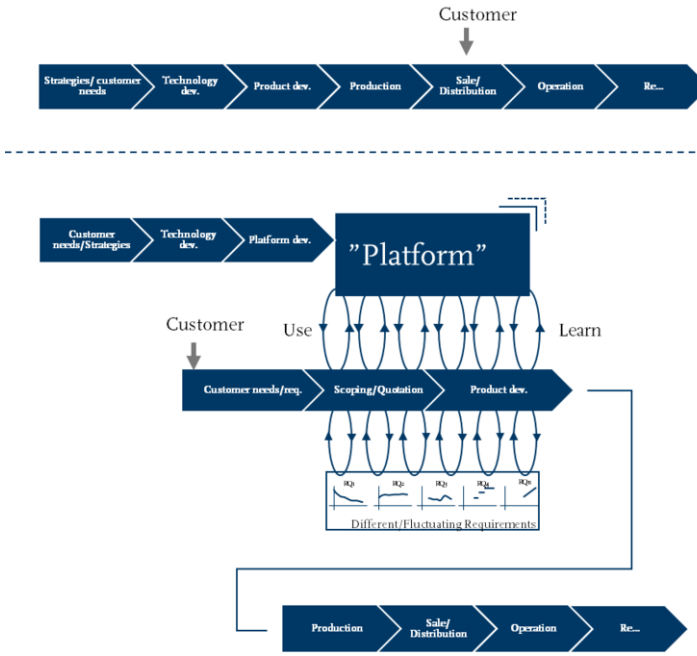


Figure 2. Life-cycle models for Make-to-Stock (top) and Engineer-to-order (bottom).

2.2. A coherent model for management and use of mixed design assets

The concept Design Platform (DP) was introduced by the authors together with detailed descriptions of the four companies' processes, strategies to manage fluctuating requirements, supporting methods for efficient customisation and needs for improved support [19]. The need to increase re-use and to gradually build up a source of articles, components, methods, guidelines, etc., based on previous projects while technology can bring new solutions, was identified by the companies as essential. It was also important to create an ability for efficient evaluation of changes in requirements during the development work together with supporting methods to generate alternative solutions if current solutions could not cope with the changes. These needs resulted in the development of the new platform model, Figure 3.

Different types of development assets from different disciplines and of different levels of concretization is collected, organized, and mapped in a DP. A DP can include modules but the scope is limited to that. A DP can also be continuously developed and creates a "toolbox" for the development team where different resources can be found and used to create a customer unique solution. A company's DPs builds a product system with engineering assets that the organization can work with systematically to improve, in the same way as a manufacturing company is working systematically with their production systems. Deficiencies and deviations can be captured and corrective action initiated. The status of various assets can be assessed and areas where gaps exists identified. New technologies can be introduced and mapped to be available in future development projects.

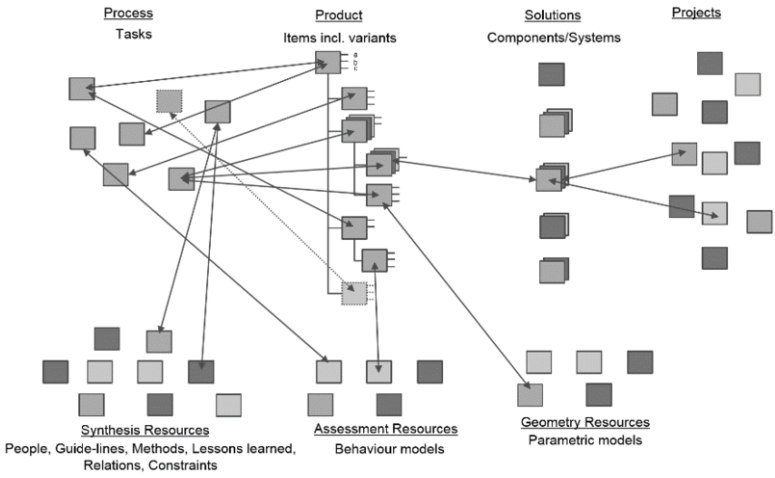


Figure 3. Constructs and relations of the Design Platform model.

2.3. Examples of assets developed in the project

A DP will consist of a variety of assets to generate and evaluate product definitions, product properties, specifications for product realization etc. In both synthesis and analysis phases, needs, requirements, constraints, and effects related to different stakeholders and disciplines are taken into account. It requires knowledge, practices, processes, guidelines, methods and tools to ensure that the final product meets all the requirements and that development can be pursued efficiently. A DP can include anything from a company expert available for consultation, checklists, lessons-learned, generic product structures, parametric CAD models as well as calculation sheets, simulation models and custom software applications. The work can be done manually, semi-automated or executed automatically if the domain is completely digitalized. Within the research project, a number of models, methods and demonstrators have been developed to exemplify and demonstrate the possibility to work according to the DP-principle. The work on this was done as industrial cases at three of the companies participating in the project and the different demonstrators represent subsets of the general DP model.

C1. A method of automatically FEM analysis of variant designs have evolved, figure 4. A large number of variants of fixing brackets are designed annually and lead-time in development is critical. The method reduces the work effort and lead time, and eliminates unnecessary loops between design and analysis.

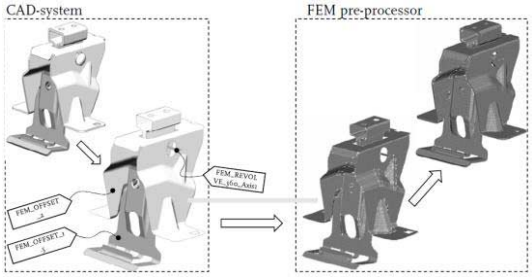
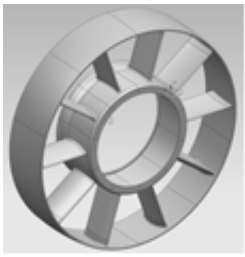
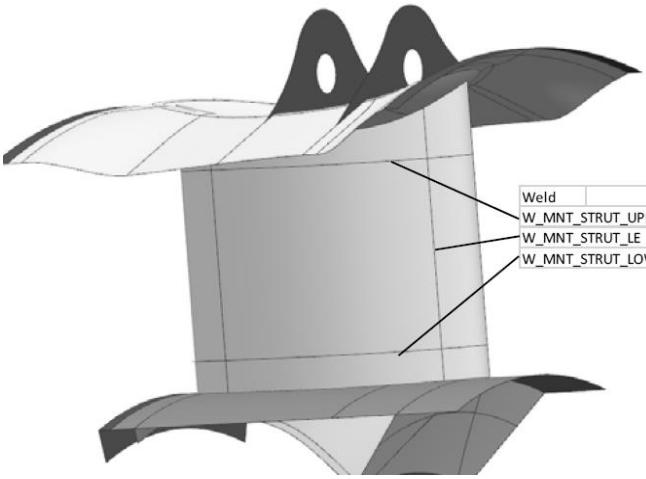


Figure 4. Engineering asset that enables automatic FEM analysis.

C3. Two methods have been developed and are part of the manufacturability evaluation of large sets product concepts automatically generated. One method evaluates the weldability and the other inspectability (Figure 5). The methods have been implemented in the company's development environment for concept design where hundreds of variants are generated and evaluated automatically based on performance, product features and manufacturability. The focus has been on introducing production aspects in the early phases of system development of unique solutions and creating an ability to manage changes in customer requirements.



4=Best 1=Worst	TIG	PLASMA	LASER	EB
Insensitive to misalignment	4	3	2	1
Distorsion	1	2	3	4



Weld	r	l	Crack length
W_MNT_STRUT_UPPER	OK	OK	10
W_MNT_STRUT_LE	OK	OK	NOK
W_MNT_STRUT_LOWER	OK	OK	OK

Figure 5. Engineering assets for producibility assessment; weldability (top) and inspectability (bottom).

C4. An approach for quotation and order design has been developed. The approach is supported by a model in which different types of assets for the development work has been structured and associated. A demonstrator has been developed in which existing components, CAD models, calculation methods are published. This is a comprehensive toolbox that designers can use to develop a solution and supports the re-work when changes in requirements arise during the project (Figure 6). Requirements vary from customers and change frequently during the development that can last for several years. The ability to efficiently assess the impact of a change in requirements and quickly find a workable solution enables a better dialogue with customers, promotes recycling, reduces costs and shortens the lead times in product realization.

2.4. Evaluation

The shared DP model evaluated at the end of the project. The companies agreed to that the DP model was applicable, it was possible to implement and a valid concept of

generalizing and re-use processes, methods and resources, i.e. engineering assets. A shared view on a development platform was emphasized as a major advantage, as well as the ability to include different formats for storing knowledge. Changed working principles that may be require was as stressed as the major challenge to fully implement a DP model. A critical element in implementing the DP-based approach was to communicate the importance of the DP model to individuals not having a holistic view of the business. Other critical factors were ease of use, implementation effort, accessibility, training needs and to be able to measure the value of the changed working procedure. The companies agreed that the concept of platforms had evolved, from focusing solely on the components to include several different classes of engineering assets. The platform model is believed to reduce misunderstanding in the dialogue with customers. The project also lead to internal discussions at the companies and further development efforts. Finally, one participant stated that the DP model had "led to a bigger understanding of the need to see the whole picture - different disciplines can get a picture of each other's problems and challenges". This will hopefully lead to smoother development processes and quicker identification of design spaces where valid solutions can be defined.

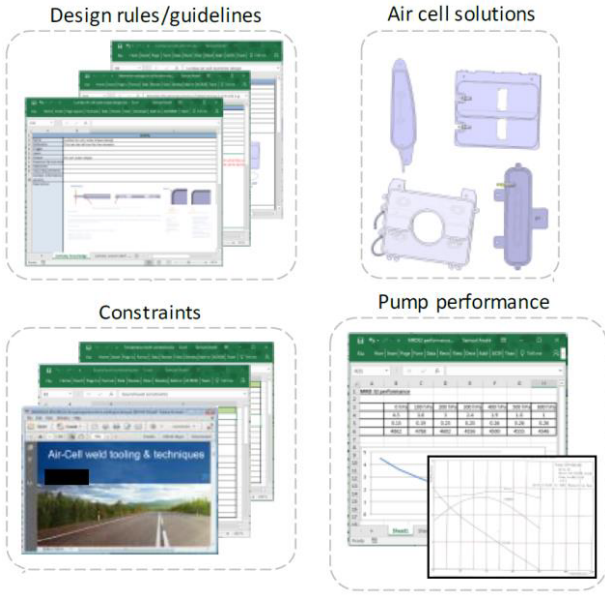


Figure 6. A selection of different engineering assets in the toolbox.

3. Conclusion

System suppliers in the automotive and the aerospace industry are very active in the development of new technologies and systems that needs to be adaptable to meet different needs, variations in system interfaces, and changes in requirements. Significant improvements of the ability to efficient and quick design customized solutions as well as manage changing requirements to stay competitive are needed. This work has resulted in increased understanding and knowledge about the development process at system suppliers and their need to build knowledge, describe

different engineering assets and support reuse. A new platform model, Design Platform, has been developed which is the basis of the overall method introduced at the companies and to be further developed for use in practice. The company representatives are positive regarding the usefulness of the concept, however, they also express a need of support in implementation and ways to motivate the investment.

Acknowledgement

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Design Method of Remote Monitoring Service for Elderly Considering Community Characteristics

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Abstract. With the rapid progress of the declining birthrate and aging population in Japan, expectations for efforts to grasp the behavior of elderly by using human resources or information technologies called "Remote Monitoring Service" have increased. There are many products and researches on remote monitoring service, but they are often made from a technology-centric viewpoint of "How to acquire the situation of elderly". However, when people actually design remote monitoring service, it is necessary to consider complex characteristics of the target community. This paper proposes a method that can design remote monitoring service by considering such characteristics. For achieving this objective, this paper utilizes the "Systems Thinking" approach that can handle the whole elements in the system. In the proposed method, a previous research called "Remote Monitoring Service Modeling" is regarded as Morphological Matrix (MM) which is one of the techniques of Systems Thinking approach, and evaluation of remote monitoring service design can be conducted by assigning characteristic values from the viewpoints of cost, quality and acceptability. Stakeholder Value Network describes the relationship of stakeholders in the system, and its analysis has a role in creating MM. By using the proposed method, Pareto optimal solutions of remote monitoring service design can be derived from possible options. The effectiveness of the proposed method is evaluated by applying method to the case of Japanese local government (Tamaki Town, Mie prefecture) which actually tries to implement remote monitoring service.

Keywords. Declining Birthrate and Aging Population, Remote Monitoring Service, Systems Thinking, Sociotechnical Systems

Introduction

Recently, with the rapid progress of the declining birthrate and aging population in Japan [1], expectations for "Remote Monitoring Service" which try to grasp the behavior of elderly by using human resources or information technologies are increasing [2]. In general, remote monitoring service are often made from a technology-centered viewpoint of "How to acquire the situation of elderly" while applying cost and quality in balance. Otherwise, in the case where local governments actually design and implement remote monitoring service , community characteristics should be taken into account in terms of not only cost and quality but also social acceptability [3][4].

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However, designing remote monitoring service considering community characteristics has difficulty in two points. The first is a problem that it is difficult for local governments to reasonably grasp the characteristics of the target community. The second is a problem that it is difficult for local governments to think complex factors [5]. For example they must think not only how to watch but also where, when or who to watch.

Tokunaga has proposed "Remote Monitoring Service Modeling" to support an exhaustive analysis of remote monitoring service [6]. This model consists of three types of person who have a major role in remote monitoring service, "Subject" to watch over, "Watcher" to observe state and "Target" to be watched, enumerate possible factors in terms of 5W1H (Why: motivation, What: kind of service, Who: who, When: time, Where: location, How: means). This model is limited to the proposion of the framework for analysis, and it cannot be said that it is sufficient for remote monitoring service design in terms of handling the two difficulties mentioned above.

The objective of this research is to develop a method for local governments to design remote monitoring service considering characteristics of the target community. Specifically, the following three are conducted.

1. Proposal of a method for designing remote monitoring service that can take community characteristics into account
2. Validation of the proposed method assuming examples of three types of area with different community characteristics
3. Confirmation of the usefulness of the proposed method using the case of a Japanese rural area tries to implement remote monitoring service

The remainder of this paper is composed as follows. Section 1 gives the proposed method. Section 2 examines the proposed method. Section 3 confirms the usefullness of the proposed method. Section 4 discusses the proposed method. The last section concludes this paper.

1. Proposed Method

This section gives a proposed method of this paper. The overview of the proposed method is shown in Figure 1. In order to overcome difficulties mentioned in previous section, the proposed method utilizes two techniques of the Systems Thinking approach. Systems Thinking is a concept that grasps the complexity composed of various things as a system and tries to solve problems by appropriately seeing the influence of the relationship of individual phenomena on the whole. There are various studies on the Systems Thinking approach, and many techniques have been proposed [7][8][9].

For reasonable grasp of the community characteristics, "Stakeholder Value Network (SVN)" is used. SVN can comprehensively represent the stakeholders in the system [10]. Analytical method has also been proposed, which identifies important information in SVN by quantifying the relationships when SVN is complicated [11]. For complexity of factors to be considered, Tokunaga's modeling framework "Remote Monitoring Service Modeling" is expanded as "Morphological Matrix (MM)". MM can exhaustively express design candidates [12]. A method has been proposed in which a characteristic value is given to MM to calculate the overall evaluation values [13].

The proposed method consists of the following two processes. The first is the creation of MM referring to SVN, and the second is the calculation of evaluation values. In the following, each process is explained.

1.1. Creation of MM referring to SVN

MM is a table in which individual explanatory variables constituting the system are arranged in each row and those choices are arranged in each corresponding column. The proposed method uses the framework of Remote Monitoring Service Modeling as explanatory variables of MM. However, since "Why" and "What" are not elements constituting remote monitoring service, they are excluded from explanatory variables of MM to be created. For listing the choices that correspond to each line of MM, the first thing to do is to create SVN. By creating SVN and arranging the stakeholders in the target community, the demerit of MM that creation itself is difficult can be relieved. When SVN is complicated, SVN can be simplified using the method [11] of quantifying the relationships to extract important information.

Next, characteristic values are given from the viewpoint of cost, quality and acceptability taking into consideration community characteristics. The characteristics are divided into two types according to the difference in calculation method of evaluation values. The first one is "addition type", which is used in cost. The second one is "multiplication type", which corresponds to quality and acceptability. The characteristic value is a relative evaluation between choices of each explanatory variable.

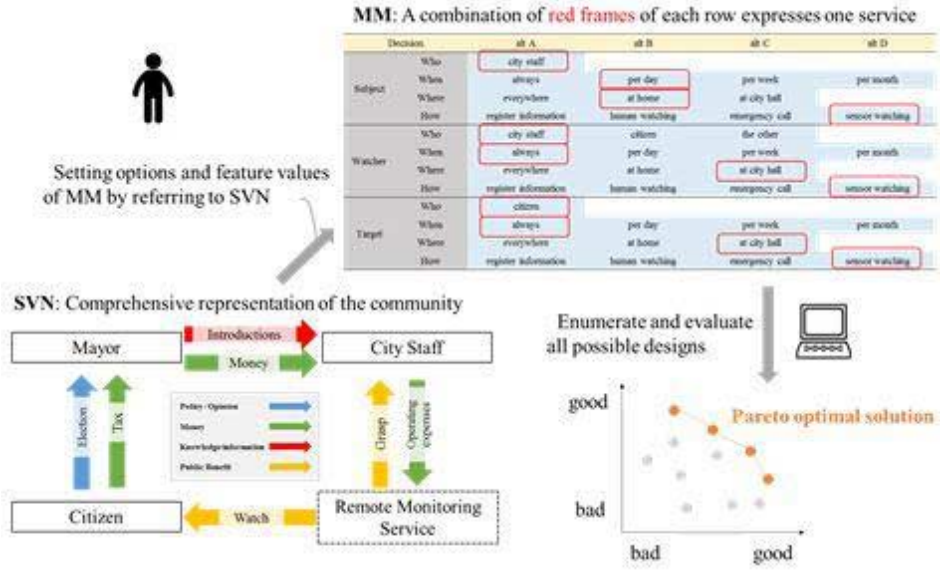


Figure 1. Overview of the proposed method.

1.2. Calculation of evaluation values

In order to calculate the evaluations values, all possible combinations of explanatory variables are enumerated. Each combination expresses a single remote monitoring service design. For each combination, the evaluation value can be calculated. The evaluation value is calculated as a sum in the case of addition type for the characteristic value given to each explanatory variable, and as a product in the case of multiplication type.

Finally, Pareto optimal solutions are derived from all combinations. The Pareto optimal solution is a solution in which other characteristic values are worsened when trying to improve any of the characteristic values [14]. In this paper, this Pareto optimal solutions are regarded as "Remoto Monitoring Service design considering community characteristics".

2. Verification

This section examines the proposed method. In order to verify the proposed method, the following three kinds of areas are assumed and the influence of the difference of the characteristic value given to MM for the evaluation result is investigated. For simplicity, only the characteristic value for "How" are changed.

I. Metropolitan area
II. Suburban area
III. Rural area

Table 1. Characteristic values of the "How" for I, II and III.

Decision		alt A	alt B	alt C	alt D	alt E
	How	Emergency contact registration	Human watching	Emergency call	Sensor watching	Nothing
cost	I. Metropolitan area	0.30	0.90	0.80	1.00	0.00
	II. Suburban area	0.10	0.85	0.75	1.00	0.00
	III. Rural area	0.05	0.80	0.70	1.00	0.00
quality	I. Metropolitan area	0.05	0.70	1.00	1.20	0.00
	II. Suburban area	0.20	1.00	1.00	1.25	0.00
	III. Rural area	0.10	1.10	1.00	1.30	0.00
acceptability	I. Metropolitan area	1.10	0.90	1.30	1.20	1.00
	II. Suburban area	1.40	1.10	1.10	0.70	1.00
	III. Rural area	1.70	1.30	0.80	0.20	1.00

As an example, the characteristic values are assigned for the "How" shown in Table 1. Paying particular attention to "Human watching", it is understood that cost is high due to the problem of labor costs in the metropolitan area and the quality and acceptability are low because the relationship is poor. Similarly, the other characteristic values are also given by considering the characteristics of each community.

Calculating evaluation values for all combinations, 37, 45 and 48 Pareto optimal solutions are obtained respectively. Figure 2 shows the distribution of the number of Pareto optimal solutions from I to III. It can be confirmed that Pareto optimal solutions are different by the difference of the characteristic values given to each MM. By analyzing the obtained results, it can also be confirmed that the derived Pareto optimal solutions are useful information for remote monitoring service design.

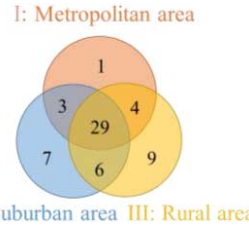


Figure 2. Distribution of the number of Pareto optimal solutions

3. Case Study

In this case study, by using the case of a Japanese rural area (Tamaki Town in Mie prefecture) tries to implement remote monitoring service, the usefullness of the proposed method is verified. Tamaki Town is a rural area where aging rate is over 25 %. Major public transportation system is "On-Demand Bus" developed by the University of Tokyo [15], and a watching method utilizing the log data of On-Demand Bus (ODB watching) is being studied as to remote monitoring service design. The following two are comfirmed through the case study.

- Whether the proposed method can be applied to actual cases
- Whether ODB watching matches the characteristics of Tamaki Town

3.1. Creation of MM referring to SVN

In order to create SVN, interviews with town mayor and town staff in Tamaki Town and questionnaires to townspeople are carried out. Figure 3 shows SVN of Tamaki Town created based on the obtained information. Since SVN is complecated, SVN is

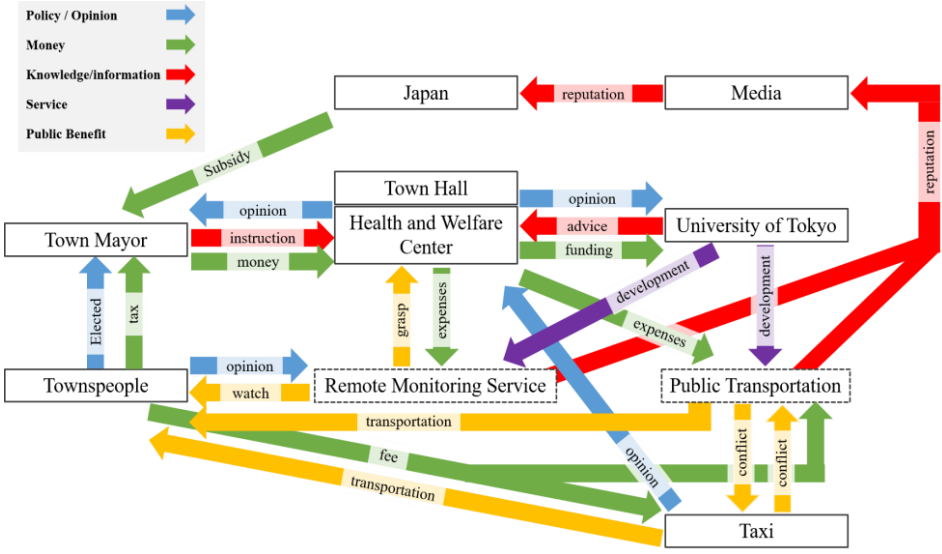


Figure 3. SVN of Tamaki Town.

simplified by the method explained in Section 1 in order to extract important information for creating MM.

In the step of creating MM, compared to the MM created in the previous section, ODB watching is added as one of the options in "How". When assigning characteristic values to MM with regard to "How", for example, low value as for cost is set for "Emergency contact registration" and "Human watching". Regarding quality, "Human watching" is a relatively high value. These are because good relationships are established in rural areas generally. As for acceptability, "Sensor watching" is set to a particularly low value because it can be assumed that the population flow is low throughout the day.

3.2. Calculation of evaluation values

There are 7200 combinations enumerated, and evaluation values for each combination are calculated as explained in Section 1. Here, all combinations have three kinds of evaluation values (cost, quality and acceptability). Figure 4 shows the results of the evaluation values for all 7,200 combinations. Looking at acceptability by choices of "How", for example, it can be found that combinations including "Emergency contact registration" and "Human watching" have high values, and combinations including "Sensor watching" have low values. It can be confirmed as a result of considering the characteristics of Tamaki Town.

50 combinations are judged to be Pareto optimal solutions, and there are 8 combinations including "ODB watching". It is possible to choose one from among these and use each element of the combination as a requirement definition of concrete development of remote monitoring service.

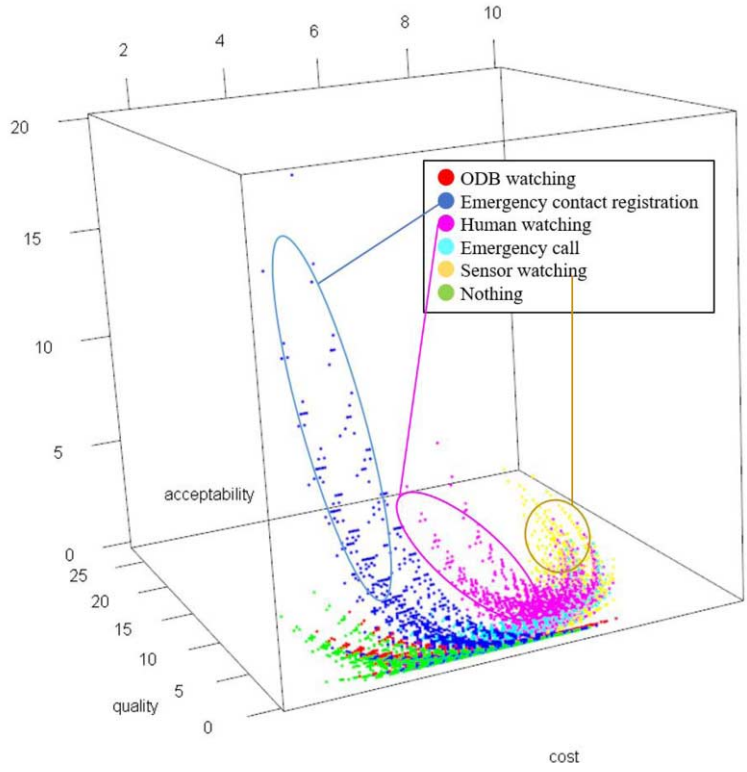


Figure 4. Three dimensional scatter plot for three evaluation values.

4. Discussions

This section discusses the proposed method in two terms.

4.1. How to use the proposed method

When the proposed method is actually used by local governments, the following two processes are assumed.

1. Set choices and characteristic values of MM referring to SVN
2. Conducted concrete remoto monitoring service design using derived Pareto optimal solution

With the above relatively simple processes, it is possible to design remoto monitoring service considering the characteristics of the target community. It is understood that the proposed method is a framework in which local governments can design remote monitoring service reasonably and easily.

On the other hand, the proposed method can only define the requirements of remoto monitoring service. Further examination is necessary for the detailed design. However, the proposed method is useful in view that it is possible to narrow down the remote monitoring service design with enormous choices.

4.2. Sensitivity analysis of characteristic values

As a sensitivity analysis of characteristic values given to MM, it is examined how much the derived Pareto optimal solutions change when randomly changing the characteristic value within the range where the magnitude relation does not change.

In the analysis, MM created in the case study is used. For all the characteristic values, values determined by uniform random numbers of [0.00, 0.05] are added respectively. A value of 0.05 is the smallest change width among the characteristic values given in the case study. Similar trials are carried out 10 times in total, and for each Pareto optimal solutions in the case study, it is investigated how many times Pareto optimal solution remained.

The results are shown in Figure 5. The vertical axis represents the number of times that the Pareto optimal solution remains in 10 times, and the horizontal axis represents the id of the remote monitoring service design. From Figure 5, it can be confirmed that Pareto optimal solution remains as it is in many cases even if the characteristic values are increased randomly within the range where the magnitude relation does not change. Such sensitivity analysis leads to identification of a Pareto optimal solutions which is hardly influenced by variation of characteristic values. And it is considered that setting reasonable characteristic values becomes possible by using AHP [16] which sets values based on magnitude relation.

5. Conclusion

This section concludes this paper. In this paper, a method was developed for local governments to design remote monitoring service considering community characteristic by using techniques of Systems Thinking approach. Also, verification assuming three types of communities with different characteristics confirmed the relevance of the proposed method. Furthermore, the case study with Tamaki Town which is actually considering introducing remote monitoring service confirmed the usefulness of the proposed method.

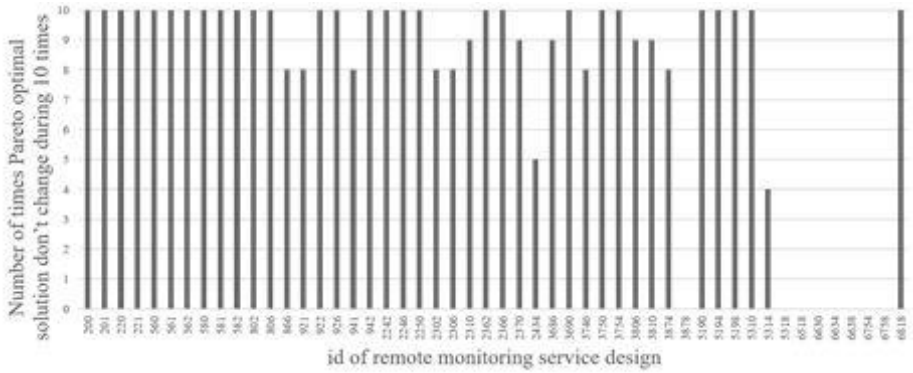


Figure 5. Number of times Pareto optimal solution remained as randomly increasing characteristic values.

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Firm's Potential for Co-Creation

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Abstract. Co-creation, an active end-users involvement in product development process, has been recognized as an effective way of minimizing risk of misinterpretation of end-users needs and of achieving product success. Furthermore, high level of co-creation has seemed to create high perceived value to products. With an aim to encourage many more firms to involve their end-users in the product development process, presented in this paper is a quantitative tool developed to help the firms evaluate their readiness and potential for co-creation. Important characteristics of firms for co-creation established in an earlier study have been classified with the help of expert opinion into three different levels: must-have, should-have and nice-to-have. The firms that fulfil all the must-have characteristics are ready for co-creation and their potential is evaluated from the should-have and nice-to-have characteristics. An exploratory case study on three shoe manufacturers was conducted for illustration.

Keywords. Co-creation, product development, potential, customer involvement, co-production

Introduction

Economic growth of most firms mainly relies on their ability to successfully identify end-users needs and quickly transform these needs into successful products. Unfortunately, many products introduced in market do not meet end-users expectations and result in failure. To overcome the product failure, benefits of the active involvement of end-users during NPD commonly referred as co-creation has been long recognized by both practitioners and researchers [1]–[3]. Co-creation is defined as, active end-users involvement during one or all phases of firm initiated NPD projects [2], [4], [5]. Furthermore, it is argued that the high level of co-creation (the extensive involvement of the end-users) will fetch more benefits for the firm during the NPD projects [6]–[8]. The researchers and practitioners have been working on different aspects of co-creation to achieve higher level of co-creation, but surprisingly current literature lacks any tool that can be used to find out the potential for co-creation any firm have [1], [9] or to check even if firm is ready to engage successfully in the process of co-creation [10-12]. Therefore, this study undertakes this problem by developing a quantitative tool to find out the level of potential for co-creation that the firm have.

The remaining sections of the paper are organized as follows. In the next section with the help of literature, steps to attain higher levels of co-creation are briefly summarized. In section 2, the proposed model for the study is discussed. Section 3 is dedicated to explaining the methodology of the study while section 4 focuses on results and discussion. The applicability of the developed tool was demonstrated by an

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exploratory study in section 5. Conclusion and future study directions are discussed in the last section.

1. Steos for acshieveing higher levels of Co-Creation

As aforementioned, the high level of co-creation will offer more benefits to both firm and their end-users. However, in reality firms tend to be at the different levels of co-creation [13] and some firms are not yet ready for co-creation and require preparations internally as well as externally [4], [6], [14], [15]. Therefore, a five-step plan is introduced to help firms in achieving greater levels of co-creation. First and foremost, a firm must assess whether it meets the minimum requirements for co-creation [10] because for every firm there are some predetermined competencies required to engage in co-creation [16]. Once the firm has determined that it is ready to engage in co-creation, the firm should assess the potential that it has for co-creation. In other words, what is the maximum level of co-creation that can be achieved by the firm in current settings[1], [9]. After knowing the potential for co-creation, the firm needs to identify what is the most appropriate method to engage in co-creation [10], [17]. There exist several methods and techniques that can be employed by firms for co-creation and these methods are different from each other not only in means of applications but also results and benefits obtained [6]. In the fourth step, the firm will need to examine its current level of co-creation [13]. This can only be done once the firm has already engaged in co-creation. Knowing this information will allow the firms to assess the amount of efforts that will be required to achieve targeted level of co-creation. The last step is to develop the methods and techniques to increase the level of co-creation to fully enjoy the benefits of co-creation.

This study only covers step one and step two out of the five steps introduced due to the limitation of time and resources. In following section the model proposed in this study is discussed.

2. Proposed model

Successful end-users involvement into the process of NPD is not possible without communication. If a firm is willing to engage in co-creation, it must first build a channel to communicate with its end-users [18]. The channel must be two-way, strong, reliable and active [15]. The firm may choose to use multiple channels if needed. Without these characteristics of the communication channel, the firm cannot freely engage into co-creation process and has to spend more efforts and time to successfully co-create [19]. Along with effective communication, previous literature suggests that there are several other characteristics that are important for co-creation but their levels of importance for co-creation are not the same [15] . Some characteristics are very critical for co-creation, and if they are not available, the firm cannot successfully engage in co-creation. Some characteristics are not that critical but are very important for co-creation. Without them, the firm can still co-create, but it will be very difficult and time consuming for the firm to manage the co-creation operations. Some characteristics are good for co-creation and will ease the process of co-creation. Not having them, however, will not pose any difficulties for the firms during the co-

creation project. Therefore, characteristics important for co-creation can be classified into three levels of importance for co-creation, as described below.

- **Must-have:** A firm must have these characteristics, if the firm wants to co-create. Otherwise, the firm cannot co-create.
- **Should-have:** A firm should have these characteristics, if the firm wants to co-create. Otherwise, it will be difficult for the firm to co-create but still the firm will be able to co-create.
- **Nice-to-have:** If a firm has these characteristics, it will be an advantage for the firm but not having them will not result in any difficulty during co-creation.

To utilize different importance level of co-creation characteristics, a two-step model was proposed to check readiness and potential for co-creation for any firm. The first step focuses on basic must-have requirements for co-creation. If the firm does not possess these basic requirements, it is not ready for co-creation. If the firm passes these minimum requirements, it will be evaluated for its co-creation potential. The second step focuses on the characteristics that impact the potential for co-creation, and at this step as per the potential score, the firm will be classified as high, medium or low potential firm for co-creation.

To investigate firm readiness and potential for co-creation, seventeen characteristics identified in an earlier study are utilized. These characteristics are not related to firms' technical or operational capabilities, but they focus on the managerial approaches and mindset of the firms instead. Therefore, it can be argued that they are equally applicable to all industrial sectors and product categories. The characteristics identified are summarized in Table 1.

Table 1. List of characteristics important for co-creation.

Screening system	Two- way-communication channels	Multiple communication channels
Effective IMS	Staff training in customer relation	Manage customer contribution
Openness to Ideas	Manufacturing personalized items	Mass customization experience
R&D activities	Willingness	Effective information sharing
Flexibility	Communication among end-users	Exploitation
Large market share	High satisfaction level	

3. Methodology

Even though literature mentioned several characteristics of firms that are important for co-creation and has also provided indications that their levels of importance are not the same for co-creation but failed to identify, their degrees of importance. Thus, expert opinion has been explored in this study to determine the importance levels of characteristics obtained in an earlier study through literature. These characteristics were converted into a questionnaire and sent to both researchers and professionals (referred as the experts here onward) working in the field of co-creation and new product development. Respondents were asked to rate the importance of these characteristics individually, according to their experiences into earlier mentioned three categories (i.e., must-have, should-have and nice-to-have). Not-related choice was also provided in the

questionnaire to filter out characters that the respondents may believe are not related to co-creation potential but were mentioned in literature.

The selection criterion for researchers was a minimum of two published journal papers related to co-creation fields and for practitioners was a minimum of 10 years working experience in NPD or associated fields. To evaluate the responses, this study utilized weighted average method. The simple weighted average approach is useful in dealing with multiple criteria decision problems. It assumes a set of weights indicating the relative importance of each criterion. The weight score of five, three and two were assigned to must-have, should-have and nice-to-have respectively. Not-related was assigned a weight score of zero as characteristics falling in this category have no impact on co-creation potential. The difference among must-have and should-have weight scores were kept high to reflect the respective difference of importance among two categories. For calculating weighted score for each characteristic, Equation (1) was utilized.

$$W_i = \frac{\sum_{j=1}^{4} w_j x_{ij}}{w_{\max} \sum_{j=1}^{4} x_{ij}} \times 100\% \tag{1}$$

$$W_{cj} = \frac{w_j}{w_{\max}} \times 85\% \tag{2}$$

Where,

W_i = Weighted score for characteristic i

w_j = Weight of category j

x_{ij} = Number of votes of characteristic i received for category j

$w_{\max}$ = Maximum weight among categories

W_{cj} = Cut off weighted score for category j

After a weighted score was calculated, each characteristic was then assigned to one of the four categories. A floor for each category was set at 85% of unanimous votes for that category and a ceiling was limited by the floor of a next higher category. According to Equation (2), the cut off weighted scores were 85%, 51% and 34% for must-have, should-have and nice-to-have respectively. As aforementioned, the characteristics falling under the importance level of must-have will be used to investigate a firm's readiness to engage in co-creation. They are the minimum requirements for any firm to engage in co-creation. Should-have and nice-to-have characteristics will be used to investigate the potential for co-creation with assigned weights of three and two respectively. Different Likert scales can be applied to evaluate these characteristics. An average weighted score obtained from these two categories will be then calculated. Any firm scoring 75% or above of maximum potential score

will be classified as a high potential firm for co-creation. Similarly, a firm scoring 50% or more but less than 75% of maximum potential score will be classified as a firm with medium potential for co-creation, and lastly a firm scoring below 50% of total potential score will be classified as firm with low potential for co-creation.

Table 2. Summary of responses from both groups of respondents.

Characteristics	Number of responses received				
	Must have	Should have	Nice-to have	Not related	Totald replies
Screening system	17	8	1	1	**27**
Effective IMS	11	12	5	0	**28**
Openness to ideas	21	5	1	0	**27**
R&D activities	17	6	4	0	**27**
Flexibility	17	10	1	0	**28**
Two- way-communication channels	17	10	1	0	**28**
Staff training in customer relation	16	10	2	0	**28**
Manufacturing personalized items	5	5	13	5	**28**
Willingness	24	4	0	0	**28**
Effective information sharing	19	7	2	0	**28**
Manage customer contribution	15	10	3	0	**28**
Mass customization experience	1	6	12	9	**28**
Multiple communication channels	7	14	6	1	**28**
Exploitation	8	17	2	1	**28**
Large market share	4	2	9	13	**28**
High satisfaction level	1	10	9	8	**28**
Communication among end-users	9	12	5	2	**28**

4. Results and discussion

The developed questionnaire was emailed to a total of 112 researchers and 43 professionals whose qualification met the criteria. First and second reminders were sent after seven and fifteen days. A total of nineteen and ten responses were received respectively from researchers and professionals. One response from the researchers group was discarded as it contained same answer for all questions i.e., nice-to-have. After summarizing the responses from practitioners and researchers, T-test was conducted to check if there was any significant difference in opinion of both groups of respondents for each characteristic. The test revealed that out of seventeen characteristics the opinion was different significantly on two characteristics willingness and two-way communication. For the remaining fifteen characteristics, the differences in opinions were not significant at 95% confidence level. The reason for the differences in opinion in two groups for these two characteristics can be credited towards the fact that the practitioners emphasized more on practical requirements while the researchers focused on mindset of the firms. Analyzing these two characteristics separately revealed that researchers have placed willingness in must-have category with 100% weighted score while professionals have placed it in should-have category with 84% weighted score. Even though the opinion of the two groups differed but both groups considered willingness very important for co-creation. According to the definition of co-creation, without the firm's willingness the process of co-creation cannot start [4]. Therefore, willingness of firms to co-create is a must-have characteristics for co-creation and combining the responses of the two groups will result in same i.e. classify willingness into must-have importance level. Similarly, two-way communication was ranked low in must-have importance level by researchers and low in should-have importance level by practitioners. Combining the response from both groups of the respondents will keep two-way communication on the high side of should-have

importance level that will approximately represent the opinions of the two groups. Therefore, it was concluded that the responses from the two groups can be combined and analyzed together. The combined responses are summarized in Table 2 and calculations were undertaken using the equation (1) and results were summarized according to the set criteria. The results obtained from the calculation are presented in Table 3.

Table 3. Summary of results from all calculations.

Characteristics	Must have	Should have	Nice to have	Not related	Total replies	Maximum possible score	Total obtained score	Weightage ratio	Importance Level
Willingness	24	4	0	0	**28**	140	132	94.3%	Must have
Openness to idea	21	5	1	0	27	135	122	90.4%	
Effective information sharing	19	7	2	0	28	140	120	85.7%	
Flexibility	17	10	1	0	28	140	117	83.6%	Should have
Two way communication channel	17	10	1	0	28	140	117	83.6%	
Screening system	17	8	1	1	27	135	111	82.2%	
R&D activities	17	6	4	0	27	135	111	82.2%	
Staff training in customer relation	16	10	2	0	28	140	114	81.4%	
Manage customer contribution	15	10	3	0	28	140	111	79.3%	
Effective IMS	11	12	5	0	28	140	101	72.1%	
Exploitation	8	17	2	1	28	140	95	67.9%	
Communication among end-users	9	12	5	2	28	140	91	65.0%	
Multiple communication channels	7	14	6	1	28	140	89	63.6%	Nice to have
Manufacturing personalized items	5	5	13	5	28	140	66	47.1%	
High satisfaction level	1	10	9	8	28	140	47	33.6%	
Mass customization experience	1	6	12	9	28	140	47	33.6%	Not related
Large merket share	4	2	9	13	28	140	44	31.4%	

According to the set criteria three characteristics: willingness, openness to ideas, and effective information sharing were classified into must-have importance level. These results comply with the previous literature and can be justified by the definition of co-creation. Similarly, according to the results mass customization experience and large market share were considered not related to co-creation potential by the experts.

5. Case study

The results of the study were analyzed through an exploratory case study of three shoe manufacturing firms and the potential for co-creation for these firms was evaluated. The purpose of the study was to demonstrate the applicability of the developed tool during practical situations. All three firms selected for the study are global with multiple manufacturing units worldwide and are engaged in designing and production of versatile range of products. First firm, referred as Firm A is well known for its sports

shoe wear and global market leader for football shoes. Second firm, referred as Firm B is known for its low-cost, high-quality shoes and famous for formal shoes and is market leader in category of school shoes. Last firm, referred as Firm C is known for its luxurious and comfortable leather shoes. The firm is among top brands for leather shoes in Europe.

The goal of the case study was only to demonstrate the applicability of developed tool therefore the data of three case study firms was gathered from different sources on the internet. To begin the process of checking the potential for the co-creation, it was assumed that all of three selected firms have all the must-have characteristics for co-creation and have fulfilled the minimum requirements needed to engage in co-creation. Also, the scale for the exploratory case study was used 0-1. Zero was assigned to characteristics that firms do not possess and one to the characteristics that firm possess. The 0-1 scale was used due to the limited amount of information available for the selected firms. More precise scale can be employed when accurate information is available. The co-creation characteristics of the selected firms are presented along with their potential scores in Table 4.

Table 4. Summary of potential score calculations for three shoe manufacturers.

Characteristics	Firm A		Firm B		Firm C	
Flexibility	1	3	0	3	1	3
Two- way-communication channels	0	3	0	3	0	3
Staff training in customer relation	1	3	1	3	1	3
Screening system	1	3	0	3	0	3
R&D activities	1	3	1	3	1	3
Manage customer contribution	1	3	0	3	0	3
Effective IMS	1	3	1	3	1	3
Exploitation	1	3	1	3	1	3
Communication among end-users	0	3	0	3	0	3
Multiple communication channels	0	3	0	3	0	3
Manufacturing personalized items	1	2	1	2	1	2
High satisfaction level	1	2	1	2	1	2
Mass customization experience	1	2	0	2	0	2
Total score	**27**		**16**		**19**	

Once the characteristics that the selected firms possess have been identified, the scores were given to the firms and calculations were made according to preset values. After calculating Firm A received a final score of 27 out of 33 that is above 75% and was classified as the firm with high potential for co-creation. Similarly, Firm B scored 16 (below 50%) and was classified as the firm with low potential for co-creation and lastly Firm C scored 19 (more than 50% but less than 75%) and was classified as the firm with medium potential for co-creation. Even though the Firm A managed to land into the high potential for co-creation zone but the firm is still missing two important characteristics of two-way communication, and communication among end-users for co-creation. Therefore the firm needs to pay more attention towards its communication methods and platform to improve its co-creation potential. Similarly, Firm B and Firm C landed in low and medium potential ranges for co-creation respectively as they were missing several important characteristics that are helpful in co-creation.

6. Conclusion

Besides steps for achieving high level of co-creation, a two-step quantitative tool has been introduced in this research to help firms evaluate their readiness and potential for co-creation. According to the experts in the field, fifteen out of seventeen characteristics used in this study were found to have influence on co-creation and were

classified into three different importance levels for co-creation: must-have, should-have and nice-to-have. The three must-have characteristics have been set as criteria for checking readiness. Unless they all are fulfilled, the firms are not ready for co-creation. The remaining twelve characteristics have been used to evaluate the potential of the firms that are ready. The higher the score is, the higher the potential the firm have for co-creation. The exploratory case study was conducted to illustrate how the tool can be applied. Due to limited access to the required information, the three firms' potential was calculated based on binary scale. Availability of information will improve the evaluation. It is also foreseen that it is possible that a few characteristics may be swung from one importance level to another level, additional responses from the experts will confirm their importance.

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Identifying Firm Characteristics for Successful Co-Creation - Literature Review

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Abstract. In the last decade, active involvement of end-users in new product development (NPD) commonly referred as co-creation has emerged as an effective strategy to overcome barriers that hinder firms from understanding customer needs. In response, co-creation has generated a great deal of interest for both practitioners and researchers in different areas of NPD. Despite co-creations growing trend, relatively little is known about this new form of product development. Hence this study provides a ready reference of recent literature on co-creation. First, this study distinguishes between the roles and responsibilities of firm and end-users at different phases of NPD during traditional and co-creation projects. Second, after an extensive literature review of marketing, innovation management and product development it identified important managerial characteristics needed by the firms to successfully implement co-creation.

Keywords. Co-creation, new product development, customer involvement, characteristics, success factors, firm characteristics

Introduction

Co-creation or active involvement of end-users during New Product Development (NPD) is not a new concept. It was first introduced in Europe in 1970s and was referred as "participatory design" [1]. Ever since, researchers and practitioners alike have tried to utilize the concept to minimize the product failure rate and have given it different names such as, co-designing [2], [3], design by customer [4], participatory design [5], [6], user generated content [7], mass collaboration [8], [9], co-production [10] customer participation [11], co-creation [9], [12]–[14] and so on. Despite the name given all these methods emphasize on the same thing that is end-users involvement in the process of NPD.

In the last decade, the concept has been generally termed as co-creation and received a large amount of attention from both practitioners and researchers to minimize the risk of misinterpretation of end-users needs during NPD. This rise in the use of the concept has caused the literature to grow and not only many folds but in many directions. This breadth of literature has created difficulties for the new researchers and practitioners beginning to work in the field. This study with the help of literature published in the fields of marketing, innovation management and product development identified important managerial characteristics needed by the firms to successfully implement co-creation.

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Along with the breadth of literature the use of term co-creation in many contexts has led to confusion, where it is argued that all NPD projects (traditional or co-creation) heavily rely on end-users input and involve them in the process. But involvement during traditional NPD is passive and end-users only provide feedback when they are asked [15], whereas emphasize during co-creation NPD is on active end-users involvement where firms assume the role of mere supporters during many phases of the project. Therefore, co-creation can be defined as an active, creative and social process which includes some special methods and strategies applied by firms to engage the end-users into the firms' initiated NPD projects [13], [16], [17]. To clear this confusion following section is dedicated to distinguish between the roles of end-users during traditional and co-creation NPD.

1. Role of end-user in traditional and co-creation NPD projects

The main idea of co-creation is to involve its end-users into the process of NPD. The end-users involvement in co-creation projects not only differs in points of interactions, but also in intensity, role and goal from these interactions when compared to traditional NPD projects. For the traditional NPD projects as shown in Figure 1, the role of the end-users is supportive. All the primary functions /decisions are made by firms, and the end-users only provide feedback when they are asked [15]. Concepts/ideas are generated by the firms and after that the end-users feedback is obtained through surveys or interviews to verify and validate the generated concept [18], [19]. Often the surveys and interviews are designed to support the concepts generated by the firms and only a few adjustments based on the feedback obtained are made and the concepts are finalized by the firms. All important activities of designing, developing and prototyping are conducted solely by the firms and are governed by price, quality and technical capabilities of the firms [19]. After the development of prototypes, the end-users are asked to provide the feedback on the developing products [20], [21]. Few changes are possible at this point as most of the product development work is already completed and it is very difficult for the firms to make any major changes in the designs due to competitive market pressure to launch the products [22],[23]. Based on the obtained feedback, the firms refine the products and prepare for full production. No further end-users involvement is considered until the products are available in the market. The end-users are then asked to provide feedback on the products offered for the concept generation of the future offerings [12].

Contradictory to the traditional NPD projects, the role of the end-users in co-creation NPD projects at many phases is also primary [1], [13], [24], [25], as shown in Figure 2. The ideas/concepts are mainly generated by the end-users while the firms only provide support/platform for the end-users to use their creativity to find solutions for the problems presented to them [1], [26], [27]. Once the ideas are generated, the firms usually refine the ideas through the evaluation, on the basis of feasibility and technical capabilities of the firms [1], [24]. After the concepts are refined, the end-users and firms again work together to finalize the concepts. All the other remaining phases of the NPD projects completed by the collaboration of the firms and end-users until the products are ready to be launched into the market [13], [28]. In the co-creation NPD projects, the end-users not only contribute to the manufacturing of the successful products but also to promote the products to the market at little or no cost for the firms [9], [29].

In short, it can be concluded that the NPD projects that only take the feedback from the end-users, provide multiple options to choose from the offered variations or even try to tap the current experiences of the users for future offerings are not the co-creation NPD projects [12]. In contrast, the projects in which the firms facilitate the involvement of the end-users into the process of NPD where end-users lead the way for the firms to act according to their wishes can be classified as the co-creation projects [1], [12], [30]. For example, a firm offering its end-users colorless cars with tools and platform to design on their own. This activity may result in a normal car with regular color paint or may result in different types of design or graffiti on the car as happened in Daimler AG 2010 "Style Your Smart" competition. This type of projects can be classified as co-creation NPD projects. On the other hand, if a firm offers cars to its end-users and provides them multiple color options to choose from for those cars, it is not co-creation.

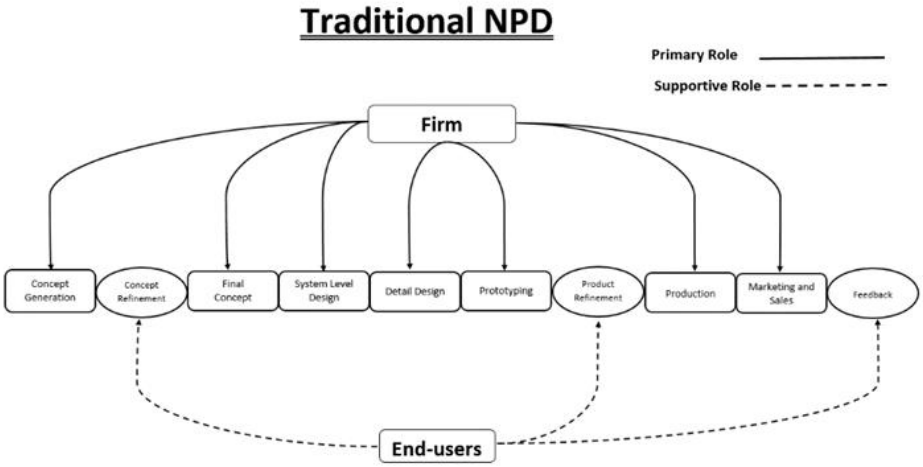


Figure 1. Role of end-users in traditional new product development process.

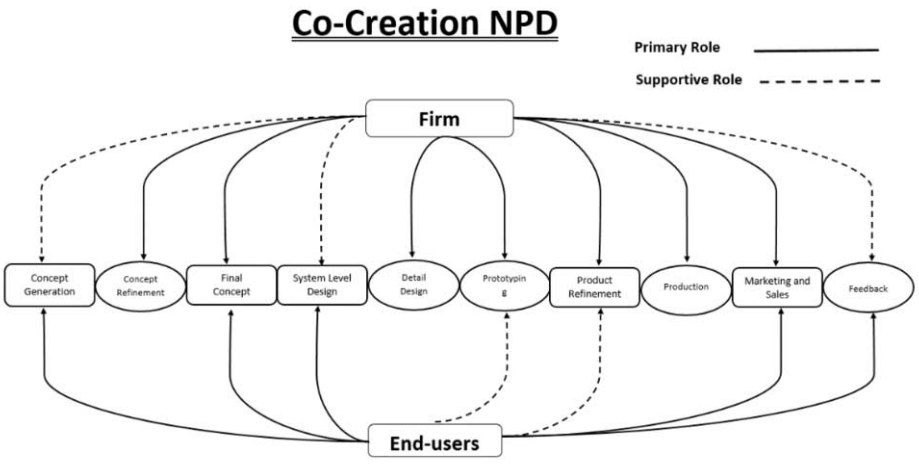


Figure 2. Role of end-users in co-creation based new product development process.

2. Firm characteristics for co-creation

In last decade co-creation has received an overwhelming response from both researchers and practitioners and literature body has grown not only many folds but in many directions. Though the work related to co-creation has been primarily published in marketing literature, yet a great number of original contributions have been published in innovation management and product development literature. This breadth of literature resulted in difficulties for new researchers and practitioners looking to employ the concept. This study attempts to identify a list of important managerial characteristics for co-creation that will serve as ready reference for new researchers and practitioners in the field.

2.1. Two-way communication channel

Co-creation is a process of engaging end-users into NPD projects and a reliable two-way communication channel is necessary for nourishing this engagement [14], [31]. Therefore, unless a communication exists between a firm and its co-creators, successful co-creation will be very difficult.

2.2. Staff training in customer relation

Irrespective of roles played, every employee who interacts with end-users is responsible for the success of co-creation [32]. According to a study conducted by Paul and Seddighi [14], on the management and operational capabilities for innovation via co-creation, the importance of staff training was highly emphasized by the managers of the best performing firms in the northeast region of England.

2.3. Manufacturing personalized items

Previous studies have confirmed that relationships between firms and end-users depend upon the types of services/products offered by the firm. High interaction personalized products (i.e. watch, smartphone, laptop) offers much more opportunities for co-creation in comparison to non-personalized items [33], [34]. That is because the end-users are more motivated to participate in such projects.

2.4. Firm willingness

Willingness is self-motivation that individual must have to initiate any activity. This is held true also for co-creation. The degree of a firm's willingness to co-create is directly proportional to the degree of co-creation the firm can achieve [34], [35]. Therefore, the willingness of the firm to co-create is a key requirement to engage in co-creation as the process needs to be initiated by the firm itself [13].

2.5. Effective information sharing

In NPD projects, appropriate/effective information sharing with end-users is very critical because this information will be available to not only end-users but competitors

also. Therefore, the extent and method for information sharing is a strategic decision [36] and should be taken carefully.

2.6. Effective management of the new content

For a firm engaged in co-creation, a large amount of information is expected to be shared from its end-users. If it is not properly managed, it will soon lead to information overload [37] and may become a challenge for the firm.

2.7. Mass customization experience

Firms already engaged in mass customization have the experience to manage end-users feedback and have already developed the concept of listening to the end-users. Thus, these firms can develop competencies required for co-creation easily compared to those with no mass customization experience [14], [34].

2.8. Communication among end-users

Communication among end-users is important [14], especially for a firm using its end-users for marketing, idea generation, and screening of ideas generated by other users. The process of using the end-users to do all these can be exploited with the help of platform provided by the firm to its co-creators. With the help of the provided platform, the co-creators not only can discuss the new ideas with each other but also can help each other in obtaining better conclusion by providing instant feedback and recommendations to the peer co-creators [38].

2.9. Exploitation

Exploitation refers to the ability of a firm to quickly convert innovative ideas into successful products for financial benefits [36]. As the ideas available on the public domains are vulnerable to be copied easily by competitors. Therefore, having ability of to quickly exploit the ideas will increase the success of co-creation projects.

2.10. Current market share

The degree of willingness of end-users to co-create determines the level of co-creation a firm can achieve [34]. It is more likely that the end-users will be motivated to co-create with the market leader or well-known brands in comparison to those with little market acceptance.

2.11. Satisfaction level

According to a study by Füller [39], one key reason for end-users to engage in co-creation was their current satisfaction level with firms' offerings. The end-users participated in the firms initiated co-creation projects to improve their experience for future offerings.

2.12. Multiple communication channels

As previously mentioned, communication between end-users and a firm is the core of co-creation, and high number of interactions will have positive impact on co-creation results [31], [38]. Therefore, it will be advantageous for the firm to have multiple communication channels to interact with the end-users during co-creation.

2.13. Screening system

Co-creation activities yield a large number of ideas that will soon lead to information overload if they are not properly managed [37] and may result in unnecessary complexity during the process. Therefore, a firm is required to have a screening system for filtering ideas given by its co-creators to save time and efforts.

2.14. Effective Information Management System (IMS)

Information Management System (IMS) is an information storing, searching and retrieval system that presents right information to right users according to their requirements and responsibilities. Information sharing within a firm is very important during co-creation projects [14] and with the help of effective IMS, the firm can distribute important information timely and efficiently.

2.15. Openness to ideas

Willingness of a firm plays a vital role in the level of co-creation it can achieve [34]. That includes not only top management but also managers and designers working on a project. Many firms face "Not Invented Here" (NIH) syndrome [39] where design teams do not accept ideas generated by anyone else. This attitude affects directly the level of willingness of the firm to co-create. Therefore, it is very important for the firm to develop a mindset to be open to ideas from everyone [35].

2.16. R&D Activities

A firm that does not engage in R&D activities cannot act according to the voice of end-users as it only produces what has already existed and well established in a market. The firm does not look into ways to fulfill latent needs of the end-users. That is why R&D activities were marked necessary for co-creation by many managers of high performance firms during investigation of firm capabilities for co-creation [14].

2.17. Flexibility

During the relevant literature review it was observed that the firm engaged in co-creation may receive novel/creative ideas from end-users at any phase of NPD and may have to incorporate them quickly into ongoing projects to be the first to offer the solution to the market and gain competitive advantage. Therefore, the firm willing to engage in co-creation should have flexibility incorporated into the existing system. But this important characteristic of the firms was missing from the literature and hence was added into the list to make it more robust and complete. Where, flexibility refers to a

firm's abilities to incorporate ideas/suggestions created by co-creators rapidly into its existing system.

These identified attributes not only reflect on the managerial capabilities of the firms, but also the mindsets of the firms and their readiness and intentions towards co-creation. It was also noted that the importance level of these characteristics of co-creation is not same and different characteristics may have different levels of impact on co-creation success. Further studies can confirm these importance levels. It is also foreseen that these identified characteristics can be used in future studies for developing methods/frameworks for successful co-creation.

3. Conclusion

Besides highlighting the shift in roles and responsibilities of both firm and end-users during NPD, seventeen important characteristics needed by firms for co-creation are identified from recent literature. During the identification of these characteristics the focus was intentionally kept on managerial approaches and mindsets of the firms. The characteristics related to technical and operational capabilities of firms were ignored as their need may vary depending upon the nature of industry and size of the firm. Therefore, it is argued that these identified characteristics are equally applicable to all industry sectors and product categories. This list of characteristics will serve as a ready reference for not only practitioners but also new researchers beginning to work in the field of co-creation by providing them highlights of what qualities/characteristics are needed from firms for successful co-creation.

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Transdisciplinary Engineering: A Paradigm Shift
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Transdisciplinary Innovation: Connecting Ideas from Professional and Community Networks

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Abstract. Transdiscipinary innovation - what is it and how does it work? In this paper, the way disparate professional and community actors may work together is considered, drawing on case study data from three different Australian-Indian academic research collaborations. One considered food sector SME innovation practice in the two countries and the other two considered the deployment in India of radical technologies developed by international teams to deliver social benefits. The collection of knowledge artifacts from disparate sources was the norm. Implementation of an innovative idea or technology application commonly involved parallel processes of interactive learning from testing possible combinations. Six facilitating mechanisms to be explored further were identified in this exploratory study.

Keywords. Transdisciplinary innovation, Concurrent engineering, Bricolage, Community engagement, social capital

Introduction

Innovation is a social process involving a number of actors - it is people who come up with ideas and promote them. A colleague once likened the evolution of an innovation to making a movie. Whilst the process has a beginning and an end, the script may be adapted along the way and some scenes may have to be filmed several times. Some of them may never appear in the final cut. The plot will have twists and turns, and whilst there will be a few central actors, as shown in the credits at the end, there will be support from many others having particular specialisations. A particular film will be framed and shaped by considering the intended audience.

Consistent with this analogy, a study of research methods in theatre and performance by Kershaw et al [1] describe transdisciplinary innovation as ‘practice as research' associated with creative enquiry. In reviewing approaches to transdisciplinary research in the health sector, Kessel and Rosenfield [2:S225] observed that "far-sighted [World Health Organisation] medical doctors and international health workers began to realize that the effective delivery of health care, especially in cross-cultural settings, involved sociocultural as well as purely medical factors." What we take from this is that the concept of transdisciplinary innovation involves the melding of social, technological and organisational perspectives oriented towards the needs/wants of the

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intended beneficiaries. Some see this as requiring a new thought style for the innovators involved (e.g. Darbellay [3]), and as being a powerful tool in developing economies (e.g. Schensul, Nastasi, & Verma [4]). Our review of the literature identified three contexts in which the term transdisciplinary innovation was used, as outlined in Table 1.

Table 1. Some issues associated with transdisciplinary innovation identified in the academic literature.

References	Transdisiplinary Innovation Context
Hadorn et al [5]; Nowotny, Scott, & Gibbons [6], Stokols et al [7]; Gray [8]; Klein [9]	Issues related to the utility and practice of transdisciplinary research
Boujut and Laureilland [10]; Sobolewski [11]	Issues related to implementing the design of an innovative new product or service
Emmons et al [12]; Schensul et al [13]; Keating et al [14]	Issues emerging in confronting a real-world complex problem where there were multiple stakeholder interactions

We suggest that the process of transdisciplinary innovation involves all three aspects, as illustrated in figure 1.

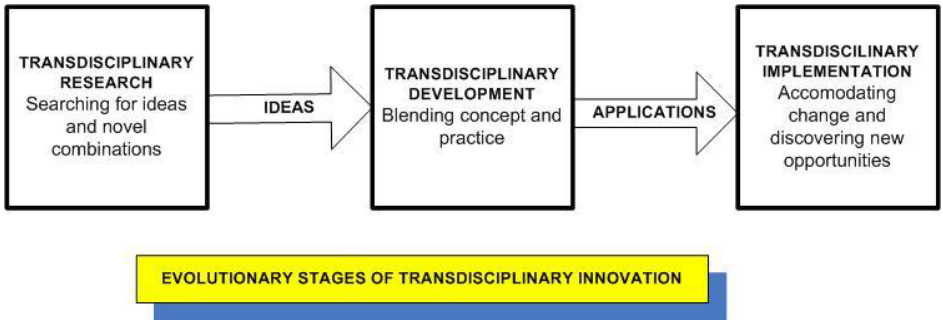


Figure 1. Transdisciplinary innovation model.

In this paper we reflect on what transdisciplinary innovation might look like in practice in three joint Australian - Indian academic cases. We explore the research question 'what mechanisms might facilitate transdisciplinary innovation', drawing on inferences from our case study analysis.

1. Research Approach

A longitudinal multiple case study approach based on Yin's [15] methodology was used to establish rich data sets covering all stages in the evolution of an innovation and preserving context at this exploratory stage of the research. The purposive sample of cases sought to cover a variety of situations. The literature had suggested that transdisciplinary innovation may be enacted differently depending on technological and community context. We draw on three cases involving collaboration between an Australian and Indian academic institution which considered topics of national importance. One had a business outcome orientation, and two had a social outcome orientation.

Cross case analysis was conducted using Eisenhardt's [16:540] tactic of selecting a particular dimension, and considering similarities and differences between cases in the

context of that dimension. The dimension chosen was the evolutionary stage of a transdisciplinary innovation illustrated in figure 1. Each of the ten references cited in table 1 was examined to identify a central theme, and observations from the cases were compared in relation to each theme. Some themes related to matters of agency and some to matters of structure. By way of example, Gray [8] considered leadership challenges and collaboration competencies. In this context, an innovation champion role and the value of social networking were oberved in the cases. The process provided thirty observations about some aspect of transdisciplinary innovation. The results were tabulated to facilitate comparison, but space limitations precluded their presentation here. A brief outline of each case data set follows.

1.1. Case 1: Food Sector SMEs: Feeding Growing Populations

This data set came from a collaboration between an Australian and an Indian university exploring the dynamics of innovation in food sector SMEs. The original research question was: what are the sources of innovation for SMEs in the food products manufacturing industry? Both governments regarded growth in this sector as important. Secondary data from websites, company documents and news media plus direct senior executive interview data was collected from seven SMEs in Australia and five SMEs in India that had been in business more than 10 years. Representatives of a regional cluster were interviewed in each country. This data set was analysed to explore the nature of the innovation process at work and business sustainability mechanisms. Food security and quality were community concerns. We specifically asked the enterprises studied in Case 1 about their use of transdisciplinary/open innovation practices in considering such concerns whilst maintaining economic sustainability. They did not recognise or use the formal processes described in the literature. They collected external ideas via personal networking with regional community groups, communities of practice and trade events. They not only sought ideas for a product innovation, but ideas about process innovation and what customers valued. Innovative products were developed from novel combinations of readily available ingredients and established practices, homing in on ‘recipes' via a process of trial and error. Business models changed in response to market pressures / opportunities.

1.2. Case 2: Deploying Vision Science to Confront a National Health Problem

This data set provided information on the cumulative effect of multiple prior collaborations and project management approaches aimed at deploying radical eye treatment innovations where proof of concept had been demonstrated in the laboratory. The Indian partners were experienced eye surgeons, an enterprise that could manage extensive patient field trials in India, and an industrial firm that might make novel implants. Data was collected from private meetings with the Australian researchers over a six-month period and participation in a one-week partner workshop involving medical and technological experts where suitable project management and initial production arrangements for the complex technologies involved were explored. A multi-national researcher-practitioner in-kind collaboration was established to confirm the product practicality of two new research concepts through pilot scale production and field trials. It was intended a start-up company funded by venture capital be established to manage commercialization, but problems emerged. The Global Financial Crisis impacted the availability of venture capital.

1.3. Case 3: Kerala Disaster Management: Pre-emptive Action to Avoid Disasters

This data set related to a collaborative project involving Amrita University in India teaming with some international universities, also involving a consulting firm (the Sustain Group), and the local community that had been financed by Amrita. A natural disaster had struck a particular village and, as a result, there was a significant land shift at the top of a pass that hung over many of the houses. The local community was primarily engaged in the tea industry and many villagers were living on or below the poverty line, so they could not easily relocate. Amrita University worked with the local community and the Sustain group to install high technology measurement equipment that enabled data to flow directly back to a team to assess land movement and make predictions, enabling the local community to move to safer ground in the event of another impending disaster.

An early warning system was deployed in a landslide prone area where two major landslides had occurred. Eighty geological sensors in twenty deep earth probes collected and transmitted data to the Amritapuri Data Analysis Center using a wireless sensor network of twenty-five nodes and satellite connections, as establishing a hard-wired system in the area was impossible. Large-scale data collection and power management algorithms facilitated management of the system. Data has been continuously transmitted from the deployment site in real time to the university since 2008.

2. Observations from the Cases

Multiple disciplines were involved in all cases:

- In case 1 this included agricultural science, food science, production engineering, logistics and marketing, much of which was combined in a business model - a strategy for the delivery and extraction of value.
- In case 2 this included polymer science, manufacturing engineering and medical science
- In case 3 this included sensor science, systems engineering, geo-physical science, and data processing/interpretation

There was a common focus on interaction mechanisms. Whilst cases 2 and 3 had a traditional scientific heritage, the implementation of that research also involved significant field learning: learning *for* innovation and learning *from* innovation in conjunction with users/beneficiaries.

Six recurring themes emerged from the cross-case analysis outlined earlier, and these were viewed as mechanisms facilitating transdisiplinary innovation. Table 2 outlines each mechanism with reference to associated literature.

Table 2. Mechanisms facilitation transdisciplinary innovation.

Facilitating Mechanism	Observations from the cases
The influence of Social Networking	Purposeful social networking was a common practice of the SME firms in case 1. Different networks were accessed for different purposes - some to passively receive information, some to actively broadcast information, and some for intimate exchanges of information. In case 2, the latter was facilitated by project workshops, whilst broadcast information was held in an on-line knowledge management system. Third parties were sometimes involved in facilitating network connections. In case 3, the Indian university had established professional connections within the international science community and regional community engagement connections.
Network Thinking and Interface Protocols	Whilst the literature refers to arrangements for organising transdisciplinary teams, we suggest it is more appropriate to think of transdisiplinary networks of autonomous agents and interfaces to enable them to interact. This recognizes that individual actors are also connected to external actors who may indirectly contribute to a transdisciplinary project. For example a biomedical engineering practitioner may have links to biology, medical and engineering scientists. Who is connected to who, what is connected to what, and what protocols facilitate communication? Industry associations provided strong connections in case 1. A strong orientation towards managing interfaces was observed in cases 2 and 3 both in relation to the product/system under development and in relation to management arrangements. This way of thinking recognizes that particular actors may be linked in different ways at different times. For example, in case 2 the field trials actors had a limited involvement until regulatory approval was obtained to begin trials.
Boundary Objects and User Stories	In case 1 interface artifacts were prototype products and processes constructed to get user feedback in an iterative style of development. In case 2 early prototypes were used to understand what was possible before moving on to what was practical. Face-to-face workshops were used to share knowledge and provide an opportunity for critical questioning. In case 3 funding bodies required regular reviews and reports, which caused the participants to document their viewpoints. Boujut and Laureilland [10] raised the matter of interface artifacts, interface roles and interface knowledge that facilitated cross-discipline engagement in a design setting, and related observations. Star and Griesemer [17] refer to boundary objects where the viewpoints of both expert and community contributors from different backgrounds were pooled in considering an archeological artifact - what was it, what could it be used for, and how was it made? A story related to the artifact emerges, and can be discussed and elaborated on. Having cohesive user stories about their needs is an important starting point in agile software design [18], and can represent a desired future if a complex problem is well framed.
The Utilisation of Backcasting	Backcasting is seen as a practice of imagining future options applied to long-term complex issues (as seen for example in our cases 1 and 2), then working out what has to be in place to realize a particular future (e.g Dreborg, [19]) . For example, how can we achieve the goal of providing safety for people living in a landslide-prone area (Case 3). The next question is how to put the supporting infrastructure in place and how to utilize it. Can we combine current knowledge in some way, or do we need to develop new knowledge? What kinds of knowledge are needed (e.g. system, target or transformational knowledge - Hadorn et al [5]) This led to a variety of R&D activities, some within a particular discipline and some transdisciplinary.

Facilitating Mechanism	Observations from the cases
Unifying Transdisiplinary Knowledge Elements	Madni [20] saw transdisciplinary innovation as bringing together elements of knowledge from disparate sources. Hargadon [21] has suggested: "it is the recombinant (rather than inventive) nature of revolutionary innovations that contribute to their dramatic effects". Weik [22] introduced the idea of improvisation as a mindset associated with creativity and innovation, spontaneously putting together combinations of ideas, some of which succeed and some of which fail. Baker and Nelson [23] refer to "creating something from nothing: resource construction through entrepreneurial bricolage" - drawing together whatever resources may be readily available to pursue a current need or opportunity. There are some common themes here - being aware of or assembling a parcel of knowledge elements, experimenting with combinations of them, appreciating the utility of a particular combination, and building an expanded resource platform to support further innovation. This is illustrated in the evolution of mobile phones from telephones to messaging devices, to the inclusion of image capture, to the incorporation of computing and GPS capabilities. Albeit in a different way, this kind of journey has also been taken by our case 1 firms. In case 2, the participants were building on what was learned in a successful prior project [24]. In case 3 Australian, European and Indian participants with particular expertise were drawn together
The Interplay of Two Modes of Innovation	It has been suggested that: "The old paradigm of scientific discovery (Mode 1) characterised by the hegemony of disciplinary science, with its strong sense of an internal hierarchy between the disciplines and driven by the autonomy of scientists and their host institutions, the universities, is being superseded - although not replaced - by a new paradigm (Mode 2). This mode is socially distributed, application-oriented, transdisciplinary and subject to multiple accountabilities" [6]. We will call these discovery mode and interaction mode respectively. Discovery mode was rarely observed in our case 1 firms, but was an important element of innovation in cases 2 and 3. In case 1, interactive mode multiple influence factors related to shareholders and Corporate Social Responsibility undertakings, recognizing that most of the firms involved were embedded in their local communities.

3. Concluding Remarks

Exploring the academic literature using the keywords transdisciplinary and innovation identified studies framed in three different contexts: in research practice, in product/process development and complex community problem-solving. We contend that all three are combined in the evolution of a transdisciplinary innovation, as illustrated in the model shown in figure 1.

Drawing on longitudinal case studies that embodied these three contexts in different ways, we identified six facilitating mechanisms (see Table 2). Social networking between both professional and regional communities was seen as important, along with ways of facilitating interaction between these communities such as the adoption of common interfaces, including language and jargon, and the use of boundary objects. Having a broad long-term common goal supported each discipline member of multiple social networks to identify how they could contribute to achievement of this goal. A focus on multi-stakeholder outcomes had the effect of unifying transdisciplinary knowledge elements.

It had been suggested in the literature that transdiscplinary innovation required a different, interactive research approach, described as Mode 2 by Nowotney et al [6]. In

our cases, this supplemented rather than replaced discipline-based discovery research, which provided new ideas that could be combined with other ideas.

It has been suggested that transdisciplinary innovation emerges from the combination of diverse knowledge elements. In this regard, we like the observation of Kanter (25:73) that "Innovation is always a surprise. By definition, it is something no-one has thought of before. Its very existence shows that reality is not fixed in predictable patterns. Instead creative new possibilities can emerge in any field, in any industry. Innovators see new patterns in the familiar, apparently immutable, situations. It is though they see the world through a kaleidoscope, which creates endless variation from the same set of fragments".

Using this analogy, both turning the kaleidoscope and changing or adding elements to it can yield quite different patterns. In our cases, social networking facilitated the identification of new knowledge elements and new viewpoints.

We did not come up with a design for a transdisciplinary innovation kaleidoscope, but we identified six questions that might be asked in contemplating transdisiplinary innovation initiatives:

- What social networks (professional and community) need to be engaged to pursue a particular innovation - what exists and what needs to be created?
- Who are the network nodal actors and what interface protocols have to be in place for their effective interaction?
- What kinds of ‘boundary objects' and ‘user stories' are needed to facilitate common understandings?
- How can backcasting techniques be used to realize a unifying, but broadly stated goal?
- How can we identify, share and unify transdisplinary knowledge elements?
- What might be the appropriate interplay between two models of research, characterised as discovery and interaction?

These questions might be asked in relation to each stage in the evolution of an innovation illustrated in figure 1.

One can only draw limited conclusions from three case studies, and whilst there were interactions between multiple disciplines in all cases, the extent to which they deliver transdisciplinary innovations requires further investigation. Insights from the cases suggest this occurs at the micro-level, but further study is beyond the scope of this paper. The model shown in figure 1 and the six interaction mechanisms identified provide a foundation for future research.

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Transdisciplinary Engineering: A Paradigm Shift
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Trans-Disciplinary Systems as Complex Systems

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Abstract. The system concept is a widely-used concept in research and practice. Already in the 50s of the previous century, a community was created to investigate interrelationships between domains and create a theory surpassing and comparing domains. The General Systems Theory (GST) community has tried to come up with such a theory for several decades. The ambition has grown more realistic in the years after, recognizing that an all-encompassing theory would not be possible. Since then, systems research was aimed at generating useful and usable approaches to compare and interrelate domains, thus creating a trans-disciplinary approach to enable description and analysis of large, and even complex, systems. The concept of systems, however, is often loosely used. Levels of abstraction are neglected, and interrelationships between systems ignored. In this paper, the concept of system is put in historical context, and further elaborated upon in the context of complex and trans-disciplinary systems. Two examples of transdisciplinary systems are presented and discussed to illustrate the use of the system concept.

Keywords. Systems, system hierarchy, system complexity, trans-disciplinary system

Introduction

Systems and systems thinking take a predominant place in current practice and research. Also the concept of systems of systems is used quite frequently. Systems are encompassing concepts with different structures, aspects, and layers. It is often not clear what actually is meant with systems and whether the concept is used consequently and consistently in academic and industrial circles.

In this paper, the concept of system will be explored based on the discussion found in the literature, including the concept of a complex system. Specifically, we will refer to general systems theory (GST) as already conceived in the 50s of the previous century. Specific attention will be given to trans-disciplinary systems, in the context of trans-disciplinary engineering, as a special example of complex systems. Such systems normally include many subsystems, each of which may be complex also. Subsystems may also be information systems, which are not characterized as complex systems in this paper. However, information systems play an essential role in complex systems like trans-disciplinary systems. The relationships between an information system and the trans-disciplinary system need to be characterized carefully. In this paper, we will make an attempt to do this for two examples.

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By explaining the concept of complex system in the context of trans-disciplinary systems into more detail, the paper provides handles to use the system concept more deliberately in trans-discipinary research and practice.

The paper is outlined as follows. Section 1 discusses the concept of system based on literature already originating in the 50s of the previous century. The subsequent sections present some examples of information systems used in the context of trans-disciplinary engineering. These examples serve to explore complex systems like trans-disciplinary systems, as well as their subsystems, complex and other ones, like information systems, which may be far from simple. Finally, section 5 presents a summary and ideas for further work.

1. What are systems

The concept of system is widely used in theory and practice. However, in many cases it is not very clear what really is meant with system. In an attempt to give a formalized account of a fundamental theoretical issue in general systems research Marchal has given a very elementary definition of a system [1]:

S is a system only if $S = \{E, R\}$, where

(i) *E* is an element set, and

(ii) $R = \{R_1, \ldots, R_n\}$ is a relation set, i.e., $R_1, \ldots, R_n$ are relations holding among the elements of *E*.

This definition is a very generic one, but can be given content in any domain and on any level. Even systems of systems can be characterized here, when systems on a lower level are seen as the elements of the higher-level system. Relations between elements of a system can be of any kind, e.g., part-of or functional, but also fixed, like in natural systems, or intentional, i.e., created by somebody and existing as long as needed [2].

Any object, artifical or natural, can be viewed as a system. Every such system has a function in its context, like a stone, putting weight on the surface it lays upon or storing and disseminating solar heat. A house is a system with many different functions, depending on the context in which the system is considered.

General Systems Theory [3] (GST) has emerged in the 1950s and describes a level of theoretical model-building that lies between highly generalized constructions of pure mathematics and specific theories of specialized disciplines [4]. Mathematics abstracts away from content and context. On the other hand, disciplines, like physics, chemistry, biology, psychology, etc., have their specific theories and correspond to a particular segment of the empirical world.

General Systems Theory is the result of a quest for a systematic theoretical construct that describes the general relationships of the empirical world. It is not a single, self-contained general theory of practically everything that replaces the special theories of particular disciplines [4]. As Boulding claims, such a theory would be without content. GST seeks a place between the specific without general meaning and the general without specific content. The objectives of GST can be defined with varying degrees of ambition and confidence. At a low level of ambition, but with high degree of confidence, GST can point out similarities between theoretical constructs of the different disciplines. At a higher level of ambition, but with possible lower confidence, it aims to develop a spectrum of theories – a system of systems. Like the

periodic table of elements, it may show gaps in theoretical models, which direct research to filling those gaps. This ambition, however, is still not achieved.

The merit of system theory can be found in specifically framing and defining the focus of attention. This can be disciplinary, like a waste treatment model, but also inter-disciplinary, combining two or more different disciplinary systems, like the waste treatment model and the eco system [5]. Of course, such an integrated model is less acceptable to each of the disciplines, but is a compromise to support communication and the search for trans-disciplinary solutions. Trans-disciplinary systems add a level of analysis which does not exist on the level of each of the disciplines [6].

Much discussion can be found in the literature on the concept of complex systems. When we simply count the number of elements, systems with a large number of elements may appear to be rather simple, like the solar system [7], because only a limited number of the pairs of interaction appear to be of significance. In addition, systems that occur in nature are mostly hierarchic and nearly decomposable. Approximations on higher levels are often made possible [7]. The weather system, on the other hand, is still hard to simulate and predict. Much of our perception of complexity may be due to the fact that we base our models on wrong assumptions, like in forecasting models to guide economic policy [7].

For the purpose of this paper, system complexity as defined by Nelson [5] is useful. Nelson defines a complex system as a system having at least two conflicting goals. Such a system always contain human beings, otherwise there would not be goals. Systems functioning without persons have functions to reach the goals of human beings, possibly assembled in societies. The central idea here is intentionality [5].

In the context of transdisciplinary engineering, complex systems, as defined above, are the organizational systems in which multiple disciplines and multiple organizational roles work together to develop new products or services. Such a system consists of many subsystems, which may not be trans-disciplinary but may still be complex. For example, in developing an electro-mechanic product, the subsystems are the electronic design department and the mechanical design department, each with its own processes, its own goals, people, equipment, and knowledge. In the trans-disciplinary system they have a separate, integrated, process, shared people, shared equipment, shared knowledge, and, above all, shared goals. These goals may possibly conflict, requiring negotiation and possibly adaptation of the goals, process, people, equipment, and knowledge. Other subsystems may not be complex, in the sense defined above, like information systems used to manage product and process information.

In the next section we will dive a bit more into the concept of a trans-disciplinary system.

2. Trans-disciplinary system concept

In Figure 1, the system of trans-disciplinary engineering is depicted [8]. It shows the innovation process as the central element of the system. The innovation process is performed by and involves many different stakeholders, such as engineers, designers, manufacturers, marketing and sales people, maintenance. Other stakeholders, like financial institutions, governments and certification bodies, may have a strong influence on the process, but are often not directly involved. The innovation process uses new technology, either from within the company, but more often from outside the

company. The trigger of the process may be a new idea, which may range from brakethrough to evolutionary. This idea may concern the product, the market, the process or even the organisation. The process, used knowledge and stakeholders require organisational arrangements, like rules, norms, and contracts, to enable collaboration and protect knowledge misuse and leakage [8].

The product of the innovation process is a production system, which is capable of producing, selling, maintaining and recycling the new product for the intended market. For example, when the product is a new household appliance, the production system is intended to produce, market, sell, maintain or take back the appliance. When the product is an information system, the production system is the software company that maintains and updates the system. It also markets and sells the information system and offers services to customers.

It is clear that the system depicted in figure 1, is a complex system as defined in section 1. It is a system in the sense that it is an element set and a relation set as defined above. Many elements, however, are complex systems, while the relationships are many and highly different in nature. Other elements of a trans-disciplinary system are not complex, like information systems.

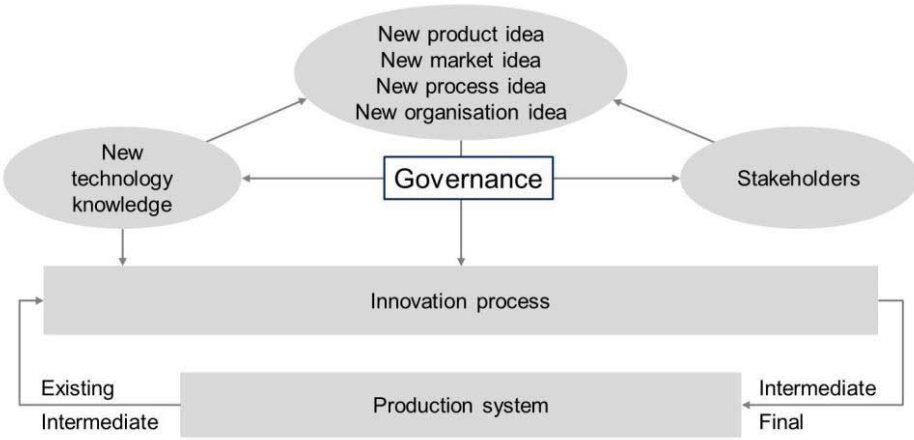


Figure 1. A trans-disciplinary engineering system.

Information systems can be large, with many elements and relationships. They are not complex, however, because output can be predicted from input provided. As soon as humans are involved the system in which the information system is used is complex. Humans may not sufficiently understand the system, this using the system in a way not intended. In addition, the user interface may be difficult to comprehend and use, making users reluctant to use the system in a proper way. Also, users or organizations may have their own goals with the system, like forcing a particular way of working or gaining more power.

There have been attempts to develop frameworks for studying and analyzing complex systems. One example is the soft systems approach by Checkland and Holwell [9]. Another approach is the process model of organizations [10]. Both approaches emphasize that systems thinking supports framing the system of focus. Such models are used to depict a complex system. They are useful to support communication between stakeholders of the system and to identify problems that require further analysis and

definition. The system descriptions are not sufficient for problem solving as such, but help to understand the complexity, structure, and context of the problem. Often, problems concern only a subset of the system under study, but may have an impact on the system as a whole. The systems approach helps to see the relationships between problems and between problems and the behavior of the system. Additional theories and methods are then needed to dive into the problem to come up with ideas for solutions. The context of a system is not depicted in Figure 1, but is very important to consider, because system behavior depends on its context as well as impacts upon and influences its context.

Coming back to trans-disciplinary systems, it is important to clearly distinguish the boundaries of the system at hand in its context as well as the internal structure of the system. For example, one may want to focus on a particular phase of the innovation process, for example, the detailed design phase. In this phase, a subset of stakeholders is involved with a more limited number of functional roles and coming from a more limited number of departments or companies. Still, the system under study is complex. The context of this system are the preceding and subsequent phases and the innovation system as a whole.

In trans-disciplinary engineering, information systems are in use, often more than one. These information systems may be used in a particular phase of the innovation process or may be used throughout the whole process. Important questions in depicting and studying a particular phase or two or more phases of the process are, for example:

- What is the main process of focus with its input and output?
- Who are involved?
- What are mutual relationships between people involved?
- Are goals possibly conflicting?
- What are the information systems in use?
- What are the relationships between the different systems, i.e., information systems and organizational systems?
- Who is using which information system for what purpose?
- Are there potential data conflicts?
- Etc.

In the next sections, examples of information systems are presented with their contexts, the complex system in which the information systems are used.

3. Information system: Aircraft maintenance documentation

Aircraft maintenance focuses on multiple, often contradictory objectives. A primary objective of aircraft maintenance is to keep the aircraft in an airworthy state, i.e., a state in which it is safe to operate the asset. Safety of aircraft operations is paramount in the aerospace business. However, this is in potential conflict with another objective of maintenance: to deliver airworthy aircraft at the lowest cost, in order to be economically productive. In theory and in practice, economical pressures may compromise the level of safety which is offered, as evidenced by various studies into human factors in maintenance [11]. A third objective of aircraft maintenance is to minimize time spent, such that the aircraft operator can utilize the asset to the highest extent possible in order to generate revenue. Each of the aforementioned objectives can be associated with a set of stakeholders (e.g., the maintenance company, the airline, the

manufacturer (also known as Original Equipment Manufacturer, OEM), national aviation authorities, passengers, air traffic control, etc.).

This multitude of objectives and stakeholders and the associated web of relations contribute towards characterisation of the aircraft maintenance system as a complex system, part of a wider transdisciplinary system which involves various product lifecycle stages as well as expertise from various disciplines (e.g., aerospace, information systems, law). The maintenance system itself is, however, also composed of a great variety of interacting systems and processes.

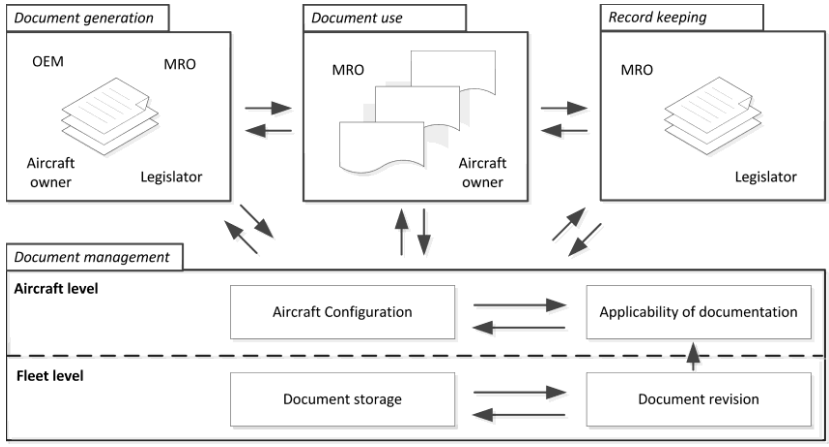


Figure 2. Aircraft maintenance documentation environment.

One example of a subordinate aircraft maintenance system is the aircraft maintenance documentation system. Revisiting the previous questions posed in Section 2, this system can be described as follows:

- **What is the main process of focus with its input and output?** The process focuses on the access, use and generation of documentation to support and monitor the correct accomplishment of maintenance tasks. Inputs are provided by multiple stakeholders towards the maintenance company (MRO): the OEM for instance provides Aircraft Maintenance Manuals (AMM), Troubleshooting Manuals (TSM), Illustrated Parts Catalog (IPC), Service Bulletins (SB), and many more. All of these documents contain pertinent information for task preparation and execution. The legislator provides documentation in the form of Airworthiness Directives, which mandate certain tasks to be accomplished to rectify potentially unsafe items. Furthermore, the aircraft owner and/or operator (frequently the airline) provides inputs towards the MRO as well, such as the Minimum Equipment List (MEL), describing systems and parts which are allowed to fail under strict rectification criteria. On the output side, the MRO generates maintenance records as well as various certificates associated with continuing airworthiness of the aircraft at hand. Traceability of the generated information is critical, as strict regulations are in place towards the historical maintenance records and the governing quality system.

- **Who are involved?** The MRO plans, executes, monitors, and reports on maintenance tasks. The OEM sets constraints in terms of aircraft design itself as well as required maintenance procedures. The airline also imposes constraints in terms of aircraft configuration as well as the time available for maintenance. The legislator controls the MRO, both directly and indirectly, for instance via maintenance record checks and audits of the MRO organisation.
- **What are mutual relationships between people involved? What are the information systems in use? What are the relationships between the systems?** Figure 3 highlights the main elements and context involved in aircraft maintenance documentation, as well as some information systems that are used to govern access to documentation. The documentation process faces additional complications in the fact that 1) significant amounts of additional documentation are generated during the life of the aircraft; 2) the existing documentation is subject to frequent revision; for instance, one European OEM is moving towards a monthly update cycle for its set of documentation, which comprises dozens of documentation types, each consisting of 1000+ pages.
- **Are there potential data conflicts?** As soon as an airline buys an aircraft, the OEM is mandated by contractual terms as well as regulation to share commercially sensitive product information with the airline, and typically the associated MRO. In turn, the MRO generates commercially sensitive maintenance information, which could be used by the OEM to generate and sustain its own after-sales market. However, the regulator does not mandate sharing of information from MRO to OEM, except when safety issues are involved. In practice, it is not uncommon for MROs and OEM to set up bilateral collaborations to explore issues of mutual interest and benefit.

Various research efforts are underway to digitalize and streamline maintenance documentation practices, including access, use and generation [12][13][14][15].

4. Information system: Digital Twin

The Digital Twin is an information system which encompasses the design, validation, manufacture, use, and disposal of both the physical and the digital version of a product developed in a trans-disciplinary system. This product can even be a trans-disciplinary system itself, as is indicated below. The Digital Twin fully describes a manufactured spatial physical product on all necesssary levels of detail (micro to macro). In an ideal case, information on the physical product can be obtained from its Digital Twin. Digital Twins are Digital Twin Prototype (DTP) and Digital Twin Instance (DTI) which operate in a Digital Twin Environment (DTE) [16]. A Digital Twin emerges by four conceptual types of interactions: operations, adaptation, evolution, and profileration [17].

The main elements of the Digital Twin are real space, virtual space, the interconnection of data flows from real space to virtual space as well as from virtual space to real space and virtual sub-spaces [16]. A typical example of Digital Twin is a production environment, which is itself a complex system, a trans-disciplinary system. The challenge is a seamless data exchange between planning and executing domains to enable virtual try-out or simulations of mixed virtual and real data. Such an exchange is

still hampered by a lack of standardization on organizational and technological level. Thus, true benefits of synced real and virtual factories are not realized yet [18].

A DTP comprises the prototypical physical artifact. It contains the information sets necessary to describe and produce a physical version that is a twin of the virtual version. These information sets include among others Requirements, Fully annotated 3D model, Bill of Materials (with material specifications), Bill of Processes, Bill of Services, and Bill of Disposal [11][16]. Alternatively, it could be described as a product and process model.

A DTI describes the corresponding physical product to which an individual Digital Twin remains linked throughout the life of that physical product. Such a Digital Twin may contain the following information sets: A Digital Master (fully annotated 3D model with geometric dimensioning and tolerancing), a bill of materials that lists all effectivities, a bill of processes with operations that were performed in creating this physical instance, system metrics with full range of inspection and test results [19], a maintenance log that describes past services performed and components replaced, and operational states from actual sensor data, as well as past and predicted future data [16].

The significant innovation of Digital Twin ensures that performance evaluation is done in the context of the whole product system design, in which the achievement of system design requirements cascades to the design specification of components, subsystems, information integration and standard work by people themselves [19].

A DTE is an integrated, multi-domain physical application space for operating on Digital Twins for a variety of purposes such as prediction (describing future behavior) and interrogation (aggregating data from multiple instances).

In case of a Digital Factory, three building blocks, “Seamless & Comprehensive Product Data”, “Synced Factory Twins” and “Digitized Production” were derived within the framework Digital Twin in Manufacturing [18]. The aim of the block Synced Factory Twins is to ensure that the planning data and simulation models from product development, production planning and production are always synchronized with the values from the real factory. This is supported by two main function blocks: Seamless & Looped Information Flow, and Mixed Simulation Environment (Figure 3).

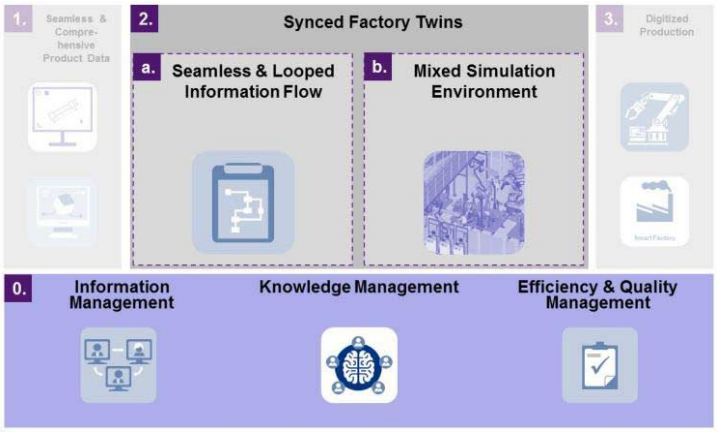


Figure 3. Reference Data Model For Mixed Simulation Environment.

In using a Digital Twin (DT) approach, a product and a product environment can be created without too much waste of time and material. A DT is used in a trans-disciplinary environment in which many different disciplines work together to create a product (environment) that would not be possible by any of the disciplines themselves. A DT approach also helps to support people in making decisions based on simulations and performance estimates. The Digital Factory (DF) is an example of the intimate collaboration between the information system and the trans-disciplinary system in which is is used, in particular the development process in which the DF is developed [20]. Even the role of people in the digital factory should be part of the total virtual and physical design. In sum, in case of the DF, there are three high-level systems to consider [21]:

1. The trans-disciplinary development system, a complex system, consisting of designers, engineers, manufacturing automation people, etc [22].
2. The Digital Twin system, an information system, used to create, manage and maintain data of the virtual production system design and the physical DF design [23][16].
3. The physical DF, which is a complex system, consisting of many production machines, people with more or less standard tasks, and a standardized process.

Each of these systems may have different contexts [24]. Each of them also consist of many layers of interacting subsystems [25].

5. Summary and conclusions

In this paper the system concept has been discussed. Since the 50s of the previous century many researchers have used the concept in an attempt to identify similarities and congruences between different domains. It has become clear that an all-encompassing system theory is too high an ambition. On a more practical level, system research and system thinking have appeared useful for crossing domain borders and enable trans-disciplinary collaboration [22]. Especially in trans-disciplinary engineering, the recognition of a shared goal and the need for cross-domain information exchange require a systemic approach [26].

The concept of complex system has been defined as a system in which multiple goals exist, which may conflict. A trans-disciplinary engineering system is, hence, a complex system. The shared goal is not a fixed one. It may shift during the process due to the differences in and evolution of goals of the many stakeholders.

In a trans-disciplinary engineering system information systems are used to create, manage, exchange, process, and maintain the many data, models, and documents. These systems are indispensable to support, among others, the decision-making processes of the people involved in the trans-disciplinary engineering system [22].

It is important to clearly distinguish the many systems that make up the trans-disciplinary engineering system as well as the levels on which they operate or function [26]. With this paper we have tried to support a more explicit use of the system concept.

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Part 11

Engineering for Sustainability

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A Value-Oriented Methodology for Cost-Oriented Re-Engineering in the Packaging Sector

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Abstract. Anticipating the analysis of cost and performances before the detailed design stage is difficult, but possible thanks to a synthetic analysis of the manufacturing knowledge, a successful collaboration among the numerous actors involved, and a methodology able to highlight the cost issues and to guide a cost-oriented machine design. This paper presents a methodology integrating Design for Manufacturing and Assembly (DFMA), Design To Cost (DTC), and Value Analysis (VA) to support companies in cost-effective machine design and cost-oriented re-engineering. This paper demonstrates the validity of the proposed methodology by an industrial case study focusing on packaging machines, developed in collaboration with a world leader company in tissue packaging machines. Thanks to the proposed approach, the company was able to identify those parts to be re-engineered (e.g., oversized parts, parts with unnecessary tolerances, similar parts to be merged into a unique one, common groups to be reused in similar machines, parts or material substitutions, wrong suppliers' selection) and possible technological improvements. A significant cost optimization and global machine sustainability improvement were achieved on a specific packaging machine line, mainly due to product structure simplification, part reuse, improved design solutions, and optimization of selected manufacturing processes.

Keywords. Cost optimization, Value analysis, Design for Manufacturing and Assembly, Design To Cost, Sustainability.

Introduction

One of the biggest challenges in machine design is to achieve the trade-off between cost and performances. According to a traditional approach, costs are completely defined at the end of the design stage and only at that time compared with the obtained machine performance. However, the majority of the product and process characteristics are already fixed by their design and late changes are very expensive and time-consuming. Anticipating the analysis of cost and performances before the detailed design stage is difficult, but possible thanks to a synthetic analysis of the manufacturing knowledge, a successful collaboration among the numerous actors involved in cost and performance evaluation, and a methodology able to highlight cost issues and guide a cost-oriented re-engineering.

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Traditionally, the target product cost is defined at the beginning of the design process and verified at the end of the detailed design process: whereas it is not respected, design is iteratively changed in order to find a compromise between performance and cost objectives by minor incremental improvements and long optimization loops [1]. Studies in literature and practical cases from industry demonstrated that a large percentage (at least 70% up to 80%) of the product cost is already determined during the conceptual design phase and, once the product concept is defined by product architecture, assembly procedure, quantity of components and their related manufacturing process, and costs for the following product modification grow exponentially along the development process stages [2].

Today several methods and tools are available to assist product managers in decision-making to evaluate the cost of alternative design solutions [3]: for instance, Design for Manufacturing and Assembly (DFMA) allows assessing the product cost by analysing the production processes when the product is designed in details, while Group Technology (GT) and Computer-Aided Process Planning (CAPP) can manage the knowledge connected to cost definition. However, such tools are usually "static" tools suitable for validation and verification, not really for Design To Cost (DTC) purposes, and they require a lot of information to provide a clear cost structure, so that they can hardly be used from the preliminary design stages. Moreover, the concept of "value" is not usually considered in technical design, by introduced only later on for business and marketing evaluations.

At the present moment, the most common tool adopted by companies all over the world for early cost estimation and optimization is represented by excel worksheets supporting the experience of very skilled people able to make the right assumptions. However, such an approach is highly time-wasting and subjective, and not fully reliable due to the necessary approximation and the possibility of human errors.

According to these evidences, the present paper proposes an integrated method that combines different approaches to practically support companies in cost-effective design and cost-oriented re-engineering of complex products. It includes Design-To-Cost (DTC) approach to estimate the product cost and compare with a target cost, Design for Manufacturing (DFM) to model industrial processes and create a structured process knowledge base, Design for Assembly (DFA) to model the human-related actions and create a structured human knowledge base, and Value Analysis (VA) to assess if the production cost for the product functions is respected by the value perceived on the market. Finally, it adopts Feature-Based Costing (FBC) principles to fasten the analysis by recovering the 3D geometrical features and link them to the related processes, both machining and human-driven, to predict the final costs.

1. Cost optimization in the packaging machine sector

The study focuses on the packaging machine sector, which has experienced an annual growth rate of 2.6% in the five years, from 2006 to 2011, and underwent a further acceleration from 2012 to 2016 with a growth of 3.1% annually worldwide. It means that is a very promising market, but very little research has been done in packaging machine cost optimization. The three main packaging sectors (i.e., food, beverage, and tobacco) realize over 90% of the world packaging machine volume. In particular, some specific areas such as tissue, Hygiene, and beauty & personal Care recorded higher growths (3-4%) [4]. In the packaging industry the demands for

performance have increased over the years. This has led to research and development of products that are more effective and less costly. In particular, in the market, the growing need for enhanced performance, environmentally friendly packaging materials, hermetic seals for the tissue area, food and pharmaceutical and cosmetic sectors, have imposed a gradual path of specializations for technologies and application areas [4]. The actual value and the packaging function are hardly perceived by the consumer, but it represents a fundamental aspect for any finished product, whether it is a container, coating or packaging. Packaging must be economical, therefore, will not unduly affect the final cost of the product but rather will enhance the content so as to justify their purchase by the customer. It must be easy to work but at the same time durable, lightweight, easy to transport, store and use. The identification of a product, in fact on the packaging are shown a series of useful information for the consumer such as additives present, the mode of use, the amount or expiration date. One of the main roles of the packaging of the products is to contain food, to protect the product from contamination by chemical and physical lengthening preservation, or to convey to consumers the product information.

With regard to the packaging industry, the innovation required for packaging manufacturers focus primarily on cost reduction and sustainability. Nowadays they ask more and more lightweight packaging, an increase in productivity in applications (e.g., balers, moulding, labelling), a reduction in waste throughout the production process (e.g., production of the print media, printing and processing, packaging), recyclability and reusability extended the raw materials used for packaging. With regard to the main needs of automatic machines the main value is created by the obtained process speed, the possibility of managing several films (with variety of dimensions and thickness of the film), the creation of totally integrated lines, the high dosing precision, the high productivity rate, compared with the final machine cost. A peculiarity of packaging machines is given by high performance with low investment without, however, regardless of the quality of the final product. All these features, as required by the market, imply that companies producing packaging machines have to pay more and more attention to the industrial cost. A robust and structured industrial cost estimation is fundamental for those companies to determine the "right" selling price for their machines. The final price of course must be definitely higher than the unit production cost since it is necessary to cover up even the overheads, but when a new machine is designed, the main hidden part is represented by the production costs. In particular, the correct identification of the direct cost of the finished machine is crucial for companies operating in a saturated and competitive market such as packaging industry. Traditional estimation systems and rough cost approximation could be sufficient when the margins also allowed committing blunders, but nowadays have become highly risky. For this reason, the analysis of the direct production cost and the operating margin has become essential to drive also the design activity. As a consequence, cost optimization is a fundamental issue to face for machine builders in the packaging sector worldwide.

2. The research approach for structured cost-oriented re-engineering

The proposed approach is based on DTC approach, which starts from the definition of a clear target cost at the beginning of the design activity, to be respected along the process by properly managing the knowledge related to the production process [5]. According to DTC approach, cost analyses are fallen back to the early design stage so

that the conceptual models continually interact with cost considerations. DTC is hard to implement in practice due to the management of the product complexity and the variety of the production processes to be estimated and refined along the design process. Furthermore, the relationships between performances, geometries, manufacturing process, aesthetics, and costs and the reciprocal effects of such factors make cost estimation a critical job in the conceptual stages. Moreover, costs are highly variable according to market demands, production volume, cost amortization, and other logistics costs. In order to be successful, DTC needs robust analytical cost estimation models able to estimate the production costs according to consistent assumptions, when specific data are not available [6].

A good review of the existing cost estimation methods has been recently provided by [7] as quantitative and qualitative. Qualitative estimating techniques, also called intuitive, rely on experience and knowledge of product cost estimators, being cheap and fast in implementation. Differently, quantitative estimating techniques use mathematical algorithms and statistical tools, and set the value of product cost with respect to the manufacturing process specifications [8]. In this context, the Design for Assembly and Manufacturing (DFMA) theory allows to assess efforts and costs related to fabrication and assembly processes [9]. In particular, DFA aims at reducing the number of components providing a list of criteria through which the effective need of each part can be evaluated, and DFM allows the manufacturing process optimization and provides elements of cost for each component (e.g., raw materials, set-up costs, processing costs, additional costs) [10]. In addition, the FBC approach suggests to identify the product features as geometric information and collect all functional and technological information (e.g. tolerances, surface finishing, manufacturing cycle, etc.) and to use knowledge-based systems to apply the most proper cost models [11].

Furthermore, product cost must be related also to the market. Indeed, a product is generically able to satisfy certain user needs and fulfil certain functions [12]. Value Analysis (VA) considers the product "value" and verifies if the industrial cost for each offered functions is coherent with the cost expected by the market [13]. The "value" means the ration between functions and costs as well as the ratio between offered performance and market price. As a consequence, a mismatching between functions and performance brings to customer dissatisfaction for inadequate performance or money wasting for unneeded capabilities.

2.1. The design methodology for cost-oriented re-engineering

The methodology used for cost analysis and cost-oriented re-engineering combines the above-mentioned approaches to carry out a synthetic product cost estimation. It uses the product 3D CAD model and, according a FBC approach, the main manufacturing processes are defined. After that, it combines DFMA and VA to improve the general design quality and identify the main areas of improvement. Such a methodology has been conceived for cost-oriented re-engineering of existing machines, which is one of the more complex activities in the packaging sector. Indeed, re-engineering of existing products is usually very hard due to the need of a critical analysis and the resilience to change decisions taken in the past. Furthermore, usually production processes and available technologies can greatly vary in ten of twenty years, and new solutions could be identified over the years for product optimization. New machines and materials can be available to replace old processes, and can achieve higher performances, not possible in the past years. However, such re-engineering is complex and time-

consuming if not properly structured. Furthermore, a critical analysis of the product features' perception and the added value perceived by the customers can support the machine functions' redefinition to reduce machine costs and reach a good saving.

The proposed method starts with the analysis of the product Bill Of Material (BOM), the critical analysis of the BOM according to the Pareto's principles (80-20), a structured cost analysis by detailing the different contribution for each part (i.e., raw material, manufacturing, treatments, etc.), the selection of the most appropriate technique for cost reduction among DFM, DFA, DTC and VA (Fig.1).

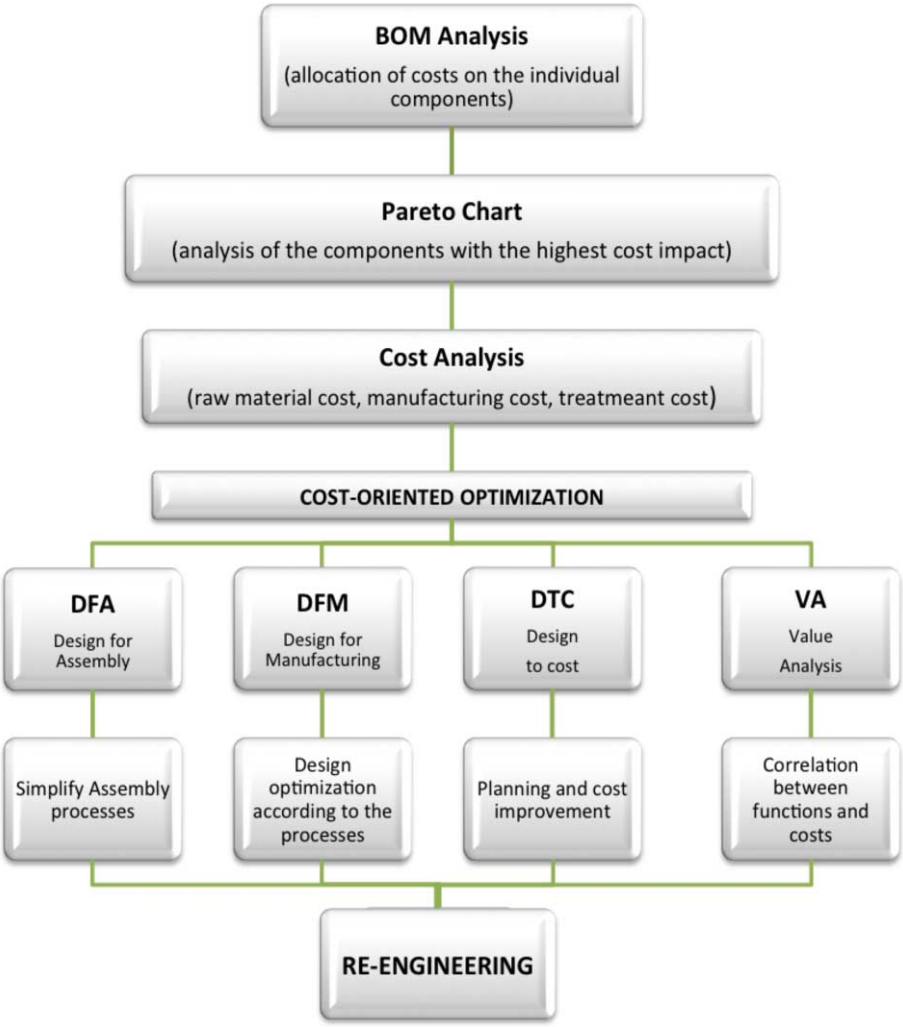


Figure 1. The proposed methodology for cost-oriented re-engineering.

3. The industrial case study

3.1. The company

The case study was developed in collaboration with a leading company in the field of tissue converting and packaging machines, which realizes complete lines for the production and packaging of industrial rolls, toilet rolls and kitchen towels, with 6 production sites in different countries. The company has recently implemented a very detailed system analysis and cost management process according to its need to analyse and manage production costs to compete with competitors and react to environmental changes that have occurred over the years. In the actual demand for more competitive products that led to global and unstable markets, the company is prepared to offer new products with shorter time to market and ensure a wider market share. The machine design is today characterised by the following aspects:

- Highly customizing products according to customer requirements;
- Need to define the cost perceived by the customer and how much is willing to pay for the goods produced;
- Adoption of methods to achieve the level of profitability for the company;
- Adoption of design to cost method to define precise target cost and verify the design at the different stages, according to a formal "step and gate" process.

For each verification step (gate), functional and performance features are compared with the expected costs, by using appropriate checklist. The bottom line is to not incur costs but to build them in advance on the basis of the choices made in the early design phases, with reference to the customers' needs and expectations. Thanks to the "step and gate" process (Fig. 2), the company passed from using traditional costing methodologies feedback (feed-back costing) to predictive methodologies (feed-forward costing) to push the company to optimize and reduce the production cost from the early stages of machines' development.

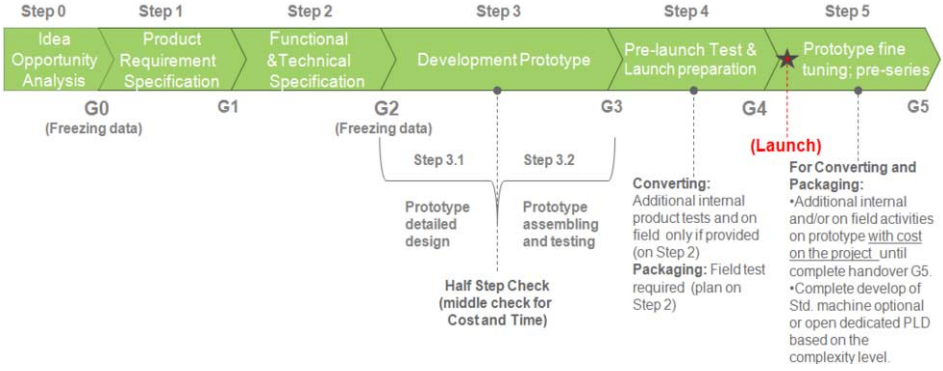


Figure 2. The actual "step and gate" process in the company.

Since 2015, the company has decided to carry out the cost estimation on 3D models by the adoption of a dedicated software tool (i.e., LeanCOST, www.hyperlean.eu). The use of 3D models and the possibility to estimate the cost of each single component, directly from the analysis of the 3D models according to a FBC approach, have opened new scenarios for cost-oriented re-engineering. Furthermore, the tool was integrated with the company enterprise resource system (i.e., SAP) for an automatic recovering of the necessary data. As a result, a more structured feature-based

cost estimation allowed a great reduction of the time required for estimating complex parts and simplify the analysis.

3.2. The case study

The case study is represented by a roll/pack high-speed machine (Fig. 3) designed and produced the company. It is an automatic machine for high-speed bagging of toilet rolls or kitchen packs, by means of polyethylene that is automatically done by a single coil. The machine production rate is up to 30 bags per minute.

The proposed method has been adopted for its re-engineering. In particular, the machine BOM has been analyzed and, thanks to the Pareto analysis, 14 components were identified for cost optimization. Each case has been analysed carefully and the most appropriate technique for cost estimation has been adopted. Among them, 2 parts were re-designed according to DFA principles, 6 parts were re-designed according to ne processes by DFM principles, and 6 parts were re-designed by adopting DTC and VA in a combined way. Figure 4 shows a synthesis of the main re-design actions. 60 different design alternatives were analysed among all cases and, finally, a 59% of the cost saving was obtained with respect to the original cost (limited to this 14 parts). The DTC actions were implemented considering the value for the machine functions and alternative designs, and VA allowed to validate the different alternatives. The DFA actions were oriented to simply the product structure and reducing the number of parts. Finally, DFM allowed to change the technological process and coherently the design.



Figure 3. The roll/pack high-speed machine (CMB 202 EVO).

Code	Component	Quantity	Estimate ZVALN	Current Cost	Best Alternative	Method Used	%	Scanned Versions	Raw material cost	Processing cost	Treatment Cost
K075L0004	SHEET	5	943,45	1.050,00	295,15	DFM	69%	2	34,33	30,13	138,99
K075L0003	SHEET	4	758,48	840,00	180,66	DFM	76%	2	31	27,21	145,24
K000L3122	PLATE	2	530,24	630,00	204,66	DFM	61%	4	35,96	272,29	6,74
K030J9947	PLATE	2	734,58	800,00	529,66	DFM	28%	4	178,4	109,22	15,56
K031F9675	SIDE FRAME	2	767,74	920,00	317,9	DFM	59%	4	170,29	132,07	26,25
K030L3862	SHOULDER	2	270,9	238,00	191,4	DFM	29%	4	41,33	64,91	12,76
K031G2937	SHOULDER SX T/S	1	617,65	765,00	357	DFA	42%	2	244,01	320,99	135
K031G2938	SHOULDER DX T/S	1	612,4	765,00	368,42	DFA	40%	2	242	295,4	75
K030F6820	SHOULDER	2	150,54	90,00	80	DTC + VA	47%	6	27,5	60,63	0
K063E5549	FEED TABLE	1	83,65	120,00	55	DTC + VA	34%	6	58,43	25,22	0
K075H0336	SIDE GUIDE PLATE SX	1	71,2	80,00	35,5	DTC + VA	50%	6	13,33	45,87	12
K075H0337	SIDE GUIDE PLATE SDX	1	71,2	80,00	35,5	DTC + VA	50%	6	13,33	45,87	12
K060F8572	CARTER	1	48,74	40,50	10	DFC + VA	79%	6	11	12,09	14,25
K031E5548	FINAL BEAM	1	22,89	27,00	0	DTC + VA	100%	6	5,1	17,79	0
	Tot		5.683,66	6.445,50	2.660,85		59%	60			

Figure 4. Main re-design action taken in the case study.

3.3. Savings obtained by the re-design actions

Figure 5 shows the main outcome of the implemented re-design actions and the obatined savings, while Figure 6 compares the cost savings between AS-IS configuration of the machine, the analyzed solutions, and the potential savings obtained if such an analysis was extended to 100% of the machine parts (not only 14).

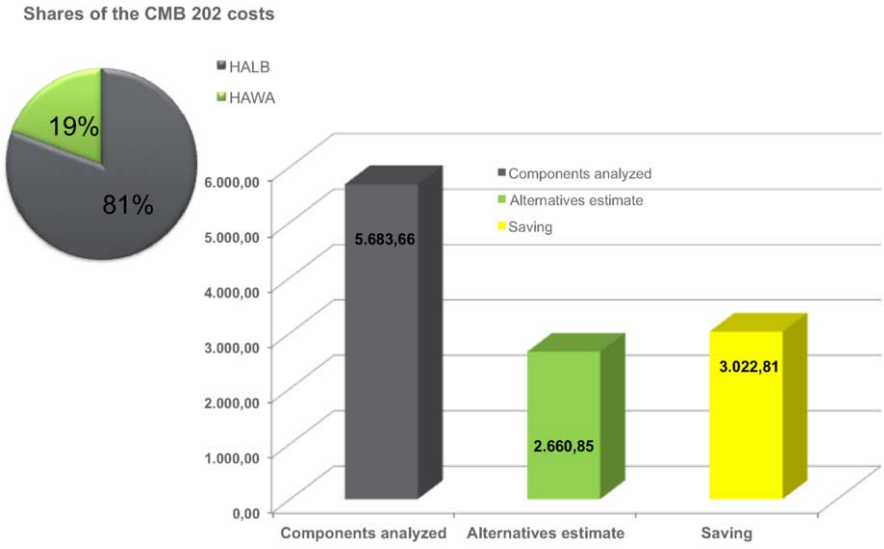


Figure 5. Main re-design action taken in the case study.

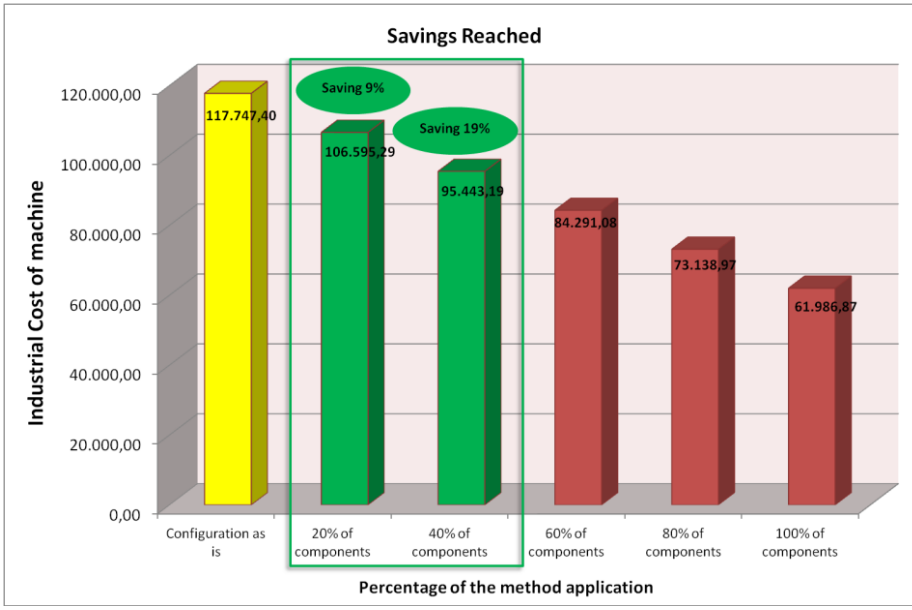


Figure 6. Reached cost savings by the implemented method and the potential savings for its adoption to the entire machine.

4. Conclusions

The paper presents a cost-oriented re-engineering methodology combining DTC, DFMA and VA techniques, and its application to a real industrial case study. Although these techniques have been implemented only to a limited number of parts, cost saving was impressive. Such result pushes to extend the method application to the entire machine. Future activities will be focused to a more accurate assembly costs analysis and optimization, and the application to other industrial cases, also to other sectors.

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Research on Form Attractiveness of Electric Vehicle

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Abstract. Electric vehicle (BEV) is different from the traditional vehicle with technology and structure. It has high creative freedom of the appearance design. However, whether this new concept can meet user preferences is a common problem which is also facing by designers. Research methods of Miryoku Engineering can effectively deal with the emotion evaluation between user preferences and product attractiveness. This study analyzed the user preferences of BEV form characteristics through the Evaluation Grid Method (EGM) and the Quantification Theory Type I (QT-1), captured the effective form attractiveness and design factors which come from the users' perceptual, and put forward the conceptual design method of attractiveness factors. Through the Miryoku Engineering application, this study aims to explore a more reliable method to enhance customer satisfaction of BEV in appearance design.

Keywords. Electric Vehicle (BEV), Miryoku Engineering, Industrial Design, Evaluation Grid Method, Quantification Theory Type I (QT-1)

Introduction

With the improving emission standard of the vehicle all over the world, the development of electric vehicle (BEV) has received the widespread attention [1]. Different from traditional vehicle, BEV has no engine, gearbox and fuel tank parts [2]. So there is significant difference between BEV and traditional vehicle in body layout [3].

From another perspective, with the limited of the current battery technology and cost, BEV is difficult to reach or exceed the driving range of fuel vehicle [2]. Therefore, BEV in Chinese market is based on urban commuter orientation; the driving range is within 200km [2]. Since that the target is miniature commuter vehicle, many products take modeling style of miniature fuel vehicles for reference. But due to the lack of quantization design research based on user preferences, it is difficult to accurately reflect the technology characteristics of BEV [3].Thus, under the premise of the current technology, the style of BEV still needs to study around the user preferences [4]. It is the key to design research for the designers to clearly get the form factors of the automobile modeling which improved user satisfaction [5].

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The principle and method of using the Miryoku Engineering, which can effectively discover and evaluate the vehicle form of attractiveness, and accurately capture the user perceptual image, so as to provide a positive reference for the modeling designer [6].

1. Related Work

Miryoku Engineering is a design concept based on consumer preferences and builds a bridge between designers and consumers [7]. Miryoku Engineering is put forward by the Japanese scholar Ujigawa Masato and other scholars in 1991 [8]. Miryoku Engineering is a theoretical method for preference-based design and is used to develop attractive products or systems [8]. The main research methods of Miryoku Engineering are EGM and QT-1 [9].

EGM is put forward by the Japanese scholar Sanui Junichiro [10] who studied Repertory Grid Method (RGM) by Kelly [11] and improved to help for understanding psychological method of cognitive level of subjects. EGM is derived from the psychology category, which is mainly the method of capturing personal cognitive concept and build hierarchical diagram [10]. This method is mainly through personal interviews, through the paired comparison between objects A and B to discuss similarity and difference of the object to sort out the target object of individual qualities [10]. First step is to compare objects to be evaluated. People are asked to response what is satisfied or unsatisfied and what they prefer or disfavor about them. Second, according to their answers, the meaning or conditions are made clear through supplemental questions. The mechanism of their reasoning in a hierarchic structure can by codified in this step. This method is called the “Evaluation Grid Method” [10].

The qualitative EGM of Miryoku Engineering can structure the abstract feelings of interviewees as concrete feelings [9]. The results are expressed using the hierarchical diagram of the appeal factors for evaluation [9]. Professor Min-yuan Ma from Taiwan has used EGM to evaluate festival attractive factors [12]. By researching attractive factors of app icons, Chun-Heng Ho found that EGM is a quantitative method that was used to analyze the influence of design factors [9]. In the study of the attractiveness of Heavy Duty Motorcycle’s front face [13], EGM was applied to find out the structure of attractiveness.

QT-1 is a branch of multivariate statistical analysis which is put forward by the Japanese scholar Hayashi [14]. In the situation of the independent variables for qualitative variables, and dependent variables for quantitative variables, using multiple regression analysis, QT-1 build the mathematical model between them, so as to solve the problem for the forecast of the dependent variable, revealing the inner link and laws of things [14][13]. QT-1 is an effective tool for determining the design rules of the correlations between users’ Kansei perception and product specifications [9]. QT-1 has been used for qualitative and quantitative investigations, such as the analysis of the relationships between “people’s Kansei of qualitative properties” and “design elements of quantitative properties” [9]. In the aspect of product design, Hayashi's QT-1 also could be adopted to access the weight between the design factors from user preferences.

In the result of QT-1, the higher value the partial correlation coefficients (PCC) shown, the higher degree of the item influence (attractiveness or preference) [9]. And the higher the multiple correlation coefficient (MCC) value (R) which is shown by QT-1, the more credibility of the QT-1 analysis [9]. In Miryoku Engineering, a determination coefficient (R^2) should be greater than 0.5 ($R^2>0.5$), it means the result

from QT-1 being acceptable [9]. If the value greater than 0.7 (R^2>0.7), it means the result very reliable, and the calculation model has higher precision [9].

In this study, QT-1 was used to analysis the results and determine the weighted relationships among the upper level (participants' Kansei feelings), middle level (BEV front face attractive factors), and lower level (concrete design factors). This facilitated the understanding of the attractive values of BEV form characteristics [15][16][17].

2. Method

This study combines 20 samples of BEV's front face to study reflects corresponding relation between characteristics of the products and user experience, and then extract the factors that influencing user emotional appeal. In order to get more reliable data from the experiment, this study respectively organized two groups of interviewees: Group A consists of 12 product designers and 8 car fans (age from 21 to 45 with driving experience); Group B consists of 30 college students majoring in Industrial Design (including 11 with driving experience and 19 with no driving experience).

2.1. EGM interviews

In the experiment, every interviewee is arranged to separate interview for 20 to 30 minutes in separate room to avoid surrounding information interference. The whole EGM interview process is as follows:

First stage: Capture the preferences characteristics items

Prepare 20 small vehicle samples cards (samples containing electric vehicles, hybrid vehicles and electric vehicles under same fuel models appearance with same size. Each card consists of two images of the axis side view and the front view of its face. Eliminate brand information and color style.) Invited Group A interviewees to browse each card and pick out the cards which are attractive. Then, let them rank the cards according to personal preferences.

Second stage: Build the hierarchical diagram by EGM

Selecting cards in sequence which are chosen by the interviewees, let interviewees answer for the reasons of attractive characteristic items, enquiring 1-3 attractive items (middle level) for each card，and describe the abstract style (Kansei words) of the attractive characteristic items -the upper level and the concrete design factors –the lower level. Through analysis and comparison, combine the similar descriptions. So as to know the attractiveness of the BEV form and feeling from the interviewees, then build the hierarchical diagram (Figure 1). The numbers in the right side means the number of times that the same opinion mentioned. For example, in the middle level, "Headlight" the number "14" means 14 times had been listed from 20 group A interviewees.

Third stage: Capture the form attractiveness factors

According to the listed results of the hierarchical diagram, the BEV form style could be divided into 9 parts. Then weights ranking according to the middle level and upper level -mention times of abstract concepts. Take the top three groups of abstract concept vocabulary, respectively are: "Hi-tech", "Vogue" and "Dynamic". Then list the related middle level -attractive items and the lower level -concrete design factors.

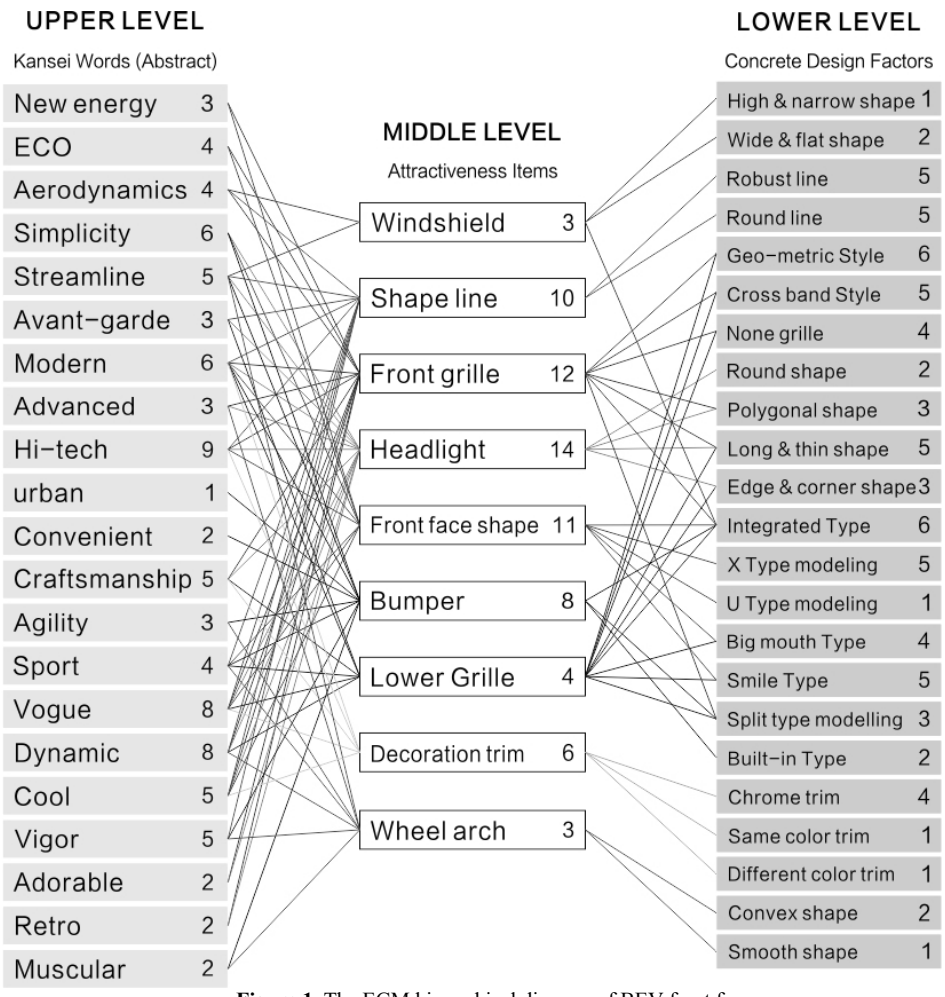


Figure 1. The EGM hierarchical diagram of BEV front face.
Note: The right numbers means the number of times that the same opinion mentioned

2.2. Data analyzed by QT-1

Organize Group B interviewees to grade the preferences for 20 samples with three groups of abstract concept words. And let interviewees to attract scores according to the degree of sample attractiveness by Likert Scale (Rensis Likert, American social psychologist), with "strongly agree (SA), agrees (A), is undecided (U), disagrees (D), or strongly disagrees (SD)" on behalf of the five kinds of preferences, and scores for: 5、4、3、2、1. After weighting the average scores of the samples respectively got the final score.For each group of upper-level words correlating the lower-level words, take QT-1, specific style lower-level words integrate into the independent variables, illustrate the relation between the corresponding reaction (qualitative projects) with 0 and 1. Remark 1 with these factors and remark 0 without these factors. Input all the results of the survey into matrix, use QT-1 calculation tool (VBA tool by Professor Shigenobu AOKI, Japan) to analysis.

3. Results and Analysis

3.1. Hi-tech

Through the EGM method of ranking weight and calculated by QT-1, “Headlight”, “Front grille” and “ Front face shape” are the most likely components which will bring participants with sense of “Hi-tech” (Table 1 shows the PCC results from multiple regression analysis). The PCC is higher for “Headlight” (PCC=0.838) and “Front face shape” (PCC=0.778). The corresponding attractive factors are respectively “Long and thin shape” (CS=0.716) and “X type modeling” (CS=1.265), that is to indicate, “Long and thin shape” headlight and “X type” front face shape will bring interviewees relatively strong sense of “Hi-tech”. Of course, there are some negative factors like: “Round shape” headlight (CS= -0.337), “Polygonal shape” headlight (CS= -0.481), “Long & thin shape” front grille (CS= -0.291) and “Big mouth type” front face (CS= -0.328), which influence interviewees’ perceptions. This design factors may bring negative effects for “Hi-tech” style creating. It requires the designers to pay more attention. In additional, the determination coefficient R^2 =0.810 (R^2>0.7) shows that the model has higher precision.

Table 1. QT-1 results of Hi-tech.

Items	Attractive factors	CS[a]	PCC[b]
A1 Headlight	A11 Round shape	-0.337	0.838*
	A12 Polygonal shape	-0.481	
	A13 Long & thin shape	0.716	
	A14 Edge & corner shape	-0.137	
A2 Front grille	A21 Geo-metric Style	0.033	0.506
	A22 Cross band Style	0.396	
	A23 None grille	0.049	
	A24 Polygonal modeling	-0.034	
	A25 Long & thin shape	-0.291	
A3 Front face shape	A31 Integrated Type	-0.055	0.778
	A32 X Type modeling	1.265	
	A33 U Type modeling	0.005	
	A34 Big mouth Type	-0.328	
	A35 Smile Type	0.455	
Constant		3.040	
R=0.900			
R^2=0.810			

Note: [a] Category scores, [b]Partial correlation coefficients. R-Multiple correlation, R^2- Determination coefficient

3.2. Vogue

Under the association of “Vogue”, “Front face shape”, “Headlight” and “Shape line” are the most likely components which will bring interviewees with sense of “Vogue“ (Table 2). The partial correlation coefficient of “Front face shape” (PCC=0.779) and “Headlight” (PCC=0.768) is higher, which will bring strong “Vogue“ sense to the participants. In addition to the higher scores factors, we also need to pay attention to negative factors, they may bring negative effects on design style “Vogue”. If the designer wants to build “Vogue” style on BEV appearance, these negative factors should be used more careful. The determination coefficient R^2=0.734 (R^2>0.7) shows that the model has higher precision.

Table 2. QT-1 results of Vogue.

Items	Attractive factors	CS[a]	PCC[b]
B1 Front face shape	B11 Integrated Type	-0.231	0.779*
	B12 X Type modeling	1.598	
	B13 U Type modeling	0.197	
	B14 Big mouth Type	-0.070	
	B15 Smile Type	0.330	
B2 Headlight	B21 Round shape	-0.420	0.768
	B22 Polygonal shape	-0.224	
	B23 Long & thin shape	0.698	
	B24 Edge & corner shape	-0.239	
B3 Shape line	B31 Robust line	-0.219	0.444
	B32 Round line	0.179	
Constant		3.193	
R=0.857			
R^2=0.734			

Note: a Category scores, bPartial correlation coefficients. R-Multiple correlation, R2- Determination coefficient

3.3. Dynamic

Under the association of "Dynamic", "Shape line", "Front face shape" and "Lower Grill Grille" are the most likely components which will bring participants with sense of "Dynamic" (Table 3). The partial correlation coefficient of "Front face shape" (PCC=0.777) and "Lower Grill Grille" (PCC=0.664) is higher. "X Type Front face" (CS= 0.692), "U Type Front face" (CS= 0.634) and "Smile Type Front face" (CS= 0.831) show the higher scores, which means these design types could be used to improve "Dynamic" sense of BEV. So are the others positive factors. The determination coefficient R^2=0.646 (R^2>0.5) shows that the model has mostly acceptable.

Table 3. QT-1 results of Dynamic.

Items	Attractive factors	CS[a]	PCC[b]
C1 Shape line	C11 Robust line	0.027	0.078
	C12 Round line	-0.022	
C2 Front face shape	C21 Integrated Type	-0.259	0.777
	C22 X Type modeling	0.692	
	C23 U Type modeling	0.634	
	C24 Big mouth Type	-0.206	
	C25 Smile Type	0.831	
C3 Lower Grill Grille	C31 Geo-metric Style	0.028	0.664
	C32 Cross band Style	0.305	
	C33 None grille	-0.657	
	C34 Big mouth Type	-0.031	
	C35 Smile Type	-0.589	
Constant		2.977	
R=0.803			
R^2=0.646			

Note: a Category scores, bPartial correlation coefficients. R-Multiple correlation, R2- Determination coefficient



Figure 2. The attractive factors of BEV front face: X Type modeling, Smile Type, Cross band Style, Long & thin shape**.**



Figure 3. None grille (left) and retro style (right).

4. Discussion and Conclusion

Through the research of EGM, we can explore and clarify the main influence attractive factors (Figure 2) on the BEV modeling style. However, in the innovation of some BEV modeling characteristics, such as None Grille (Figure 3 left, corresponding to the integrated mode of none grille and front face mode) got the negative score, which means that the accepted degree of interviewees is lower. From another side, it also confirms that the conventional grille form is so deeply into the interviewees' mind. And for the BEV technology, design with none grille which will reduce the wind resistance is still difficult to get most of the interviewees' preferences. At the same time, we found that round headlight from the word "Vogue" scored lowest. But the reference related sample models, round headlight models still have the vogue car –Minicooper (Figure 3 right) which positioning in retro style. This means that the others round headlight models were not giving vogue feeling which leaves a deep impression on the interviewees. It also has another possibility is that the capacity of the sample is not sufficient enough to a certain extent which affected the results of the analysis of individual samples. In QT-1 analysis with more samples presented, it means there are more design factors can be predicted. So that we can analysis the other design factors: like interior, side body modeling and rear shape modeling at the same times. And the results will be more reliable.

In this study, the BEV market is still in the early stage. Although some new energy vehicles design concept samples were presented, the analyzed samples are still insufficient. With the continuous release of the new BEVs, we hope to enrich the samples in the future. Besides that, by using this method to comparative analysis existing samples and improvement design samples, the attractive factors could be validity tested which were implanted to the new BEV modeling. That will be an interesting design experiment, and we are looking forward to getting more accurate analysis data in the further research.

Most of the selected interviewees are designers who familiar with automobile modeling design; it promoted the professionalism of the user preferences in certain extent. But considering BEV's product positioning and user attribute (nationality, age, gender, career and other factors), we cannot be certain whether we could still get

relatively stable measurements. We are expected to expanding the scope of subjects in the follow-up further study, so as to obtain more reliable data.

To sum up, through research methods and analysis tool of the Miryoku engineering, we can effectively grasp the attractive factors in the emotional level of design. For new product types, Miryoku engineering can effectively discover attractiveness from users, so as to help designers to improve user satisfaction of their design works.

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Material Flow Mapping and Industrial Ecosystems: A Literature Structured Review

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Abstract. Global instability can be seen as a reflection of the increasing demand for natural resources and the reduction of personnel expenditures. Yet, this is often associated with industrial systems, whose main objectives are to increase productive capacity and reduce costs. This scenario identifies the need for changes in strategy establishment in the organization's operation mode focusing on sustainable development. Industrial ecosystems, through the symbiotic relationship of industries, aim to achieve sustainability goals. Material flow mapping is essential for the construction of these industrial ecosystems. Hence, the present article carries out a structured literature review process in order to identify the state of the art and the research opportunities in material flow mapping. This aims to achieve industrial ecosystems through industrial symbiosis. For the accomplishment of this revision, the methodological procedure called Knowledge Development Process - Constructivist (ProKnow-C) was adopted. The bibliographic portfolio is represented by 35 articles of the research theme. Through the bibliometric analysis, some aspects are determined in order to perform a statistical analysis of the articles that compose the portfolio. In general, the main opportunities detected in this research theme are presented in the systemic analysis. Finally, conclusions and recommendations for future research are presented.

Keywords. Material Flow Mapping, Industrial Ecosystem, Industrial Ecology, Industrial Symbiosis.

Introduction

Industrial systems, whose main objectives are to enhance productive capacity and reduce costs, induce an increase in the demand for natural resources and the reduction of personnel expenditures. Environmental degradation and the generation of social problems occur as a consequence of those systems.

Nevertheless, organizational management have been taking different approaches to develop strategies focused on the creation of new alternatives. Hence, the promotion of sustainable development along with the industrial chain must guarantee social, economic and environmental well-being. In agreement with [1], supply chain management is highly relevant both to compete successfully in the market and to approach responsible behavior at all stages of the supply chain. Furthermore, it represents a potentially important area to integrate environmental and social aspects achieving the goal of sustainability.

Industrial ecology refers to tools and strategies that includes an industrial symbiosis. This scenario allows the industrial system to act according to the ecological limitations of our ecosystem. For this reason, it studies ways of joint use of natural resources, recycling of waste, and reuse of inputs through the construction of networks

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among organizations. Thus, this network allows a conservation of natural resources combined with a better use of industrial inputs and waste to preserve the ecosystem. Moreover, this will result in an optimization of the industrial process in order to achieve sustainable development [2].

The physical exchanges of materials are extremely important within the concept of industrial symbiosis, whose major focus is on closing material cycles. These cycles use waste from one facility as an alternative input to another facility [3]. Thus, the material flow mapping is an essential step in the development of supply chains focused on the establishment of industrial symbiosis, since the verification of the inflows and outflows of materials determines the possibility of such a practice [4].

Regarding social and environmental issues in supply chain management, although the interest in research about this subject is growing, the focus on reverse logistics prevails due to the relevance given to the environmental dimension from both academics and practitioners. Other themes, related to social and environmental issues appear in a limited, punctual and narrow way [5]. The attention given to topics such as the closed circuit, the "green" concept and sustainability in supply chains is still relatively sparse and dispersed [5] [6].

Thereby, this article presents a structured literature review with the main purpose of identifying the state of the art and the research opportunities related to material flow mapping establishing industrial ecosystems through industrial symbiosis. The relevance of this article is oriented to the consolidation of the research results about the theme, and thus, to map and enable the evolution of scientific knowledge.

The article is structured as follows: after the introduction, section 1 involves the methodological aspects of this research. In section 2, 3 and 4, the structured review of the literature which consists of the selection of the bibliographic portfolio, bibliometric analysis and systemic analysis are respectively presented. The main conclusions as well as the recommendations for future research are outlined in section 5.

1. Methodological Aspects

For the present study, Proknow-C-Knowledge Development Process-Constructivist was adopted to adress the literature review of material flow mapping and industrial ecosystems domain. Developed by the Laboratory of Multicriteria Methodology in Decision Support (LabMCDA) of the Federal University of Santa Catarina [7] [8], this methodological procedure is similar to other systematic approaches oriented to literature review, such as the Systematic Literature Review (SLR). However, ProKnow-C was selected because it provides a structured process which itself guides researchers in the development of a literature review, facilitating this task and avoiding the demand by other tools and support techniques [9].

Furthermore, the procedure has transparency in its descriptive and flowchart form. In addition, the analysis criteria are integrated, which provides a holistic view of the analysis [10]. The stages that constitute this procedure are: i) bibliographic portfolio (BP) selection, ii) BP bibliometric analysis, iii) BP systemic analysis, iv) elaboration of the research question and definition of the general and specific objectives [11]. The way these stages are interconnected can be identified in Figure 1. Therefore, to achieve the objectives of this study, only the first three stages of the ProKnow-C will be performed.

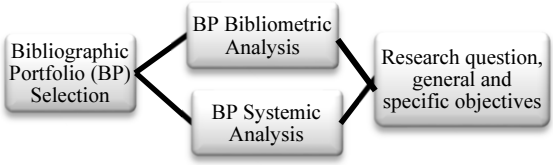


Figure 1. Stages of Proknow-C methodological process.

Moreover, this procedure has been already used in other studies by many researchers, consolidating it as an important research tool for the academic community [7-12]. Finally, to support this literature review the software Endnote X7, a bibliography manager, and Microsoft Excel for data tabulation were used as tools.

2. Bibliographic Portfolio Selection

The bibliographic portfolio is a set of publications with scientific recognition that are aligned with the research theme. The bibliographic portfolio selection stage consists of three main steps: (a) selecting article sample, (b) filtering article sample and (c) testing BP representativity [7].

In the BP selection stage, the research axes, keywords and databases were defined. In order to conduct this research, two main research axes were determined: (i) industrial ecology and (ii) collection of information. Moreover, the keywords were derived from these research axes. In changeable words, the "*" was used as an operator to search for these their variations. In addition, the boolean operators "and" and "or" were used to perform the combination of the two research axes. Therefore, the following sentence search standard was adopted: ("material flow" OR "waste flow" OR "resource flow" OR "input output flow" OR "industrial waste management" OR "sustainable value stream" OR "industrial symbiosis" OR "industrial ecology") AND ("map*" OR "collect*" OR "captur*" OR "analy*" OR "measur*" OR "data gathering" OR "data collection" OR "identif*" OR "quantif*").

Databases were defined according to the availability of access through the periodical portal of the Coordination for the Improvement of Higher Level -or Education- Personnel (CAPES) and the alignment with research interest areas (Engineering, Multidisciplinary and Social Sciences). In this way, the used databases were: Web of Science, Science Direct, Scopus, Proquest, EBSCO, Engineering Village, Emerald, Willey and Springer. Only the scientific articles published between 2010 and 2016 were considered in this research. Besides, this search was conducted in databases with title, abstract and keywords filters.

From these parameters, the search of articles in the databases, the filtering of the articles, the test of keywords' adherence and the test of BP representativeness were carried out. The first stage of constituting the bibliographic portfolio consists of four steps in order to select the most relevant articles to perform the research. This process started with a sample of 4,052 articles, which were analized to consolidate a final BP composed of 35 articles. The results achieved can be seen in Figure 2.

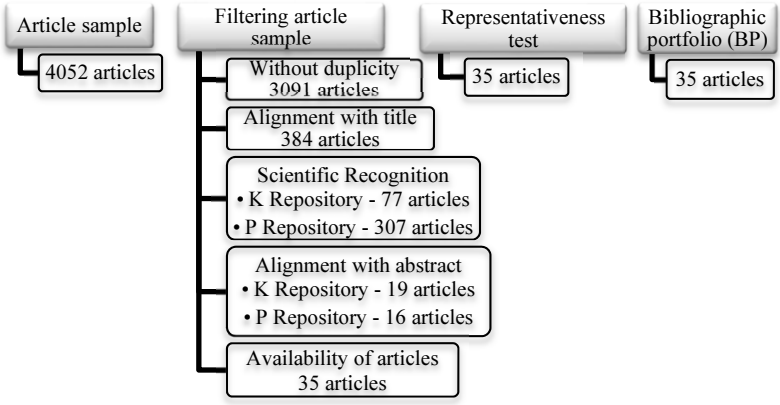


Figure 2. Bibliographic portfolio selection stage.

3. Bibliographic Porftolio Bibliometric Analysis

In the bibliometric analysis stage, a simple statistical analysis was performed on the set of 35 articles that comprises the BP. It is noteworthy that this bibliometric analysis was adapted due to time constraints. Hence, the step of analyzing the references used by the BP articles was excluded from this research, which is considered a recommendation for future work. Thereby, in order to acquire the main characteristics of BP, the following analyses were executed [7, 11]:

3.1. Estimation of journals' relevance

From this analysis, it is possible to identify that the BP is formed by 15 journals, and the most frequent periodical was the Journal of Cleaner Production, comprising 20% of the BP articles. In addition, around 17% of articles were published by the journal Resource, Conservation and Recycling, 14% by Journal of Industrial Ecology, 11% by Environmental Science & Technology and 9% by CIRP. The other journals published only one article.

3.2. Estimation of articles' scientific recognition

According to this analysis, it was possible to identify that 88% of BP was constituted by the 20% most cited articles that composed the sample. Thus, it is noteworthy that there is scientific recognition in the portfolio. The most cited article in the sample was intitled "Steps towards sustainable manufacturing through material modeling, energy and waste flows", by P. Smith and P. Ball, which was cited 81 times by other authors.

3.3. Estimation of authors' relevance

The 35 articles that constitute the BP were written by 114 authors. About 92% of the BP authors just had published only once. In terms of publication, 4 authors contributed with 3 articles each: K. Matsubae, S. Nakamura, T. Nagasaka and Y. Kondo. Other 5

authors published 2 articles each: F. Badurdeen, K. Nakajima, M. Despeisse, P. D. Ball and P. H. Brunner. These 9 authors developed around 17% of the BP articles.

3.4. Estimation of the most frequent used keywords

Regarding the keyword analysis, 126 words were identified and around 90% of them appear only once in the BP articles. However, 13 keywords appeared more than once. Among these, "material flow analysis" is the most relevant one, being used in around 25% of the BP articles, followed by "industrial ecology" (17%), "substance flow analysis" (14%), “value stream mapping” (11%) and "resource flow" (9%). It is noticed that the keywords defined at beginning of this research were aligned with this analysis.

3.5. Analysis of impact factor

The impact factor analysis was based on the Journal Citation Report (JCR), which reports the average number of articles citation published by journals over the last few years. For analysis purposes, the 2015 edition of the Journal Impact Factor was considered as an indicator. The journal with the greatest impact factor was the Environmental Science and Technology, which published around 11% of the BP articles, and had an indicator of 5.393. It is also worth noting the importance of Journal of Cleaner Production that had an indicator of 4.959, which published most of the BP articles (20%). The other journals that also had a great impact factor were: Resource, Conservation and Recycling (with an indicator of 3.28), and the Journal of Industrial Ecology (with an indicator of 3.265).

3.6. Analysis of theme evolution

In 2010, only 3 articles were written about the research theme. On the other hand, in 2016, 7 articles were published. It is possible to conclude that the number of articles published on the research theme more than doubled from 2010 to 2016. Thereby, it was noticed that the research theme is still a study on expansion.

4. Bibliographic Porftolio Systemic Analysis

The systemic analysis stage consists of content analysis according to the criteria defined by the researcher. So that, in order to perform the analysis of the BP articles content, the following criteria were initially defined: (i) type of article, (ii) problems detected by the authors, (iii) objective, (iv) methodology, (v) measurement, (vi) unit of analysis, (vii) results, (viii) contribution, (ix) future recommendations, (x) existing gaps. Through a close reading of papers, the information regarding each criteria was extracted in order to generally identify the gaps in this research theme.

The main methods of solving the material flow mapping problem adopted by the authors found in the BP were: (i) Material Flow Analysis (MFA)/Substance Flow Analysis (SFA); (ii) Value Stream Mapping (VSM) adapted; (iii) Exergy approach; (iv) Input-output (IO) analysis; (v) Combination of techniques – such as Material and Energy Flows Analysis (MEFA) and Life Cycle Assessment (LCA); and (vi) Other ways of solving the problem – such as using the tool IDEF0.

4.1. Main opportunities found

Complexity of methods - most of the methods presented in the BP are quite complex in terms of problem solving, since they involve a large amount of information and calculations. As an example, the use of matrices and multiple linear regression [13-17]. Another exemple is the IO analysis tools, which are difficult to execute because they involve a complex enterprise network for most products within the supply chains [18]. This same complexity is identified in MFA studies, which require the use of computational methods and softwares, and consider a large number of flows and processes [19].

Lack of support tools - Although there are IT tools to support analyzes for improvements in complex systems, these tools do not present a practical approach. There are no modeling tools that cover building modelling, product flows and time of process flows in manufacturing to account for all resource flows, intermittency of process and spatial dimensions [20. It is possible to detect the need to create automated tools that support the continuity of the mapping over time, considering the changes resulting from this variable [21], as well as to support the modeling and evaluation [22]. In addition, the creation of a sustainable practice database which is able to inform the previous generated solutions is a potential topic to be developed. This database will intend to improve the selected solutions or reduce the time to establish solutions [22].

Lack of definition about the type of data to be collected - there is a lack of definition about the type of information that should be collected during the mapping. Moreover, the means of obtaining these data are generally unclear. The selected authors only presented the types of data to be collected at a macro level and they briefly described the possible ways of obtaining them. Thus, the recommended methods of gathering these data are retrospective data analysis, asset performance calculations and empirical measurement, however it remains unclear the type of data that should be collectd [22, 23].

Lack of information and metrics - the lack of systematic data is the biggest obstacle to using M/SFA [21, 24]. On the other hand, much effort must be invested to obtain technical information, know-how, among others. However, cooperation among organizations is not always guaranteed [21]. In addition, there is a lack of research demonstrating the effective metrics and how they should be combined with performance indicators to direct appropriate actions to the shop floor [22]. In this sense, there is a need for customization and selection of different metrics to be used [18].

Quality of data collected - studies generally do not involve data quality issues such as frequency and accuracy [22]. It is possible to identify dispersed uncertainties over the input data provided in the studies [21].

Improvement of waste management – to complete data collection is important to identify waste patterns [20]. The real challenge for the near future is to innovate and improve recycling technology for each fraction of waste, which will improve the recycling process and the sustainable performance. The waste management system cannont only focus on the generation of ordinary waste. It should focus on the substances, because this analysis allows to visualize if a certain residue has the potential to be transformed into a resource, or if it is constituted of hazardous material [25]. Another recommendation for future research is the consideration of

a simultaneous flow of materials since the combination or mixture of materials may become an obstacle to end-of-life recycling [14].

Product development - the design of new products should consider the most convenient material combinations in order to select those less likely to result in problems for the recovery of materials [26].

5. Conclusion and Further Research

The present article accomplished a structured literature review, in order to identify the state of the art and the research opportunities on the mapping of materials for the development of industrial ecosystems. Therefore, a methodological procedure called ProKnow-C was used, focused on the selection of the bibliographic portfolio, and on the implementation of the bibliometric analysis and systemic analysis.

From the 4052 articles initially selected in the databases, only 35 articles constituted the bibliographic portfolio representing the research theme. Through the bibliometric analysis, it was noticed that the Journal of Cleaner Production is the most relevant in number of publications in the portfolio. At the same time, the impact factor analysis verified that this same journal presents an excellent index (JCR of 4.959), compared with the others. Nevertheless, according to this index, the journal Environmental Science & Technology is the best journal (JCR of 5.393). Looking at the scientific recognition of the articles, it was inferred that 88% of BP was composed by the most cited ones. According to the authors' relevance, 9 authors who published the most about this research theme were identified: K. Matsubae, S. Nakamura, T. Nagasaka and Y. Kondo (3 publications each), and. F. Badurdeen, K. Nakajima, M. Despeisse, P. D. Ball and P. H. Brunner (2 publications each). A keywords' analysis indicates an alignment with the words defined at the beginning of this research. Finally, it was recognized that this research theme is in wide expansion in the academic community due to the increased number of publications in the last 6 years.

During the systemic analysis stage, the 35 selected articles were thoroughly read. Furthermore, the opportunities for future research were detected in terms of: complexity of methods; lack of support tools; lack of definition about the type of data to be collected; lack of information and metrics; quality of data collected; improvement of waste management; and product development.

The ProKnow-C methodological procedure proved to be an excellent tool to the literature review in a structured way. Finally, it is recommended that an analysis of the references that comprise the bibliographic portfolio should be performed in order to complement this research. Another recommendation is to redo the steps of the methodological procedure with new keywords from this first study, since the process is iterative.

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Disassembly Complexity-Driven Module Identification for Additive Manufacturing

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Abstract. Additive manufacturing (AM) is revolutionizing product development by producing complex 3D objects directly. AM supports energy efficiency during manufacturing by speeding up the whole product development process, reduction in process and resource usage, and a vast range of different parts with different characteristics by supporting multi-material usage. Accordingly, AM is a sustainable manufacturing technology than current manufacturing technologies. Through these advantages of AM, most research has focused on how to fabricate products with complex structures like lattice and honeycomb structures without considering product lifecycle in product development. Therefore, this study proposes a modular design method to enhance a product recovery strategy using AM technologies. The objective of this paper is to identify modules that are fabricated by AM based on minimizing the disassembly complexity of products. In order to quantify the disassembly complexity at the end-of-life stage, the disassembly complexity of products (PDC) is assessed by considering the number of components and interfaces, and design complexity of the components and interfaces. The PDC is modified to single component complexity index (SCCI) with component and interface complexities simultaneously in this study. Based on the SCCI, a module is identified by consolidating components with high complexity, and can be fabricated by AM. The module contributes to improving product recovery processes by reducing the disassembly complexity. A case study is used to demonstrate the usefulness of the proposed method by comparing disassembly complexities.

Keywords. Additive Manufacturing, Complexity, Disassembly, Modular Design, Product Recovery

1. Introduction

A product recovery strategy is a process of restoring inherent performance of retired products. By reusing the retired product and recycling materials, companies can minimize usage of raw materials, pollution during manufacturing, and wastes at end-of-life stage [1, 2]. To facilitate product recovery, a disassembly process is necessary to detach materials, components, and modules from the retired products. The disassembly process is closely related to minimizing cost and time for the product recovery, and avoid damage to the quality of detached parts [3]. Therefore, managing product complexity for the disassembly process plays important role in sustainable product design and development. The product complexity during disassembly processes increases according to design and the number of parts and interfaces. In order to

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manage the complexity, a design methodology has been researched to determine product architecture with compromising functionality and performance, because of the limitations of the conventional manufacturing technologies [4]. The design methodology including modular product design and design for X, such as design for assembly, design for disassembly, and design for manufacture and assembly, aimed to reduce the product complexity for enhancing assembly and disassembly processes by minimizing the amount of components and interface in a product.

Since design freedom is severely restricted by conventional design methodologies, it is difficult to achieve an optimal product architecture by consolidating components. However, after additive manufacturing (AM) process has been introduced, the product complexity can be managed efficiently. The AM has been evolved from rapid prototyping, which is to create a part or system rapidly as a prototype, to product manufacturing process for creating final products directly. It alleviates design and manufacturing constraints, so that design freedom is extremely expanded [4]. In this sense, design for additive manufacturing (DfAM) has been introduced to take full advantages of the design freedom with concerning part consolidation and redesign, and hierarchical structures [5]. However, most of the previous studies for AM is to enhance performance of products while reducing costs [6-8]. For an example, Thompson, et al. [8] which shows trends, opportunities, and constraints of AM explores issues related to design for AM but does not mention the necessity of modularity for maintenance, repair, and recovery when complex components and products from AM approach the end-of-life stage.

The objective of this paper is to identify modules that are fabricated by AM based on minimizing the product disassembly complexity. The product disassembly complexity is measured to understand how difficult a product is for product recovery. It is modified to single component complexity index (SCCI) for considering component and interface complexities at the same time. Based on the SCCI, modules are identified by grouping components with high SCCI value. The identified modules are fabricated by AM and contribute to improving product recovery processes.

In this paper, Section 2 describes the proposed method. A case study is performed with electric shavers in Section 3 to demonstrate the usefulness of the proposed method. The conclusion and future work are presented in Section 4.

2. A method of disassembly complexity-driven module identification for AM

The proposed module identification method for AM is shown in Figure 1. The process is similar in identifying modular product architecture based on relationships between components. However, design team would consider the product recovery process into product architecture design. In this study, modular architecture for AM is determined by consolidating components with high complexity into a module in order to enhance characteristics of products at the end-of-life (EOL) stage. The first step is to analyze dependency between components in current products by using design structure matrix (DSM). In second step, a method of product disassembly complexity (PDC) from [9] is extended to provide information on which components are difficult to disassemble for product recovery based on design attributes. The single component complexity index (SCCI) is introduced by modifying the PDC to cluster modules. The SCCI is a modular driver for product recovery in this research. In third step, modules are identified based on adjacency matrix that is a combination of the DSM and the SCCI by using Markov

Cluster Algorithm (MCL). The modules would be assessed to check whether or not it can be manufactured by an AM technology in terms of material types of components in fourth step, so that the components in a module can be consolidated as a single component. It means that the concept of the module can be reinterpreted as the single component after applying the AM technology. Finally, the PDC between products with modules and products with containing additive manufactured modules is compared.

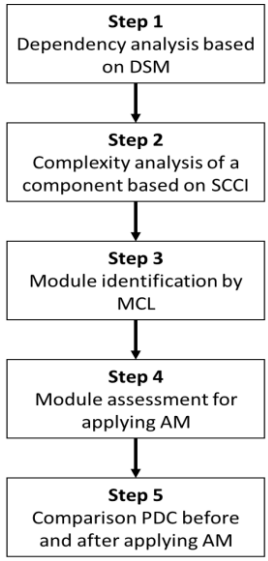


Figure 1 Overview of the proposed method

2.1. Assessing product disassembly complexity

This research considers a 'product disassembly complexity' term as the degree of disassembly difficulty based on design information related to components and interfaces [9]. The complexity contains two levels which are component and interface complexities. For the component complexity, it contains four attributes related to handling components: weight effect factor, size, symmetry, and grasping components. For the interface complexity, the connector between components is a key element for manual disassembly operations because the connector links components' geometric and functional relationships through material, energy, and signal flows. There are three attributes of the connectors for disassembly: mechanical connector types, non-mechanical connector types that would help strongly attach components, and an intensity of tool use. These attributes are critical to detach components or modules from a product.

These attributes, descriptions, and difficulty factors for components and interfaces are represented in Table 1. For the component complexity, difficulty factors are determined by measuring assembly handling time and normalizing it based on [10]. For the interface complexity, U-rating values are applied to measure mechanical and non-mechanical unfastening processes. The U-rating value is developed to estimate disassembly efforts based on a survey by [11] and [12]. Since the range of the U-rating

value is not between 0 and 1, the U-rating value is normalized. Consequently, the difficult factors for the complexities are shown in Table 1.

Table 1 Disassembly attributes for manual disassembly (Adapted from [9])

Group	Attribute	Description	Difficulty factor
Component	Weight	<4.5kg	0.50
		>4.5kg	1.00
	Size	>15mm	0.74
		6mm to 15mm	0.81
		<6mm	1.00
	Symmetry(α+β)	<360	0.70
		360≤ α+β≤ 540	0.84
		540 < α+β≤ 720	0.94
		=720	1.00
	Grasping and manipulation	Easy	0.91
		Not easy	1.00
Interface	Mechanical unfastening process (U-rating)	Screw/bolt standard head	0.35
		Screw/bolt special head	0.55
		Nut and bolt	0.53
		Retaining ring/circlips	0.63
		Interference fit	0.45
		Rivets/Staples	0.50
		Pin	0.45
		Cylindrical snap fit	0.40
		Cantilever snap fit	0.33
	Non-mechanical unfastening (U-rating)	Welding process	1.00
		Adhesive	0.53
	Tools required with low intensity/ high intensity	1	0.3/0.4
		2 (sequential use for a part)	0.6/0.8
		More than 2	1.00/1.00

Based on the aforementioned information, the PDC can be measured to represent a tendency of disassembly complexity logarithmically according to the number of components (N_c), the number of interfaces (N_i), component complexity index (CI), and interface complexity index (II) as the following equation. Detailed information of this equation is described in [9].

$$PDC = \left(\frac{n_c}{N_c} + CI \right) \log_2 \left(N_c + 1 \right) + \left(\frac{n_i}{N_i} + II \right) \log_2 \left(N_i + 1 \right) \quad (1)$$

The PDC focused on assessing the component complexity and interface complexity for a product. However, when assessing a single component or a module design, the PDC has a difficulty of representing complexities for a single component and module design. Accordingly, the component design and interface design of a corresponding component should be considered at the same time. Therefore, the SCCI was introduced with the equation (2). For determining the SCCI of kth component, the weighted average value is applied to consider of component (C_k) and interface complexity indices (I_k) to quantify complexity for a single component simultaneously.

$$SCCI_k = \frac{C_k \sum_{1}^{J} C_{\mathrm{c,j}} + I_k \sum_{1}^{N} C_{\mathrm{i,n}}}{\sum_{1}^{J} C_{\mathrm{c,j}} + \sum_{1}^{N} C_{i,\mathrm{n}}} \tag{2}$$

$$C_k = \frac{\sum_{1}^{J} C_{c,j}}{J} \tag{3}$$

$$I_k = \frac{\sum_{1}^{N} C_{\mathrm{i},n}}{N} \tag{4}$$

Where, $C_{c,j}$ is a difficulty factor value of the jth attributes; $C_{i,n}$ is a difficult factor value of nth interface attributes; C_k is the average of difficulty factors for kth component; J is the number of attributes for component complexity (here, J=4); I_k is the average of difficulty factors for interfaces of kth component; and N is the number of attributes for interface complexity (here, N=3).

2.2. Module identification based on graph clustering

In order to consider relationships between components for modularization for AM, Markov Cluster Algorithm (MCL) is applied to group components with high complexity into a module for AM. The MCL is used to cluster complex biological networks in the field of bioinformatics [13, 14]. The MCL is a fast and scalable unsupervised clustering algorithm based on the mathematical concept of random walks.

First, an adjacent matrix, A, is developed with the value of the complexity as weight value on the edges. However, since the SCCI represents the complexity value of a single component, the SCCI value has to be converted as the value of edges between ith component and jth component with the following equation.

$$A(i,j) = \begin{cases} w(i,j) & \text{if } i\text{th and } j\text{th components have relationships} \\ 0 & \text{else} \end{cases} \tag{5}$$

$$\mathrm{w}(i,j) = SCCI_i + SCCI_j \tag{6}$$

After building the adjacency matrix, secondly, Markov matrix, M, is developed to identify random walks from the adjacency matrix based on the equation (7). The equation describes stochastic flow from ith component to jth component, which is the probability transition of the random walks. The detailed working principle of MCL is described in [14].

$$\mathrm{M}(i,j) = \frac{A(i,j)}{\sum_{k=1}^{n} A(\mathrm{k,j})} \tag{7}$$

Thirdly, the MCL process performs two operations: expansion and inflation. The expansion is to allow the flow to connect different regions of the graph, while the

inflation prunes edges with low disassembly complexity. Then, modules are generated by consolidating components with high disassembly complexity.

3. Case study

To demonstrate the usefulness of the proposed method, a case study with a coffee maker was performed. As shown in Table 2, Philips coffee maker (HD7450) was analyzed to know complexities of components. And then, the values of the complexities were converted to SCCI. The SCCI can be presented in the adjacency matrix in Figure 2. Element values of the adjacency matrix were calculated by the sum of the SCCI values of two components that had interconnections in accordance with the equation (6). For example, a value of the element between bottom cover (1) and bottom casing (15) was 0.022 and it was calculated by a sum of PDC value of the bottom cover, 0.011, and of the bottom casing, 0.011.

Table 2 Complexity information of the coffee maker

No.	Component name	No.	J	C_k	N	I_k	$SCCI_k$
1	Bottom cover	1	4	0.748	3	0.217	0.011
2	Silicon ring	1	4	0.828	3	0.327	0.015
3	Hot plate	1	4	0.748	3	0.217	0.011
4	Casing for heater	1	4	0.713	3	0.217	0.010
5	Heater	1	4	0.748	3	0.150	0.011
6	Power cord	1	4	0.748	3	0.483	0.016
7	Water tube set	1	4	0.748	3	0.150	0.011
8	Silicon tube	4	4	0.713	3	0.150	0.010
9	Water reservoir	1	4	0.788	3	0.110	0.011
10	Steam sprout	1	4	0.713	3	0.150	0.010
11	Filter basket	1	4	0.748	3	0.033	0.010
12	Filter	1	4	0.713	3	0.033	0.009
13	Lid of coffee maker	1	4	0.788	3	0.133	0.011
14	Decanter	1	4	0.713	3	0.217	0.010
15	Bottom casing	1	4	0.748	3	0.217	0.011

MCL was applied to determine module boundaries for product recovery when using AM based on interrelationships of components in a product and SCCI. Since MCL is unsupervised learning algorithm unlike K-means clustering algorithm, the number of modules are determined randomly. In this case study, the number of modules was converged as 7 based on SCCI as shown in Table 3. In order to decide which module can be produced by AM, the modules have to be assessed based on material type. Since the material type was critical when components in a module were consolidated as a single component in terms of a type of manufacturing processes, we used the material type of components to assess the possibility of modules that can be fabricated by the same AM process. Accordingly, components in modules 5 and 6 could be consolidated by using AM, which is 9' and 11' in Table 3.

By consolidating components into a module as a single component by AM, the number of components was decreased. As a result, the product disassembly complexity (PDC) of a product with modules by AM was lower than the PDC of the product with conventional modules as shown in Table 4. The AM can contribute to reducing disassembly complexity by components consolidation in this research. It will enhance the efficiency of product recovery.

PDC		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Bottom cover				0.021											0.022
2	Silicon ring			0.026	0.025											
3	Hot plate		0.026		0.021	0.022									0.021	0.022
4	Casing for heater	0.021	0.025	0.021		0.021										0.021
5	Heater			0.022	0.021		0.026		0.020						0.021	0.022
6	Power cord					0.026										0.027
7	Water tube set								0.020							
8	Silicon tube					0.020		0.020		0.021	0.019					
9	Water reservoir								0.021		0.021	0.021		0.023		0.022
10	Steam sprout								0.019	0.021		0.020		0.021		
11	Filter basket									0.021	0.020		0.019		0.020	
12	Filter											0.019				
13	Lid of coffee maker									0.023	0.021					0.023
14	Decanter			0.021		0.021						0.020				0.021
15	Bottom casing	0.022		0.022	0.021	0.022	0.027			0.022				0.023	0.021	

Figure 2 Adjacency matrix for the SCCI of HD7450

Table 3 Module identification and assessment

Module No.	A product with conventional modules	A product with components from AM	Assessment of modules
			Material type
1	2, 3	2, 3	X
2	4	4	-
3	5	5	-
4	7, 8	7, 8	X
5	9, 10, 13	**9'**	O
6	11, 12	**11'**	O
7	1, 6, 14, 15	1, 6, 14, 15	X

Table 4 Comparison of PDC when considering modules and components consolidation

	A product with conventional modules	A product with components from AM
Nc	18	15
nc	15	12
Ni	8	8
ni	3	3
PDC	8.449	7.975

4. Closing remarks

AM has been focused on manufacturing products with complex structures by consolidating components, minimizing materials and energy usage while keeping performance. However, since maintenance and product recovery including reusability are important issues to prolong product lifecycle, this study proposed how to decide modules fabricated by AM, which are a consolidation of components. The modules

were generated to minimize disassembly complexity based on difficulty factors of disassembly process, and then components in modules were consolidated as a single component by AM technologies. By consolidating components into the modules, the product disassembly complexity of a product with AM technology was reduced rather than the product disassembly complexity of a product with modules.

This research has focused on disassembly complexity for modularization but used less information related to AM technologies. More information on design for AM will be considered to determine and assess proper modules for AM. Also, future work will be performed to identify module boundaries for maintenance, repair, and recovery.

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Concurrent Evaluation of Functions and Visual Features for Resource Efficient Design

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Abstract. Visual design features are important for customers as well as function designs to make product attractive. Enhancing product functions can increase cost and environmental impact, while improvement of visual design may not cause increase of environmental impact.This paper discusses a method to quantitatively evaluate the importance of functional and visual design. Using smartphones as a case study, the paper proposes a procedure to evaluate both functional and visual design. The paper applied pair comparison to evaluate the relative importance of 4 visual design features. Then, the result of our previous survey regarding relative importance of 4 functional design items were integrated. Then, the value of smartphones was defined by considering both functions and visual design features.The result showed that functional design features are basically more important than visual design features. However, difference of the most important visual design feature and the least important functional design feature was rather small. This fact suggested that by focusing on providing fancy visual featues rather than increasing unnecessary functions can be a good strategy for resource-efficient design.The paper also measured material compositions of three models of smartphones and calculates environmental impacts based on TMR (Total Material Requirement [1]). Finally, actual values of the resource efficiency were calculated and some general strategies to design resource-efficient products were discussed. Through this effort, an idea to integrated evaluation of functional design and visual design of products were shown and the first step to resource-efficient design has been made.

Keywords. Functional design, Visual design, Resource efficiency, Smartphone

Introduction

Visual design features such as color, texture, shape, etc. are important for customers as well as function designs to make product attractive and motivate purchasing. However, theoretical analysis of visual design features exists [2, 3], but is insufficient compared with functional design study, since such visual design strongly depends on designers' "KANSEI." On the other hand, enhancing product functions can increase cost and environmental impact, while improvement of visual design may not cause increase of environmental impact. Thus, focusing on visual design can be a good strategy to make the resource efficient product which has higher value for customers and lower environmental impact.

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This paper discusses a method to quantitatively evaluate the importance of functional and visual design. Using smartphones as a case study, the paper proposes a procedure to evaluate both functional and visual design. The study applied pair comparison often used in AHP (Analytical Hierachy Process [4]) to evaluate the relative importance of 4 visual design items that are "color," "texture," "thickness, "variations of optional items." And one functional design item, "battery capacity" is added. Then, the result of our previous survey [5] regarding relative importance of 4 functional design items, "battery life," "storage capacity," "monitor size" and "pixels of camera" were integrated. Then, the value of smartphones was defined by considering both functions and visual design features.

1. Quantitative Design Evaluation Method

In the study, using smartphones for the case study, these steps were taken.

1. Listing up of visual design specifications.
2. Screening of the visual design specifications in the aspect of relevance with functional design specifications and design flexibility.
3. Extraction of visual design specifications that are not relevant with functions and have certain design flexibility.
4. Investigation of the extracted design specifications by a questionnaire to university students.
5. Integrated analysis with functional design specifications.
6. Discussion of visual design specifications that are relatively important for users and not having large environmental impacts.
7. Proposal of a basic design plan for resource efficient smartphones.

Since the purpose of the study is to find out a good design strategy which does not affect product functionality, but enhance attractiveness of the product, design specifications which have to consider functions should be eliminated from the list by step 2. Design specifications that will be automatically determined should be also eliminated, since there is no space to change. Although LCA (Life Cycle Assessment) [6] will be the best way to quantify environmental impact, TMR is used to carry out a simple quantification in this study.

2. Evaluation of Visual Design Features

2.1. Target Design Features

The paper first tried to find out all the visual/functional design features and tried to eliminate unnecessary design features by applying a screening process mentioned in the former section. As the result, following design features have been selected as the targets of evaluation.

2.1.1. Color

Although a color of a smartphone does not directly affect the functionality, fancy (or cool, gorgeous, etc.) color can be a good reason to purchase it.

2.1.2. Texture

Some products have matte surfaces and some have polished surfaces. Environmental impact due to surface finish might be a little different. However, the surface texture apparently does not affect functionalities such as storage capacity, data transfer speed, etc. Thus, texture is a pure visual design feature.

2.1.3. Thickness

Smartphones need a certain thickness to install all the necessary functions. But, still there are some different design options to choose a thick and reliable design, or thin and smart design.

2.1.4. Customizability

It is often seen (in Japan) that young people deco-rate their smartphones by attaching a fancy case. This "customizability" does not mean the choices with a case or without a case. This feature shows how many options users can have, in attaching a case, headset, strap, touch pen. Thus, a standard design which has common sizes increases the customizability. Contrarily, a specialized design can disturb the customizability. So, customizability itself won't affect the environmental impact. The difference is that the users can select from many options, or can only select from a few options.

2.2. Design Space

In evaluating the weight of design features to customers, how many options or how much variations can be selected is important. Therefore, it is necessary show how many options can be choosen, so-called width of the design space to respondents of the questionnaire. These are the widths of the design space based on practical design options of smartphones.

2.2.1. Color

Corresponding to the examples in the market, we assumed that the color can be selected from following nine.

- Pastel blue, Blue, White, Pink, Black, Red, Emerald green, Gold, Silver

2.2.2. Texture

Considering the market examples, these two are the only available options for texture.

- Matte surface, Polished (mirror) surface

2.2.3. Thickness

As the design space, minimum and maximum in Japanese market were considered. This specification was assumed that the users can choose from 6.8mm to 14.2mm.

2.2.4. Customizability

It is common for young users of smartphone cases that they purchase some options such as cases, headsets, touch pens, accessories, etc. to make their favorite style of smartphones. Thus, customizability seems ot be an important feature to choose product.

3. Quantification of Weight of Visual Design Features

3.1. Method of the quantification

In the study, a pair comparison was carried out through a questionnaire. In order to check the importance of functional and visual design features, one factor regarding function was added in the list. 4 visual design features (color, texture, thickness and customizability) and one functional design feature (battery capacity) were compared through pair comparison. As shown in Figure 1, one question consists of a comparison of a pair of design features. Comparing A and B, if the respondent thinks A is definitely important, "9" should be marked. Totally, there are 9 different options to answer one question from 9 to 1/9, as it is shown below the figure. By answering all the possible combination with 5 features, weight of 5 features can be calculated. The questionnaire was carried out to 78 3rd grade undergraduate university students.

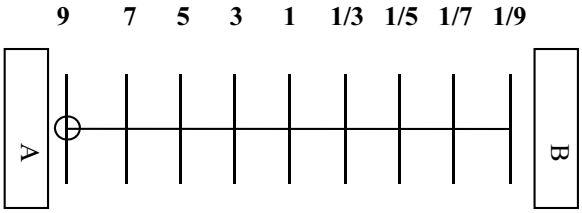


Figure 1. Scale bar used for pair comparison.

- If A is absolutely important than B, 9 is marked.
- If A is rather important than B, 7 is marked.
- If A is important than B, 5 is marked.
- If A is somewhat important than B, 3 is marked.
- If A and B is equally important, 1 is marked.
- If B is somewhat important than A, 1/3 is marked.
- If B is important than A, 1/5 is marked.
- If B is rather important than A, 1/7 is marked.
- If B is absolutely important than A, 1/9 is marked.

3.2. Result of the quantification

Table 1 is the raw result regarding the weight of five design features, calculated by the procedure of pair comparison. Figure 2 is indicating the same result by a viewgraph.

Table 1. Importance of design specifications

Design specifications	Relative weight
Color	0.1007
Texture	0.0980
Thickness	0.1615
Customizability	0.1904
Battery capacity	0.4495

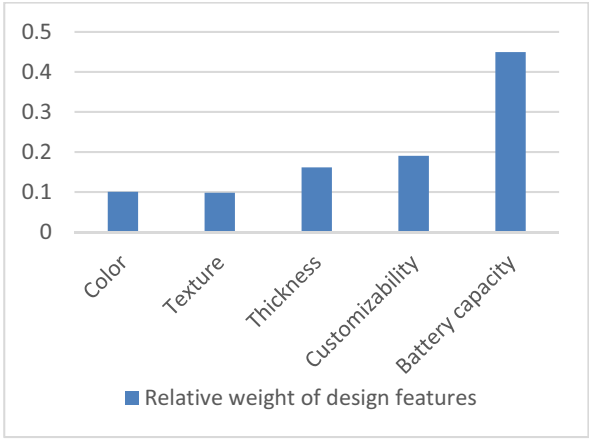


Figure 2. Calculated weight of design features.

The next procedure is to adjust the previous result in order to compare with weight of visual and functional features shown in Table 1 under the same standard. In Table 1, importance of "battery capacity" is calculated as 0.4495, while it is calculated as 0.4031 in the previous survey shown in Table 2 and Figure 3. We assumed that the same specification was estimated relatively higher in the new survey. And, it is also assumed that there is no change in ratio between battery capacity and other three specifications. Thus, by adjusting the value in Table 2 to compare with the values in Table 1 directly, relative weight of all the design features can be expressed. Then, Figure 4 shows the comparison of all the design features including visual and functional features.

Table 2. Weight of functional design features in previous survey.

Design specifications	Relative weight
Battery capacity	0.4031
Display size	0.2179
Camera resolution	0.2022
Memory size	0.1768

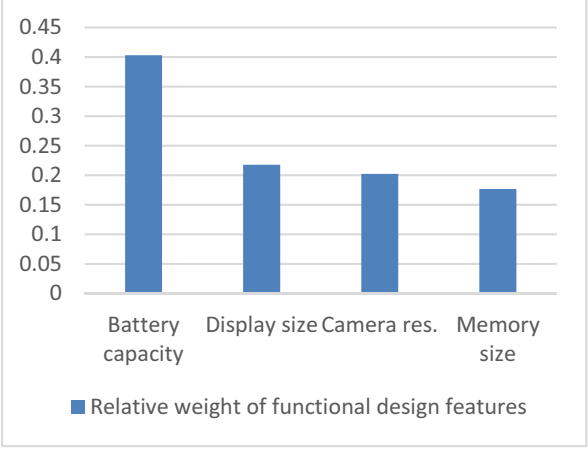


Figure 3. Weight of functional design features in previous survey.

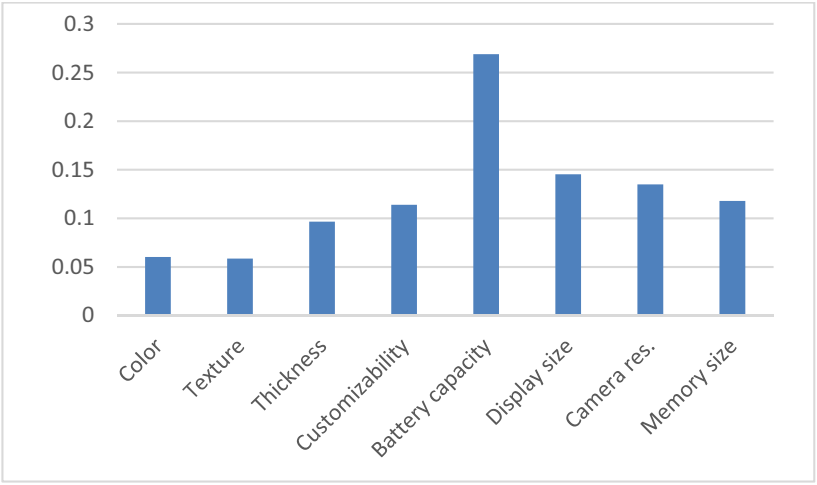


Figure 4. Comparison of relative weight of design features.

4. Case Study on Practical Resource Efficiency

4.1. Resource Efficiency Index

Recently, resource efficiency as an analogy of eco-efficiency [7] is strongly focused [8][9]. Resource efficient product design is one of the keys to achieve decoupling growth [10]. In this study, an index of resource efficiency is discussed. Based on the authors' previous study [5], basic index to evaluate resource efficiency has been proposed as equation (1).

$$resource\ \ efficiency = \frac{\left(\sum_{i=1}^{n} \frac{specific\ \ value\ \ of\ \ design\ feature\ \ i}{reference\ \ value\ of\ design\ feature\ \ i} \right) \times wi}{\sum_{ir=i}^{nr} TMR} \quad (1)$$

TMR_{ir}: TMR of material ir, w_i: relative weight of design feature i

4.2. Total TMR of Smartphones

The measurement of material compositions and included amount were carried out by XRF (X-Ray Florescence [11]) analysis. The amount of Au was measured by ICP (Inductively Coupled Plasma [12]). After measuring, TMR of corresponding amount of element in the smartphone was calculated by multiplying general TMR value of each elements. Table 3 shows the total TMR of example smartphones measured in the previous study.

Table 3. Total TMR of smartphones.

Type	Market released date	Price (JPY)	Weight (g)	Total TMR (t)
A	24/6/10	57,800	138.6	0.0360
B	23/12/10	58,170	137.5	0.0480
C	15/3/12	60,480	150.0	0.0362

4.3. Evaluation of Resource efficiency

Specifications of 3 smartphone models from different makers shown in Table 3 have been investigated. Table 4 indicated next shows the specification values, reference values, weight of each design feature, total TMR and resource efficiencies based on the proposed index shown in equation (1). Reference specifications in the table were decided based on the average values of smartphones released to the market in 2015. Some design features cannot be evaluated quantitatively. For example, it is difficult to compare "matte surface" and "mirror surface." In such cases, the specification value and the reference value are assumed to be the same

Table 4. Specifications and calculated resource efficiencies.

Specifications	Type A	Type B	Type C	Reference value	Weight of design features
Color variations	2	3	4	3	0.0604
Texture	-	-	-	-	0.0588
Thickness (mm)	9.3	13.4	11.9	9.3	0.0969
Customizability	High*	Low*	Low*	Medium*	0.1143
Battery Capacity	1420	1400	1840	2575	0.2699
Display size (inch)	3.5	3.8	4.3	5.0	0.1459
Camera resolution (mill. pixels)	500	960	1210	1296	0.1353
Memory size (GB)	32	16	16	24.5	0.1183
Total TMR	0.0375	0.0480	0.0362		
Design value without visual features	0.458	0.435	0.522		
Design value with visual features	0.825	0.679	0.721		
Resource efficiency without visual features	12.2	9.1	14.4		
Resource efficiency with visual features	22.0	14.1	19.9		

*: As for the customizability, high, medium, and low are quantified as 3,2 and 1.

4.4. Discussions

The result of the resource efficiency calculation shown in Table 4 suggests that by focusing on visual design features, it can be possible to design resource efficient design, rather than only focusing on functional features. Only by functional aspects, smartphone type C seems to be the most resource-efficient design among 3 examples. However, by considering visual aspects, type A was evaluated to have the highest resource efficiency value. Although the estimation of the environmental impact is still insufficient, the result can be a good motivation for product designers to focus on various aspects of design. By enhancing the product features that are highly evaluated by consumers, it is possible to enhance the product attractiveness without increasing the environmental impacts.

5. Conclusions

The paper evaluates the relative weight of both functional and visual design features of smartphones through some questionnaires to university students. The results showed that functional design features are more focused by consumers. Especially, "battery capacity" was the most important product feature. However, it also showed that there was not a big difference between "customizability" which was the most important visual features versus "memory size" which was the functional feature with the lightest weight.

Then, material compositions of 3 different types of smartphones were measured and total TMR were calculated. Based on the value estimation and material compositions data, resource efficiencies of 3 smartphones were estimated based on the proposed index. Through this resource efficiency estimation, the paper concludes that resource efficient design can be feasible by focusing on both functional and visual design features based on the weights of the design features for customers. By enhancing design features that are important for consumers, but not increasing environmental impact much, resource efficient and attractive design can be realized.

As for the future work, more precise and reasonable estimation of environmental impact will be necessary. Since TMR only estimates environmental impact of elements by resource rarity aspect, it is not suitable to estimate environmental impact of components that are fabricated through complicated process, such as semi-conductor, plastic cases, LCD etc.

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Transdisciplinary Engineering: A Paradigm Shift
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Self-Sufficient Furniture Design for Farmers in Rural China for Contemporary Living

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Abstract. The objective of this research is encouraging villagers to be less dependent on outside goods and services, and embracing a more sustainable lifestyle of their own. The first task of this research is learning from several selected outdated furniture in the village and proposing prototypes that are more suitable to the contemporary living styles, while retaining the functionality, workmanship skills, and cultural traditions. This research identifies certain traditional carpentry skills used by village carpenters and demonstrates how their techniques and traditional materials can be adapted to create modern designs that meet these villagers' needs and withstand the harsh environmental conditions. Using ethnographic research, the research illuminates some of the ways the farmers' use their existing furniture, and specifies how the new furniture will meet their needs. The designs that are developed retain the functionality and beauty of traditional forms, and at the same time, upgrade the rural living environment.

Keywords. Tradition Craft, Rural, Chinese Culture, Contemporary Furniture Design

Introduction

For a long time, professional designers were mainly focusing on designing furniture for the population in urban areas, which is not affordable for rural farmers. On one hand, the well designed furniture is too expensive for rural farmers. On the other hand, the design is not suitable for the rural village living enviornment. Focusing on these problems, there is a trend from last century that more and more designers, architects, engineers, NGOs, and philanthropists, start working directly with people of limited resources, collaborating across sectors, and using emerging technology that "leapfrogs" poorer communities into the 21st century. However, through the investigations of our design team, challenges still exist on how could contemporary designers improve the lives of poor and marginalized communities [1].

Aiming at overcoming this challenge, our design team has visited Shijia Village in China to conduct immersive fieldwork research. We found that all the village houses were originally constructed with mud brick, and were situated on their land parcels in the same configuration. No new materials or new ideas were adopted to optimize

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houses to best serve occupants. When houses stopped evolving, furniture also stopped to evolve. Figure 1 shows several examples of Chinese Furniture in Shijia Villiage. We were inspired by the details and forms of them: its colours, lustre, feel, surface, body, shape, lines, and framework, which well reflect the exquisite craftsmanship of farmers. However, they did not recognize the potential of their skills and how to apply them for better design.



Figure 1. Examples of Chinese Furniture in Shijia Village.

Based on these investigations, for the society, this research aims at improving rural lives in China by appropriate and sustainable designs. Besides, it intend to help "villagers to reduce their dependency on outside goods and services". Furthermore, this research is conducted for raising the awarenness of general public on the relationship between culture, creativity, and technology. Taking these three objectives together, this research can produce interesting and modern products while employing traditional skills and retaining traditional values.

To realize above objectives, this research will create functional objects that emphasize "the idea of an assistant tool" to help farmers design their own forms, as well as exploring alternative means of manufacturing, customizing, and selling furniture. Two key issues will be addressed in this research:

- The empowerment of farmers to realize self-sufficient design for them;
- The sustainability of furniture design and manufacturing in their every day life.

This research starts with with rediscovering the Chinese culture. Firstly, we reviewed typical Chinese culture, such as Confucian philosophy, Implements of the House, and Tian Yuan Di Fang (TYDF, a Chinese word, in English it means Round Heaven and Square Earth), Yin Yan Philosophy, and the five elements (metal, wood, water, fire and earth). Secondly, we adapted forms in traditional Chinese rural style to re-interpret it with innovative ideas for contemporary living. Thirdly, this research combines theoretical research with practical applications to 1) explore the sustainability between traditional and new technology development, 2) investigate Chinese culture and traditional craftsmanship to create a new level of energy, and 3) uncover the relevance and the excitement when utilizing the traditional forms.

The design concept of this project is based on the characteristics of traditional Chinese architecture and furniture. It seeks a balance between advanced technologies and traditional values, and takes the "balance/harmony" notions of TYDF for different levels of design. On a broader level, the research highlights the value of Chinese philosophy and aesthetics in furniture design, and provides an opportunity to investigate the interplay among traditional craft, current trends, and modern techniques in contemporary furniture design. Besides, this research will foster a culture of international exchange and creativity to improve the rural lives in China.

This research will be conducted from the following aspects: 1) Assistant Tools. Create furniture prototypes and provide skills training to help farmers to make furniture themselves using basic woodworking skills. 2) Theoretical Research and Practical Application. Integrate the ideas of Chinese philosophy with western design principles to bring a new level of fusion in the furniture designs. 3) Grow Possibilities for Creative Culture Industries. Contribute design and traditional craft ideas to Cultural and Creative Industries (CCI) and communicate with audiences in both design education and creative industries who are capable to incorporate Chinese culture and traditions into furniture design.

1. Local Craftsmanship/Tools/Materials

In order to understand and re-interpret the current living culture of Shijia Village, a field visit at a typical rural farming village has been conducted to observe the craftsmanship of farmers. We also learned the tools, materials, and methods they use, as illustrated in Figure 2. The production of furniture was mainly considered locally available materials and tools.

By learning the carpentry skills of villagers, we found that Chinese people are able to revive their own venerable cultural background. This idea should comprise of a system designed to integrate culture, traditional skill and environment into a wholeness where they interact with each other in accordance with the intelligence and experience in using local materials and techniques. Therefore, this research will demonstrated how to use new techniques (Tapered Tenon Joinry System), wood working techniques, and local recources (China berry), to create the prototype furniture, which is easy for villagers to learn.



Figure 2. Examples of Local Craftsmanship, tools, and materials.

2. The Traditional Carpentry Skills

The designs used in this project blend traditional carpentry skills of the village carpenters with a hands-on, process-driven method. We aim to adapt forms from traditional rural life and re-interpret them with innovative ideas for contemporary living.



Figure 3. The Chinese Bench.

We met the village carpenter and visited his workshop to see what tools were available and what construction techniques he was using. We were inspired by the Chinese bench he had just finished making, as shown in Figure 3. The primary construction and assembly structure used on these benches is a mortise and tenon joint. We also learned that a number of farmers were also able to make such benches by giving the concept of how the parts were prepared and assembled. This inspired us to consider a similar construction approach for the prototype furniture, where prototypical models can be used as templates for copying and interpreting from.

3. Use the New Technique - Tapered Tenon Joinery System

Upon searching for mortise tenon tools, we came across a product that can be well fitted, that is electric hand drill. Through field investigations, the villagers do have some electric hand tools such as electric drill, as shown in Figure 4. This would be a great help to adopt the new technique – Tapered Tenon Joinery System (TTJS).



Figure 4. Mortise and Tenon Tools.

Based on TTJS, the wooden chairs are made, with its structure shown in Figure 5. The seat part is used as the primary structure. Legs are tenoned into the underside and supports for the back are tenoned on the topside.

The idea of an “assistant tool” could help farmers to make their own designs, and to explore and refine their means of manufacturing, so that they can customize their own furniture. Prototypes of the furniture could demonstrate how craftsmens interchange different parts to meet their individual tastes and individual needs.

Here we take chair and sofa bench as examples, which are manufactured by applying traditional craft techniques and natural wood, as shown in Figure 6, 7, and 8.

This chair design was executed using TTJS that makes simple, fast work of mortise-and-tenon joinery. TTJS uses power tenon cutters and matching countersinks

to produce strong, flush-fitting joints with round or other shaped stock. This reinforces the chair's stability, and creates an elegant, simple symmetry that confers a delicate quality to the piece. The improved tension becomes an important aspect of this design, which provides a novel solution for a traditional craft, and an innovative expression of contemporary Chinese farmhouse furniture design.



Figure 5. Structure of Wooden Chairs.



Figure 6. The design of chair (a).



Figure 7. The design of chair (b).



Figure 8. The design of sofa bench.

4. Conclusion

This research focuses on integrating fresh and surprising features of furniture design with traditional rural culture to faciliate the evolutiona of products, ideas, and concepts. This research observed the construction techniques that Shijia farmers used, and adopted a similar approach to retain their original culture. The collection of furniture prototypes include chair, stool, bench, dining table, low table, and sofa bench. During doing this research, we were inspired to understand rural farmers' philosophy of life, to learn from their techniques, and derive a wealth of knowledge that is slowly being forgotten today. This transformed our research into more than just a project; and evoked meaning and depth out of their lives and mine. We used design to embrace human relationships through sharing. Moreover, there is a strong link between craft, design, and the sense of cultural identity in China, where people live with a respect for nature and an appreciation for tradition. This research will keep this spirit alive, and allow it to flow forward to the next generation.

Finally, this research project focused on the mechanical and technical details of making traditional furniture. We looked into how replacing old furniture and instituting sustainable technology could transform and renovate the lives of a rural population in China. This project opened up many possibilities and changed people's perceptions about the definition of indigenous furniture. Shijia Village will be viewed as possessing unique, high-quality homes.

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Part 12

Service Design

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Transdisciplinary Engineering: A Paradigm Shift
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An Empirical Study of the Social E-Commerce Services Model in Taiwan

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Abstract. In recent years, the rise of social media has driven business opportunities. This study explored the economy of closed social media fan groups, which represent a type of customer-to-customer (C2C) model. On the basis of the analysis of the current situation, we propose a three-step process that sets up the integration models for (1) the channel and stock, (2) supplier orders, and (3) consumers; compare As-Is and To-Be logistics on the one hand and cash flows and information flows on the other; and offer corresponding plans and suggestions.

Keywords. Social Ecommerce, Logistics, Cash Flow, Taxation, Test Platform

Introduction

Online shopping is already normal behavior for many people. From personal website shopping to group shopping, they gradually transform community media into export community platforms such as Facebook and LINE [1][2]. According to MIC data, 96.2% of Taiwan's users usually use community sites, with Facebook being the most popular. Facebook users constitute 95.8% of Taiwan's population [3].

Most sellers within community media do not use a professional e-community platform, instead choosing communities such as Facebook and LINE. Therefore, the cash flow and logistics are inadequate for community platforms. If there is a system that can contain the pricing of goods, wholesalers' price, and price, among other things, the information flow between sellers and wholesalers would be clear. It would also be more convenient for the customer to make reservations. Therefore, we look to Taiwanese community businesses as the focus of this problem analysis. We aim to design a system that includes an operations and logistics model that would optimize the existing and future service models. The strategy is divided into three stages. (1.) Understanding the status of Taiwan's community e-commerce market. (2.) Understanding the community business flow and logistics. (3.) Planning logistics with the community operators and logistics operators.

1. Model planning and analysis

A community is a group of people who share the same interests or goals and gradually understand each other and assemble as groups [4]. People's use of community e-

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commence platforms is becoming increasingly frequent as community e-commerce becomes more popular. People customarily use community sites such as Facebook, PIXENT, Plurk, WeChat, LINE, and Weibo. Because of their high saturation levels in Taiwan according to MIC data [5], these community sites are used by many businesses to disseminate their product information. Among non-self-sites, the community is at the core of the Taiwan online community; hence, consumers want to interact and do business with the communities on social media such as Facebook and LINE.

The most popular community e-commerce mode in Taiwan is through Facebook, divided between fan clubs and groups. Fan clubs are more succesful with community e-commerce because they operate as open shops and have multiple systems, such as marketing data analysis and customer management [6]. Through this feature, the seller understands the store better. However, Facebook groups are more closed to membership than are fan clubs and are divided into three different types: public, private, and secret groups [7]. Most sellers choose their model on the basis of whether the group is open or not. Each group has a leader who runs the team. This is a common marketing technique.

Community businesses provide many business opportunities but can cause certain problems as well. In marketing, Facebook can be used to disseminate many messages simultaneously. However, if untargeted, this strategy could cause fray people's tempers. Facebook is complicated to customize to an exclusive look as the sizes, colors, and font types are limited. This means that catching the attention of viewers becomes more difficult when compared with traditional layouts. When it comes to managing transactions in groups, members can just contact the concerned parties on Facebook, and it is not easy to attract new members because the group is closed. Groups are different from fan clubs in that they do not generate data for analysis and users need to scan the data by themselves. The posts are affected by consumers' preferences and time efficiently. In addition, groups have operational problems such as order processing and customer service questions, among other things. The As-Is model of Facebook's group shipping is shown in Figure 1.

Wish Grass Co., Ltd., is our research object. The company's suppliers have jewelry factories and plastic injection facilities, among other things. Their primary trading platforms are their blog, Yahoo, PChome, and Momo. The supply chain of the company has global businesses, small businesses, and factories. Their part in the relationship is limited to disseminating information on goods, providing order information, and conducting consignment delivery. Through a self-marketing platform, Wish Grass sells products to the sellers through e-commerce and conducts group shipping through Facebook; those sellers are called "Group-Moms." The Group-Mom usually posts information on goods on the Facebook group page. Customers order products by leaving a message. Customers have two settlement options: transfer or cash payment. When the Group-Mom receives payments for goods, they transfer the money to Wish Grass, which in turn sends the products to the Group-Mom's home. If these items are large, then Wish Grass send the products to the consumer's address. Other products allow customers to choose the delivery method; for example, customer pick-up, through a convenience store, or by home delivery as shown in Figure 2.

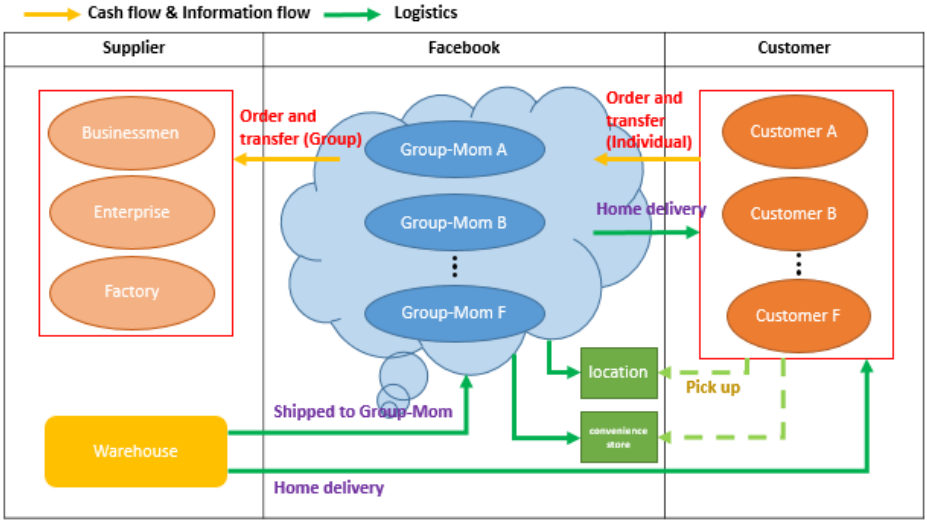


Figure 1. As-Is model of Facebook's group shipping.

After discussing this issue with manufacturers, this research found that the logistics, cash flow, business flow, and information flow of Taiwan's e-commerce community are not perfect, particularly when dealing with orders and logistics using mostly manual processes. If the company can develop a system on Facebook that can attract Group-Moms by enabling them to use the system for selling wares, it would auger well for all parties.

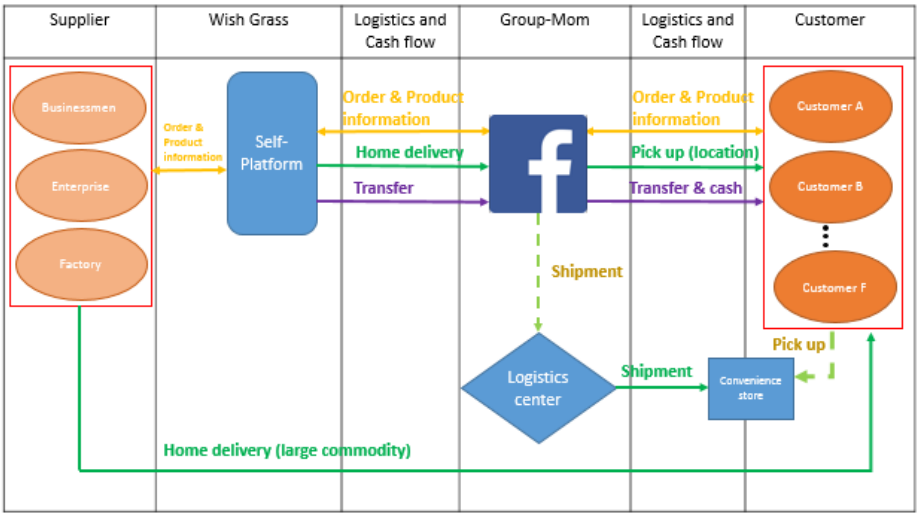


Figure 2. Wish Grass's supply chain analysis.

The flow of the community e-commerce business model is from the supplier to the Group-Mom and then from the Group-Mom to the customers. We aim to save transfer time and provide quicker delivery to customers. After our discussion with the manufacturer, we concluded that the Group-Mom stage be skipped and that goods be transferred directly to the customers by an intermediary as shown in Figure 3. This not

only improves the smoothness of the transaction but also reduces the time required for processing orders. The logistics model is divided into three types: delivery service, convenience store delivery service, and pick-up by the customer. Most customers like to pick up items themselves; however, from the manufacturer's perspective, direct delivery is preferable in terms of cost. This way, the problem of keeping the goods in Group-Moms' homes is obviated and the delivery (logistics) time is decreased.

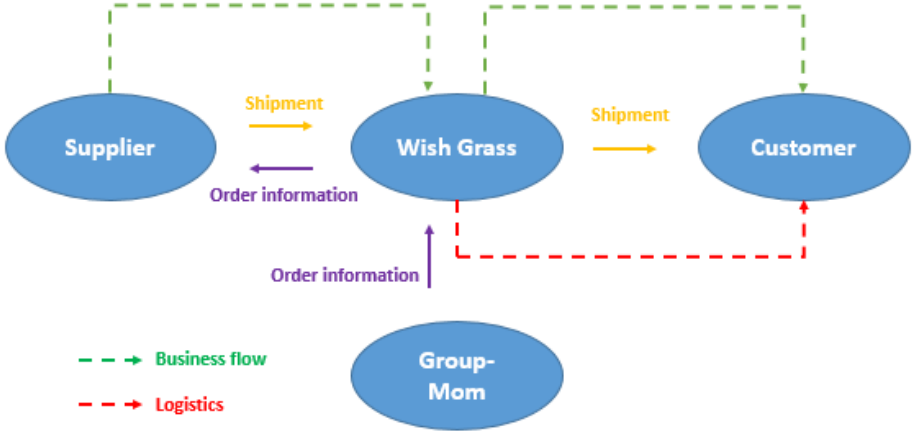


Figure 3. Improved model of business flow and logistics.

Up until now, Group-Moms transmitted information on the number of goods to the manufacturers, who then aggregated the information for the shipping supplier. To eliminate the need to aggregate data in the Group-Mom step, we should ask the Group-Mom for data regarding the order and apprise the manufacturers of the order information simultaneously, thereby reducing the logistics cost involved in achieving our goal. The research for the current situation analysis results proposes the model shown in Figure 4. The main model consists of three parts. The integrated model of the channel and the inventory, that of the supplier's order, and that of the customer's order. In the integrated model of the channel and the inventory, we propose using the system to incorporate the goods into the stock, having the supplier update the information on the network, and then determining the logistics plan and distributing the goods on the basis of the order. In the integrated model of the supplier's order, we propose providing the order format to the Group-Mom, which can be more convenient when the supplier gathers statistical information regarding the goods. Through this system, the Group-Mom can check the order status (cash flow and logistics). The integrated model of the customer's order can provide an order format to the client. This way, the Group-Mom's statistics can speed up the order by the transferance of the order directly to the supplier. The Group-Mom can check the status of the order (logistics and cash flow) using the order query function.

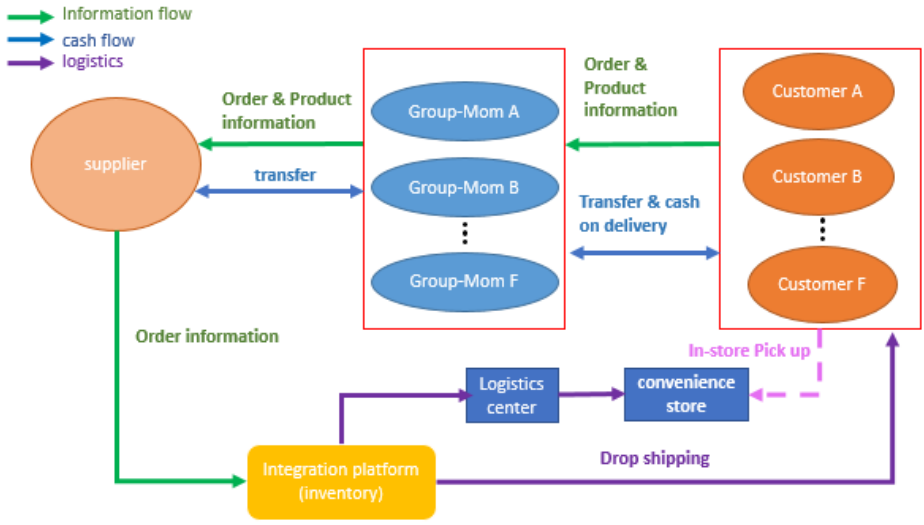
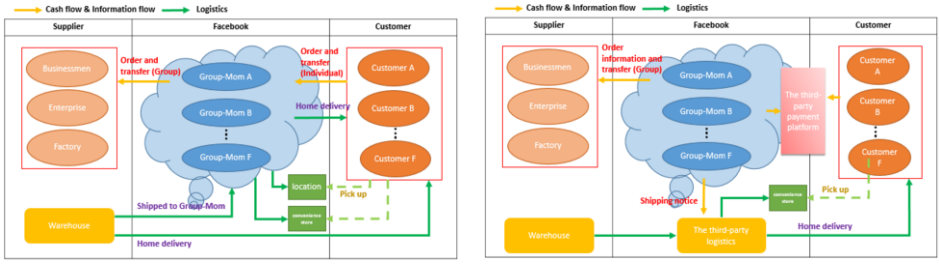


Figure 4. Logistics and cash flow models in this research.

The third-party payment platform is a neutral third-party payment organization with a certain asset and reputation and provides the cash flow service. This organization is not restricted to the business model (whether financial or non-financial). It involves the use of the organization's own information technology that include connecting to user accounts, providing payment information, taking custody of the payment, and transferring the payment. Fast and secure payment methods have become the main payment modes for customers. Today, the model of cash flow is more convenient when the third-party payment organization is well known and provides convenience of use. The third-party payment organization is a fair third-party that protects the rights of customers and creates a good trading environment for sellers.



(a) As-Is model (b)To-Be model

Figure 5. Community e-commerce on Facebook.

2. Conclusions

We provide some information regarding the integration of the manufacturing to order system and the logistics operators into the system and the provision of an available model of information flow and business flow to the Group-Mom. To logistics suppliers, logistics means providing balanced logistics services to the Group-Mom. It divides the

cost into the freight and processing fees. In community e-commerce, logistics is king as it can process stock, develop new products, and recommend goods. In the operational performance forecast, community e-commerce is at the core of operations. Savings in the cost of information and logistics (third-party) are the first profit result.

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Accelerating Retail-Innovation Design for Smart Services via Foresight Approach and Case-Based Design

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Abstract. The fourth industrial revolution (Industry 4.0) is taken as a dramatic upgrade of the third revolution. Compared with prior industrial revolutions, Industry 4.0 put more focus on the creation of networks and interconnectivities among existing assets based on Internet of things (IoT). This study attempts to depict inno-service concepts with the commonality in different categories based on IoT technology and the concepts of cyber-physical systems (CPS) from both the problem-analysis side and resolution-analysis perspective. The problem-analysis utilizes a socio-economic needs analysis, which compromises shopping district categories analysis and categories needs analysis, to obtain the main categories of the shopping district and key problems of it. In addition, the resolution-analysis utilizes a case-based design approach, which compromises case recall and case adapt to refer to the related IoT cases, and then smart shopping themes are proposed. Based on the socio-economic needs analysis including the development in the practical industry, literature of shopping-mall management and the district survey, this research identified six categories for a mega city's major district functions, namely (1) tourism, MICE (meetings, incentives, conferencing, exhibitions) and accommodations, (2) food, beverage and supermarkets, (3) cultural and creative sectors and bookstores, (4) furniture, furnishings and appliances, (5) clothing, accessories and cosmetics, (6) cinema, recreation and sports. In addition, based on the 54 smart-service cases in the global environment from the six classifications, the most valuable solutions from the case base are adapted and reused to meet the current needs and situation. Thus, six smart shopping themes are designed as a CPS-based services among the above six classifications, including (1) Ubiquitous cultural creative street side integration services, (2) Smart food and restaurant services, (3) Future make-up and fast fashion services, (4) Smart living experiential marketing services, (5) Entertainment-based innovative services, (6) MICE Integrated Services. The results can be utilized for researchers to better find more foresight themes efficiently and effectively and for firms to adopt these six new concepts to design the detailed service specification with business concept innovation or business process improvement.

Keywords. Internet of Things (IoT), cyber-physical systems (CPS), Industry 4.0, smart shopping, case-based design, foresight research, retail-innovation design

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Introduction

The fourth industrial revolution (Industry 4.0, I 4.0) [1] is the next incremental advancement for industry. This revolutionary trend is enabled with micro intelligence such as cyber-physical systems (CPS), Internet of Things (IoT), cloud computing, and big data analytics. In this evolutionary economy, companies may differ in terms of their innovation behavior. Firms and organizations within the same industry are argued to adopt the same technological and knowledge conditions, which drive correlated behavior. To achieve I 4.0, smart systems or ecosystems, such as smart manufacturing, smart transportation and smart meter and smart living, consisting of CPS and the IoT are built and integrated. In this research, the novel service-based, CPS-based themes are eager to be carried out through IoT to IoS (Internet of services) [1].

Foresight is "a university human capacity which allows people to think ahead and consider, model, create and respond to, future eventualities" [2]. Foresight is, however, usually an unconscious thinking process. In a business-organizational context, foresight is not necessarily recognized or universal [3]. It generally needs to be put in the specific scope, supported by specific methodologies, to develop an organizational capacity for foresight, or so-called business foresight [2, 3, 4]. The future challenge in the research of innovation systems is to see and understand what the strategic role is and actual importance of foresight systems in firm-level innovation processes [5, 6]. It is hoped that this work would help narrow the gap between foresight research and innovation systems research. Thus, we proposed a hybrid approach of the foresight research incorporated with case-based design.

This paper is based on the various outputs obtained from a smart IoT-based commerce district development project conducted in Taiwan. After three years (2013-2015) of systematically business foresight research, nearly 25 IoT-based innovative services were carried out as Proof of Services (POS). In 2015, 15 smart shopping themes were designed and proposed to lead the future applications and scenarios of the shopping mall in Taipei Xin-Yi district in the six categories for a mega city's major district functions. The purpose of the research is to understand the context and problems of a smart shopping field as a specific aspect to figure out the suitable smart shopping themes for better living scenarios. According to the research outcomes, the proper system design and operation teams will be selected, so as to develop the concepts and establish the smart shopping themes as a real demonstration application in the specific space.

1. Case based reasoning and Case based design

1.1.Case based reasoning

The concept of CBR refers to a methodology of using the prior experiences to infer and deal with current problems of similar features. It is a computer technique that is attracting increasing attention in many pieces of research in different domains. CBR combines the knowledge-based and memory-centric support philosophy with a simulation of human reasoning while using experience [7, 8]. The system adopts some specific principles or rules to solve the current problems in the same way that people do, to ensure consistency of response when solving similar problems. The prior experiences or cases are stored in a specific database. Since the system learns from its

past experiences, this is called a dynamic memory-based learning system. By searching in the past, similar problems provide solutions through a process of inference. Moreover, as the system continues to grow, its ability to deal with the problems increases. CBR process includes five steps, namely case represent, case retrieval, case reuse, case revise, case retain [7].

1.2.Case based design

Case based design (CBD), which is a concept of case based reasoning (CBR) in design, is an approach based on CBR to support the design with problem solving [8]. It is also the process of creating a new design solution by combining and/or adapting previous design solutions. There are two major processes in the framework of a CBD model, namely the case-recall process and the case-adapt process [8]. CBD can enhance creativity for designers by the solution searching mechanism in finding innovation ideas.

- The case-recall process
  The process includes indexing, retrieval and selection. While encountering a new problem, we can index and retrieve previous cases from case base via key features. Then, the retrieval cases are selected by the ranking of case-similarity.
- The case-adapt process
  The process includes modification and evaluation. Modifying source case so that it can fit the new problem by comparing the useful design and problem-solving information. After evaluation, put new solution into case base.

2. Research Framework

Due to IoT technology is an advanced field, we use multidisciplinary research framework (see Figure 1) to achieve the research objectives. Socio-economic needs analysis, namely shopping district categories analysis and categories needs analysis will be taken for problem analysis. In addition, case-based design is taken as the approach for resolution analysis. By these two dimensions of analysis, we attempt to find the main categories and opportunities, key problems and customer's unsatisfactory points and then refer to and adapt the corresponding innovative-service cases with IoT to propose the smart-shopping themes.

3. Research outcomes and findings

For knowing and developing the IoT-related innovative services, this research focuses on the scope of smart shopping to find out the future themes and blueprints to lead industrial service providers, device providers, and service integrators to explore possible topic as a value-chain team. Thus, more and more applications can carry out to the service industry among our surrounding. Industries can form an innovative eco-system based on IoT. In this paper, foresight research, namely socio-economic needs analysis will carry out 6 domains and their main issues (or domain needs). By collecting 54 global service innovation cases and adapting and transforming the cases [8, 9] into the local ones, we propose 15 themes of internet of services in the 6 domains.

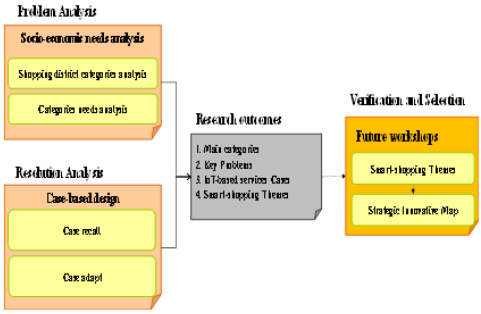


Figure 1. Research Structure.



Figure 2. Major categories of shopping malls.

3.1.Socio-economic needs analysis

3.1.1.Discovering main domains

A distinguished shopping mall plays an integrated role for a city's commercial district, especially when building a smart city. For discovering main domains of shopping mall, we conduct a practical investigation of 12 distinguished shopping malls in the main business area in Taipei city, Tainan city and Kaohsiung city, including Taipei 101, Att 4 FUN, Unified Hankyu, Xinyi Eslite, Lin department store, Fareast Mall, Shin Kong Mitsukoshi (SKM) A4, SKM A8, SKM A9, SKM A11, Regent Taipei, Taipei International Convention Center. The practical investigation was conducted to observe and analyze the online service, environment and facility, major brand and differential service and promotion activities. After the practical investigation, we discover the one specific six categories and one generic category of the shopping mall functionality for a mega city district. The discovered 7 categories (see Figure 2) for a mega city's major district functions, namely (1) tourism, MICE (meetings, incentives, conferencing, exhibitions) and accommodations, (2) food, beverage and supermarkets, (3) cultural, creative and bookstores, (4) furniture, furnishings and appliances, (5) clothing, accessories and cosmetics, (6) cinema, recreation and sports (7) parking and public information services. The first six categories are the specific categories that can be treated as a unique position to bring marketing, and the seventh one is the generic one.

3.1.2.Finding Key Problems

For the purposes of understanding the customers' requirements and user behaviors [10], we conducted a survey of customer shopping behavior with central location test (CLT) method from 1,050 questionnaires. Random sampling was applied to this study. About the issue of "find a place", parking problem (34.4%) is the top concern issue. About the issue of "find/ buy products", "counter staffs' over-aggressive introduce" (13.3%) and "required heavy lifting after shopping" (13.1%) are the most concern issue. Moreover, meal experience is the category with the highest inconvenience of negative experience. "Having seats after meal-ordering at food court"," "Knowing available space in advance" and "Worrying about placeholder items missing" are the most concern problems in this category. Other detailed survey results about customers' inconvenience are listed in Table1. Some other findings may be meaningful for understanding the customers' behavior. The proportion of respondents in Taipei

Business District was significantly was significantly higher than that of the other two business districts (Tainan and Kaohsiung) in terms of "watching movies", "visiting bookstores" and "course activities". In Taipei's business district, the percentage of respondents who went to the business district attempt to search for relevant information before going to business district was significantly higher than those of the other two business districts. The proportion of respondents in the Kaohsiung's business district was significantly higher than that other two business districts in terms of "having meals", "attending arts and culture activities." After the survey, we conclude three major issues of customer's inconvenience to shop in business districts: "insufficient attractiveness to appeal to visitors", "too many service fragments on the customer journey", and "offline attractiveness need to be higher than online shopping to reduce online shopping's threats".

Table 1. Survey results of customers' inconvenience.

Issues	Customers' inconvenience	percentage
Find a place	Parking is not available	34.4%
	Cannot find specific brand shop	10.6%
Find/buy products	Counter staffs over-aggressive introduce	13.3%
	Required heavy lifting after shopping	13.1%
	Cannot find proper brand goods	11.4%
Make shopping decision	Do not like to shop without discounts	21.3%
	Friends' comments are required	13.2%
Watching movies	Long queuing while buying tickets	10.6%
Meal experience	Having seats after meal-ordering at food court	43.3%
	Knowing available space in advance	27.6%
	Worrying about placeholder items missing	22.4%

3.2.Case-based design

For using the concepts of case-based design, we conduct a case finding and collection from different countries to find the opportunity and study for the attributes and context of each case. We collected 54 inno-service cases based on Internet of things by our research team according to six categories (see Figure 3). These case base can be utilized in the design for service themes by case-recall process and case-adapt process.

After the practical case survey and analysis, we conduct the expert panel approach with research team members to consider the different issues and customer requirements and then propose and conceptualize six new service themes, namely (1) Ubiquitous cultural creative street side integration services, (2) Smart food and restaurant services, (3) Future make-up and fast fashion services, (4) Smart living experiential marketing services, (5) Entertainment-based innovative services, (6) MICE Integrated Services. The six new concepts of service themes (see Table 2) consist of 15 inno-services for the six categories The IoT-based services of the six categories and themes are summarized in Table 2 and are described as follows.

Table 2. IoT-based services of the six categories

Categories	New service themes	Inno-services with IoT
Cultural, creative and bookstores	Ubiquitous cultural creative street side integration services	† Timeline and location-guidance service for Cultural and creative performance † Landmark-oriented interactive service † Smart street bookcase and face-recognition book recommendation service
Food, beverage and supermarket	Smart food and restaurant services	† Smart food queuing management and reminder service † Meal and instant food integration marketing † Fresh ingredients cooking and bundle-selling service
Clothing accessories and cosmetics	Future make-up and fast fashion services	† In-store smart clothing shopping service † Automatic make-up service on demand
Furniture, furnishings and appliances	Smart living experiential marketing services	† Home furnishings and appliances visiting experience transferring into bonus-points service † Augmented reality display and demo service
Cinema, recreation and sports	Entertainment-based innovative services	† Personalized adaptive advertising † Virtual personalized sports coach
Tourism, MICE and accommodations	MICE Integrated Services	† Service fragment self-scheduling services † Location-based recommendation signage with map service † Interactive social information exchange service

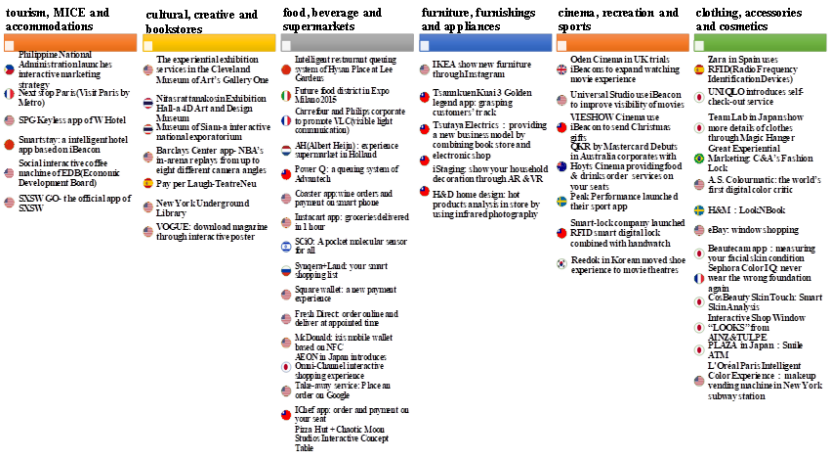


Figure 3. Case base of IoT-based services.

The concepts of each inno-services are introduced as follows:

(1) Timeline and location-guidance service for cultural and creative performance: to search the timeline and location of the cultural and creative performances at the business district on smartphone.

(2) Landmark-oriented interactive service: to gather customer by compelling landmarks and multi-dimensional interactive services.

(3) Smart street bookcase and face-recognition book recommendation service: to equip the street corner with the virtual book wall, e-book preview downloading and guidance to shop services to conduct the bookstore O2O (online to offline) shopping guidance efficiently.

(4) Smart food queuing management and reminder service: to provide the food court or restaurant in the shopping mall with the reservation and queue reminder service.

(5) Meal and instant food integration marketing: to get the shopping behaviors of consumers by checking their food traceability and purchase records for demassified marketing.

(6) Fresh ingredients cooking and bundle-selling service: to integrate the functions of the supermarkets and restaurants in the shopping mall for customized cooking by providing the bundle-selling service of the fresh ingredients.

(7) Personalized adaptive advertising: to identify the facial features or phone records for making the personalized and accurate movie advertising.

(8) Virtual personalized sports coach: to collect the sports, recreation, training and body information with the equipment and provide suggestions to the sport menu and scheduling services.

(9) Service fragment self-scheduling services: to integrate the information of the fragmented time during the exhibition by App and recommend the nearby attractions, restaurants and recreations, and provide self-scheduling service of the day.

(10) Location-based recommendation signage with map service: to recommend the attractions, activities and location information near the residence using the interactive signage.

(11) Interactive social information exchange service: to provide the access of the e-DM, exchanging of business card and interactive instructions during the exhibition.

(12) Home furnishings and appliances visiting experience transferring into bonus-points service: to give the promotion to customers by their bonus-points which are accumulated by visiting and on-site experience the home furnishings.

(13) Augmented reality display and demo service: to provide customers with immersive experience of the home furnishings leveraging the VR technology.

(14) In-store smart clothing shopping service: to provide customers with the personalized adaptive advertising or contents and to guide the in-store shopping and routing.

(15) Automatic make-up service on demand: to support the immediate makeup self-service by selecting makeup style on the smart phone or interactive signage.

After designing the above new service themes, we held a workshop with 95 people and introduce the industrial background, issues and service concepts. After that, we had more discuss with experts and got 47 available questionnaires. We have some statistics and make a strategic innovative map (as shown in Figure 4) including 4 quadrants based by the value of market attractiveness and the market acceptance. In the quadrant with high attractiveness (average higher than 5 scores) and high acceptance (average higher than 30%), there are six new service themes which are in the top right dimension of Figure 4.

4. Conclusions

IoT-based technologies, products and services will lead to a series of new strategic choices, such as how to create and acquis new value of IoT-based products or services, how to collect, use and manage large numbers of new data, and how to re-define and maintain the new channel relationship with traditional business partnership [11]. Under the situation of expansion of industry boundaries, enterprises should play what kind of new roles while facing the wave of business transformation is a crucial issue [12]. The research outcomes have the contributions to fit the above challenges. Firstly, the 6 categories with 6 service themes and 15 IoT-based inno-services are highly market-potential and can be taken as a knowledge base for practical use. The development of the above concepts can be conducted and transformed by the specific context of enterprises, especially the six highest potential IoT-based services in the top-right

quadrant of the strategic innovative map. Secondly, the retail-innovation design with foresight methods incorporating with case-based design is with novelty and verified with practical experience in Taiwan. The systematic approach is also with academic contribution and can enrich the design methods of reference about how to develop efficient IoT-based or CPS-based inno-services. By the innovative services and solutions, customers can feel the new scenarios with smartness, convenience and thoughtfulness.



Figure 4. The four quadrants of the strategic innovative map.

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A QFD-Enabled Conceptualization for Reducing Alarm Fatigue in Vessel Traffic Service Centre

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Abstract. Alarm fatigue refers to distrust or neglect of triggered alarms. Alarm fatigue in Vessel Traffic Service (VTS) centre would impair the performance of VTS operators (VTSOs), and reduce their situation awareness. To reduce alarm fatigue, some advanced technologies have been applied in the alarm system. However, human limitations, which may be the root cause of alarm fatigue, remain to be further studied. In this study, user requirements (URs) were analysed by the qualification function deployment (QFD) method to propose new modules for the alarm system of VTS. These modules are expected to reduce alarm fatigue by considering human limitation. To achieve this aim, three steps were conducted. Firstly, URs were obtained through expert interviews in local VTS centre. Secondly, the QFD method was adopted to select prioritized design requirements (DRs). Finally, three modules for the alarm system of VTS were proposed to meet DRs. They are automated case-based track assignment module; adaptive multi-parameter alarm generation module; and adaptive multimodal alarm presentation module.

Keywords. Quality function deployment; vessel traffic service; alarm system; user requirement

Introduction

The use of alarm systems in traffic management system has become common in recent years [1]. In Vessel Traffic Service (VTS) centre, the alarm system is adopted as an important supporting system that warns VTS operators (VTSOs) to notice the abnormal situations. However, the alarm system of VTS induces alarm fatigue, which impairs situation awareness and motivations of operators [2, 3]. During our field observation in local VTS, we found that VTS operators (VTSOs) tend to ignore most of traffic alarms. Some VTSOs said:

"I received hundreds of warnings per day. However, I ignore most of them. I think they are unhelpful and useless. I detect abnormal situation before the alarm system. I rarely use the alarm system. The voice alarms interrupt my communication, I preferred to silence them."

Alarm fatigue is apparent in VTS. It may lead to high possibility of human errors [4-6], and be reported as the number-one health technology hazard [7]. In general, alarm fatigue is resulted from alarm flood, false alarms, indistinct alarms, and more. Existing technologies such as adaptive threshold, process data filtration, alarm delay,

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and alarm dead band can be implemented to reduce alarm fatigue [8]. However, these technologies have not addressed alarm fatigue fundamentally. The radical reason of alarm fatigue should be the neglect of user requirements (URs) [9]. The alarm system design guide book, which was released by the Engineering Equipment and Materials Users Association (EEUMA), pointed out that the alarm system should take account of human limitation and URs during the design process [9].

Focus on this, this study studies URs to propose new modules for the alarm system of VTS. However, there are several research challenges to be addressed before we can achieve this aim. Firstly, design requirements (DRs) of the alarm system in VTS is still not clear. URs can be obtained through expert interviews, while corresponding DRs require further research. Secondly, the relationships between URs and DRs of alarm system are complex and never studied. Representing these relationships is challenging. Finally, too many DRs may be identified. Critical DRs should be selected and analysed to propose new modules for the alarm system of VTS. To overcome these challenges, the quality function deployment (QFD) technique is adopted. QFD is a method to transform qualitative user demands into quantitative parameters [10]. It has been applied to enhance user satisfaction and improve product performance in a wide variety of fields, such as services, consumer products, and military needs [11-13].

The main objective of this study is proposing new modules for the alarm system to reduce alarm fatigue in VTS. To achieve this aim, we firstly collected URs of the alarm system by expert interview in local VTS. Secondly, a QFD relationship matrix was established to link URs to DRs. The QFD relationship matrix provides clear relationships between URs and DRs, and can identify critical DRs. Based on the DRs identified by the QFD method, corresponding modules of the alarm system can be proposed. Section 1 introduce the process of identifying URs and DRs. The proposed modules of the alarm system are discussed in Section 2. Section 3 concludes this study.

1. QFD-enabled service conceptualization for the alarm system in VTS

1.1. User requirements (URs) analysis

The expert interview was conducted to collect URs. Twelve (12) operators (8 males and 4 females) participated in this interview and described problems they encounter during work. Their average experience is 10 years. All audio of interview was recorded for review. Twenty seven (27) URs were collected during the expert interview. Table 1 shows the collected URs. Then, experts interpreted, eliminated, and clustered these original URs into seven refined URs. Similar URs were interpreted into one UR, repeated URs were eliminated. Table 2 summarizes the refined URs. The relative importance ratings of refined URs were obtained by analysing interview scripts with a 1 to 5 Likert scale, where 5 represents very important and 1 represents very unimportant.

1.2. Design requirements (DRs) analysis

Five software quality characteristics including usability, efficiency, maintainability, reliability, and functionality [14] were utilized as DRs. We broke them down into sub-characteristics that are specific for the alarm system of VTS.

Table 1. Initial URs.

No	URs	No	URs
1	Less false alarms	14	Easy to detect
2	Less missed alarms	15	Short system response times
3	Less repeat alarms	16	Noise is not greater than 74db
4	Less alarms per minute	17	No need recall
5	Less noises	18	Sound bigger under fatigue
6	Less colors to dazzle the eyes	19	Different alarm time for different vessels
7	Color is matching with background	20	Different alarm time for different speed
8	Good shape of alarm message	21	Easy to learn
9	No need of manual assign alarms	22	Easy to understand alarm message
10	Be silent during normal situation	23	Easy to select high priority alarms
11	Operators can make minor errors	24	Easy to respond to alarms
12	Less annoying audible alarms	25	Less unrelated information
13	Less high priority alarms	26	More time to deal with alarms
		27	More information to understand alarms

Table 2. Refined URs.

No	URs	Definition	From	Importance
1	Accurate alarms	The system provides less false, missed alarms.	1,2, 12, 19, 20	5
2	Effective alarms	The system provides less repeat alarms. Operator has enough time to deal with alarms.	3, 26,	5
3	Comfort	The system is comfort to use. The system style is match with VTS console.	5,6,7,8,16,10	4
4	Safety	The system provides human error protection.	9,11	5
5	Easy to use	The system provides simple operation. E.g. The alarm messages can be detected easily.	4,13,14, 18, 21, 22,23,24	4
6	Responsive	The system provides rapid-response.	15	4
7	Informative alarms	The alarm messages provide enough information.	17,25,27	5

Product quality characteristics may be described as follows. (a) The usability of the alarm system correlates with alarm trigger algorithm, alarm assignment rules, and alarm shelving rules. The detectability of alarm message has strong correlation with the operability of the alarm system, since poor detectability of alarms leads to visual fatigue and missed alarms. (b) Functionality includes learnability, suitability, security, and accuracy. The learnability of the alarm system is mainly related with alarm shelving and alarm assignment. They are two most important steps in operating the alarm system. The suitability is mainly affected by alarm message. Color, font, size, shape and sound of alarm message should be suitable with the human-machine interface. Security is one of the most important qualities of the alarm system. To ensure the security of the alarm system, alarm trigger algorithm should have the function of error correction. Moreover, proper standard operating procedure (SOP) should be established. As for accuracy, sensor and alarm trigger algorithm should be considered.

(c) The reliability of the alarm system is affected by alarm generation coverage, sensor sensitivity, interface design, and fault tolerance. Noisy signals and missed signal would influence the reliability of the alarm system. (d) Maintainability refers to stability, changeability, and analyzability. The aptness of alarm trigger algorithm and alarm presentation is important to ensure changeability. The alarm log should be stored for analysis. (e) The efficiency of the alarm system correlates with system response speed and sensor efficiency. Moreover, the convenience of sensor data transfer affects the efficiency, too. All the DRs of the alarm system are shown in Table 3.

Table 3. DRs of the alarm system in VTS**.**

	DRs	Maritime alarm system meaning	Alarm system DRs
Usability	Understandability	The alarm system provides well-understood structure, alarm trigger, and alarm messages etc. Operators must fully understand why alarm triggered, how to shelve alarms, and what the alarm is.	(1) Alarm assignment rules (AAR) complexity (2) Alarm trigger algorithm (ATA) complexity (3) Alarm shelving (AS) rules' complexity
	Operability	The alarm system provides easy operations. Operators can respond to alarms easily.	(4) AS operability (5) Alarm message detectability (6) Alarm handling operability
	Learnability	The alarm system requires little training time. Operators can learn how operate alarm system quickly.	(7) AS training time (8) AAR training time (9) Alarm handling training time
Functionality	Suitability	The alarm system is suitable to the corresponding VTS console.	(10) Alarm message match
	Security	The presented alarms guide operator to do right response.	(11) Correct guide security (12) SOP security
	Accuracy	The alarm system provides accurate alarms.	(13) ATA accuracy (14) Sensor accuracy
Reliability	Miss rate	The alarm system can be trusted. All alarm information can be collected.	(15) ATA latency (16) ATA miss rate (17) Sensor sensitivity
	Maturity	The alarm system can cover full range.	(18) System Maturity
	Fault tolerance	The alarm system can deal with noise disturbance. Signal filter can filter part of noise. ATA can avoid noise impact.	(19) Signal filter (SF) ability (20) ATA fault tolerance
Maintainability	Stability	The alarm system is stable even under serve situation.	(21) System stability
	Changeability	The alarm system provides parameter change functions.	(22) ATA aptness (23) AP aptness
	Analyzability	The alarm system provides alarm log to analyze potential problem.	(24) Alarm log trackability
Efficiency	Time behavior	The alarm system provides fast computation speed.	(25) System response speed (26) Sensor efficiency
	Resource behavior	The alarm system provides less repeat alarms.	(27) Sensor data transfer convenience

1.3. Relationship analysis between URs and DRs

A QFD relationship matrix was constructed (as shown in Figure 1) based on the identified URs and DRs. Numbers utilized in the QFD matrix, and their corresponding meanings are described as follows: "9" indicates strong correlation; "3" denotes ordinary correlation; and "1" represents weak correlation. The measure "absolute importance" refers to "the correlation score" and "importance of URs" multiplied together to achieve a total value.

Absolute importance score of $Q_j = \sum_{i=1}^{7} C_{ij} * U_i$,

Where Q_j is the overall score of the jth quality, U_i is the importance score of the ith user requirements, C_{ij} is the score related to the relationship between URs and DRs. Therefore, for instance, the score of "ATA accuracy" is as follows:

$$9\times5+9\times5+9\times5+0\times4+0\times4+3\times4+9\times5=192$$

After calculating absolute importance scores for all design requirements, the six top- ranked DRs, including "ATA accuracy", "AAR complexity", "ATA aptness", "AP detectability", "ATA latency", and "AP aptness", are selected to improve the performance of the alarm system in VTS.

DRs / URs		Usability						Functionality								Reliability						Maintainability				Efficiency		
		AAR complexity	ATA complexity	AS complexity	AS operability	Alarm handling operability	AP detectability	AS training time	Alarm assignment training time	Alarm handling training time	Alarm message match	Sensor data transfer convenience	SOP security	Appearance	ATA accuracy	Sensor accuracy	ATA latency	ATA miss rate	Sensor sensitivity	system maturity	SF filtering ability	ATA fault tolerance	System stability	ATA aptness	AP aptness	Alarm log trackability	System response speed	Sensor efficient	ATA efficient
Accurate alarms	5	9	9									3			9	9	9		9	9	9	9		9					
Effective alarms	5	9										3			9		9		9					9				9	9
Easy to use	5	9	3	9	9	9	9	9	9	9	9			9	9		3	3				3	9	9	9	3	3		3
Responsive	4		3									3					3										9		
Informative	4						9																		9				
Comfort	4				3	9	9	9			9			9	3									9	9				
Safety	5	9				3	9					3	9		9	9	9	9					9		3		9		
Absolute Importance		180	72	45	57	96	162	81	45	45	81	57	45	81	192	90	162	60	90	45	45	60	90	171	132	15	96	45	60
Rank		2	16	21	12	7	4	12	21	21	12	20	21	12	1	17	4	9	9	21	21	17	9	3	6	28	7	27	17

Notes: AAR: Alarm Assignment Rules; ATA: Alarm Trigger Algorithm; AS: Alarm Shelving; AP: Alarm Presentation; SOP: Standard Operation Procedure.

Figure 1. The QFD matrix for the alarm system in VTS.

2. The new framework for the alarm system of VTS

To overcome the deficiency of the existing alarm system and meet requirements of VTSOs, a new framework for the alarm system of VTS is proposed. The key modules and functions of the proposed alarm system are listed in Table 4.

Based on the analysis of URs and DRs, three modules including (1) automated case-based track assignment, (2) adaptive multiparameter alarm generation, and (3) adaptive multimodal alarm presentation modules are proposed. These new modules are described as follows.

Table 4. Modules and main functions of the proposed alarm system.

Design requirements	Proposed Module	Main Functions
AAR Complexity	Automated case-based track assignment module	Screen the security level of entering vessels automatically Assign track assignment automatically Collect operators' feedback and modify database
ATA accuracy ATA aptness ATA latency	Adaptive multi-parameter alarm generation module	Utilize multi parameters to trigger alarms Modify alarm threshold based on human performance Modify alarm threshold based on environment factors
AP detectability AP aptness	Adaptive multimodal alarm presentation module	Utilize multimodal interface to present alarms Customized style of alarm presentation based on human preference (e.g. fatigue level)

- By automated case-based track assignment module, operators can free from manual track assignment. In the current alarm system, operators must check every entering vessel, and determine which kinds of assignments should assign to them. Most of assignments require manually setting, except assignments of collision prediction and grounding prediction. Each track assignment is associated with one or more alarms. Alarms would not be triggered without corresponding track assignment. Thus, track assignments are essential for the alarm system of VTS. With automated case-based track assignment module, less experience, knowledge and skills are required for VTSOs. Therefore, automated case-based track assignment can reduce workload and prevent human error. Moreover, fresh operators can get more decision support from it.
- Adaptive multi-parameter alarm generation module can generate accurate alarms and efficient alarms to reduce alarm fatigue, since false and nuisance alarms are the major source of alarm fatigue. The traditional alarm system of VTS utilizes one or two predictors to generate alarms. However, the same values of these predictors may depend on, e.g. vessel type, relative vessel course, lead to a different risk interpretation. Therefore, much more parameters are used as input in the proposed alarm system to reduce false alarms and enhance situation awareness of VTSOs.
- Adaptive multimodal alarm presentation module can achieve the versatility of the alarm presentation, attract the attention of distracted VTSOs and can provide customized presence of alarms. Voice and visual alarm messages are two main typical alarm messages of existing alarm system. Compared with visual alarms, sound alarms can attract more attentions. However, sound alarms cannot provide enough information and may lead to unnecessary noises. This module includes haptic alarms to attract the attention of VTSO. Haptic alarms can overcome the problems of background auditory noise, and present directional signals to operators. Thus, new multimodal alarm presentation

module, which involves sound alarm, visual alarm, and haptic alarm, can be more user-friendly and useful.

3. Conclusion

Three modules for the alarm system of VTS are proposed based on URs. They are (1) automated case-based track assignment module, (2) adaptive multiparameter alarm generation module, and (3) adaptive multimodal alarm presentation module. In comparison with the current alarm system, the proposed system has advantages of easy operation and high accuracy. With automated track assignment module, VTSOs can spend more time in monitoring vessel traffic. Moreover, automated track assignment reduces the risk of making human errors. Adaptive alarm generation module can improve trust of VTSOs, increase response rate and reduce response time. Adaptive alarm presentation can provide detectable alarms and encourage participation of operators.

For the generalization of the proposed solutions, the automated case-based track assignment module, adaptive multiparameter alarm generation module, adaptive multimodal alarm presentation module can be generally applied to the vessel traffic industry such as vessel terminal management operators. This work is an empirical case study of an enterprise, as it tries to reduce alarm fatigue by meeting URs. The main contribution of this study is to extract design concepts for the alarm system of VTS by analysing URs. In additional, the method utilized and the DRs discussed in this study can be applied in other types of services or products to reduce alarm fatigue. In the future, feedback of VTSOs can be collected and analyzed to verify the performance of the new system.

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Toward Resilient Vessel Traffic Service: A Sociotechnical Perspective

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Abstract. Vessel Traffic System (VTS) is a typical complex sociotechnical system that provides various supporting services for vessels. With the booming of maritime transportation, VTS becomes more and more important in promoting traffic fluency, efficiency, and safety in designated geographical areas. However, the performance of VTS is frequently threatened by external and internal incidents, which leaves the maritime traffic in a dangerous situation. Therefore, VTS must be resilient to cope with these disturbances and maintain an acceptable service level. Focusing on this problem, this paper first analyses the architecture of VTS from the perspective of sociotechnical systems. Thereafter, the definition of resilient VTS is introduced. Through interaction network analysis, the key contributing factors for resilient VTS are identified. Finally, based on the results, several guidelines for realizing resilient VTS are proposed.

Keywords. Vessel Traffic Service (VTS), Resilience Engineering, Sociotechnical Systems, Systems Engineering, Human-Machine Systems.

Introduction

Vessel Traffic Service (VTS) refers to the integrated shore-side system that provides various navigational support for vessels and extensive traffic management within a port or waterway. It is a typical sociotechnical system that requires seamlessly cooperation among organizations, humans, and various information systems [1]. VTS is usually implemented by a competent authority to guarantee the safety and improve the efficiency of vessel traffic, as well as protecting the environment in its area [2]. With the booming of maritime transportation, especially the continuous and rapid growth in the number, size, and cargo volumes of merchant vessels, the importance of VTS has been widely recognized for promoting traffic fluency and safety in designated geographical areas [3]. Extensive research and practices have also been made to improve the service level of VTS from various aspects, including the technical aspect [4, 5], managerial and operational aspect [6, 7], and organizational aspect [8]. However, in the current practices, the performance of VTS is frequently threatened by various external and internal incidents, such as the sudden increase of traffic or cargo volumes, traffic accidents, changes of organizational regulations, fatigues of operators and pilots, and even technical failure of information systems, leaving the maritime traffic in risks. Therefore, VTS must be resilient to cope with these disturbances to maintain an

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acceptable service level, and finally ensure a safe, smooth, and efficient traffic environment within its area of responsibility.

The concept of resilience was initially introduced in ecological system to describe its ability to adapt the condition changes and keep a balanced situation from disruptions [9]. Recently, the importance of resilience has been broadly recognized in diverse areas, such as disaster management [10], transportation system [11], service system [12], and supply chain management [13]. Extensive methods have also been proposed to improve their resilience, such as optimizing network structure (e.g. in transportation systems [14] and supply chain management [15]), providing redundant or backup resources [16], and using "stronger" components [17]. Research has also been conducted on understanding and improving the resilience of sociotechnical systems. For instance, Ruault, et al. [18] studied the relationships between the resilience of sociotechnical systems and systems engineering and architecture, and identified the key influencing factors that should be considered for improving the resilience. Guarino, et al. [19] identified the importance of transparency in realizing resilient sociotechnical system, and presented the necessity of ontology-driven sociotechnical systems. In addition, Duff, et al. [20] proposed a multi-level model to diagnose and measure the team resilience in sociotechnical systems. In VTS, there are also some efforts have been done. Through modelling the daily operations in three VTSs, Praetorius, et al. [21] identified the key functions that need to be improved to realize safe, efficient, and resilient VTS. Besides, taking the arrival part of a mission as an example, Praetorius, et al. [22] compared VTS with Air Traffic Control (ATC) from the aspect of resilience engineering, and presented recommendations to deal with the complex operations for both of them.

Although these works have brought great moves toward resilient VTS, the research is still limited and incomplete. Specifically, research is still needed on identifying the key contributing factors for resilient VTS, and methods for improving its resilience. Due to the complexity of VTS and its safety-critical nature, it is also challenging to directly apply the existing knowledge accumulated in resilience engineering from other domains.

Taking these into consideration, this research is conducted from the perspective of sociotechnical systems to unfold the myths of resilient VTS. More specifically, four questions are to be answered in this research: (1) How to understand VTS as a sociotechnical system? (2) What is resilient VTS? (3) What are the key contributing factors for resilient VTS? And (4) how to improve the resilience of VTS.

The rest of this paper is organized as follows. Section 1 makes a thorough analysis of VTS from the perspective of sociotechnical system. Section 2 identifies the system disturbances in VTS and introduces the definition of resilient VTS. In Section 3, the key contributing factors for resilient VTS is figured out through interaction network analysis and Section 4 gives the guidelines for effectively improving the resilience of VTS. Finally, Section 5 concludes the whole paper and points out the future works.

1. VTS – A Complex Sociotechnical System

The delivery of VTS services is a group activity that requires extensive and intensive cooperation among various parties, from organizations, humans, to various information systems. According to the classification of complex systems [23], VTS can be treated as a typical complex sociotechnical system. The overall architecture of VTS can be

depicted as shown in Figure 1. The key components involved are derived from extensive review on VTS standards, systems, and literatures, as well as unstructured interviews with watch managers in Singapore. Following the sociotechnical theory [24], all these components are categorized into four parts: environment, information system, organization, and human.

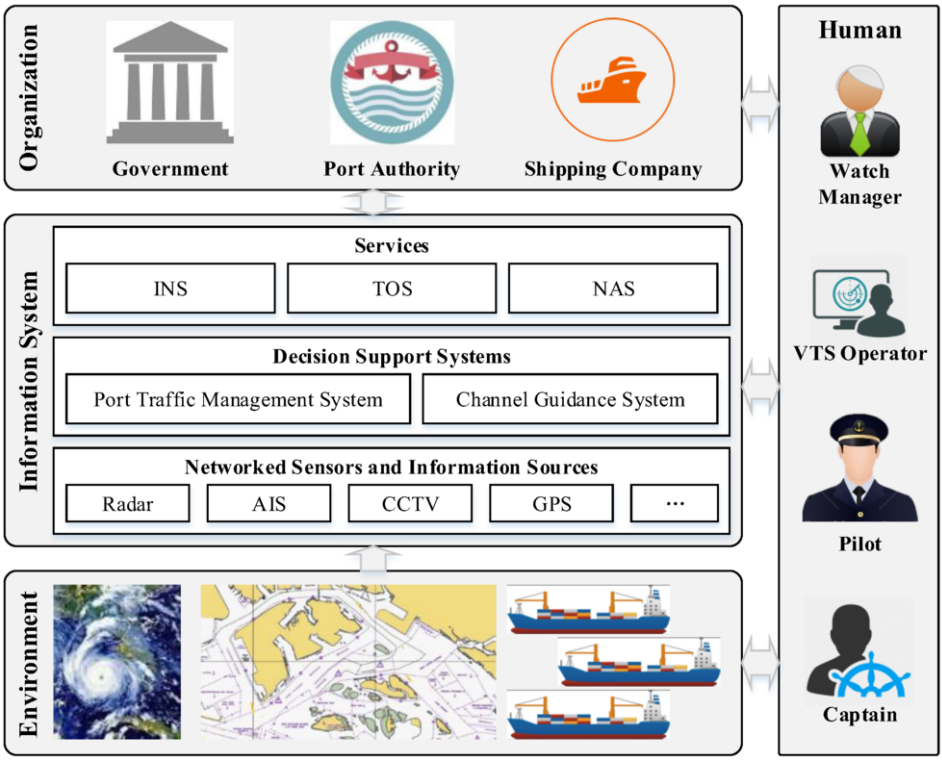


Figure 1. Overall Architecture of VTS.

Environment part refers to the targeted external maritime environment in the area of responsibility. The environmental information that would be monitored in VTS includes the meteorological and hydrological conditions, port and strait traffic information, and real-time status of vessels.

Information system part can be treated as the technology part in sociotechnical system. It contains all the technologies adopted, which is responsible for monitoring the real-time environmental conditions and providing decision support for managing the vessel traffic. Basically, this part contains three layers, they are Networked Sensors and Information Sources (NSIS) layer, Decision Support Systems (DSSs) layer, and Services layer. NSIS layer contains various sensors and systems that are responsible for collecting various real-time data from the environment. Typical sensors and systems involved include radar, AIS (Automatic Identification System), CCTV (Closed Circuit Television), GPS (Global Positioning System), etc. Based on the real-time information collected by NSIS layer, various DSSs are built, like Port Traffic Management System (PTMS) and Channel Guidance System (CGS), to support the decision-making processes in VTS. Services layer contains the services provided by the DSSs. It also serves as the interfaces between humans and information systems. According to the

specifications given by IMO (International Maritime Organization) [2], these services include Information Service (INS), Traffic Organization Service (TOS), and Navigational Assistance Service (NAS). INS provides environmental information and other transit influencing factors to all the participated vessels through broadcasting. TOS aims at preventing congestions and other dangerous situations in VTS area. It mainly focuses on the operational management of traffic through VHF broadcasts. NAS provides navigation support for vessels in difficult and extreme circumstances. It is usually provided upon request of a vessel.

The organization part includes government, port authority, and shipping company. Government is responsible for enacting the regulations and rules for VTS, while port authority is responsible for implementing VTS in its area of responsibility. For the shipping companies, they should follow the regulations provided by government and port authority to manage related vessels, and update necessary shipping information to the port authority.

Humans are the key to deliver the services provided by information system, satisfy the goals of organization, and control the vessel traffic environment actively. Basically, humans can be divided into four roles. Watch managers are the decision makers in all these organizations. They are in charge of the working schedules of VTS operators, the assignment of pilots, and the voyage or passage plan of vessels. They also serve as the bridge between the other three roles and the organizations. VTS Operator is responsible for monitoring and coordinating the movement of all the vessels in VTS areas based on the services provided by information system. Pilot here refers to the professional staff of the port that provides navigational support on broad for the incoming vessels. They will get on the pre-assigned vessels at the designated place to help them on sailing in the port area and berthing at the port. Captain (Master) is the person who is in charge of a vessel.

2. Resilient VTS

During the execution of VTS, all its four parts would encounter various disturbances that decrease the service level of VTS, thus expose the maritime traffic in a dangerous situation. Through field observation and unstructured interview with watch managers and VTS operators, the typical system disturbances in VTS can be listed in Table 1.

In general, these disturbances would affect the VTS from two aspects. On the one hand, they would decrease the capability and performance of service supply from VTS, such as prolonged response time, decreased accuracy, increased error rate, and missed actions. On the other hand, these disturbances would also increase the demands for VTS services. For example, when facing bad weather or traffic congestions, relative more vessels will need to be served, and the workload of VTS will increase accordingly.

Once the service supply of VTS cannot satisfy the demands for services due to these disturbances, the imbalanced situation is occurred and the VTS area would be in danger. Aiming at dealing with such situations and ensuring a safe maritime traffic environment, resilient VTS is thus introduced. More specifically, the resilience of VTS refers to the ability of VTS to recover from an imbalanced situation to a safe situation, where its service supply can meet the demands of services.

Based on this definition, the resilience of VTS can be measured from three axioms: 1) Time: The recovering time from imbalanced situation to the safe situation; 2) Extent:

The recovered extent of VTS; 3) Cost: The cost for recovering from imbalanced situation to the safe situation.

Table 1. System Disturbances in VTS.

Parts	Typical Disturbances
Environment	Bad weather; Change of hydrological conditions; Maritime accidents; Traffic congestions; Sudden increase of maritime traffic or cargo volumes; Decreased manoeuvrability of vessels.
Information System	Interruption of power supply; Break down of operation console; Technical failure of DSSs; Damage to information infrustracture; Disconnection of networks.
Organization	Changes of organizational regulations or management objectives; Job rotation; Work shift.
Human	Human fatigues; Communication Failure; Operational errors; Absence of VTS operators; Delay of actions.

3. Influencing Factors for Resilient VTS

In order to improve the resilience of VTS, it is a prerequisite to identify the influencing factors for resilient VTS. As a typical complex sociotechnical system, the factors are also diverse and complex [18, 21, 25]. Besides the resilience of all the involved system components, the interactions among them will also contribute to the resilience of VTS. However, in practices, due to the limited budget and labour forces, it is impossible to enhance all of them for resilient VTS. Therefore, it is urgently needed to identify the key influencing factors, and then make targeted enhancement for effectively improving the resilience of VTS.

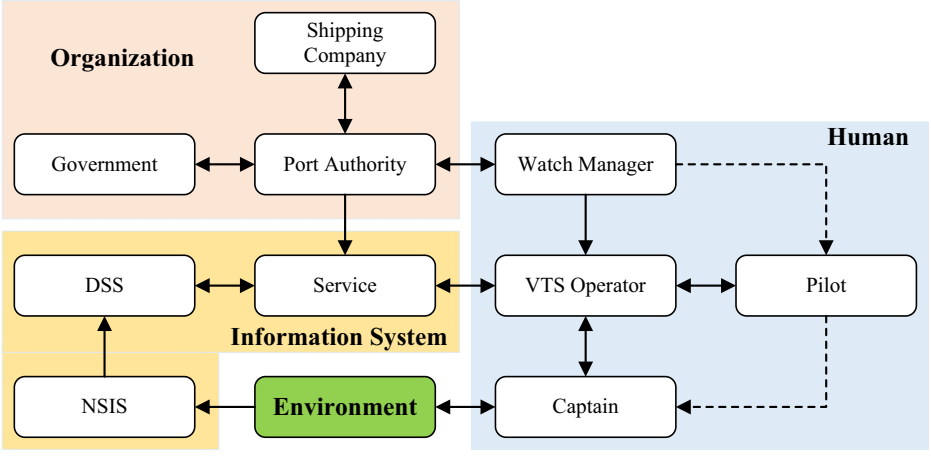


Figure 2. Interaction Network in VTS.

Based on the VTS architecture discussed in Section 1, through field observations at one VTS centre in Singapore, and unstructured interviews with VTS operators and port mangers, the interactions among the system components in VTS have been identified and illustrated as a directed graph, as shown in Figure 2. The blocks (nodes) refer to the

key components in information systems, organizations, and humans, while the arrows (edges) stand for the interactions among these components. The arrow with dotted line means the interaction is out of the control scope of VTS.

Many methods are available for measuring the importance of nodes in networks [26]. Considering the context of VTS, the idea of local centrality is adopted, which considers not only the degree of node itself, but also the degrees of its nearest neighbours. Besides, since the out-degree of a component means it has the power to affect the others, it should have higher importance compared with the in-degree. Furthermore, since environment represents the management target of the whole VTS, it should have higher importance compared with the others. In addition, the shortest distance between the evaluating node to the environment node should also be considered in the importance measurement.

Let α represents the weight of out-degree of a node, e_{ij}^{out} represents the weight of jth out-degree of node i, while β and e_{ij}^{in} represent these of in-degree, the degree of node i can be calculated as follows:

$$d_i = \alpha \sum e_{ij}^{out} + \beta \sum e_{ij}^{in}$$

The importance of component i can be measured as follows:

$$\mathrm{K}(i) = \gamma_i d_i + \sum_{j \in N_i} \gamma_j d_j - l_i$$

Where γ_i refers to the weight of node i, N_i is the set of the nearest neighbours of node i, and l_i is the shortest distance between node i to the environment node.

Through consulting with VTS expert and without loss of generality, all the weights involved are assigned with 1 (normal) or 2 (important). More specifically, except the environment node (γ_0=2), all the weights of the other nodes are set as 1. For the edges, the edge with dotted line is assigned with 1 and the others are assigned with 2. Finally, to differentiate the out-degree and in-degree, α is set with 2 while β is 1.

Based on the equations and parameter settings given above, the importance of every component in Figure 2 can be evaluated. Start from the most important one, the components and their importance values are listed as follows: VTS Operator (64), Service (61), Captain (59), Watch Manager (58), Port Authority (56), Pilot (50), NSIS (33), Government (29), Shipping Company (29), and DSS (26). From the results, VTS Operator is the most important influencing factors for realizing resilient VTS, followed by Service and Captain. DSS has been identified as the least important factor, which is consistent with the result found in ATC [27].

4. Guidelines for Improving the Resilience

Based on the above analysis, several guidelines can be given to realize resilient VTS.

Firstly, in order to effectively improve the resilience of VTS with limited resources, relatively much more efforts should be paid on VTS operators, services (INS, TOS, and NAS), and captains.

Secondly, the interactions among the three most important factors should also be enhanced to improve the resilience of VTS. Efforts can be made from two aspects: (1) Considering the interactions between services and VTS operators, Human-Computer Interface (HCI) should be improved to enhance situational awareness of VTS operators, which has also been identified as a key to realize operational resiliency in VTS [21]. (2)

For the interactions between VTS operators and captains, the communication channel should be diversified and robust to cope with disturbances, and standard terminology is also recommended to facilitate the communications between them.

Thirdly, among the three most important influencing factors, VTS operators serve as the bridge between the other two factors. The resilience of VTS operator is thus vital for realizing resilient VTS. Aiming at improving the capabilities of VTS operators on dealing with the disturbances, effective training of them, rational job rotations to decrease their fatigues, and sufficient backup operators should be considered. Besides, the cooperation among operators should also be improved through standard communication channels and unified terminologies and marks.

5. Conclusions

In order to unfold the myths of resilient VTS and provide effective recommendations to improve the resilience of VTS, this research has made a thorough analysis of VTS from the perspective of sociotechnical systems. Firstly, based on the sociotechnical theory, the architecture of VTS, as well as the interactions among its components, has been analysed. Besides, the system disturbances of VTS have also been identified. Secondly, in accordance with the research in service systems, the definition of resilient VTS has been proposed with three measurement axioms. Thirdly, through interaction network analysis, the key influencing factors for resilient VTS have been identified, which are VTS Operator, Service, and Captain. Fourthly, several guidelines for improving the resilience of VTS have been proposed.

This research can be further extended from three aspects. First, more investigations should be made to make a deeper analysis on the VTS interaction network, and adjust the parameters for evaluating the importance of influencing factors. Second, efforts can be paid on building the quantitative model for measuring the resilience of VTS. Third, focusing on every aspect of VTS, research can be conducted on the effective methods for improving its resilience.

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Service Design for Smart Shopping Service via a TRIZ-Based Service Engineering Approach

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Abstract. With service innovation, the shopping mall industry could optimize their service process and provide more intelligent services to improve customers' shopping experience, which serves as the catalyst for the development of the industry. To apply the service innovation to shopping mall, this study adopts an incorporated TRIZ methodology and a service blueprint approach to design new services for the case company in three service-design stages. In the problem definition stage, the initial service processes are presented in service blueprint approach and all the current problems are identified. In the service resolution stage, the TRIZ contradiction analysis is conducted and the corresponding innovation principles are pointed out and transformed into service resolutions. With this novel service-design approach adopting in the shopping mall indusry, a new mobile app and its six function modules are proposed in the solution evaluations stage.

Keywords. shopping mall services, service innovation, service blueprint, Theory of inventive problem solving (TRIZ), service design and service engineering

Introduction

With the consistent growth in retail business around the world, the shopping mall industry is facing tremendous difficulties under the pressure from online shopping and increasingly high operating cost. There are still many common and frequent complaints about the shopping mall services, including: 1) difficulty in finding stores and parking spaces; 2) insufficient information of goods, discounts and restaurants; 3) difficulties in figuring out the optimized products portfolio; 4) too much waiting time in making payment; and 5) failure to bring or obtain the deduction. This study investigates the shopping mall in Taipei, applying TRIZ methodology and service blueprint method to depict and analyze the service process, then proposes a new service system for solving the existing problems and improving the customers' shopping experience.

1. Literature review

TRIZ was proposed by Altshuller in 1946 after studying one million of worldwide patents. The first paper of TRIZ came out in 1956. The uniqueness of TRIZ is that it

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combines the studies of nature, society and artificial objects [1]. It can provide a systematic approach for ones who are with less experience but attempt to seek for innovative solutions with concepts of contradiction, evolution and resources [2]. Initially, it was mainly applied in the technical field to solve the engineering problems, but currently it can also be applied in non-technical fields, such as banking, marketing, management and education [3,4,5,6]. Lee et al. applied TRIZ method in combination with service blueprint in the service innovation of a parking lot [5]. They formulated and resolved the problems, then reconstructed the service process, and successfully decreased the time of parking cars. Altuntas and Yener [2] evaluated the service quality of healthcare center with SERVQUAL Scale and then applied TRIZ method in resolving the problem to improve the service quality. Shahin and Iraj [7] proposed a combined QFD and TRIZ approach for banking service. In this paper, the TRIZ engineering parameters related to the service problems are interpreted as shopping mall service field, then the contradiction analysis is carried out and the appropriate innovative principles are adopted to design the new shopping mall service system.

The first description of service blueprint was proposed by G. Lynn Shostack [8] in 1984. Service blueprints visually depict objectives and steps in a service process to reduce the complexity and help clarify the process [4]. As a technique for innovation, service blueprint drills the complete service process down to tasks and methods with all the steps fully describted, which enable the managers to identify the current problems of the process [5, 6, 9, 10]. The customers' actions, front and back stage actions, support actions and physical evidence are also involved in interpreting the service delivery [11,12]. Chen and Cheng [13] combined service blueprint and ISO 9001 approach for improving the effectiveness of hospital patients service system and the customers' satisfaction had been significantly enhanced due to the improvement of service quality. Albrecht [4] applied service blueprint to depict the visitors' tourism experience from the visitor management perspective. The limitations of services were separated and new micro mobility patterns were proposed to reconstruct the service process, which significantly improve the visitor experience. In this study, service blueprint will be adopted to depict the existing shopping mall service process and identify the failure points clearly.

2. Problem analysis of existing shopping mall service process

2.1. Case description

Located in Xinyi district, which is regarded as Taipei Manhattan, U shopping mall is one of the leaders in Taiwan retail business. To improve the shopping experience, U

shopping mall attempted to adopt IoT-based service system, which aggregates the information of new products or real-time discounts and connects all the stores. However, there are still many customer complaints about the service quality, including the difficulty in finding the store location, difficulty in finding the parking space, difficulty to find a suitable restaurant, etc. To satisfy the customers' demand for convenient and intelligent service, U shopping mall decides to reconstruct its service process with service innovation based on IoT system. Thus, we designed the new service system that can restructure the new process for U shopping mall as an empirical case study using TRIZ method and service blueprint approach.

2.2. Current service process analysis and problem definition

The current service process of U shopping mall is depicted with the service blueprint and shown in Figure1. The service process includes seven phases: gain information, arriving, introduction, store reception, payment, catering service and leave. After depicting the service process, seven failure points and three waiting points, which impose adverse effects on the customers' shopping experience, can be figured out and marked in Figure 1. They reveal the following four major issues:

- Difficulty in finding location. It includes failure point 2, failure point 7 and waiting point 1. It is always difficult for customers to find the location of stores or parking space in a huge shopping mall without detailed guidance.
- Insufficient information. It includes failure point 1, failure point 3 and failure point 5. The current method to provide information is not so effective that many customers are unable to get enough information to figure out the most suitable goods or restaurants. Sometimes they may even ignore this shopping mall.
- Too much waiting time. It includes waiting point 2 and waiting point 3. Customers have to wait for a long time when making payment, especially in the parking lot.
- Failure to get the deduction. It includes failure point 3, failure point 4 and failure point 6. Some customers might forget to bring the coupons or ask for the deduction after payment so they can not enjoy the discounts. And the methods to receive the real-time discounts and special discounts for particular stores are also needed.

3. Problem resolution

3.1. TRIZ contradiction matrix analysis for the shopping mall

After service process description and problem analysis, TRIZ method is used to find out the feasible resolutions. To apply TRIZ to the service innovation problems, 11 TRIZ engineering parameters corresponding to the problems are selected and then transformed into service parameters in Table 1.

According to the service parameters, we can construct the TRIZ contradiction matrix to identify the most significant principles and translate them into service resolutions suitable to shopping mall industry, as shown in Table 2.

3.2. New service system design with Apps and interactive signages

The service resolutions can give directions to the design of the functions with the new mobile app: "i-love-shopping" to improve the shopping experience. This new service system "U shopping service" includes six function modules, namely 1) City encyclopedia, 2) Smart parking, 3) Mall directory, 4) Shiok, 5) Smart pay, 6) Smart recommendation. The introduction of these function modules is presented in Table 3.

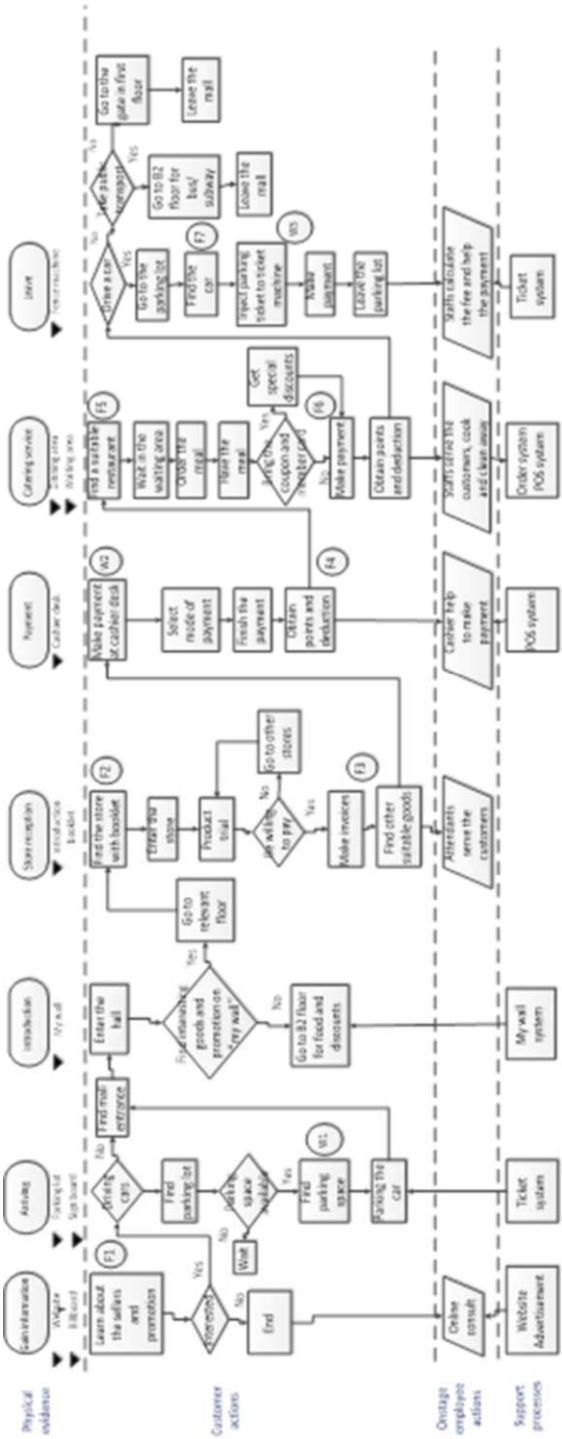


Figure 1. Existing shopping mall service process.

Table 1. TRIZ paramteres and corresponding service parameters.

Engineering parameters	Service parameters	Service parameters for shopping mall specific
9. Speed	Responsiveness	Efficiency of shopping mall services
12. Shape	Exterior	The appearance and equipment of shopping mall
19. Energy spend by the moving object	Cost	The cost of customers while they are shopping
22.Waste of energy	Waste	The waste due to the unbalance of customer flow
24. Loss of information	Unspecific information	Information of shopping mall which the customers cannot receive
25. Loss of time	Waiting time	Waiting time in the shopping process
27. Reliability	Reliability	Reliability of shopping mall services
28. Accuacy of measurement	Communication	The accuracy of demand evaluation
35. Adaptability	Service flexibility	Personalized service
38. Level of automation	Service intelligent level	Intelligent and automated services provided by shopping mall
39. Productivity	Service performance	The quality of service provided by shopping mall

Table 2. TRIZ innovation principles and corresponding service resolution.

Principles	Original definition	Service resolutions for shopping mall industry
1. Segmentation	1. Divide objects into independent parts 2. Make an object easy to disassemble. 3. Increase the degree of segmentation and fragmentation.	Design personalized services according to customers' differentiated demand. Construct customers' personal profiles with the trial and purchase records. Individualized product recommendation according to customers' profiles.
2. Taking out	1. Separate an interfering part or property from an object, or single out the only necessary part of an object.	The most attracting stores, products and services are selected and recommended to customers with mobile app.
5. Merging	1. Bring closer together identical objects; assemble identical or similar parts to perform parallel operations. 2. Make operations contiguous or parallel; bring them together in time.	All the coupons, member cards, consumption points and parking deduction are integrated in one module and the discounts provided by shopping mall are applicable in all the stores.
10. Preliminary action	1. Perform the required change of an object before it is needed, 2. Pre-arrange objects so that they can come into action from the most convenient place without losing time for their delivery.	Record customers' cars position when they leave the parking lot and provide guidance when they get back to find their cars.
11. Beforehand cushioning	1. Prepare emergency means beforehand to compensate for the relatively low reliability of an object.	Automated integration of coupons, member cards and parking deductions into a single module.

Principles	Original definition	Service resolutions for shopping mall industry
15. Dynamics	1. Design the characteristics of an object, external environment, or process to change to be optimal or to find an optimal operating condition.	Provide real-time discounts to customers according to the change of customer flows and turnovers.
17. Anaother dimension	1. To move an object in three-dimensional space. 2. Use a multi-story arrangement of objects instead of a single-story arrangement.	Provide three dimensional direction guidance with mobile app
24. Intermediary	1. Use an intermediary carrier article or intermediary process.	Introduce the attracting points of shopping mall to customer with the interactive AR system.
28. Machanics substitution	1. Replace a mechanical means with a sensory means. 2. Use electric, magnetic and electromagnetic fields to interact with the object.	Provide automated services in shopping mall, such as self-service payment, in substitute for traditional services.
32. Color changes	1. Change the color of an object or its external environment. 2. Change the transparency of an object or its external environment.	Bringing more light to the empty parking grid Provide detailed information of products and restaurants to assist customers to make choice.

Table 3. Function modules of the mobile app : i-love-shopping.

App modules	TRIZ principles	Main functions
Module 1: City encyclopedia	2, 24, 32	1. This module bases on interactive AR system and allows customers to discover the surrounding area. 2. Recommend the attracting and high rated stores and services.
Module 2: Smart parking	10, 28	1. Direct the cars to the empty parking grids. 2. Record the cars location and provide cars finding guidance.
Module 3: Mall directory	15, 17, 28	1. Show the detailed routine guidance between any two locations in the shopping mall and present the routines on the 3D map.
Module 4: Shiok	5, 15	1. This module integrates all the member cards, coupons, parking deductions and consumption points 2. Receive the real-time discounts provided by the stores nearby
Module 5: Smart pay	11, 28	1. This module allows customers to make payment by scanning QR code and they can also pay for the parking fee on the self-service machine. 2. The parking deductions, consumption points, coupons and other prizes will be automatically integrated by Shiok module once after the payment is finished.
Module 6: Smart recommendation	1, 2, 32	1. Construct customers' personal profile according their trial and purchase record. 2. Recommend the suitable products based on the customers' profile and maximize the discounts. 3. Provide detailed information of restaurants, including the rating of courses, the environment, the service attitude and the length of queue.

The resulted design has the following advantages to deal with the four major problems, seven failure points and three waiting points. Detailed descriptions are listed as follows:

- City encyclopedia module can solve failure point 1
  This module can help the customers to figure out the interesting and high-rating stores with AR system, which may attract them to step in the stores. The interaction between stores and customers can be enhanced.
- Smart parking module can solve waiting point 2 and failure point 8
  This module can show the location of empty parking grid and provide detailed routines when the customers drive into the parking lot so that it can shorten the time of finding parking space. When customers want to leave the mall they can find their cars with the guidance of the app since the car position has already been recorded in the module. With the function of this module, the customers' satisfaction of parking service can be improved.
- Mall directory module can solve failure point 2 and failure point 3
  Customers should just select their current location and their destination on the map menu interface, and then the shortest routine between them will be displayed on the 3D map interface of the app with detailed guidance.
- Shiok module can solve the failure point 3, failure point 5 and failure point 7
  This module can integrate all the coupons and member cards. All the consumption points and parking deductions will be involved in this module automatically after the payment. Customers will also look for real-time discounts provided by the stores nearby with this module.
- Smart pay module can solve waiting point 2 and waiting point 3
  This module allows customers to make payment by scanning the QR code instead of waiting in front of the cashier desk. If customers want to leave the mall they should just insert the parking card into the self-service machine, scan the QR code to pay the parking fee and then get the card back. The deductions will also be used automatically. They can insert the card into fence machine at the exit of the parking lot and leave, which can save a lot of waiting time.
- Smart recommendation module can solve failure point 4 and failure point 6
  This module can record the customers' trial and purchase to construct their personal profiles so that it is able to provide intelligent recommendation and optimized products portfolio to customers and maximize the discounts. Furthermore, customers can also get detailed information of restaurants, including the rating of courses, environment, service attitude and length of the queue, which make it more convenient for the customers to select the most suitable restaurants. This module can help restaurants reduce the complaint rate and also increase the turnover rate.

4. Conclusion

This study depicts the service process of the shopping mall with service blueprint. The problems are analyzed and corresponding service resolutions are formulated based on TRIZ methodology. A new mobile app with 6 function modules is also designed to reconstruct the service process. To the customers, the service innovation enables the

customers to minimize the waiting time and optimize the discounts. Some customers' complaints, such as forgetting the deduction, are also prevented by the app. To shopping mall, the indoor guidance is enhanced by the mobile application, which can provide the direction guidance, the detailed information of goods or restaurants, real-time discounts and recommendation. This paper is an empirical case study of a shopping mall in Taipei and it tries to improve the service quality and shopping experience. It also enriches the literature of shopping mall service design by extending the application of TRIZ methodology into shopping mall area. For the generalization of the proposed solutions – "i-love-shopping", it can be generally applied to other shopping malls or department stores and the module of City encyclopedia can also be used, more generally, as a discovering service by other service providers in the specific commercial district. Due to the research limitation of project time, we will collect some more empirical data of the launching system in our future work for the service evaluation. The comparison with the as-is system and the to-be system will be conducted as the approach of our evaluation. Moreover, more TRIZ-related approach and other design methods will be incoporated into the extended reserch of this work.

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Design of Personalized Product Service System Utilizing Multi-Agent System

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Abstract. In the dynamic changing world, problems of uncertainty are doubtlessly crucial issues for firms, investors, customers, and all other members in the value constellation. To achieve sustainability, reduce the risk of uncertainty, and fulfil a variety of customer needs, the concept of Product Service System (PSS) has been proposed as a solution. Although there are several previous studies working on PSS development, there is no dynamic methodology to quickly adjust for external changes and customer response. According to the above gap, this paper presents a Multi-Agent-based Personalized Product Service System (MAPPSS) development model. An agent-based model is built to develop a personalized PSS prototype. In this model, users are able to decide the expected service characteristics, and service composition would be conducted by searching related product and service. Different synthetic solutions are then prioritized by the evaluation agent module, and the final PSS prototype is generated. With the application of the proposed method, competence of enterprises can be enhanced due to the improved agility and user-oriented features. The generated PSS can also be improved immediately by constantly monitoring the performance and through the iteration of the proposed method.

Keywords. Product service system, Multi-agent system, Service engineering, Personalization.

Introduction

According to the sustainability becomes an important issue, the product itself can no longer satisfy customer due to the changeful world and diverse customer needs. Through the conversion of PSS, the recently concentrated issues, sustainability, uncertainty, and the emphasis on customer needs could be well discussed. There are plenty of previous studies which discussed about different types of PSS design process. However, none of them provide a dynamic and agile development framework for PSS. The aim of this paper is to fill the gap of lacking a PSS development methodology which is able to quickly respond to external changes and diverse customer demands. A Multi-Agent-based Product Service System development model is introduced in this study to solve the problems of uncertainty while designing a PSS.

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1. Literature Review

To achieve sustainability, the concept of Product Service System (PSS) have been initially proposed in 1990s. Through the combination of tangible products, intangible services, and backend supports, a product service system is established, and firms' competitiveness can be increased by fulfilling specific customer demands and achieving the goal of sustainability. Plenty of PSS development methods have been invented in recent years. Chiu et al. [1] proposed a process which could develop a PSS business model to extend current products or services into new market segments. Berkovich et al. [2] proposed a Requirement Data Model for PSS, assumes the PSS can fulfil various requirement and considers the relationships of each requirement. Through systematic process, Marilungo et al. [3] support PSS design from early lifecycle with User-Centered Design principles to enhance the satisfaction.

Durfee and Lesser [4] initially defined MAS as follow, "a loosely coupled network of problem solvers that interact to solve problems that are beyond the individual capabilities or knowledge of each problem solver". These problem solvers also named agents which have their self-interest, and they can reach to agreements by communicating, coordinating, and negotiating with others. Agents group up into organizations, and in the organizations, agents are able to interact with one another. Through interaction, organizations can affect current environment simultaneously. MAS has been applied to many previous fields. Yu et al. [5] introduced a Problem-Oriented Multi-Agent-based E-Service System to support remote maintenance decision-makings. Mishra et al. [6] proposed a multi-agent framework for reverse logistics planning. In the previous studies, the researchers indicated the unsolved requirements for the next generation manufacturing, such as full integration of heterogeneous software, hardware systems and quick response to external changes

Customers become more difficult to choose products due to variety of product alternatives. Enterprises are struggle to survive due to various and ambiguous customer requirements. To overcome these new problems, the new marketing strategies proposed. For example, Amazon recommend products based on user preference and purchase histories, Google provides advertisement based on web usage. Both of them apply the concept of mass personalization [7]. Recommendation systems have been widely applied to recommend products to customers [8]. Collaborative filtering algorithms has been known as the techniques that have been applied in numerous different applications. Cacheda et al. [9] compared the techniques of recommendation system. Memory-based and Model-based are considered as two main algorithms. Memory-based algorithms generate the recommendations based on the user rating data, model-based algorithms construct a model by experts to represent behaviour of users.

2. Methodology

This study aims to propose a personalized PSS development model which applied recommendation system for mass personalization, multi-agent system to deal with dynamic environment. In the following sections, we would introduce the structure of proposed system and the algorithm (Figure 1).

2.1. Multi-Agent Based Personalized Product Service System Development Model

- Sensor Agent Module & Rating Agent
  Sensor Agent module is built by several individual agents who are responsible for detecting environmental changes such as weather condition, inventory, logistics…etc. The collected data avoid proposed system from providing the unavailable, unsuitable item. In recommendation system, rating score considered as the factor to judge the users' preference. Rating Agent is responsible for guiding users to evaluate the products or services with photographs, descriptions, price and reviews written by other users.
- Similarity Agent
  In the proposed system, we applied memory-based algorithm to generate personalized solution. The procedure of algorithms can be divided into two phase similarity computation and prediction computation. Once a new rating score update to database, Similarity Agent would dynamically conduct similarity computation to keep the accuracy of algorithm. Through the computation, the similarity between items can be calculated. The computation would be demonstrated in section 2.2.
- User Package Agent
  The tasks assigned to User Package Agent is to organize the requirement submitted from users as the package. The user submit specific requirement with predefine parameters such as budget, period, situation…etc.
- System Agent & Selection Agent
  System Agent aims to ensure the sustainability of PSS prototype. After receiving the user package, System Agent would formulate the constraints and the goals respectively for searching products or services. Once the products and services selected by Selection Agent, System Agent would assess the possibility of the combination, judge whether the estimated cost meet the budget or not. The solutions would be displayed by Recommendation Agent. Through the formula proposed by Sarwar et al. [10], Selection Agents computes the prediction value and pick up the most suitable items for target user.

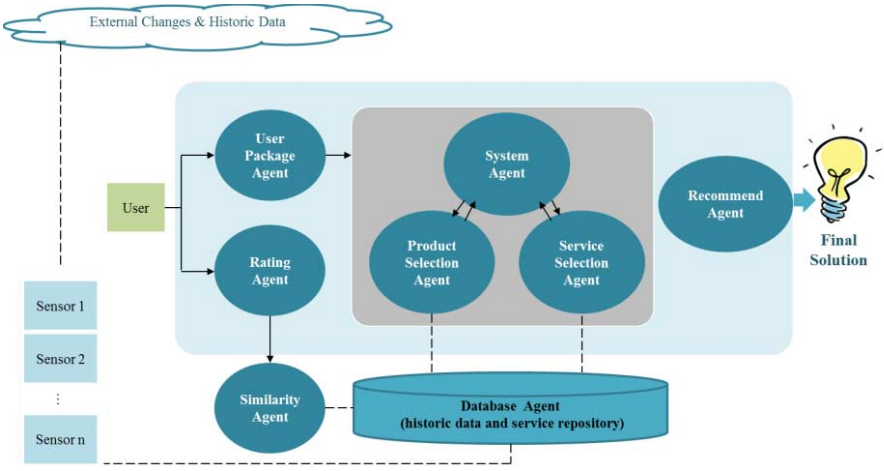


Figure 1. The Architecture of Personalized PSS Development Model.

2.2. The Algorithm of Recommendation System

This study applied the memory-based algorithms to generate the personalized recommendation. Memory-based algorithms utilize the user-item dataset. Through the computations, the user would receive a personalized list of items.

Pearson-r correlation applied to calculate the similarity in several studies. However, the difference in rating scale between different users impact the performance of computation. To overcome the problem of rating scale, Sarwar et al. [9] proposed the adjusted cosine similarity that replace the average score of specific item with the average score evaluated by target user. The formula is shown as Equation1.

$$S_{i,j} = \frac{\sum_{u \in U}(R_{u,i} - \overline{R_u})(R_{u,j} - \overline{R_u})}{\sqrt{\sum_{u \in U}(R_{u,i} - \overline{R_u})^2}\sqrt{\sum_{u \in U}(R_{u,j} - \overline{R_u})^2}} \tag{1}$$

Based on the similarity, the system applied weighted sum to computes the prediction value which is shown as Equation2. Each rating would be weighted by the corresponding similarity with similar items. Through the computation, the prediction value of each item would be generated. The computed prediction value indicated how good the item might meet target user's preference.

$$P_{u,i} = \frac{\sum_{j \in I_i}(s_{i,j} \times R_{u,j})}{\sum_{j \in I_i}(|s_{i,j}|)} \tag{2}$$

3. Case Study

In this study, we took male clothing industry as case. The users utilize the proposed system to get personalized PSS. The application of proposed approach can be illustrated in two aspects which include interfaces and backend system. Through the interface, users could submit their personal requirement with predefine parameters. According to the requirement, Sensor Agents would collect the data with specific situation in the backend. For example, once a requirement submit from city A, Sensor Agents would collect the data which include local weather forecast, inventory hold by nearby shops, logistics system. Through the rating page shown as Figure2, Rating Agent would guide users evaluate the items depending on photograph, price, and description from 1 point to 10 point. In backend, Similarity Agent, System Agent and Selection Agent would remain active. Similarity Agent dynamically update the similarity matrix with new updated rating scores. Based on the similarity matrix and the constraints set by System Agent, Selection Agent conduct prediction computation to pick up the items meet the target users' preference. System Agent not only set the rule for searching products/services but combine the selected items as the most suitable PSS prototype. In the last stage, the interface present the final solution for user shown as Figure 3.



Figure 2. Rating page.



Figure 3. Recommendation page.

As we mentioned, PSS is proposed to achieve sustainability. The performance index of sustainability could be classified into three aspects which include people, profit and planet. In this study, a total of 8 criteria — people (customer acceptance), profit (cost, equipment, inventory and transportation fee), planet (product utilization efficiency and energy utilization efficiency) — were employed to evaluate the performance of PSS.

In order to evaluate the performance of proposed approach, we conduct the simulation to compare the proposed approach with original business model. First, we defined User Agents and Provider Agents to simulate the behaviour of customers and providers. User Agent differentiate with preference, the size of clothes, budget, location…etc. On the other hand, each Provider Agent has its own inventory, location, working time, price list. Second, we adjust the number of customers and provider with randomized scenarios and conduct the simulation. Hence, the proposed system and original business model could be compared with several scenarios.

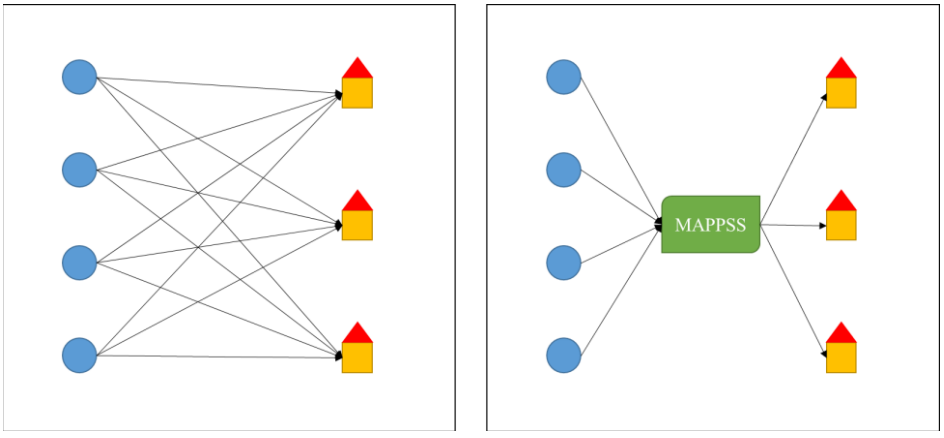


Figure 4. Comparison between original business model and MAPPSS.

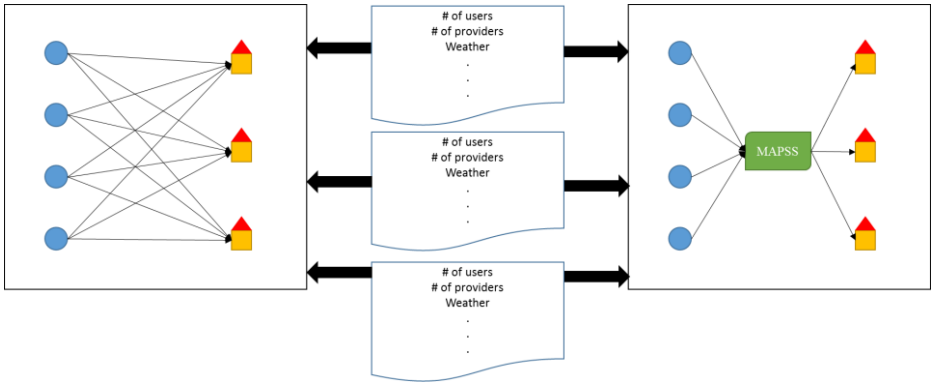


Figure 5. Simulation with Different Scenarios.

4. Conclusion

With proposed system, companies could enhance their competence by combining products and services in the real-time, dynamically. The personalized PSS solutions could assist enterprises in increasing customer value. The proposed system can also be treated as an operational management tool which firms can test their current PSS to see whether it's potential, or performs well in economic, environmental, and social aspects.

Through customer's preference, this study aims to design personalized PSS for target users. The quality of data is ignored in this study. Hence, the performance of the proposed system could be enhanced by eliminating the noise of data in future. In addition, the changing customer preference considered as a problem for designing new product/service. The limitation of this study is that it could only design PSS with the rating score evaluated by customers in past. The problem of changing preference could not be solved.

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Service Development and Style Planning of Wearable Posture Correction Products

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Abstract. Abstract goes here Various statistics show that due to the recent increase in smart phone and computer users, there has been a rise in patients visiting hospitals due to cervical herniated nucleus and forward head posture symptoms. Furthermore, this is occurring in younger age groups, and is thus developing into a social issue. Due to such needs, this study aims at finding the experience patterns and hidden needs of users in order to find 'service' development, 'product benefits' and 'user value' to create their future experiences through service design methodologies. For this, issues were found through analysis of circumstances and contextual inquiries to deduce ideas. Then, style plans were established through service blueprints per target market, and a simple products architecture was drafted to propose prototypes of wearable devices.

Keywords. Analysis of circumstance, As-Is & To-be Analysis, Service Blueprint, Style Strategy, Turtle Neck.

Introduction

With the recent increase of computer and smart phone users, improper sitting posture and longer duration of looking down has caused a huge rise in patients visiting hospitals due to inconveniences in daily life resulting from cervical herniated nucleus and forward head posture symptoms [1]. In October 2016, the Health Insurance Review & Assessment Service analyzed data on diseases related to cervical herniated nucleus. Results showed that while 62% of patients with 'cervical herniated nucleus and neck pains' were in their 40s to 60s, 61% of 'forward head posture symptom' were in their teens to 30s [2]. Taking this into account, it appears that efforts are required to prevent forward head posture among those in their teens to 30s. For health care products to prevent this, it appears that it will be necessary to development service designs that create future experience patterns by reading the empirical patterns of users rather than styling processes of general health care product designs that monitor and diagnose patients with such symptoms to share the results.

The purpose of this study is to apply service design methodologies to create various service models for wearable devices related to posture correction and to optimize such service methodologies. In order for this, this study applies service extraction techniques to extract user experiences to develop final services through quality verifications of services as scenarios suitable to the target market. Furthermore, based on the service scenario, it aims at creating a style plan and come up with simple products architecture to develop prototypes for wearable devices.

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The process of this study is shown in Table 1 below. This study focuses on establishing service development, verification and style plans centered on the hidden needs of users.

Table 1. Research process.

<table>
<tr><th>Planning</th><th>Research</th><th>Strategy Development</th><th>Strategic Verification</th></tr>
<tr><td rowspan="7">Selecting and specifying users according to service development target</td><td rowspan="2">Analysis of circumstance</td><td rowspan="3">Specific Target Market Setting</td><td>Service Strategy Validation</td></tr>
<tr><td rowspan="2">Creating a Service Scenario</td></tr>
<tr><td rowspan="2">Issue Extraction, Organize Issues</td></tr>
<tr><td>Service Blueprint Strategy</td></tr>
<tr><td>Contextual Inquire</td><td rowspan="3">Idea Map</td><td rowspan="2">Determination of Service Value and Benefit</td></tr>
<tr><td rowspan="2">As-Is, To-be Analysis</td></tr>
<tr><td>Style Strategy</td></tr>
</table>

1. Contents of Research

1.1. Issue Extraction after Analysis of Circumstances

The Analysis of circumstance was divided into Client business, User (consumer), Related technology, Competitors, Laws (regulations, regulations, certifications), Market environment (trend), Press reports, Intellectual property rights, Word of mouth.

1.2. Organize Issues

Analysis of circumstance was made based on massive and diverse data. It may not be able to extract major points or issues that should be taken into consideration, or it may lose the purpose of the analysis of circumstance due to the massive amount of data. Therefore, issues must be clearly organized after the situational analysis.

As shown in the table below, the patterns or issues from each field (analysis of circumstances + other additional areas) were summed up into three fields (user experience pattern, issue to know, issue to ask). As not all three areas are extracted depending on the target of surveys, only the contents extracted on facts were entered.

The Tables 2, 3 and 4 were not filled in due to lack of space, and only a part of the contents were filled in.

Table 2. User experience pattern.

<table>
<tr><th colspan="2">User experience pattern</th></tr>
<tr><th>Service / System</th><th>Style</th></tr>
<tr><td>- Tendency to have posture that puts pressure on lower back and neck
- Tendency of wanting to avoid showing others of posture being corrected
- Tendency of poor posture lowering concentration on work
- Tendency of leaning forward even when standing up due to smart phones. .....</td><td>- Tendency of having high preference for accessory types
- Tendency to be uncomfortable because chairs do not fit the user's physical size
- Wore rubber/silicon wearable devices, but had severe contamination.. .....</td></tr>
</table>

Table 3. Issue to Know.

		Issue to Know
Consumer	User	Living in Uniforms. .....
	Buyer	Slow adaptation to smart devices than expected. .....
Trend	User	The Wellness Wearable Device focuses more on the user's self management than treatment. .....
	Buyer	Because wearable devices are always attached, it is possible to accumulate living habits and health information.. .....
	Developer	The existing wearable device market is normally of an accessory type linked with smart phones .....
Word of Mouth	User	Excessively frequent feedback reactions of products can cause stress. .....
	Buyer	Prefer high quality products even if it costs more
	Developer	Offers intensity control functions to gradually increase intensity. .....
Related Technology		When using fitness-related wearable devices, the form of the device should not interfere with activities. .....
Competitors		Competitors are creating platforms that can share personal health information to form a market. .....
Press Release		Press releases to understand economic trends IOT hot topic in healthcare .....
Intellectual Property Rights		It is easy to use because it is used in everyday life and is not inconvenient .....

Table 4. Issue to Ask.

	Issue to Ask
User	What fashion products are you interested in? What type of wearable do you think is comfortable to wear? .....
Buyer	What are the functions that cause desire for purchase? .....
Developer	What is the easiest and fastest form of charging? Is it possible to wash and laundry? How fast is the charge? .....

1.3. Survey (Interview) Interview content

The below Figure 1 is a survey (interview) drafting table classified as 'Before Use Question, In Use Question, After Use Question', and the question type is divided into questions related to product styles, questions related to users, questions related to services, and questions related to system.

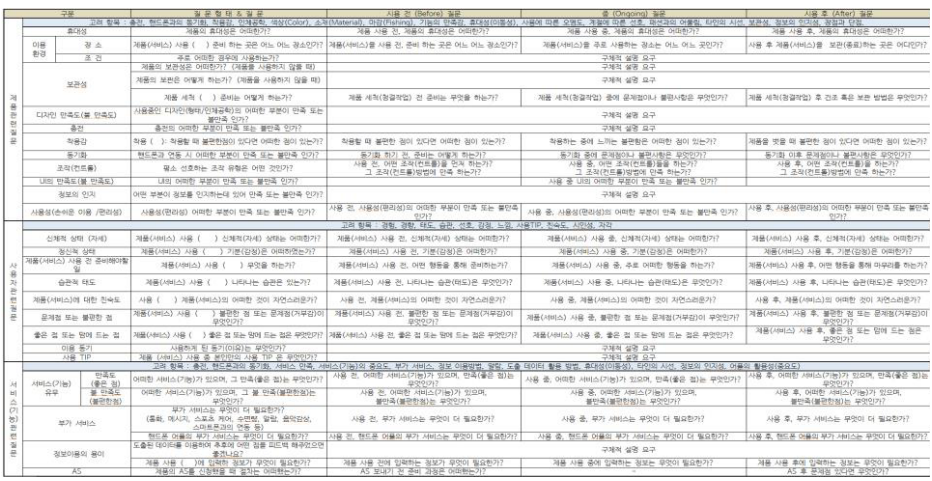


Figure 1. Survey (Interview) Interview content

1.4. Contextual Inquire

Interviews listen to answers for questions and create new questions related to the answer, and continuously expands questions, and responses to such questions are used to extract the hidden needs and insight of respondents. It was conducted as one-on-one interviews (30-60 minutes), and was carried out from October 24 to October 28, 2016. Subjects included were 18 people who experienced using wearable products for posture correction or health management for more than three months.

1.5. As-Is / To-be Analysis

The sequence of As-Is / To-Be Analysis is shown in Figure 2 below.



Figure 2. As-Is Analysis, Extracted Ideas, Organized ideas, To-be Analysis

The ordered order is arranged in chronological order, organized as Before purchase, Before use, In use, After use and Stand by.

1.6. KANO MODEL[2] Quality verification

Idea and service quality inspections were carried out through the KANO model. It was carried out from October 24 to October 28, 2016, and there were 11 subjects who experienced using wearable products for posture correction or health management for at least three months or those who experienced using such devices for at least three months in middle or high school for comparative evaluations. For evaluation of services, 11 design majors also joined for a total of 22 people.

Table 5. KANO MODEL Survey Results

Service (Idea)	One-Dimensional	Attractive	Must-Be	Indifferent	Reverse	Satisfaction	Dissatisfaction
1. Provides schedule management and posture management application for posture correction	4	13	1	5	0	0.74	-0.22
2. Services that use transparent materials to avoid the gaze of others	4	13	1	5	0	0.74	-0.22
3. Using the same design and materials as uniforms, it reduces the sense of heterogeneity.	5	10	2	5	1	0.68	-0.32
.....							
58. Services that make AS inquiry through smart phone	11	7	3	2	0	0.78	-0.61
59. a service that Lend other wearable device during repair period.	5	13	3	1	0	0.82	-0.36

Table 5 is a list of attractive quality services obtained through the KANO questionnaire. As a result of the survey, the list below is a list that needs to be strengthened when implementing the service.

1.7. Creating a Service Scenario

Through the KANO survey, excluding ideas and services found to be quality of no interest, the service scenario was drafted as shown in the below Figure 3.

The below Table 6 is part of the service scenario configured for the corresponding target market explained through texts.

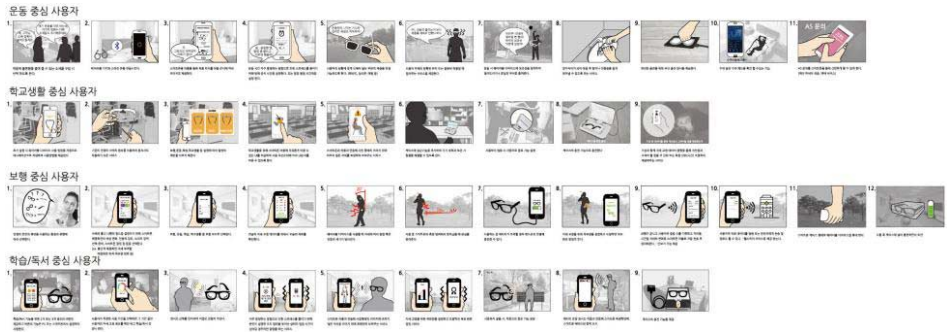


Figure 3. Service scenarios based on target markets

[2] Kano Survey Method: This is a product planning theory developed by Mitsuyoshi KANO at the Tokyo University Department of Business Administration in Japan. The questionnaire is comprised of positive and negative questions to examine the reaction of customers in order to apply in new product strategies

Table 6. Service scenario for school life target market.

1	In the initial setting, learn how to use wearable device by animation.
2	Easy to wear by using the principle of magnet on existing glasses
3	Walking, exercise, learning, school life, etc., depending on the different patterns of alarms.
.....	
9	Back up the measurement data to the PC, record the data by date, and check the status.
10	Charge through case charging function.
11	Service that summarizes posture correction data when waking up in the morning to designate and inform areas of improvement and areas needing improvement in weekly units or specified units (hours)

1.8. Service Blueprint Strategy

Service blueprints include Scenario, User Service, Weaknesses of services, Plan or System, Products Benefits, User Value, and Style Plan. These enter the contents for each scene in the corresponding scenario (Table 7).

The Style Plan, which is the criteria for style, designates the formative standard that must be configured based on the scenario to act as the source for Products Architecture that acts as the standard in the future.

Table 7. Wearable service for posture correction or health care for learning / reading users Blue print.

Theme	Wearable service for posture correction or health care for learning / reading users								
	scene 1	scene 2	scene 3	scene 4	scene 5	scene 6	scene 7	scene 8	scene 9
Service Blueprint									
Scenario	Offer two or three buttons for study/reading functions, and the functions of buttons are set and used in the PC or smart phone.	When the user selects a specific time period, check the posture correction information of the user during that period to prepare for study/reading.	The sensor recognizes the body and turns on automatically.	In order to reduce stress caused by frequently alarms, offer option to set off alarm only when a certain amount of time passes while the set angle range is exceeded	Service that indicates the location where there is a problem on a human-like image by synchronizing with the smart phone.	Set the goal for posture correction, alarm when finished	Set to shut down automatically when not in use	Displays the remaining battery level of the device on the smartphone screen	Provides charging function in case
User Service	The operation of the wearable device can be made quick and comfortable.	Can check and plan his / her correction	Easy to use	Prevent frequent alarms to concentrate on studying and reduce stress caused by alarms.	Through an intuitive interface You can check posture problems immediately.	You can set a posture correction schedule, and you can plan your goals.	Easy to use	Quickly determine battery discharge status	Charging is possible anywhere.
Weaknesses of services			Battery exhaustion due to standby	Sync with your phone is required	Sync with your phone is required	Sync with your phone is required	Battery exhaustion due to standby	The battery time of the mobile phone is reduced by the Sync of the mobile phone.	The case must be charged.
Plan or System	Device, App, and Web Sync System. Button press function when device is worn	Time selection function, check feedback information	Body Recognition Sensor	Time setting function, alarm service	스마트폰 어플과 연동해 사람형태의 이미지에 바른자세 잘못된 자세를 이미지 위에 표현해줘 보여주는 서비스	Goal setting, goal completion notification Service	The system will turn off if it does not move for a period of time.	Display the remaining battery level on your smartphone. Smartphone and device sync function	Case charging function
Products Benefits	Depending on the situation, various functions can be set by setting different functions of the buttons.	Acquire feedback information before use to prepare for study/reading time, and detect poor posture to correct posture	Battery saving, User-friendly convenience	Battery-efficient, efficient system approach	Easily grasp your own wrong posture		You can save battery.	Battery level can be easily seen.	Storage and charging can be done at the same time.
User Value	Simplified buttons make it convenient to use various functions.		User-friendly convenience	Reduces stress		Achievement	You can save battery, You can reduce the number of charge and increase the use time.	It is easy to see the remaining battery level.	It is convenient to store and charge at the same time.
Style Plan	Place the icons on the main screen and design the UI of the app to match the functions of the buttons.	UI that can select time zone by application		You can set the alarm time in the application	You can easily identify a person's position in the application. Good UII	UI that can easily see the target value from the application		Mobile phone desktop battery remaining UI required	Charger terminal required on case

1.9. Determination of service value and benefit

Value and benefits are the final objective for configuring services, and the final value and benefits of products act as the standard of designs in various areas such as product marketing and packaging. The below Table 8 shows one of four that summarizes the product benefits per each target market, consumer value, and final value.

Table 8. Benefits and Value of Learning / Reading Focused Users.

Theme	Wearable service for posture correction or health care for learning / reading users Blue print
Products Benefits	Depending on the situation, various functions can be set by setting different functions of the buttons. Time Saving Battery (energy) saving, User-friendly convenience Battery (energy) savings, efficient system approach Easily grasp your own wrong posture Battery level can be easily seen. Storage and charging can be done at the same time.
User Value	Simplified buttons make it convenient to use various functions User-friendly convenience Reduces stress. / Achievement You can save battery, You can reduce the number of charge and increase the use time. It is easy to see the remaining battery level. It is convenient to store and charge at the same time.
Value	Right posture to reduce physical pain, Convenience (storage and charging) / Achievement

1.10. Style Strategy

The below Table 9 is the Style Plan obtained through the service blueprint per target market, and it is the basic type for the wearable device.

Table 9. Style Strategy by target markets

learning / reading users Style Strategy	Place the icons on the main screen and design the UI of the app to match the functions of the buttons. UI that can select time by application You can set the alarm time in the application. .....
Walking users Style Strategy	Easily removable front and back of glasses. Sturdy design Do not make displays on the product itself. Apparatus for controlling the intensity of vibration Sensor that can detect distance between product and user. .....
School life user Style Strategy	Design the magnet to the size that can be used.
Exercise user Style Strategy Style Plan	Various design suggestions using various materials Can separate part of product to change material A structure that can attach and detach auxiliary lines to prevent loss.. .....

1.11. User-oriented design plan for products architecture[3]

The below Figure 4 is the Main Products Architecture and is a conceptual diagram illustrated based on Table 9. Such conceptual diagram is part of the process for mapping functions in types needing configuration in products focusing on users, rather than reflecting styles, and its criteria is based on the Style Plan of the service blueprint provided previously.

[3] Process of mapping functions in form (type). It is a process of integrating mechanisms that carry out intended actions and functions to the parts and sub-systems of products. It refers to the process of converting to product function type, and the component of internal parts of the product, sub-system and interaction for its communication is called Product Architecture.

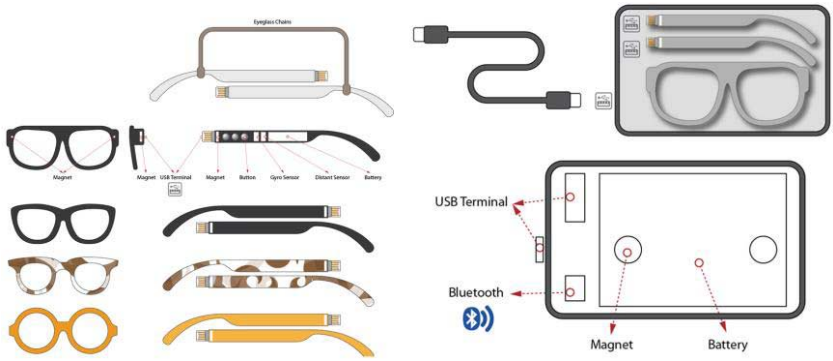


Figure 4. Main Products Architecture & Case Products Architecture.

2. Conclusion

As mentioned in the introduction, this study applies service design methodologies to create various service models for wearable devices related to posture correction and to optimize its service methodology. To achieve this purpose, experiences of those who had used them in the past were extracted and significant issues were extracted through analysis of circumstances. Through such processes, the service scenario was developed and a basic frame for optimizing services according to scenarios was proposed. Such prototype was drafted based on services, and therefore, benefits to be provided to users were included, and placed emphasis on the value of the final user.

There has recently been various service design methodologies proposed. The reason why such various methodologies are being proposed is because it cannot help but to change depending on the extraction method of user experience patterns and types of products. Hence, proposals of such various methodologies can contribute in various development of service designs, and continuous proposals are essential. As mentioned in the introduction, the purpose of this study is to develop wearable devices for posture correction. Therefore, surveys were carried out on users with experience using posture correction wearable devices. However, due to the limited number of those with such experiences, this study was carried out on about 20 people. It is necessary to carry out studies on more participants in future studies. This study is not on style development, but service development, so it does not present style development procedures.

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Transdisciplinary Engineering: A Paradigm Shift
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Dynamic Enhancement for Customer Experience by Incorporating Customer Experience Journey Map and Service Assembly Concept

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Abstract. The objective of this paper is to redesign a service in exhibition and tourism industries to dynamically improve the customer experience. To achieve greater customer experience, an integrated method which incorporates Customer Experience Journey Map and Service Assembly Concept was introduced. In doing so, two mechanisms were proposed in this study based on the service assembly concept. The service assembly mechanism was applied to respond to dynamic customer requirements. The other service mechanism, so called service replacement, was used to optimize failure handling by replacing the service failures. Using this method, a smart expo service system was designed. In the smart expo system, the customer experience of exhibition journey was enhanced from four aspects, viz. customization, flexibility, information sharing, and conformability.

Keywords. Service innovation, service design, service failure, service assembly, customer experience journey map

Introduction

Customer experience has become a significant competitive advantage over traditional elements, such as price and quality. It contributes great "progression of economic value" as an emerging product in the economy [1, 2]. The definition of customer experience is "a set of interactions between a customer and a product, a company and a part of its organization, which provoke a reaction" [1]. Customer experience implies customer involvement at different levels, such as rational, emotional, physical, and spiritual. Their expectations are one of factors of customer experience evaluation [3]. In product or service design, an excellent customer experience means it greatly satisfying the customer expectations [4]. The gap between customer perception and service value causes customer complaints and leads to service failure [5, 6].

With advanced international trade and market economy, the MICE (Meetings, Incentives, Conventions, and Exhibition) industry provides a high value to other industries, especially the tourism. Taiwan government startup has promoted the MICE industry since 2005. According to ICCA (International Congress and Convention

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Association) recent report, Taiwan hosted 145 times of international conventions in 2014. The frequency is ranked the 28th in the world and the 4th in Asia.

This paper presents the use of a customer experience oriented method, namely customer experience journey map (CXJM), which was incorporated with a service assembly concept, to enhance the customer experience of MICE industry in Taiwan. Firstly, the paper introduces the service assembly concept and discusses how to improve customer experience and service failure handling through dynamic service assembly. Secondly, a new approach that integrates customer experience journey map and service assembly is proposed. The customer experience is evaluated by the emotional range of customer behaviors. Thirdly, a case study of exhibition center design was conducted for verifying the proposed approach. A smart expo service system is designed and developed for enhance the customer experience, is designed and developed.

1. Literature Review

1.1. Customer Experience Journey Map

Customer experience journey includes all touch points over different channels that lead to the customer task [7]. Customer Experience Journey Map (CXJM), also called touchpoint or "moment of truth" map. It is a service design tool that depicts the journey of a customer, and maps the different touchpoints or moments of contact with the interactions between customers and the service. CXJM is made up of four channels: attitude, behavior, on stage experience, and backstage support. It helps the organizations reframing an outside-in presentation to customer experience [8].

Service Blueprint (BP) is an essential service design tool that focuses on representing the service performance process and relevant the human and support resources. BP helps to clearly identify and analyze the serving process flow step by step in order to improve the service quality [9, 10]. CXJM presents a similar structure and context as BP. But BP requires accuracy or precision, CXJM applies a rough customer experience to service design. Compared with BP, CXJM adds emotional attachment study to depict the pain point from customer attitudes during customer experience. CXJM takes both customer side and service side into account and can be integrated by personal and resource complementarity separately.

1.2. Services Assembly Concept

Service assembly refers to service composition. It is the replacement monolithic e-service (electronic service) with a set of smaller, more easily managed, and executable service components [11, 12]. Software environment applied numerous implementations, component-oriented or object-oriented programming design the architecture and packaging, besides interoperation between objects [13]. Process-centric assembly of service represents a discrete Web Service Component by encapsulated, iconographic building blocks to be executed within a business service [14]. There are some dynamic service composition architectures which used several different techniques to achieve service assembly at runtime. Carleton University suggested a related high-availability system called Software hot-swapping to provide heterogeneous services [15]. However, compared with e-service, non e-service faces

some challenges in implementing service assembly. It has more touch-points for different interaction modes, which could be accessed by a person, or different devices. E-service interacts between human and computer through a single touchpoint that makes the service relationship less and simple.

Similar to service assembly, Business Process Reengineering (BPR) is also a process restructuring tool. BPR aims at dramatically improving business process through fundamental rethinking and radical redesign, which reflects in time, cost, quality, and customer's regard to company's products and services [16, 17]. However, service assembly differs from BPR, it works on minor activities and coordinates with major activities to enhance overall customer experience. It is an activity-oriented approach that enables customers to dynamically assemble service instead of accepting the service delivery from the service provider.

2. Incorporating Method of CXJM and Service Assembly

This paper analyzed current service by CXJM and applied service assembly concept to the redesign. To achieve this, CXJM added a channel of emotional range, which is statistic data of sample customer attitudes not only a persona. Referring to Salovey and Mayer's consideration of emotional intelligence, and their three scoring of measures, consensus, range, and amplitude, the customer emotions were analyzed [18]. Based on the concept, a fluctuation of emotions for the same service was considered as an index of customer experience. In this regard, time is considered a contributing factor that causes the fluctuation. Three statuses of the emotion fluctuation and corresponding handling approach are presented below:

1. *A narrow fluctuation in good emotional range*, the customer experience is well, there is rare service failure occurred.
2. *A wide fluctuation across good and bad emotional range*, the customer experience is unstable, the recovery measures are required. And it presents the service is still effective for providing good customer experience as well.
3. *A narrow fluctuation in bad emotional range*, that means the service failure occurs, the customer experience is unacceptable. Redesign a new service is required.

The customer behavior in CXJM can be presented as the activity and the service components. It contains major service component and minor service component which might come from different service industries. Major activities must consider experience for the customer. Minor activities can be completely replaced or ignored, and no effect on other customer behaviors. Major activity cannot pass up but can be postponed or ahead among customer journey.

Before a planned service start, a service with potential highest failure risk is the last service the customer want to compare with other services. The customer can replace this service if there is another service which is more preferred and satisfies customer requirement. This mechanism is shown in Figure 1. It predicts most possible of good CX to reducing possibility of service failure. The failure handling concept is similar to maintenance and repair of a product. As shown in Figure 2, after a planned service start, once the customer feels the decreasing customer experience exceed their tolerance, if there are available and desirable new services provided, the customer shall transform to the new service immediately, and avoid CX worsened. This mechanism

prevents the CX continue worse to fail and the failure handling response time is zero. It is predictive and preventive maintenance of service, by replacing service failure in early stage. Compared with accuracy and complex failure analysis and recovery means, the replacement is a roughish methodology but efficient. The service with high attractiveness have higher probability of good CX. It prevents service failure before experience. Once the quality of CX is beyond customer personal acceptance, the customer can immediately replace it by new service without continuous enduring.

The physic limitations is a great challenge of implementation of service assembly concept, thus IT is a popular way and technology with less cost [19]. The process of

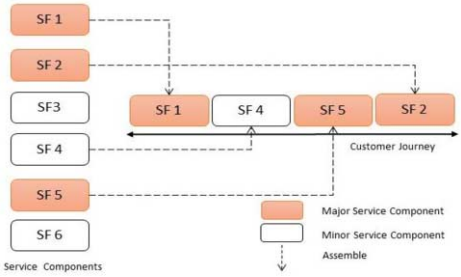


Figure 1. The service assembly mechanism.

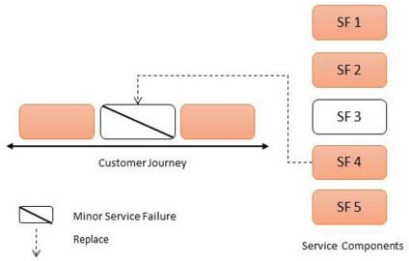


Figure 2. The service replacement mechanism.

realizing the assembly concept contains three steps. Firstly, the obtainment of service component. Different and adequate service components satisfy customization and services integration. There are two approaches of gaining service components: fragmentized current service and redesign service components. Secondly, the guarantee of customer channel. A reliable customer channel which used to real-time information exchange between the customer and the service deliver need be insured. Lastly, the smooth of linkage. The linkage between two service components require spatial-temporary comfortable to the customer. The interactive design of spatial-temporary information can help customer accept the assembly and replacement easier.

3. The Current Customer Journey of the Exhibition Center

Kaohsiung Exhibition Center (KEC) owns 25,000 square meters indoor or outdoor space and about 4,000 attendance capacity. For seeking more MICE opportunities, KEC cooperates with B company and J company to conduct a pilot run of the service innovation project. The customer journey of KEC is created by twelve customers' behaviors in sequence. Then, the attitudes, support resources, and emotional range were mapped to each behavior, which is shown as Figure 3. The customer behavior is represented as individual service component and illustrated with a box in the map. The exhibition journey contains six major service components with bold line and six minor components. The map figures out nine opportunities of service fragment or redesign after the emotional range analysis. The fragment opportunity is tagged with "*" under the emotional channel which has a wide fluctuation in both good and bad emotional range. The "#" presents the redesign point when customer experience is unacceptable. The emotion fluctuation is narrow and almost in bad range. The customer attitudes are attached to analyze opportunities, which cause the bad emotional range. "Search

exhibition information" and "Check in exhibition" present two redesign opportunities to handle the bad customer experience. "Visit exhibition" can gain good customer experience from excellent exhibition service, and may cause a bad customer experience because of insufficient facilities during the same service. "Take a relax" can archive customer satisfaction due to delicious food in the food center. However, it may lose the satisfaction because of overload customer volume. Among the opportunities, "Search exhibition information", "Check-in exhibition", and "Register an exhibition event" are major service components. These three service components can be both postponed and ahead during the journey. The others are minor service components and can be reassembled and replaced by different service components.

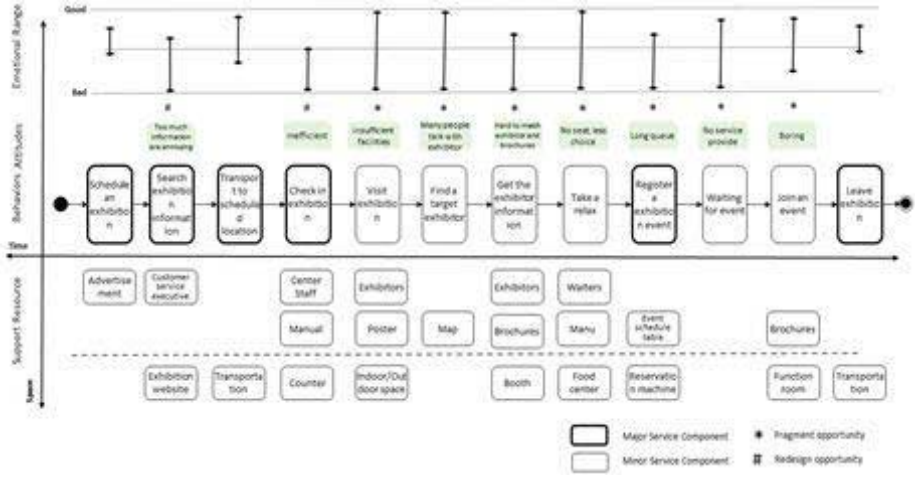


Figure 3. The current Customer Experience Journey Map of KEC.

4. Enhancing CX in New Customer Journey

Because MICE industry faces the bottleneck in Taiwan, KEC is bothered about sustaining a competitive edge in increasing exhibition issues. Meanwhile, Tourism Bureau Taiwan seeks a new opportunity to expand the tourism service. Thus, according to the three steps of service assembly, exhibitions, tourisms, and hotels fragmentize the service to service components for replacement mechanism. To ensure customers have a real-time channel for exchanging the information, B company provides service for customers to rent mobile devices. Like mobile phone with Android Kitka. 4G LTE, Bluetooth, and NFC, which provides multiple interactions with different channels. The mobile phone has been installed four applications (as shown in Table 1) to accelerate the smooth linkage during assembly and replacement. The different service components are prompted to customer channel by the applications. The applications can provide the distance from current place to where the new service provider is located, and also provide the route guide on map and transportation recommendation. The customer can be implied by that information to execute the assembly and replacement behaviors easier. KEC is a small-medium exhibition center. Taiwan has limit area and many kinds of transportations, such as bus, MRT, ubike. Due to this situation, the gap in space is eliminated, the linkage is smooth.

Table 1. The four subsystems of Smart Expo System to support the implementation of service component assembly and replacement.

Application	Features	Description
SmartLink tourism assists	(1) Exhibition information system (2) Ticket management system (3) Smart Link mobile rent service	The system integrates around shopping, tourism information and ticket management
I-Kaohsiung hotel service center	(1) Hotel management system (2) Hotels assist system	The system integrates hotels and promotions, information around KEC, and provides sites of physical customer inquiry center.
Smart KEC	(1) KEC system (2) Beacon system	The system provides the exhibition and exhibitor information by indoor locator.
O2O e-tickets	(1) e-tickets management system (2) GPS Route guide system (3) NFC tag the recommend system	The system links with other companies and integrate sharing data like weather, transports shifts.

Before a customer journey starts, new customers rent a B mobile service or initiate the service of applications into their own mobile phone to guarantee the customer information channel. The Figure 4 shows the new customer journey map of an exhibition. Through the smart expo systems, “Smart KEC” and “SmartLink tourism assist system”, the customer plans his or her particular journey and assembles the exhibition service with selected service components. The top zone presents the customer channel, which is technique-dependent and supports facilities of dynamic service assembly. The channel interacts with visitor and connects with backup support resource for real time information exchange. Within the support resource zone, the IT facilities of smart expo systems are developed to implement the interactions. The customer is susceptible by customer channel and can affect their behaviors in both positive and negative way. As shown in the Figure 4, “Search exhibition information” and “Check in exhibition” are redesigned through the “Smart KEC” system. Customers use the mobile phone to check in exhibition online, then they can gather well-represented exhibition information conveniently by mobile application. According to the customer preference, the exhibition service components are re-assembled and a new service component, “reserve hotels”, is joined by “I-Kaohsiung hotel service center” before leaving KEC. During newly assembled customer journey, “SmartLink tourism assist system” prompts local sales information and cooperats with “O2O e-tickets” system to provide online to offline services. The customer is attracted by “Take a look walk street” and accepts the distance and time of transportation. During the phase “waiting the event”, it is replaced by tourism service component. The replaced service is what the customer prefers, which reduces the possibility of CX failure. When the customer “Visit the exhibition” and “Take a relax”, it reduces customer experience over the customer’s tolerance, the tourism service component “Go to shopping” and “Enjoy local food” are selected to replace the forthcoming service failure. The replacement can be immediately responded to CX failure by customers themselves. It extremely reduces failure handling time and avoids CX continuously deteriorates. Consequently, the customer experience is enhanced on the following four aspects:

1. *Customization*, customer assembles the service by their preference, which makes service personality.
2. *Flexibility*, the dynamism of process provides more flexible service to meet dynamic customer requirement.

3. *Information Sharing*, same kind of services can share resource to increase service scale.
4. *Conformability*, services assembly can improve cooperation between different services.

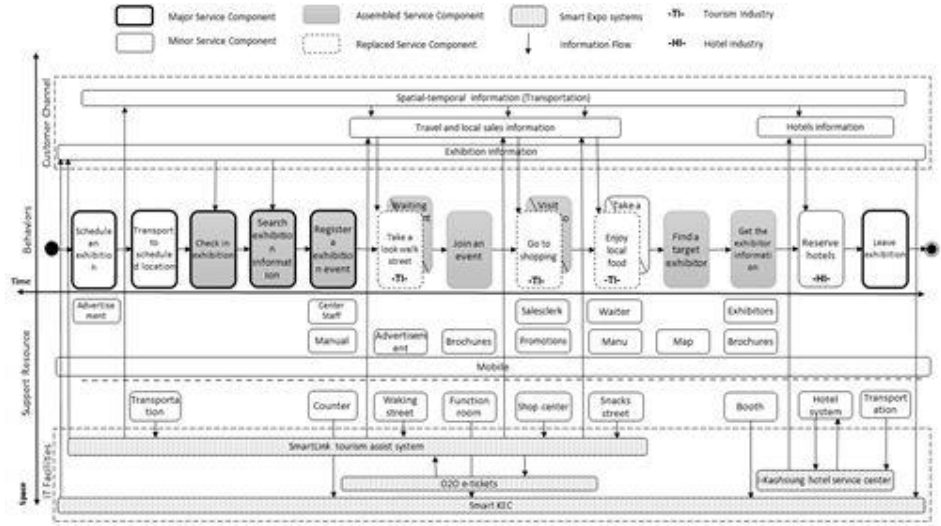


Figure 4. The new Customer Experience Journey Map of KEC with incorporated method.

5. Conclusion

A demonstration pilot project includes three trial sites: Kaohsiung exhibition center, three commercial districts with about 50 stores, 50 hotels and 100 surrounding consumer places. Meanwhile, there are four support software systems that were developed and a business service of smart mobile rent is executed to assist the implementation of service assembly. There are about 14,000 people participate the pilot run. The four systems have achieved the expected values. The project has integrated different industry services, and also improved the whole service quality and efficiency.

Acknowledgement

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Part 13

Digital Manufacturing

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Transdisciplinary Engineering: A Paradigm Shift
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Advances in Assembly Planning for Multi-Variant Production Based on 3D PDF

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Abstract. Rapidly increasing, global competition has led many companies to pay more attention to each singular requirement of their customers and, therefore, caused the tendency to small batch sizes and a greater variety of products. Assembly workload and human labor is the prime expense factor during the assembly of products. Here the hours of work by workmen multiplied with a company-specific factor equal the occurring costs. Based on the frequent use of variant-oriented product modelling, the efficiency of preparation processes has been improved. However, the assembly planning of single productions or short runs is often based on experience or the method of compare and estimate. Most production planning systems used in practice have an essential weakness in that they do not support hierarchical planning based on assembly constraints and do not observe resource constraints at all production levels. Therefore, tight synchronisation between design and production structures is necessary in early stage of the preparation and planning process in parallel to the design process. In this paper a project is presented, in which the assembly planning is put into practice based on engineering 3D CAD models in 3D PDF and a preplanned library of work steps. Through connected time values multiplied by frequency and under consideration of assembly difficulties, transparent assembly basetimes can be calculated and expectable costs can be estimated. Though connected resources the needed tooluse per workstation can be determined. Furthermore a connection of product, assembly process and resource is implicitly created by the planning process itself, which machine-readable will provide a lot of potential for future automatisms.

Keywords. Assembly Planning, 3D PDF, Cost Estimation

Introduction

Although at most manufacturing companies production and assembly costs are primarily determined by the development department, harmonization between developers and production planners is in many cases hampered by the fact that they are separate from each other in terms of personnel, organization and work at different locations and sometimes even on different continents [1][2]. The design data is not passed to the production planners until the geometry and drawings have already been worked out to a great extent and this is usually still done on paper. This means that little information that would allow concurrent engineering between development and

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production planning, and thus shorten development cycles, is exchanged during the early phase of the product development process [3].

The high level of automation exhibited by conventional manufacturing technologies (machining, forming, molding, etc.) means that assembly costs have risen proportionately measured against the total cost of production [4]. It is often the most expensive production process and is therefore subject to constant rationalization pressure [5]. A crucial corrective measure in this context is assembly-oriented product design (DfA) that facilitates efficient assembly planning [6][7][8].

1. Related work

Assembly refers to the act of putting or connecting together individual manufactured parts to create a functioning product with a high degree of complexity by means of joining, handling and control operations as well as adjustments [9]. Assembly planning comprises all of the activities that serve to create the framework conditions required for efficient assembly, precisely determine requirements in terms of human and operating resources, and deploy the resources in a targeted and efficient manner [10]. A distinction is made between operations (rough) and detailed planning (Table 1). The aim of operations planning is to develop an assembly system and to create a rough workflowchart [11]. During detailed planning, the assembly system and the workflowchart are defined in greater detail [12]. Using drawings, BOMs, the assembly structure and the rough layout, the assembly planners create the detailed layout, plan the work stations and means of moving workpieces between stations, and create the assembly plan including work instructions, calculations sheet, etc [4].

Table 1. Functions and planning phases of the assembly planning process [3].

	Task	Input Information	Output
Operations planning	Assembly System Development		
	• Work system design • Developing system structures • Capacity planning	• Assembly task • Production program • Square measures • Concatenation principle	• Assembly structure • Rough layout • Capacity requirements
	• Structuring product • Rough flow planning	• Parts list • Drawing	• Precedence graph • Rough flow structure
Detailed planning	Assembly System Refinement		
	• Principle solution planning • Workstations planning • Concentration resource planning	• Parts list • Drawing	• Detailed layout • Workstations • Concentration resources
	• Determining assembly content • Creating assembly plan and assembly documents	• Assembly structure • Rough layout	• Assembly plan • Work instructions • Spreadsheet

Generally speaking, the assembly sequence is derived from the product structure and the geometric relationships between the components in the structure during assembly planning [13]. This means that the product is broken down again into its individual parts. In some – but by no means all – cases, the assembly sequence is derived directly from the sequence in which the components were assembled [14]. Lotter and Wiendahl found that 40% of the time needed for planning is spent determining the optimum sequence for assembling the components [4]. The huge amount of time spent determining the assembly sequence has resulted in the research community focusing much of its attention on this aspect [15][16][17][18]. There are numerous approaches for determining the assembly sequence more efficiently, for example based on the sequence in which components are disassembled, an approach which however is stretched to the limit when it comes to products with a large number of variants such as large machines and systems [19]. Another major challenge is creating the assembly documents on time – documents without which the machine or systems cannot be delivered. A good overview of various planning approaches is presented by Renu.

The first result of the assembly planning is the assembly graph which represents the possible assembly sequences in a network structure as a tree structure. Herein, the individual parts are forming the leaves, inner branches are seen as sub-assemblies, which in turn are taken up by complex ramifications and, finally, end up in the root, the base element. Low-fidelity CAD models created in the early phase of product development can be used to roughly predict assembly times, thereby supporting earlier inclusion of design for assembly methods in the design process [21]. Expanding on previous work to predict assembly times from detailed assembly models, low fidelity part models are used in a series of predictive performance experiments. Results reveal that this tool can predict the assembly time of a product to within 40% of the target "as built" time using a high fidelity neural network and a low fidelity CAD model. The tool is based on structural complexity, representing the assembly graph as complexity vector of 29 metrics. A neural network is then used to build a relationship between the complexity vector (input) and the assembly time (output) [13].

Various computer-aided planning approaches are compared with an overweight of the knowledge-based and STEP-based approaches in recent years. Advanced planning approaches in the assembly planning can be subdivided in a number of categories, i.e. feature-based technologies, knowledge-based systems, artificial neural networks, genetic algorithms, fuzzy set theory and fuzzy logic, Petri nets, agent-based technology, internet-based technology, STEP-compliant CAPP and other emerging technologies [12]. It comprises a framework and organization of the conceptual assembly design system with the help of knowledge-based engineering, where it takes into integrated consideration the assembly sequence, joint configuration, and tolerance allocation in the auto-body assembly design process planning.

Heuristic knowledge and empirical knowledge play active roles in the generation of the assembly sequence and dimension chain, the configuration of joint types, and the allocation of tolerance limits [22]. Qualitative simulation is conducted by knowledge reasoning or rule reasoning with all kinds of rule, criterion, and principle [23]. In this way, the knowledge-based vehicle assembly design system can improve assembly concept quality by means of qualitative simulation to fulfil the concurrent integration between conceptual design and detail design stages. Further example of a military system is presented to demonstrate the feasibility of a three-stage integrated approach with heuristic working rules [14]. Similarly, a planning system comprises an assembled

advisory module, a knowledge-based module and a user interface. It allows users to find the best solution for the assembly process during the commercial vehicle seat assembly process. Furthermore, the planning system is able to support the design engineer in selecting the best and fastest assembly method [24].

The procedure of generating assembly instructions of complex one-of-a-kind products takes a long time, since many trade-offs between various stakeholders are needed [8]. In addition, the process can still yield some disadvantages: If errors are found in the documentation, an updated version must be created, printed and distributed. For such reason a comprehensive support by appropriate, easy-to-use tools is necessary, in particular to facilitate tasks on the shopfloor-level. Large planning systems are powerful and complex, difficult to learn and use.

To make the assembly planning process and the usability of the planning documentation more efficient, providing an assistant tool for the automation of the process is necessary [25]. In our case, the use of 3D PDF contributes the optimization of the process of assembly planning [26].

2. Planning practice and need for improvement

Most machine and plant engineers still plan and document the assembly of their systems using the object in question, i.e. they assemble the system in its entirety or in parts prior to delivery so that they can properly document the process. New photos and illustrations are often created for the assembly instructions instead of using existing material from the engineering department. This approach is not only time-consuming and labor intensive but also requires an unnecessarily large amount of space for assembling the systems.

One of the main problems, however, is that the technicians cannot start planning assembly and creating documentation until the system components have been completed, and by then time is usually short. As a result, changes made while the system is in operation are not systematically incorporated into the documentation, thus making maintenance more difficult [8]. Furthermore, detailed assembly planning can often not be started until the start of production. If it could be performed in parallel with development, problems during assembly could be detected early and cost-intensive assembly steps could be simplified. This would not only make it possible to reliably calculate assembly costs earlier but also reduce these costs by optimizing the assembly steps [1].

Companies therefore have an urgent need to start assembly planning earlier and calculate the assembly costs more reliably. Other requirements include reducing the time and effort needed to create the assembly documentation through the intelligent reuse of the 3D models from the engineering department and improving the quality of the documentation so that the risk of errors during assembly can be minimized. Companies also want to be able to update the documentation faster and with less effort when changes are made to the system.

3. Solution approach

In principle, the sequence of the assembly operations can be specified step-by-step by using a computer and 3D models of the individual components to be assembled .

However, when it comes to larger and complex systems comprising thousands of components, performance problems can quickly arise. In addition, companies would also need additional CAD workstations for assembly planning, which are relatively expensive to buy and maintain. One recommended alternative is therefore to use a lightweight format, which ideally can be animated to make the assembly operations easier to understand.

In this contribution, a solution for assembly planning is presented which is based on the 3D PDF technology.By using 3D PDF technology 3D models can be converted from all common CAD systems into the tessellated U3D or PRC format, making it more than 90 percent "lighter" than the original models [26]. 3D PDF documents and the embedded models can be viewed using the normal Adobe Reader, which is free of charge and installed on nearly every computer. Another major advantage is that the 3D models can easily be combined within the document with 2D information such as detailed views and drawings, which means that the 3D PDF is very similar to conventional assembly documentation. The documentation can be compiled to a great extent automatically with the help of the server solution PDF Generator 3D and appropriate templates.

The proposed approach is shown in Figure 1 as context diagram.

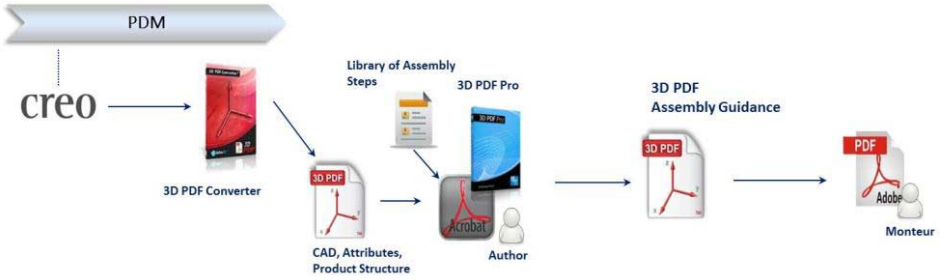


Figure 1. Context diagram of assembly planning tool based on 3D PDF

This procedure starts with either export from a PDM system or conversion of a CAD model from the archive of the product which is to be planned. This PDF data is put into a PDF pre-defined assembly template which cover all needed data for an assembly guidance.

Further work is conducted on this PDF template supported by a library of corresponding assembly steps. As the result of the assembly planning we get an assembly guidance based on 3D PDF which is used on shopfloor level as lead digital document for working instructions.

Basically, we distinguish two use cases: assembly planning (role: assembly planner) as well as assembly execution (role: assembly worker) which both must interact to achieve the optimal result. Main activities of this both roles are depicted in Figure 2.

According to this description, it is obvious that both involved business units (production planning / assembly planning, further the industrial engineering and the assembly station on the shopfloor-level) need to work interactively and collaboratively with the 3D assembly plan. The assembly worker needs the possibility to impact the planning process by his suggestions and final revision. It can be done at any time just by making a remark in the PDF document.

An important component of this solution is the assembly planning library. It comprises resources based of the Methods-Time-Measurement (MTM)

recommendation as well as the company specific experience [4]. Assembly costs are also calculated on the basis of MTM, a method that is widely used to analyze workflows and determine planned and target times. It involves breaking down all the tasks performed by humans into certain basic motions (e.g. reach, grasp, move) that can then be combined to create more complex motion sequences. This allows the time required for complex assembly workflows to be determined relatively quickly and reliably.

The concrete planning work consists of subsequent set of basic 2D/3D work instructions in regard to authoring and viewing applications. The user takes the template and adds, inserts or selects the corresponding data from the assembly planning library into the specific steps in assembly sequence. The utilization of templates simplifies the derivation of variants in case of multi-variant products which dramatically reduces costs.

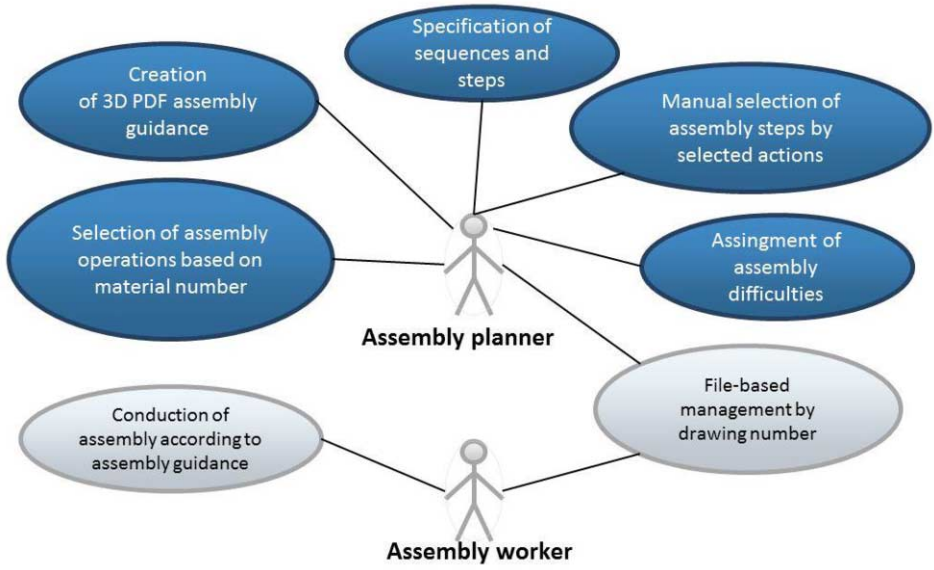


Figure 2. Activities of both roles Assembly planner and Assembly worker

The assembly guidance consists of an interactive 3D model of the related product assembly and related text description with attributes. An excerpt of the data model with main relationships between entities is given in Figure 3. This data model comprises singular assembly steps which are hierarchically structured by multiple assembly sequences. An assembly step comprises one or more assembly procedures which are linked to the related part, the needed resource and selected activity. At the definition of assembly steps, the assembly planner is supported by the assembly planning library which facilitates the selection of structured procedural objects (e.g. procedure, resource, time).

An assembly procedure gets along a text description in multiple languages, a reference to the used resource, specified activity and also reference to the parts resp. part classes by the material number as classification criterion. In particular, a reference to the product data facilitates an intelligent assistant for specific assembly functions. So in case of selection of screw joints, the assembly planner can select among several operations for join operations. Further linked variable is the time which must be

considered for the assembly time calculation and, therefore, the total manufacturing time and total costs. Repeatable operations are also considered as well as surcharge for assembly difficulties.

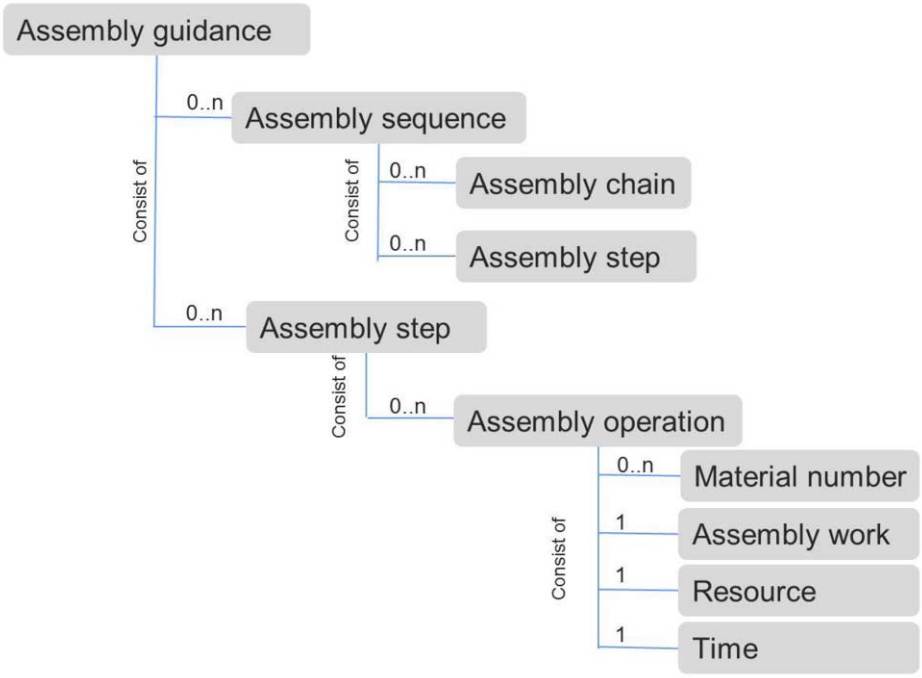


Figure 3. Entity relationships in data model.

A large library of typical assembly operations makes the planners' work easier and allows the assembly costs to be calculated reliably since company-specific cost rates can be stored for the usage. It comprises all common assembly operations, associated resources and times, and it is easy to adapt and expand to include customer-specific applications. Besides, it is easily possible to edit this data base and, for example, insert further items which describe new assembly procedures by new assembly technology in manufacturing. In Figure 4 an exemplary assembly planning process is illustrated which includes animation of singular assembly sequences and steps.

4. Interactive animation of the assembly steps

Our software for creating 3D PDFs is available in different configurations, from a desktop version to a fully-automated, server-based solution. All packages can be installed with a minimum of effort and can be used immediately. There is no need for adaptations on either the CAD or the PDM system.

Companies can use the 3D PDF-based solution to plan assembly operations digitally on the basis of the CAD models. All texts are stored in different languages, which means for example that the assembly operations can be planned in German, but the instructions can be used in English or Chinese without any need for an additional translation.

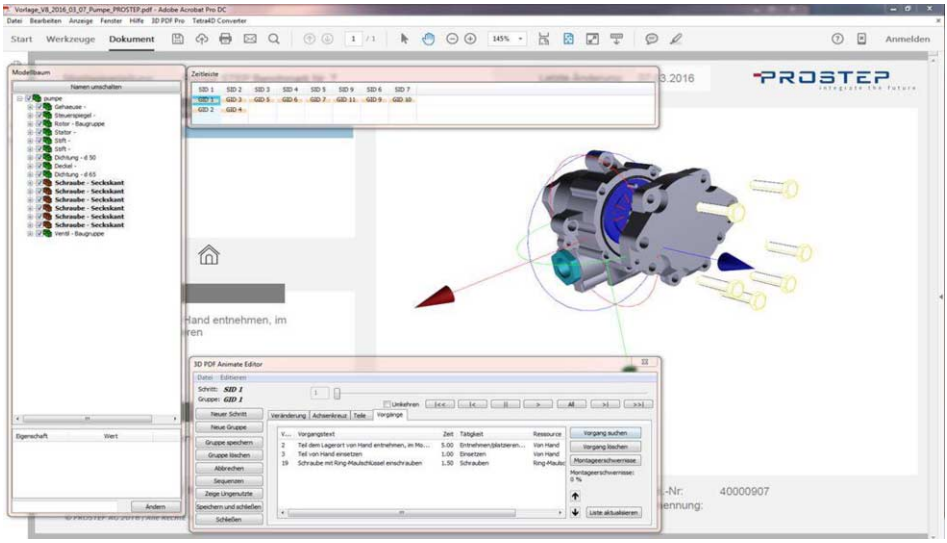


Figure 4. Authoring and assembly planning tool 3D PDF Pro.

A key strength of the our solution is the ability to animate the 3D models of specific assemblies and components irrespective of the CAD system used to create them, i.e. after they have been imported into the 3D PDF document, thus making certain assembly steps easier to understand. The 3D PDF Pro plug-in for Adobe® Acrobat® Pro provides the basis for creating the animations and allows the intuitive creation of animated documentation. The software now supports more accurate navigation in the structure tree and searches for specific component attributes. The search tool makes it easier to handle large assemblies in the 3D animations. 3D PDF Pro also makes the creation and updating of 3D PDF documents faster by automatically linking descriptive fields and buttons in the templates with the latest 3D contents. Like all the documentation, the animations created with 3D PDF Pro can also be visualized using Adobe Reader, which is available worldwide free of charge.

5. Optimal protection of intellectual property

When viewing the embedded 3D geometry, Adobe Reader, like any commercial 3D viewer, allows user to rotate and tilt the models, zoom in on them, and also take certain measurements. The functional scope of Adobe Reader can be limited when the 3D PDF documents are created in order, for example, to protect a company's intellectual property when the documentation is passed on to outside companies. It is even possible to use the optional PDF Generator 3D Rights Management module to restrict access to the documentation to certain people or impose a time limit, and also to revoke access rights previously granted.

This 3D PDF solution can very easily be integrated into an existing IT infrastructure in order, for example, to incorporate additional information from the PLM system or transfer information such as the assembly costs to the ERP system. This significantly reduces the amount of manual work required to create assembly documentation. Furthermore, the documentation can be updated pretty much at the touch of a button after changes have been made. The digitalization of assembly

planning allows this activity to be performed at an earlier phase, which contributes to shortening delivery times.

Combined with the option of incorporating animated image sequences in the 3D PDF documents, 3D visualization makes it easier for the technicians and assembly workers to understand the assembly instructions and ensures that they make fewer errors. It also allows information about problems that arose during assembly and adaptations made to be included directly in the assembly documentation using the redlining and habitation functions provided by Adobe Reader, thus ensuring ensures that this information can be used to improve assembly planning for future machines and systems.

6. Summary and Outlook

Tackling the challenge of the agile assembly planning for multi-variant production, the use of 3D PDF technology allows closer links to be established between product development and assembly planning and an earlier exchange of information between developers and planners. This is a necessary precondition for a greater parallelization of the different tasks and activities in the product creation process. Concurrent engineering offers benefits both in terms of time and costs and also contributes to improving product quality [27]. In order to reap these benefits, the tools used in development and assembly planning must be harmonized so that a seamless workflow evolves. 3D PDF documents provide an ideal means of exchanging information between both working and system environments as they contain data from different source systems and can be visualized using the normal Adobe Reader which is available almost everywhere.

The use of digital models for assembly planning makes it easier to validate the assembly of large and complex machines and systems involving a large number of variants. At the same time, 3D assembly planning is an important step towards the model-based enterprise (MBE), i.e. towards establishing end-to-end, drawingless processes and systematic utilization of existing 3D information. Thanks to its versatility, 3D PDF technology can be used to digitalize any business process in which paper documents are still used. Like assembly documentation, it can also be used to create customer-specific spare parts catalogs, maintenance and repair documents or to provide non-PLM users with 3D CAD and BOM information, for example. It also can be used as a baseline.

The presented approach contributes an important added value to production design and planning through usage of knowledge in the existing systems. The exploitation of this approach under productive conditions has recently been started and already achieved the expected results. Further development of tool sets and methods could help to reduce the high initial effort for adjustment of the data even more. Besides the evaluation of the results based on product data, it is important to investigate the behaviour and results of the methodology for new assembly and joining technologies in production [28].

This initial solution provides a basis for future enhancements using 3D PDF template technology. In order to implement future developments efficiently, the assembly planning template was designed as flexible as possible. The objective of this further development is the implementation of further derived requirements such as additional optimization algorithms [8] [18].

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The Development of Manufacturing Process Design Tool

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Abstract. Designing a design process is a crucial activity in concurrent product design environment. Though, there are several tools to design and visualize manufacturing process, e.g. Outline Process Chart, Process Flow Chart or IDEF0; the necessary information, e.g. standard, to manage processes, still can make the chart too complicate to realize. In addition, the evidence from field studies reveal that the required input variables from a considered process are not necessary to be similar output variables from the immediately predecessor process. These two findings and Control Plan as well as TQM lead to develop the novel manufacturing process design tool called the Material Alternation Product (MAP) chart. The major step forward of the new tool is accounted of which it has the capability to illustrate the important information for a considered manufacturing process, e.g. material in put requirements, variable to be controlled etc., within one chart. A hub-flange from a car is used as a case to validate the tool, moreover the validation square method is a mean to capture expert opinion on the developed tool. The results that the MAP tool is valid from the expert viewpoints.

Keywords. Concurrent Engineering, manufacturing process, design

Introduction

A process is a transformation of inputs to be a desired output, as a result each process comprises of information from required material inputs, operations as well as controlled variables and output specifications [1].

From field studies, it is found that the designing a manufacturing process is a complex activities [2][3]. Representing all required information in manufacturing processes to design team needs huge amount of document which is not in the same source. As a result, the researchers aim to develop a tool in which all necessary information can be encapsulated within one chart.

The next section reveals the available process visualisation tools each of which is examined and then research gaps are addressed [4]. Section two presents results from field studies which influence the tool developing in section three. Section three, four and five are tool validation and discussion of the results consecutively.

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1. State of the art in Manufacturing Process Visualization and Design Tools

To review the state of the art for process visualization and design tools, the researchers focus on three keywords as process flow, manufacturing process and Total Quality Management (TQM). The last keyword is necessary in industrial environment because most manufacturing entities follow the TQM philosophy especially those obey either ISO 9000 [5] or AS9000 [6] (aerospace manufacturers). From literature, IDEF0, Outline Process Chart, Flow Process Chart and Process Flow Chart are investigated. There are two aspects for analyzing the existing tools which are the capability of the tool and the capability to encapsulated information. In each manufacturing process, material inputs must be transformed to be a product output by sets of actions. In addition, both material inputs and product outputs are described by specifications, while each action is controlled by standard. The results from analyzing four existing tools are shown in Table 1.

IDEF0 represents each action in a manufacturing process as a function name each of which receives inputs and delivers outputs. At the same time, each action has to be controlled by mechanism. However, specifications of input and output are not attached in the diagram.

Table 1. The comparison of encapsulated information for charts representing manufacturing process.

Tools	Encapsulated Information
IDEF0 [7]	- Input and Output
	- Operation (function name)
	- Control
	- Mechanism
Outline Process Chart [8]	-Operation name
	-Inspections
	-Time for each Inspection or Operation
	-Material input specifications
Flow Process Chart [9]	-Operation (name)
	-Transport (location)
	-Delay
	-Storage
Process Flowchart [10]	-Start and end
	-Operation
	-Decision
	-Input and Output
	-Annotation
	-Predefined Process
	-Preparation

The Outline Process Chart and Flow Process Chart come together as a package to describe assembly process rather than explaining a single part manufacturing. The Outline Process Chart shows the overview of assembly processes and how to

manufacture each part, moreover it shows each operation name and period as well as inspection time. In addition, the specifications of material input for each part are given, but the specifications for either each part or a complete product are not considered as important information. The Flow Process Chart provides the detailed operation of the Outline Process Chart by which includes additional information on transportation, delay and storage [11]. However, the input and output specifications are still missing. Whereas the detailed information for operation getting from both tools is describes in another document.

The existing process visualization tools can be able to explain manufacturing process [12]. Though, they are tools for improving manufacturing process, the application for monitoring and control needs more discussion. For corrective action purpose, process visualization tool should ideally navigate to the locale of each problem. The researchers conduct further investigation in field studies in the adjacent section.

2. Industrial Field Studies

Data collection is conducted in two automotive tier 1 suppliers in Thailand, and the Case Study Research approach is applied.

In order to avoid bias, two questions are asked as follows:

- What kind of tools or charts do you use for designing manufacturing process?
- Apart from designing manufacturing process, do you use the mentioned tools or charts for other purposes? Please clarify.

There are three interviewees. Two from company W the other works for company X, and all of them have more than 25 years of experiences. Company W supplies stamping parts, moreover, production tools are design in-house. Company X delivers machining parts; furthermore, production lines are designed in-house.

ISO9000 and TS16949 are applicable for both companies [13]. Both companies have never experienced IDEF0 for designing process. The Outline Process Chart and Process Flow Chart are realized in manufacturing process design. In addition, the Outline Process Chart appears in Control Plan, which is crucial during production. It is assumed if all variables in a manufacturing process are in control, each final product should be in an acceptable range.

Showing material movement within a considered manufacturing process is the main purpose of the Flow Process Chart. As a result, this chart is suitable for process improvement, e.g. Kaizen, than designing a new process from scratch.

Both companies work in international environment, because they accredit ISO9000 and TS16949. It is found that the existing manufacturing process design tools are realized in automotive industries except IDEF0. In addition, the Outline Process Chart and Process Flow Chart can be able to visualize process for process design purpose, but for managing process (monitoring and control as well as analyzing manufacturing defective) the Flow Process chart is applied.

For the researchers, it is a challenge to create a tool for multi purposes of usages. There are a lot of tools which implement in product design and development. If the newly developed tools can be used for designing and managing a process, this will be beneficial for industries than separating tools as found from field studies.

3. The Development of MAP chart

The newly developed tool must show the details of how each process transform material inputs to a final output. Specifications of material inputs and outputs for each sub-process should be explicitly revealed, however, the tool must not be too complicate and overload with information. In brief, designing a new manufacturing process will be a benefit from the tool and it should simple enough for managing process during production.

The researchers develop a novel tool called Material Alternation Product (MAP) chart [14]. The critical assumption for this tool is manufacturing process is sequentially proceeded. The example of MAP chart is shown in Figure 1. Obviously, there are several sub-process in a certain manufacturing process. A rectangle is represented as an action or sub-process. Within each action, there are two rectangles, one circle and two arrows. Those two rectangles in each action contain a Planned Input (PI) and a Planned Output (PO) consecutively, these two terms specify a material input and an output conditions. Whereas the circle represents the focused action or Process Characteristics (PC). Both arrows show inflow and outflow from the PC.

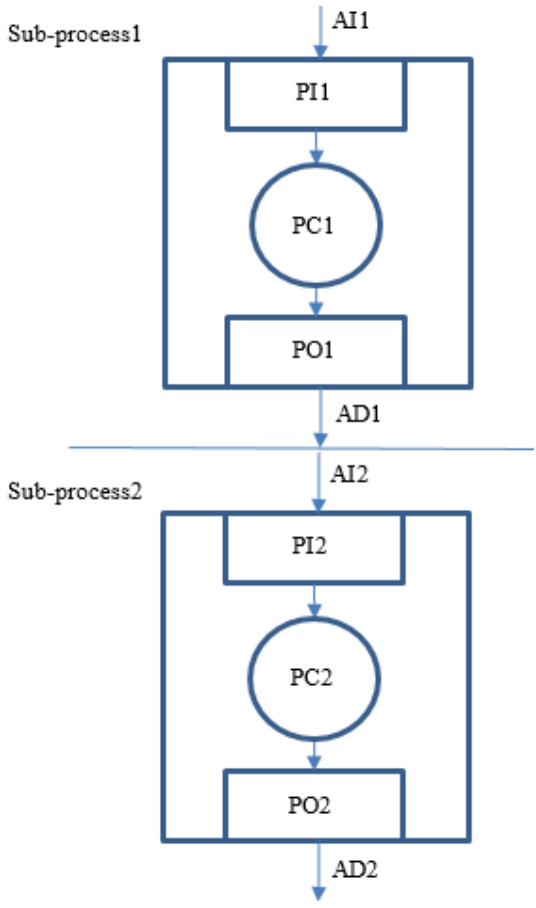


Figure 1. Schematic of the MAP Chart.

An input arrow on the top of the MAP chart explains input characteristics from which are accumulated actions upon material since upfront sub-process. As a result, it is called as an Accumulated Input (AI). PI and AI are not necessary to be alike. PI describes the needed condition of a material or a semi-finish good before receiving an action in the considered sub-process. Similarly, the output arrow at the bottom most denotes the characteristics of the physical product called an Accumulated Deliverable (AD). Again, PO defines the target conditions of the physical product as resulted by PC, while AD states the result of adding on actions to product since upfront until a current sub-process. Again, AD from the current sub-process is not necessary to be similar to AI for the adjacent sub-process.

4. The Validation of MAP chart

The MAP chart is validated with an automotive hub-flange (Figure 2). Raw material is made by hot forging, and then sends to company X for machining. Apart from receiving raw material and inspection, there are two turning processes. The critical parameters to be controlled are the surface roughness as well as parallel and dimensions. Surface S1 is at the hub while S3 is the back surface, both of which need to be parallel. Moreover, the diameter of the hub-flange is restricted as D1 while the thickness measured between surface S1 and S3 is maintained as T1.



Figure 2. Hub-flange.

In this case, the hub-flange manufacturing process is visualized in a MAP chart as shown in Figure 3. Due to intellectual prosperity, detailed information related to product are covered. Each hub-flange is produced by hot forging process. The hub position is curved out one side but the other is curved in. Supplier provide products together with mill sheet to confirm specifications as denoted AI1. Shop floor workers check the mill sheet before put each work-piece into CNC lathe machine to start turning process 1. Before clamping the specimen, workers must make sure that there are no crack, no burr and no rust (PI1). Later, the clamp position and other turning

conditions must be satisfied (PC3). Clamp positions are located at the center hole and the circumference of the hub-flange. The diameter of the hub-flange (D1) is satisfied as one outcome from PC3. Remember that the D1 is not completed at the location of clamping. Apart from D1, other elements in PO1 are conserved by visual checked whereas the measurement is taken place for AD1. Surface hardness at S1 and S2 is checked whether both surfaces are removed too much or not. Once all variables are checked, AD1 is completed. The mill sheet is developed for each manufacturing batch, while the physical products are kept in store.

To start turning process 2, shop floor workers take semi-finished products from store and check mill sheet (AI2). The surface S1 and D1 must be checked and the work-piece must have no crack, no burr and no rust. After turning process (PO2) the dimension D1 throughout the edge is satisfied visually. Surface S3 is finished and all six holes are drilled through. After checking for parallel between S1 and S3 as well as measuring all variables, AD2 is completed and mill sheet is delivered for the considered batch. Apart from deburr as visual checked, characteristics in AD1, and AD2 are sampling one from five working piece as suggested by TS 16949.

The MAP chart for manufacturing is developed by the researchers and later it is shown to process designers in company X for checking its validity. The experts accept that the method is easy and it has high ability to communicate among team members. All validation activities are supported by validation square method [15].

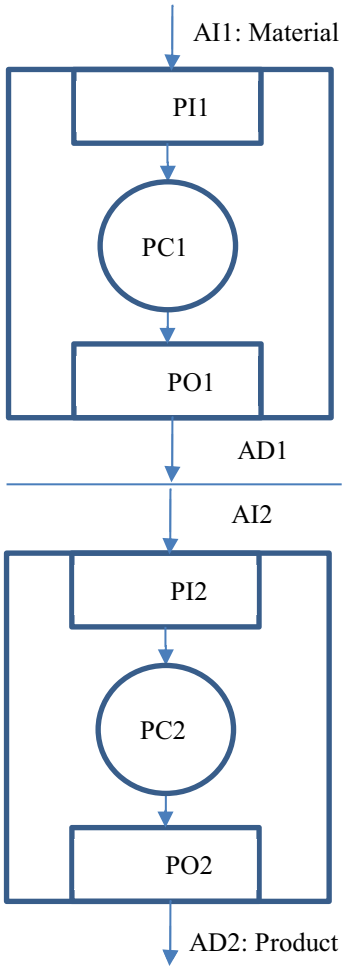
5. Discussion of the result

The MAP chart has capability to visualize manufacturing process as well as represent critical information. From last section, this is the evidence to proof that the input before receive action (PI) and accumulated input (AI) is not necessary to be similar. For output of sub-process 1, the outcome of PC1 are D1, Roughness of S1 and S2 but these three variable cannot be mearsured while turning process 1 and 2 (PC1 and 2). Once surface hardness of S3 is tested and parallel between S1 and S3 is confirmed, AD2 is commpleted. It is interesting that variables in AD2 are the result of PC1 and PC3 whereas PO2 is solely from PC2.

6. Conclusion

The MAP chart can visualize manufacturing process and represent necessary information. Moreover, the process designers from company X support the validity of the newly developed tool. As a result, the researchers claim for the success at this stage.

However, the researchers suggest to validate the tool with other complex manufacturing processes. The assumption of the MAP tool is the manufacturing process is always sequentially completed in detailed. Any processes concurrently executed are still a challenge at the moment.



AI1: Specifications (Mill Sheet)
PI1: Speciment Condition (No crack, No burr, No rust)
PC1 (Turning1): Clamp position, Spindle Speed, Coolant setup, Tool life
PO1: Visual check (D1, Roughness of S1 and S2, Deburr)
AD1: D1, Roughness of S1 and S2, Deburr, Hardness

AI2: Specifications (Mill Sheet)
PI2 : D1, S1, Speciment Condition (No crack, No burr, No rust)
PC2 (Turning2): Clamp position, Spindle Speed, Coolant setup, Tool life
PO2: Visual Check (D1, Roughness of S3, Hole dimensions and positions (6 holes), Deburr)
AD2: D1, Roughness of S3, Hole dimensions and positions (6 holes), Deburr,T1, Paralell S1 and S3

Figure 3. MAP chart for Hub-flange manufacturing process in company X.

It is found during the development that control plans are the tool for representing manufacturing process and key controlled variable, but it is a lengthly document for shop floor workers. The researchers aim to further develop MAP chart to be a handy tool.

In addition, the researchers try to apply the MAP chart for other applications such as for finding root causes of manufacturing problem. Other applications beyond manufacturing process are also future research targets.

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Simulated Annealing Algorithm-Based IMMK System for Mould Redesign

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Abstract. The mould industry, a typical single-product customized mode, has the feature of complex structures and a high degree of differentiation of engineering requirements. It is still difficult to ensure a successful mould test at the early stage considering the complexity of mould parting surface and structure. In order to to facilitate the accuracy and efficiency of the mould redesign, this study proposes an injection mould modification knowledge (IMMK) system based on the simulated annealing algorithm (SAA), in which the historical injection mould modification data can be analysed and re-utilised as IMMK. Especially, latent semantic analysis is used to build the knowledge repository. It has been applied in a collaborative mould factory to evaluate the effectiveness and some significant developments have been shown in practical case that it can significantly improve the accuracy and efficiency of the redesign process.

Keywords. Mould redesign, simulated annealing algorithm, IMMK system, knowledge management.

Introduction

The mould industry has the characteristics of high precision, efficiency and durability, which has been widely applied in all kinds of fields [1]. According to the research of [2], moulded parts represent more than 70% of consumer products ranging from computers, home appliances, medical devices, to automobiles, etc. With the booming of the mould industry, a great deal of attention has been paid to shortening the product development time to strengthen the competitiveness of the enterprise [3]. However, the enterprises often have to redesign and modify moulds due to design errors and complex manufacturing process, which result in poor mould-making and moulded products, thus wasting time, money and manpower [4][5]. Mould design has the characteristics of directly relating to the mould manufacturing processes and manufacturers often record the cases with specific parameters, which provide great potential value to improve the design activities. Therefore, the designers are eager to refer to the previous case [6].

As an essential role in the product life cycle, mould design activities are characterised by high dependency of experience and generation of vast amount of data [7], which however remain hardly underutilised and in most cases completely unexploited. Take plastic injection mould as an example, the process between order received and mass production is a typical scenario where a variety of data could be produced, like the planned project, design geometric data and modification recording.

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However, new design could share numerous commonalities in the process, parameters and even the same issues with the past cases. Nevertheless, many previous design knowledge reuse systems focus exclusively on geometrical data, which is often not applicable in early design stages [8]. Due to the uncertainty of mould materials quality, diversity of the constomer demand, etc., therefore, it is almost a necessity to modify every mould in some extent. The main purpose of this paper is to develop a knowledge management system that incorporates multiple data formats to provide a timely solution for the redesign of injection mould [9].

1. Related work

Currently, a lot of research has been made through the integration of CAD system and knowledge management to improve the efficiency and effective mould development. For instance, in order to expedite the retrieval process and provide useful information to the users, an integrated process is proposed [10], which define and calculate the similarity between free-form geometries with regard to their shape. The process can assist the users to find similar designs from the CAD database according to the similarity level. Aiming at shortening the life cycle of products, a web-based navigating system for conceptual mould design with knowledge management within the computer-aided design (CAD) embedded browser is developed [11], which integrated CAD and web-based management seamlessly by the dedicated application programming interface (API). Similarly, to use existing geometry in other contexts and applications, an analysis of formal CAD modelling strategies and best practices for history-based parametric design is presented [12].

In the research of simulated annealing algorithm (SAA) for manufacturing domain, a new hybrid optimisation approach is introduced by SAA [13], which is applied to shape design optimisation problems from automotive industry [14]. To establish an optimal size and shape of the sample designs, SAA was used by source [15] to obtain these designs for the prediction of space dependent variables. Due to the fact that aggregate production planning (APP) is one of the most considerable problems in production planning, multi-objective linear programming model for APP and optimised by SA is presented [16].

Although lots of research has been done, studies on how to reuse the knowledge of mould redesign, including text and CAD data, to achieve a more efficient and effective injection mould redesign is scarcely covered.

2. Overview of the IMMK system

As shown in Figure 1, the proposed framework has three layers, which are an input layer, the Simulated Annealing Algorithm-based Injection Mould Modification Knowledge (SAA-based IMMK) system and an output layer.

The input layer is composed of the design problems. For each problem, it consists of four representative features that include product name, the existing problems, the reasons for the problems and auxiliary information. The output layer shows the potential solutions for the design problems. Figure 2 shows the format of a redesign case. It is composed of the features of the design problem of the input layer and the

solution of the output layer. In particular, the potential solutions will be verified and stored as a redesign case for further reuse.

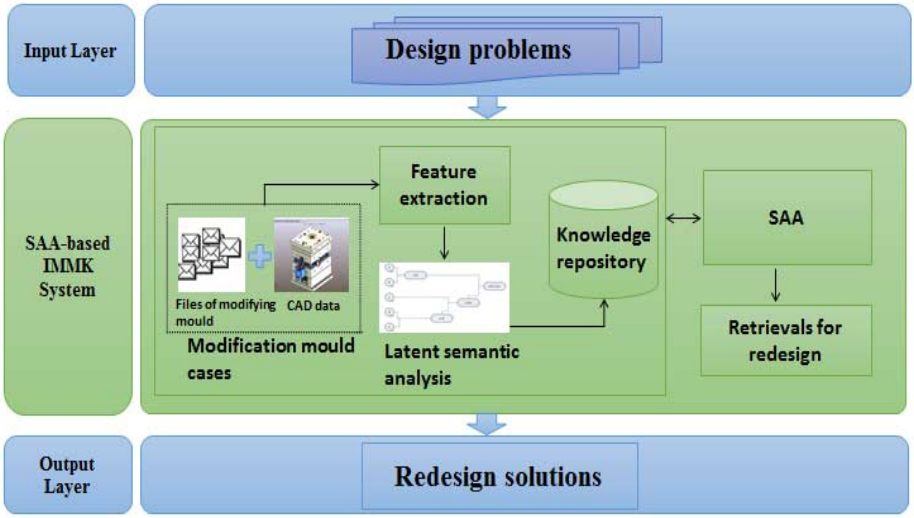


Figure 1. The framework of the proposed IMMK system.

Especially, the IMMK system is composed of five components which include feature extraction, Latent Semantic Analysis (LSA), knowledge repository, SAA and retrievals for redesign. For the reuse of the modification mould cases, it is necessary to preprocess the text on the basis of ensuring the meaning of the original text. In order to solve this problem, the most effective way is to reduce the dimension [17]. LSA, a typical technique of analysing relationships between a set of terms, is utilised for clustering the extracted features to establish the knowledge repository [18]. As the knowledge repository built, SAA, an excellent global optimization and rapid convergence algorithm [19], can be used for achieving a highly efficient retrieval process, which will be discussed in the section 2. Retrieval for redesign is the results owning the optimal similarity with the input case.

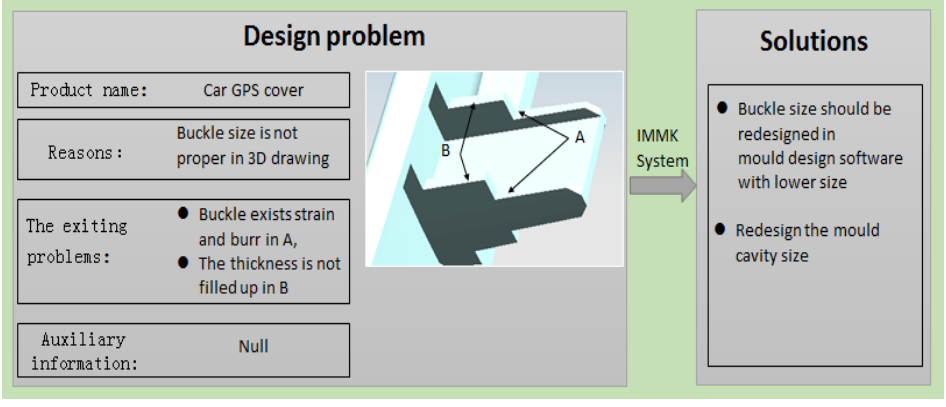


Figure 2. A redesign case in the IMMK System.

3. The operating mechanism

Considering the scarcity of experienced workers and abundance of previous redesign cases, reusing the previous redesign cases is of great importance to solve the design problems. As shown in Figure 3, the flow chart shows the mechanism of the IMMK system, which contains Learning phase and Application phase.

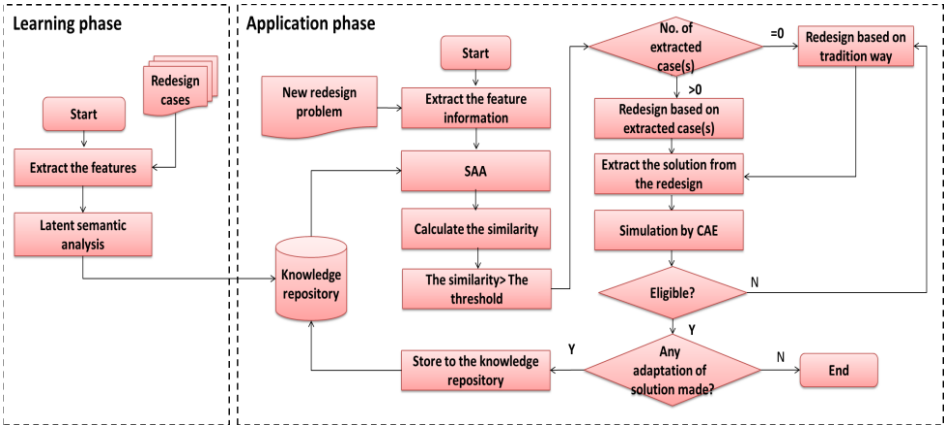


Figure 3. The flow chart of building and applying IMMK system.

3.1. Learning phase

The objective of learning phase is to build up the content of the knowledge repository so as to facilitate the retrieval process in the application phase. A template-based feature extraction method is used to extract the important features in the existing redesign cases. For example, there is a redesign case with the following information: "*There is a slight edge on the parting surface of the glove box (injection plastic mould product). The reason is that the precision of parting surface is not good enough. The solution is to grind the parting surface to improve the accuracy of parting surface.*" After the features extraction, the information stored in Excel is that product name is "*glove box*", the existing problem is "*a slight edge on the parting surface*", the reason is "*the precision of parting surface is not good enough*", the solution is "*grinding the parting surface*", and there is no auxiliary information. Considering the knowledge repository contains a large number of cases of mould modifying along with enormous mould terminology, it is inevitable that some relevant words will be repeated. Furthermore, the key words to be retrieved in this system are often large granularity text, like product name. Therefore, the terms of the features are quantified based on the term frequency-inverse document frequency (TF-IDF), which has been proved to be an effective method to cope with large-scale real corpus [20]. In order to divide the cases into smaller groups for easing computations for further processing, LSA is used in this paper. Compared with traditional vector space model, LSA has the characteristics of high accuracy and small dimension, which can dramatically simplify the computation complexity of algorithms for document retrieval [18]. After the clustering process, a centroid of each cluster is obtained based on the mean of each feature.

3.2. Application phase

In the application phase, when there is a new case, the features are extracted based on the feature extraction method mentioned in the learning phase. Then, SAA is used to retrieve the most similar previous case(s) from the knowledge repository. SAA, a typical global optimization method, has the characteristic of occasionally accepting worse solutions with a probability which helps it to jump out of any local optimums [21]. To achieve an effective and efficient retrieval, there are two steps to utilize SAA in the knowledge repository which include Class-SAA and Individual-SAA.

Class-SAA will be applied to the centroids of the clusters in order to seek for the cluster owning the highest similarity with the inputted design problem. The algorithm begins with a random initial point S_0 and temperature T_0 as shown in Figure 4. To better explore the entire state space, the initial T_0 is therefore a constant considering the discrete deterministic characteristic of the previous mould redesign [22]. The mechanism for moving around the state space is randomly selected from a neighbourhood of previous point. Suppose that S_i is the selected point with the objective function $F(S_i)$ in the iteration k, the next point S_{i+1} has value of objective function $F(S_{i+1})$. If $F(S_{i+1}) \geq F(S_i)$, the point S_{i+1} is accepted as the new estimated solution. On the other hand, if $F(S_{i+1}) < F(S_i)$, then there is a chance to accept the point (Metropolis Criterion). Therefore, a uniform random number $U_k \sim U[0, 1]$ (uniformly distributed on the interval [0, 1]) is generated. If $U_k < \exp[-[F(S_i) - F(S_{i+1})]/T_0]$, the point S_{i+1} is accepted with a probability $\exp[-[F(S_i) - F(S_{i+1})]/T_0]$; otherwise S_i remains the estimate of the optimal solution. The algorithm is terminated when the optimal value of the algorithm is kept unchanged for 10 consecutive steps.

For Individual-SAA, it is used to search for the cases in the optimal cluster that will be utilized to realize the global optimization solutions. Similar procedures are carried out in Individual-SAA. In addition, Individual-SAA is to find out the cases owning larger similarity than the threshold. Therefore, there is a comparison once the Individual-SAA extracted case gets the similarity. The terminating condition is that the desired quantity of cases is reached or that the optimal value of the algorithm is kept unchanged for 10 consecutive steps. This process is shown as Figure 4.

We assume that the optimal similarity selection criteria are {product name, existing problems, reason, structure and precision of mould}. The experienced mould workers can express the actual preferences to the searching process by assigning the relative weight of the selection criteria. For instance, if the workers consider the product name as the vital factor to find the similar case, a higher value can be assigned to the product name issue. The product name and the existing problem are regarded as more important factors, and the relative weights of the selection criteria are {0.300, 0.300, 0.200, 0.200}. Hence, the similarity can be calculated as shown in Equation 1:

$$\mathrm{Sim}(P_a, P_b) = \sum_k \omega_k \bullet \mathrm{Sim}(P_{ak}, P_{bk}) \tag{1}$$

where $\mathrm{Sim}(P_a, P_b)$ is the similarity between input design problems and the existing case in the knowledge repository; ω_k is the relative weights of the k-th selection criteria; $\mathrm{Sim}(P_{ak}, P_{bk})$ is the similarity of the k-th selection criteria between the input problems and the existing case.

TF-IDF is applied, which takes the probability distribution of the contextual information of the vocabulary as a reference for the semantic similarity calculation between the words. According to the word frequency statistics, all the words in every

selection criteria appeared in the corpus are denoted by the word frequency as a n-dimensional vector: More specifically, we can present the *k*-th selection criteria of the case *a* in the knowledge repository as $P_{ak} = < P_{ak}^{1}, P_{ak}^{2}, \cdots\cdots, P_{ak}^{n} >$. Similarly, the n-dimensional vectors of the target search $P_{bk} = < P_{bk}^{1}, P_{bk}^{2}, \cdots\cdots, P_{bk}^{n} >$. The similarity is expressed by the cosine of the angle between the two vectors shown as Equation 2.

$$Sim(P_{ak}, P_{bk}) = \frac{(P_{ak}) \bullet (P_{bk})^{T}}{\|P_{ak}\| \bullet \|P_{bk}\|} \tag{2}$$

where P_{ak} is the n-dimensional vector of the *k*-th selection criteria of the case *a* in the knowledge repository, and P_{bk} is that of the input design problem *b*.

Algorithm	Simulated annealing algorithm for IMMK system
Input:	Information of mould design problems, the threshold of similarity *Ts*
Output:	The cases owning larger similarity than the threshold with input design problems
Step 1:	Initialize temperature T_0, the initial solution state S_0 (the starting point of the iterative algorithm)
Step 2:	For $k = 0$, and , generate a new solution S_{k+1}
Step3:	Calculate the increment of $t = C(S_{k+1}) - C(S_k)$ and $t' = C(S_{k+1}) - Ts$; $C(s)$ is the evaluation function as shown in Equation 1
Step4:	If $t < 0$ and $t' < 0$, S_k remains the estimate of the optimal solution If $t < 0$ and $t' \geq 0$, S_{k+1} is accepted based on Metropolis Criterion and regarded as a output case If $t \geq 0$ and $t' < 0$, S_{k+1} is accepted based on Metropolis Criterion If $t \geq 0$ and $t' \geq 0$, S_{k+1} is accepted and regarded as a output case
Step5:	If the termination condition is satisfied, then output the current optimal solutions. If not, for $k = i+1$ and repeat step2 – step 5

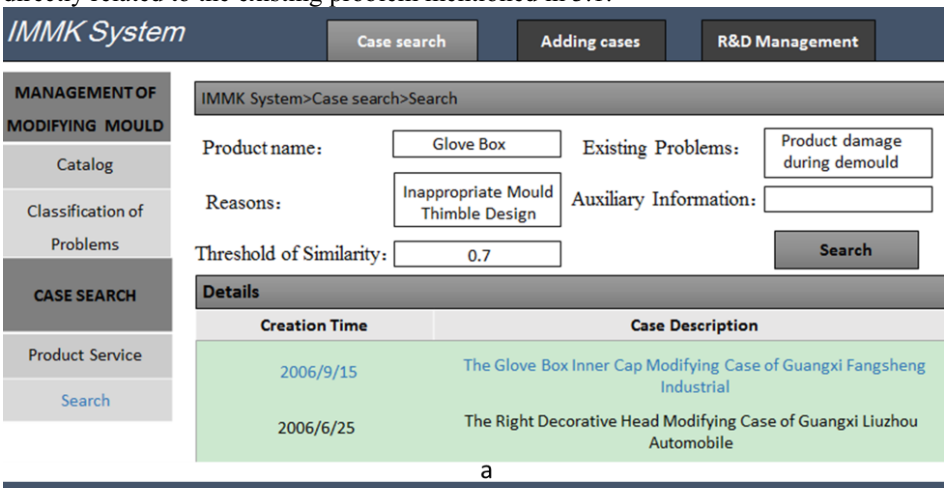
Figure 4. Simulated annealing algorithm for IMMK system.

After the system calculating the similarity based on the SAA, it is needed to compare with the threshold. And the solution from the redesign can be gotten from two aspects. One is the redesign based on the extracted samples if the number of the extracted sample is above 0; the other is redesign based on experience. Then, using CAE software simulates the formed solution of the redesign to clarify the eligibility. If the redesign is proper, the system will move to the next step to verify whether any adaptation of solution has been made. If the redesign is not proper, the redesign will be redesigned in a traditional way. Finally, if adaptation has been made to optimize the redesign activities, the designers would add new case into the related cluster in the knowledge repository by calculating the similarity between the new case and previous cases. If there is no adaptation, the whole process is ended.

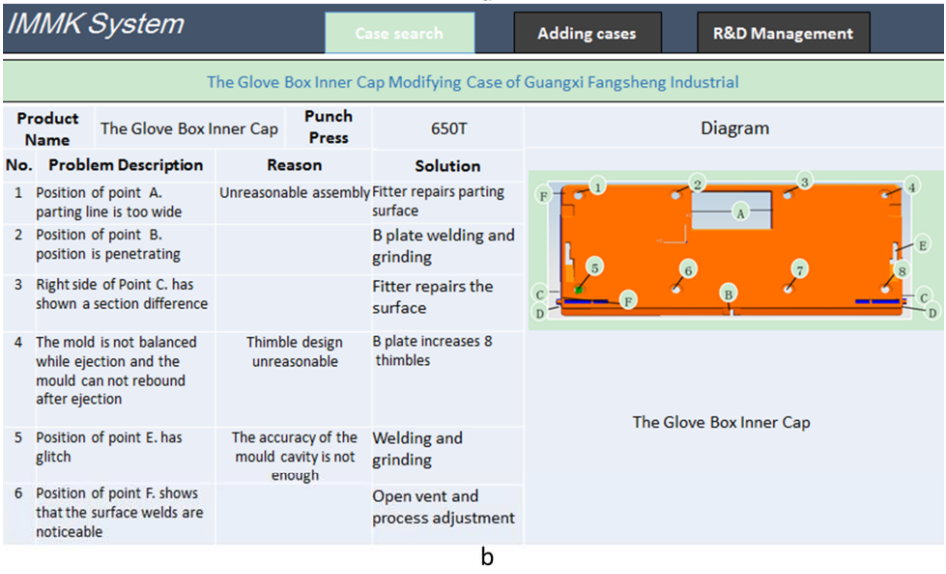
4. Case study

In this section, a case study is given to evaluate the effectiveness of the proposed IMMK system, and demonstrate its working processes. The case company, located in

Dongguan of Guangdong, is a typical medium mould enterprise in China and develops 500 moulds averagely per year. And the annual sales value of company is over 8 million dollars, with around 20 mould designers. However, with the development of the mould enterprise, it also faces several challenges: (1) due to the complexity of the modifying the mould, it is very difficult to reduce the whole development cycle effectively; (2) due to the diversity of the mould structure, it is hard to identify the potential design error; (3) due to the high rates of employees turnover, there lacks an effective method to utilise the experience knowledge of mould engineer. Currently, the information of modifying mould, including text and 2D drawing, is recorded and stored manually by the mould designer and process engineer in numerous draft documents. Thus, it is hard to utilise the valuable information to guide the further mould development process. In this paper, a prototype system has been developed for the company using more than 150 cases of modifiying mould and 100 2D drawings directly related to the existing problem mentioned in 3.1.



a



b

Figure 5. A case for applying IMMK system.

In this case, the glove box has been tested in the system and the threshold of similarity is 0.7, which means the similarity between the extracted cases and the input design problem is not less than 0.7. As shown in Figure 5 (a), the input design problem of glove box is product damaged during demoulding, and the reason for this problem is inappropriate mould thimble design. After the retrieval process, there are two extracted previous cases. Figure 5 (b) shows a glove box modifying mould case of Guangxi Fang Sheng Industrial where six problems once in the mould part and the corresponding solutions are presented in this system. Take the Problem No. 4 as an example, it matches the most similar features with the input design problem and the designer can utilise the potential solutions provided by previous case. According to the applying results, the efficiency and accuracy of mould redesign can be enhanced by reusing the previous cases. With the help of SAA-based IMMK system, the designer can set different similarity threshold to get desired cases and benefit the redesign activities.

5. Conclusion

Mould redesign is of great importance to strengthen the competitiveness of the enterprise. Based on the massive injection mould data, this paper proposed an IMMK system for accelerating the activities of the whole mould development. The contributions of this paper can be summarized as follows. Firstly, the technical architecture of the IMMK system is proposed, which can be extended into many other areas. Secondly, the multitudinous mould modifying data along with the redesigned two dimensional CAD data has been systematically organised and utilised in the proposed system, whose knowledge repository can be updated in the background. Thirdly, this system enables mould redesign activities sharing the past cases, which will facilitate the efficiency and quality of the redesign activities.

In the future, this work can be extended from the following aspects. Firstly, the scalability and compatibility of the proposed system should be further evaluated in more real-life cases. Secondly, the process of remanufacturing the mould could be explored based on the injection mould modification data. Finally, the three dimensional CAD data of the mould design can be interrelated to the system.

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Risk Analysis of the Design of a Transportation Enterprise Network System for Time Critical Manufacturing

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Abstract. The automotive manufacturing industry is under financial pressure due to massive cost structure, relatively small scale operation and strong global competition. In order to improve their operational cost efficiency, companies have adopted Toyota's lean manufacturing system in all their manufacturing activities. However, as a consequence, this policy makes the transportation network from the local supply chain time critical. This paper uses an enterprise model to study a manufacturing company's logistics system in terms of designing, monitoring and validating of the network efficiency and criticality.

Keywords. Time critical manufacturing, Enterprise model, Transportation network, Lifecycle risk assessment

Introduction

For decades, the automotive manufacturing has been regarded as a pillar of the economy of many countries. However, as manufacturing systems become global, more competitors from different countries are entering the race. In some countries, the industry is regarded as extremely competitive [1]. In order to survive, automotive manufacturers have no choice but to find ways to reduce cost and increase efficiency.

Typically, the major vehicle manufacturers are responsible for the design and assembly of their products. However, the majority of components for the car are sourced from independent suppliers. For example, one of the major automotive manufacturers in Australia has 210 domestic suppliers located in 3 states with total 5177 parts supplied through its inbound materials operations. This type of operation requires closed loop supply chain management of parts and empty packaging [2].

Due to the diversity of the supply chain, one of the common problems in the automotive industry is to implement a lean material management system by minimizing its inventory cost through Just-In-Time (JIT) transportation network. Furthermore, the small delivery quantity in the JIT system shall be just enough to cover the immediate production requirements at the given time, to keep the plant running continuously without interruption. This requires re-design of the transportation system. However, this change introduces significant risks to the stability of the manufacturing system. This paper uses the enterprise design and data obtained in this project to explore a

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lifecycle risk assessment method that forecasts risk level at different stages of the project's lifecycle.

1. Literature Review

A lifecycle risk assessment method for re-design of the transportation system in automotive manufacturing has to manage typical issues in the supply chain of automotive industry. Many automotive manufacturers are practising just-in-time supply chain but this approach often leaves the assembly plant vulnerable to disruption of parts supply. The literature review will focus on understanding these issues and explore any prior arts in assessing risks in transport system design and development.

1.1. Logistics related issues in global supply chain system

Historically, supply chains are described as activities that involve the movement of materials from manufacturer to customers. However, as the means of transportation are getting more efficient due to the fast logistics industries such as aviation, the logistics system design will need to take into account many different mixes of transportation modes. However, application of technologies would not reduce uncertainty and their connected risks in the supply chain [3][4]. Ke et al [5] found that industry characteristics had an impact on the transportation model mix in global supply chains.

The main objective of a logistics system is to meet the requirements of the customers, no more, no less [6]. The JIT system ultimately changes the way inbound materials are being delivered. Instead of using bulk carriers, less-than-truckload carriers are now used to deliver smaller lots or quantity of materials to the destination more frequently. Danese et al [7] investigated whether just-in-time supply chains had direct relationship with just-in-time production. Hence, the main issues in automotive supply chain was to maximize delivery with both JIT production and JIT supply chains.

1.2. Issues in supply chain system design

It is obvious that making changes to the logistics system is a significant challenge to both the system designer and all stakeholders in the system. Su et al [8] used several cases in Taiwan's heavy vehicle supply chains to identify major risks and influencing factors that hindered the industry in adopting performance-based logistics.

To understand the issues in a generic perspective, Kemp et al [9] presented a strategic approach for managing and analysing big data in transport applications. The big data analytics brought better understanding to the transport networks revealing unexpected choking points in the routes. Hoffman [10] examined the concept of alternative inventory financing by a logistics service provider in Switzerland. Their finding had strong implications to the development of inventory financing services.

Research shows that there are many issues in global supply chains. A systems engineering design approach is absolutely necessary for the project's success.

1.3. Risks in enterprise change

The challenge in this transition is to maintain a viable working support system while meeting the requirements of the integrated holistic capacity. Staff at different stages of a changing system will have emotional responses that need to be mitigated to avoid disruption.

Alcorn and Jarrand [11] witnessed the need of a new health care system being constructed with potential partnerships and cultures as integral parts of the operational plan. Rollenhagen et al [12] showed that organisations of the same nature going through same process exhibited similarity patterns but the process of transitioning could be different. Hutchinson et al [13] studied four commercial organizations and found that instead of technical factors, complex organizational, managerial and social factors influenced the success or failure of the change project. These literatures reveal that a holistic enterprise wide approach is required to develop an understanding of the effect of transition on the project.

1.4. Quantification of risks

Assessment of the risks in engineering change requires quantification of the artifacts for computation of risk levels. Maio [14] investigated the core tenets of joint optimization of socio technical systems and identified the need for artifacts to support the built in design of joint optimization in socio technical systems from the early stages of development.

Lockamy III [15] used Bayesian networks to examine the risk profiles of suppliers in the automotive industry supply chain. The resulting model could be used by decision makers in the automotive industry to mitigate impact on their revenue. Apostolopoulos et al [16] proposed a modelling approach named Change Risk Assessment Model (CRAM), which assessed organisational change risks with the aid of analytic hierarchy process and defined the internal dynamics of organisational change management. These studies modelled the transformation of inputs to outputs but did not quantify the risks. A new engineering-oriented method is required to represent the uncertainties that could exist in the long lifecycle of engineering project execution.

2. Theoretical background of project risk assessment

One of the most common methods is the Program Evaluation and Review Technique (PERT) [17]. According to PERT, the time for an activity in the project can be represented by a normal distribution. In this research, instead of a time value, a project success level is used. Hence, the project success level can be expressed by:

- The normal index value s_n
- The pessimistic value s_p
- The optimum index s_o.

The estimated success index is then given by:

Table 1. 3PE model of logistics system improvement project

	Plan	Define	Preliminary design	Detailed design	Build	Deploy and close
Product	• Statement of require-ments	• Existing ineffective JIT • Network document • New technology • Scanning • Wireless comm.	• Value Stream Analysis	• Software limitation • Subsystem detail design • Microsoft tools • Geocoding technology • CZAR rating system • Optimization technologies	• Implementation process	• Project Management
Process	• Software method-ology • Root definition	• Strategic assumption surfacing and testing • Build variation and manual checking	• System requirements) • Hard system definition • System requirements • Environmental factors • Operational plan	• Dynamic operation environment • Applicability to situations • Improved tracking of original orders • Network design technology	• Life cycle costing • Alternatives evaluation • Logistics support analysis • Operational analysis	• Standard Operating Procedure
People	• Logistics Team	• Group formation	• Bargaining power of service providers	• Training	• Delivery	• Supply chain management
Process/ Product	• Define context	• Supplier constraints • Loading plan • Input/packaging • Vehicle profile • Equipment plan system	• Threat of substitute • Linear regression analysis	• Transportation standard compliance • Modelling and data parameters preparation	• System testing and validation • System function architecture verification • System synthesis	• Process standardizati on
Process/ People	• Roles and response-bilities	• Declared assumptions • Synthesis	• Government policy • System dynamic • Business case approval	• Batch routing software • Network pooling, integration • Time-based schedule windows • Data validation and scrubbing • Cubic calculation origin destination	• Ready to deploy documentation	• Extent of compliance
Product/ People	• Knowledg e of people	• Project profile approval	• Baseline model principle • Baseline prediction and adjustments	• Communication user interface • Geographical data sharing • Linear code reporting • Line haul route design	• System implementation	• System debugging and upgrade
Product/ People/ Process	• CATWOE	• System support	• System breakdown structure • Subsystems and attributes • New transportation network • City considerations	• Validation	• System performance indicators	• Extent of compliance

$$s_e = \frac{s_o + 4s_n + s_p}{6} \tag{1}$$

The estimated standard deviation of the success index is given by:

$$\sigma_e = \frac{s_p - s_o}{6} \tag{2}$$

Any activity in a project can be assessed by these three indices. In a project, there are many activities happening at different stages. These indices can be denoted by s_{in} , s_{ip} , s_{io}, where i indicates the sequence number of the activity, and the corresponding estimated success index and standard deviations are denoted by s_{ie} , σ_{ie}.

To determine the probability of success, we introduce the concept of an ideal project. The ideal project is thought to be a project that has all capabilities aligned to the project and has been done with minimal disruption. From experience the ideal project can be hypothetically set by analysing those projects which are regarded as successfully completed [18]. Lets denote the success index and standard deivation by s_d , σ_d.

To calculate the risk of not achieving the ideal project, the relative distribution between the project being assessed and the ideal project is computed. The risk of the project is the probability of the project deviated from the ideal project. The relative success index and relative standard deviation are then calculated from the following equations:

$$s_R = s_d - s_e \tag{3}$$

$$\sigma_R = \sqrt{\frac{\sigma_d^2 + \sigma_e^2}{2}} \tag{4}$$

The estimated risk of the project is then computed is then defined as:

$$F = \Pr((s_d - s_e) > 0) \tag{5}$$

To determine the change of probability in the lifecycle, we use the systems engineering management plan (SEMP) methodology [19]. Due to the SEMP, it is natural to think that each of the stages are designed to mitigate or resolve some of the unknowns in the project lifecycle. Hence, as the project progresses through the lifecycle, and if the project progresses as anticipated, the risk of previous stages should be resolved/mitigated and hence are reduced to zero. It is common in SEMP that the project stages are marked by milestones. The estimated risk of the project at milestone j can be estimated by extending equation (5):

$$F(j) = \{\Pr[s_d(j) - s_e(j)] > 0\} \tag{6}$$

In a properly managed project, the project failure function $F(j)$ should decrease over time due to efforts to increase $s_e(j)$ (success estimate) at different stages of SEMP.

Having defined the mathetical formulation for estimating the risk of a project at different milestones, the question is then turned how the success index and standard deviation of a complex project can be reasonably estimated.

In this research, the 3PE model is used [20]. The main elements in the 3PE model are people, process and product, which are located within an environment. For each of the elements, a list of activities can be associated with the elements along with their interactions, so that a complete view of the project can be formulated. Estimation of the success index levels can be made separately for each element by the systems engineering team. The risk level of the project can then be represented by the sum of risks for all stages.

3. Application to the logistics system improvement project

The theoretical risk profiling methdology is applied to the logistics improvement project as an illustration of the methodology. In this case study, the automotive manufacturer is used as the basis for analysis. The company is undergoing a series of changes and one of them is the development of a transportation network that serves the supply chain. A conceptual ideal project is assumed.

Table 2. Expanded 3PE Product element.

Milestone	Activity	Pessimistic	Normal	Optimistic
Plan	Statement of requirements	3	5	6
Define	Existing ineffective network	8	8	9
	Supplementary pick up sheet	3	5	6
	Bar code technology	7	8	9
	Scanning	5	6	7
	Wireless communication	3	4	5
Preliminary Design	Value Stream Analysis	2	4	5
Detail Design	Software limitation	3	4	5.5
	Subsystem detail design	3	5	7
	Microsoft tools	5	5	6
	Geocoding technology	3	6	8
	CZAR rating system	4	5	8
	Optimization technologies	2	5	6
	Default travel speed	3	5	9
Build	Implementation process	4	6	7
Deploy and Close	Project Management	4	6	7

3.1. Quantification of risks in the logistics system redesign project

After analysing the project report, the project can be divided into 6 stages: (1) Plan, (2) Define, (3) Preliminary design, (4) Detailed design, (5) Build, (6) Deploy and close. For each of the stages, some activities are identified and these are categorised under the 3PE model as shown in Table 1. Each of the ingredients in the 3PE elements is assessed with the three possible outcomes in section 3. As an illustration, the Product element is expanded as shown in Table 2.

3.2. The risk burndown plot

Applying equations (1) and (2) to the quantified 3PE elements in Table 2, the numbers are converted to normal distributions. Using the means of the 3PE elements at each stage and compared to the conceptual ideal project with a hypothetical distribution of $N(6,0.5)$, the risk distribution of the SEMP cycle can be summarised in Table 3.

Table 3. Risk distributions at each SEMP stage.

	Plan	Define	Prelimary design	Detail design	Build	Deploy/ close
Product	0.0284	0.6785	0.0002	0.0800	0.3927	0.3927
Process	0.1160	0.0013	0.0002	0.0000	0.2945	0.0284
People	0.4104	0.0284	0.0284	0.0284	0.0284	0.0284
Process/Product	0.0284	0.1400	0.8571	0.0555	0.0002	0.0284
Process/People	0.0284	0.0070	0.0088	0.1014	0.0284	0.0698
Product/People	0.0320	0.0698	0.0026	0.3110	0.1288	0.5000
Product/People/Process	0.0320	0.6073	0.2810	0.0284	0.0320	0.0000

At the planning stage, it is assumed that the risks are progressively removed from the project as the stage of the project progresses. Hence, by progressively removing the risks for the 3PE elements at later stages from Plan, the risk levels can be represented by the "risk burn down" graph in Figure 1.

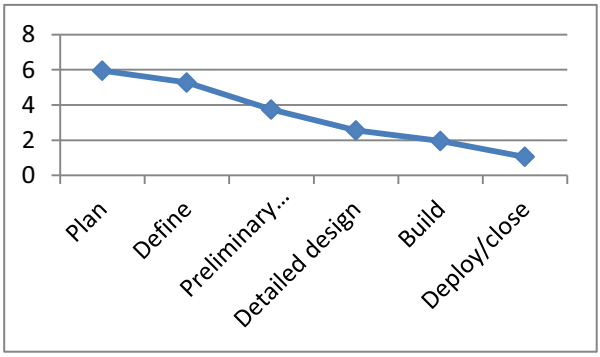


Figure 1. Risk Burndown Plot.

4. Conclusion

The automotive manufacturing industry is under financial pressure due to massive cost structure, relatively small scale operation and strong global competition. In order to improve their operational cost efficiency, companies have adopt Toyota's lean manufacturing system in all their manufacturing activities. However, as a consequence the transportation network becomes time critical and risky.

This paper uses an enterprise network model to study a manufacturing company's project to re-design its logistics system in terms of planning, monitoring and validatingof the network efficiency and criticality. The 3PE modelling framework provides a logical foundation for quantifying the risks of an engineering project. By

assessing the expected level of achieveable outcome with the ideal project, this paper has developed a new method of quantified risk indidcator that can provide a basis of future improvement planning to the execution of the engineering project. The use of a risk burndown plot allows an organisation to visualise the level of risk burnt down at each stage of lifecycle. Using the 3PE model, it also allows different senerios to be modelled and their effectiveness on burning down risk assessed.

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Novel Approach with 3D Measurement Data Management for Industry 4.0

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Abstract. The introduction of virtual product data and predominantly the usage of Computer Aided (CAx) Systems have fundamentally transformed product development. In particular, using 3D CAD and PLM systems yields to higher productivity, better quality and a simultaneous reduction of overall development time and costs. As one of the most important integration tasks for process chains, the implementation of a drawlingless process chain is a key topic in the automotive supply chain. Efficient measurement data management is an important step towards completion of this process chain. To addres this issue, a project group entitled "3D Measurement Data Management" (3D MDM) was set up in 2016 under the joint auspices of the VDA (German Association of the Automotive Industry) and the ProSTEP iViP Association. In this paper we illuminate the background of the digital transformation, and introduce the term Inspection PlusPlus Data Management Services. We highlight the specific needs and expectations of the automotive industry to 3D MDM. We describe the development approach, based on a framework successfully practised in more then 20 years. This article provides an introduction to 3D measurement data management and describes the challenges that this project group faces and the group's aims.

Keywords. Digital Transformation, Engineering Collaboration, Measurement Data Management, Inspection PlusPlus, Industry 4.0

Introduction

Product quality describes properties of a good in market which determine fulfillment of customer requirements. Manufacturers have product quality assurance units which control the produced quality. Rapid and seamless exchange of information is becoming increasingly important in order to preserve the quality of processes and products [1]. As a building block of interdisciplinary data management, the need for powerful measurement data management (MDM) arises [2]. An comprehensive MDM provides among others the potential for an enhanced automation of all operations, consistent quality control, increased efficiency of singular process steps and improved early risk identification [3].

A powerful product lifecycle management (PLM) comprises the support of product quality characteristics from the early design phase to late quality processes in the production. By the intelligent handling of geometrical dimensions and tolerances (GD&T), product manufacturing information (PMI) and measuring point definitions a

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paperless product quality management is possible [4]. That is a pre-requisite for a quality management which fulfills the requirements of Industry 4.0 [5]. That is still a challenge for the current PLM infrastructure indeed.

In spite of the unbroken trend towards digitalization, relating to the consistency and data exchange, in measurement process, still a large paper-burden is determined [6]. In particular in measurement planning, the necessary information is reported incompletely and inconsistently. Here, the absence of standardized interfaces is noticeable. The capability of the standard ISO 10303 (STEP) is not enough here (Fig. 1) [7].

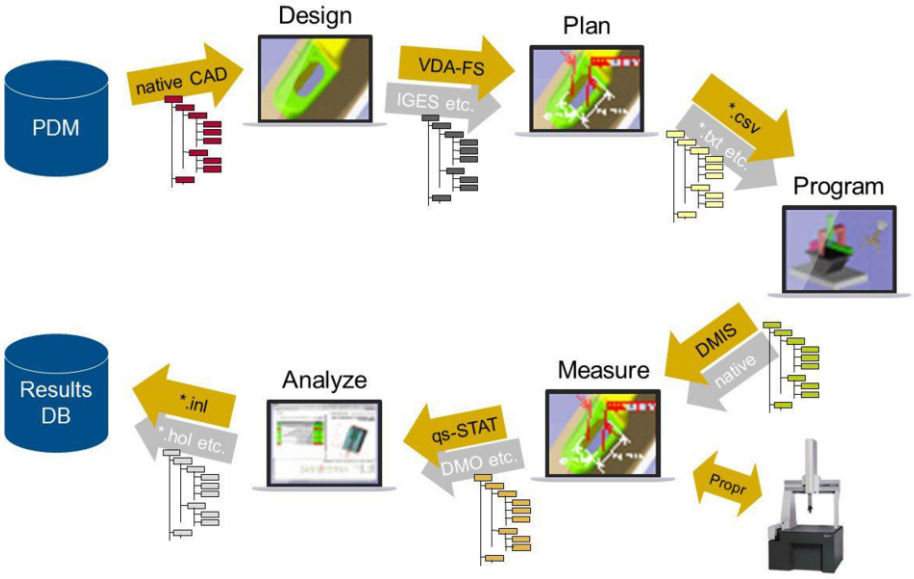


Figure 1. Interfaces in a typical measuring process.

By using a cross-functional connection of singular process steps with their domain-specific interfaces, a strong optimization potential is opened up. Therefore, the demand for a consistent digital availability of product features in particular concerns the 3D measuring technology [8].

Today, in the automobile industry, plethora of different measuring devices and methods are used to secure defined product quality [9]. For this, a high number of devices and processes are applied that differ in their functional characteristics, in their performance but as well concerning the level of their integrability into the cross-functional PLM processes [10].

Taking in mind the high number of different measuring devices for the most diverse requirements currently used in the automotive industry – and in other domains, the efforts of the users to harmonize the processes and methods is quite understandable. Especially for the use of measuring devices in the automated production, integration is required not only in the material flow but as well in the information flow of the production [11]. The integration of measurement technology into the manufacturing process further allows to faster determine and more efficiently use measured values, so that the measurement information is directly available during production e.g. for re-adjustment of devices and tools [12]. An automated data exchange realizes an additional efficiency enhancement [13].

A standardized interoperability of quality data between the particular system components shall enable the users to act flexible concerning the selection of hard- and software and to ensure a smooth data flow within the factory walls as well as with suppliers and customers [14]. To reach the named goals, a complex object model is required that includes, apart from the product model, the devices and tools as well as the relevant test and tolerance data respectively PMI and their relation to 3D geometry [15].

The structure of the paper is arranged as follows: Section 1 briefly introduces need for action. Section 2 describes the solution approach, in particular the Inspection PlusPlus initiative. The concluding remarks are presented in Section 3.

1. Need for Action

To tackle the challenge of transdisciplinarity in this issue, a collaborative project group entitled "3D Measurement Data Management" was set up in 2016 under the joint auspices of the VDA (German Association of the Automotive Industry) and the ProSTEP iViP Association in order to address this issue comprehensively [16]. This group is composed of the representatives of original equipment manufacturers (OEM) as well as their main suppliers [2].

Such an approach and structure have been successfully proven for several times on integration topics in the past 20 years. Such a group represents the most important stakeholders and actors. Then they collect the requirements and use cases, and subsequently undertake their weighting and priorization. As result of their collaboration, various recommendations emerge.

This article provides an introduction to 3D measurement data management and describes the challenges that this project group faces and the group's aims inside the ProSTEP iViP community which currently comprises 180 international members across the globe.

A variety of measurement methods and equipment are used in the automotive industry today to ensure the specified level of product quality [17]. These differ in functional properties such as way in which data is collected (contact or noncontact), the way in which measurement data is processed and in the level of integration with manufacturing equipment [18]. In addition to typical properties such as precision and speed, their performance also differs in terms of the degree to which they can be integrated in cross-domain PLM processes. The multitude of devices and processes found in the automotive industry has always provided fertile ground for the harmonization of processes and methods [2].

The desire for a standardized interface for the flexible design of the measurement process, with its numerous participants and objects, is therefore a logical consequence. It requires a complex object model that not only includes the product model but also the equipment and tools, as well as the relevant test and tolerance data (part of what is referred to as the product and manufacturing information (PMI) and its relation to the 3D geometry) [19].

In view of the increasingly drawingless quality process, the digital master approach also plays a key role in this context [6][2]. The digital master enables the enterprise to collects, maintains and provides all system information at a dedicated

point in time to all actors. Digital master baselines allow traceability for all system elements.

Cross-domain data management also gives rise to the need for comprehensive measurement data management [20]. Subsequently, factors such as data-related recording, digital master, control of the measurement process, as well as IT systems and corresponding interfaces play a role. Companies are hoping that this will bring about an increase in the level of process automation, improvements to the change process, further stabilization in the process, consistent quality statements, enhanced performance in individual process steps, as well as the early identification of all risks before they become a problem. This challenge was recognized a number of years ago in the automotive industry and was taken up by the Inspection PlusPlus (I++) initiative, a consortium of seven European automobile manufacturers [21]. This will be used as the technological basis for our work.

2. Solution Approach

I++DMS is an interface definition involving Audi, BMW and VW, that was published in 2009 with the aim of exchanging information between software applications in the field of dimensional quality assurance. It covers the areas design, planning, programming, analysis and execution in the quality process of the automotive production [22]. It is planned to transfer the gathered experience to other industries (e.g.) aerospace [23].

Version 2.0 of I++DMS takes a service-based approach and consists primarily of a UML information model and an XML schema for its accurate description and has been available since June 2014 [22]. Initial implementations are being used in the quality management systems operated by German automotive OEMs. The data is not typically exchanged directly between the data-producing and the data-consuming systems but rather via an intermediate layer for persistent data storage. In addition to the data management services, the I++ initiative has, with the I++DME, also developed a widely used specification for communication between the measurement equipment and the measurement software (Fig. 2).

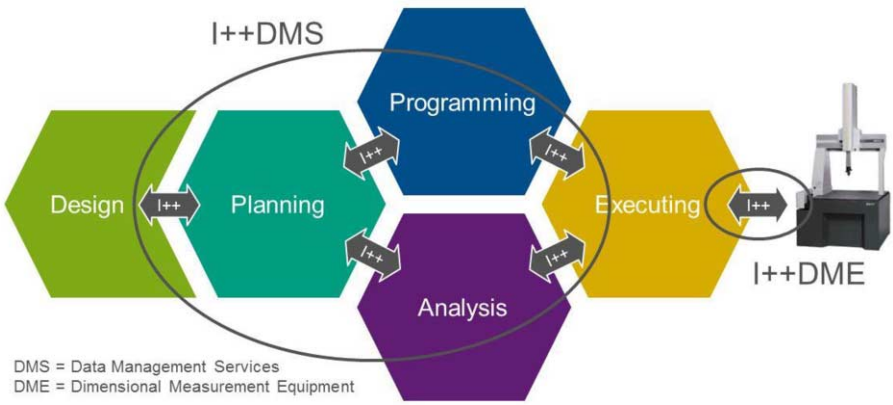


Figure 2. Definition of interfaces I++DMS and I++DME.

I++DMS has not yet been able to sufficiently establish itself as a standard in the extremely complex measurement process. Implementation of the measurement process involving many different manufacturers and components is therefore still being stretched to the limit – a limit that would vanish with the definition of a uniform interface. It is here that the project group set up by the VDA and the ProSTEP iViP Association comes into play. It is evaluating the current status of I++DMS with regard to its suitability as the standard format. As already done in precedent projects, a VDA Recommendation that makes available a revised version of I++DMS will be developed in an initial step.

The reference process created within the framework of the working group comprises not only inspection planning but also areas relating to measurement programming, measurements and analysis. This means that the I++DMS services can provide support for dimensional quality management throughout almost the entire process chain. The defined data structures are product structures that are relevant to manufacturing from the perspective of quality assurance (Product Structure) as well as inspection plans (Inspection Plan), inspection tasks (Inspection Task), measurements (Inspection), measurement programming (Inspection Program) and analyses (Analysis). Consideration of similar initiatives like Quality Information Framework (QIF) lies also in the scope of this working group [24][25].

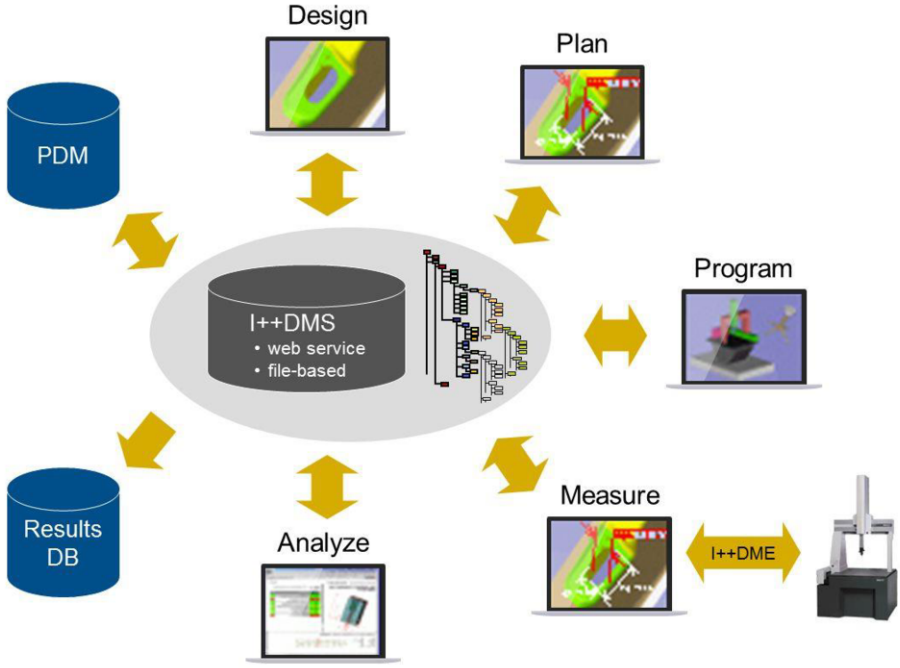


Figure 3. Vision of a measuring process based on an I++DMS data model.

Engineering, manufacturing planning and tolerance analysis are the prime sources of data for planning the features to be inspected. This data is not exchanged directly in I++DMS, but it can be assigned logically to the I++ entities by means of keys/foreign keys (Fig. 3). I++DMS thus represents a powerful basis for implementing quality processes within the automotive industry. I++ serves for transfer of measurement data and related information only. I++ is no standard for data storage – the storage resp.

processing of transferred data occurs in the application which has implemented the corresponding web service operations implementiert.

The primary aim of the ProSTEP iViP Association's working group is the definition of an executable specification for managing measurement data based on the I++ data management services. I++ DME, on the other hand, does not fall within the scope of this project. The long-term collaboration of several OEMs in the I++ working group has shown that the problems and loads are of the same nature and that cross-OEM solutions can contribute to their elimination, which ultimately yields a win-win situation of all participants. Collaboration in this project group is going to deliver first binding results in the relatively short term, with intensive support from the singular OEM committees. The group is focusing on two use cases: the process chain involved in exchanging quality data (Fig. 4) and the exchange of quality data between an OEM and a supplier (Fig. 5).

In the initial project phase, the use case and the concrete need for action were analyzed by the users of measurement software: BMW, Continental, Daimler, Ford, Adient (f.k.a. Johnson Controls), Opel, Schaeffler and Volkswagen. In the second phase, the working group is approaching system vendors with the aim of deciding together with them how further development of this model should proceed.

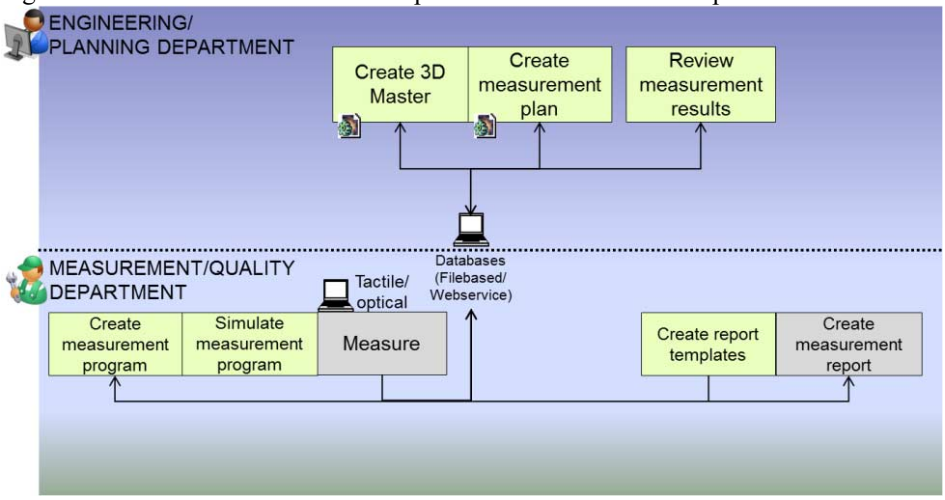


Figure 4. Process chain of an quality-related data exchange.

In line with a practice applied with great success in the ProSTEP iViP Association's working groups, the two different groups of participants, i.e. users and system vendors, will operate within the framework of two separate entities. The users will harmonize their requirements in the Workflow Forum, while the Implementer Forum provides system vendors with an opportunity to exchange information about the experience they have gained with the standard.

The project schedule provides that the working group will pass three consecutive project phases. It has started with the consideration of the following core tasks: quality features, tolerances, meta data. In the second step the following tasks follow: measuring strategies, measuring principles, and evaluation rules. The project should be finalized with the following tasks: measuring points, measuring procedures, evaluation layouts. Overriding aspects such as weaknesses in the data model and its specification, missing or incomplete use cases must also be taken into account.

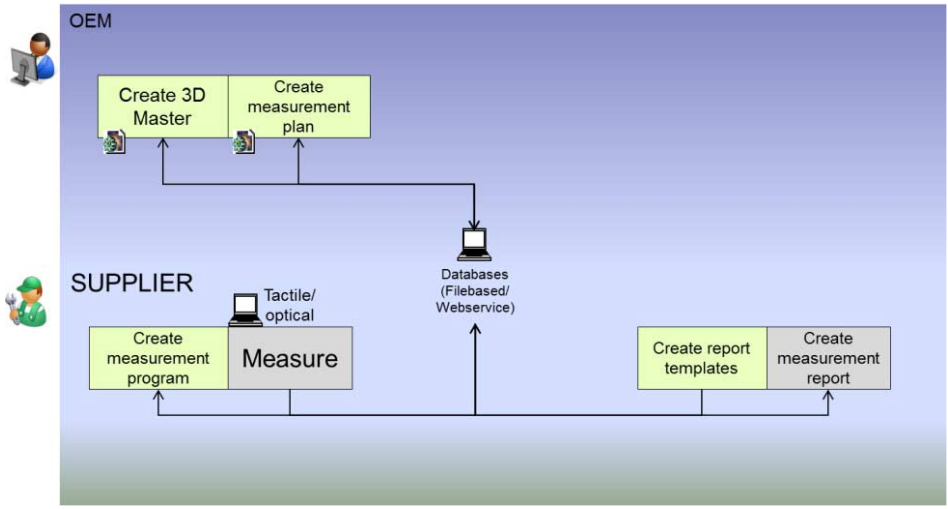


Figure 5. Quality-related data exchange between OEM and Supplier.

3. Conclusions and Outlook

Decisive for a high product quality is the early, rapid detection of all deviations in the production process. It supposes timely availability of input data (geometry and all related product manufacturing information). This requires a high level of consistency between the design, manufacturing and quality control, which must be supported by corresponding IT solutions. With the "3D Measurement Data Management" initiative a new working group is initiated to close gaps in the area of manufacturing and quality control. The working group will also create an implementors forum which will take care for rapid implementation of the recommendations. With this structure, the project is intended to achieve the rapid progress and better transfer in the practice, following to the experiences of the similar initiatives.

It is intended that subsequent developments initially focus on the areas measurement strategies, measurement principles and evaluation rules. Consideration is also being given to the topics measurement processes and evaluation layouts. It is intended that both I++DMS and the VDA / PSI Recommendation will be adapted to these developments accordingly [26][27].

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Copyright Protection in Additive Manufacturing with Blockchain Approach

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Abstract. Within "Industrie 4.0" approach 3D printing technology is characterized as one of the disruptive innovations. Conventional supply chains are replaced by value-added networks. The spatially distributed development of printed components, e.g. for the rapid delivery of spare parts, creates a new challenge when differentiating between "original part", "copy" or "counterfeit" becomes necessary. This is especially true for safety-critical products. Based on these changes classic branded products adopt the characteristics of licensing models as we know them in the areas of software and digital media. This paper describes the use of digital rights management as a key technology for the successful transition to Additive Manufacturing methods and a key for its commercial implementation and the prevention of intellectual property theft. Risks will be identified along the process chain and solution concepts are presented. These are currently being developed by an 8-partner project named SAMPL (Secure Additive Manufacturing Platform).

Keywords. Additive Manufacturing, Urheberrecht, License Management, Blockchain Technology, Plagiarism, RFID

Introduction

Within „Industry 4.0“, 3D printing technology emerges as one of the disruptive innovations. Conventional supply chains are replaced by value-added networks [1]. The spatially distributed development of printed components, e.g. for the rapid delivery of spare parts, creates a new challenge when differentiating between "original part", "copy" or "counterfeit" becomes necessary [2]. Based on these changes classic branded products adopt the characteristics of licensing models as we know them in the areas of software and digital media [3]. Further, 3D printers for synthetic materials have already become very cheap, so that plagiarism and the protection against it have naturally gained the relevant importance [4].

The entry of Microsoft into that issue even strengthens this trend. Thereby, one comes to the conclusion that this process has already become commodity [5][6][7]. Hence, it is important that counterfeiting and protection against it will be granted the required attention, as product and trademark counterfeiting cause billions of losses to German companies [2][8].

At present, the theme of plagiarism is strongly related to 3D printing. Thus, the trade association Spectaris is warning that „3D printing considerably increases the

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danger of plagiarism in the sector of medical technology". Even technology lawyers warn of counterfeiting risks through 3D printers [9]. And in case the prices of copy technologies will be constantly falling, plagiarism risk will significantly increase [10].

This also means transfer of design data for 3D printing and decentralized creation of objects by 3D printing only being economically reasonable in case there are the according security mechanisms and an according digital license management that ensures the copyright holder being fairly paid and able to control who is creating samples of the according 3D object [2][3]. This is particularly important as through local manufacturing of an additively produced component, customs control becomes increasingly more difficult.

Thus, to the integration of Additive Manufacturing procedures in the production process and the whole product life cycle, significant challenges are tied in the authorized access to product data, assured supply of the agreed quantity, distinction of original parts from counterfeits as well as prevention of intellectual property, product liability and warranty [2][3].

In the consumer area, according to §53 Copyright Law, (as well copyrighted parts additively manufactured by the enduser may be copied for private use without agreement of the author) it also applies to parts additively manufactured by the enduser that copies for private use are as well allowed without the agreement of the author. Originals of other authors - such as templates from the internet - may as well be printed. For this, a few conditions have to be taken into account: The number of copies has to be kept small. So far, with quantities of maximum 7 copies, courts have assumed private use. These copies are as well allowed to be passed on to friends and relatives free of charge. However, the printer may not receive a return service for the work pieces, as the parts otherwise serve for profit-making measures. This would be plagiarism. Furthermore, the copy may not derive from an obviously illegal source [11].

What may be right for private use in the Consumers' sphere, may quickly become a risk factor in the B2B field. It is important to answer the questions of the IP- and counterfeit protection and take corresponding protective measures [2]. Although there will not be a 100% protection, the obstacles have to be set as high as it might be economically justifiable for the copyright holder on the one side and, on the other side, it may not be financially profitable for the pirate to produce counterfeits [12]. The subject of counterfeit protection is to be bound into a company-wide concept for the product and know how protection [13]. Measures for counterfeit protection can be divided in four categories (internal security, external security, product labelling and legal safeguards) [14]. The last two categories will be specified in sections 1 and 2. In section 3 we will introduce a new concept.

1. Product Labelling

Within the scope of additive manufacturing processes, visible and invisible labelling systems may apply. They may be used during the manufacturing process or within the scope of rework. In product labelling, 2 basic principles can be distinguished: labelling information about, e.g., the product origin or the manufacturer and secondly measures for a biunique identifiability and, thus, traceability of an individual product [2].

When selecting the right procedure for individual application, it is to be paid special attention to the usability in court. Usability in court means recognition and

admission of a procedure by the Court. This may be a crucial factor in case of defence against a product liability claim or against unjustified warranty claims [13].

The labelling of products during 3D printing may be done visible or invisible. Visible product labelling can be reached by application of a security tag or by means of holograms. Here, when removing the seal for the first time, there may as well be exposed an irreversible message.

If applicable, in compliance with RFID (Radio Frequency Identification), these procedures may provide additional information about origin, supply chain or manufacturing parameters. To avoid signature fraud of Radio Frequency Identification tags, the attached label can as well be combined with a highly resolved, cloud-like printed image, the subtleties of which are not visible to the naked eye. In case a counterfeiter tries to imitate it, the picture looses precision and optical details and, thus, can be exposed as a forgery with appropriate reading devices. These images may as well be attached to additively manufactured components as direct markings and are then inseparably attached to the product. Inseparability is reached, for example, through direct application of a serial number to the surface of the component by stamping, through lasers or similar procedures. Here, it is as well possible to apply an according code or a picture not verifiable for counterfeiters.

Next to these „visible“ tagging systems, there are quasi invisible or only machine-readable labels. By adding special security pigments, optical fingerprints are introduced in the products. They are displayed as special spectral profiles in the reading device. Thereby, a bijective identification of an individual product and, thus, traceability is as well enabled.

Another method is scanning determined surface areas combined with a Barcode or RFID: An individual surface structure is to be scanned and, thus, serves as a fingerprint of this special product.

Selective introduction of foreign particles during the manufacturing process is as well possible. Owing to the foreign particles being placed inside the component, the labelling is invisible from outside and cannot be manipulated later. Further, for the defined arrangement of foreign particles, a precise process knowledge is required [15]. This method, coming from sintering, can be transferred to additive manufacturing procedures. Whereby, next to the „arranged“ installation of foreign particles, only a disordered installation may be practicable. However, this installation will result in another bijective fingerprint of the product, which can be accordingly selected and saved after production to then serve as proof of authenticity.

As displayed, next to the labelling, a product’s traceability is of vital importance. The importance of this issue is as well evidenced by the establishment of the standards committee “Measures against Product Piracy”. The according measures for counterfeit protection, authentication controls, management standards and specific protection concepts are viewed to then, in cooperation with international committees, develop the corresponding norms.

Among others, the purpose of these measures is to establish interoperatibility between identification systems.

2. Legal Aspects

Within the process chain of Additive Manufacturing, the preparation of geometry, the determination of the process parameters or the manufacturing of components is often

done by external partners, whereby copyright questions have to be answered. In case a service provider prepares the geometry model for printing and subsequently creates the print template via Slicing Software, he may eventually have created a work according to copyright law, §3 section 1 No. 1 or No. 7. The author is granted the protection by preparing the file. Thus, to protect the work, it does not have to be registered. The conditions required to classify it as a work is, on the one hand,that it has to be created by a human and, on the other hand, requires an "intellectual creation" [11].

In this case, the resulting work must not be copied and distributed without approval of the copyright holder. Public availability needs as well the approval of the author. Furthermore, the original product manufacturer might not be allowed an amendment of the prepared geometrical model. Thus, the rules for the legal boundary conditions must be defined clearly when charging service providers with the creation of a print template. On the other hand, printing a template means copying it. The reproduction rights are based on §16 copyright law. Printing means copying, because the work – the template – is made perceptible as a physical object. The work itself is not changed thereby, but merely the form of expression. Thus, the number of printed works does not matter, already the first workpiece is a copy of the template. The reproduction right according to §16 Copyright Law is the main standard for the manufacturing of the workpieces. In case the printing file is passed on to a service provider for production, he has no property rights with regard to the protected work. In case of the mere process of the printing order, the intellectual creation is missing [11][2].

In additon, product liability plays a crucial role. Process Parameters and especially layering may have a significant impact on the product features. If the suppliers produce according to the manufacturer's instructions or are these instructions not clearly defined, the manufacturer holds responsible for any defects. The requirements are to be clearly defined and the process parameters have to be agreed upon by contract. What influence have the parameters on the product features and how can they be controlled and recorded?

The best protection against plagiarism offer patents and registered trademarks. In Additive Manufacturing, 3D Trademark and registered product designs may play an essential role in future. Three-dimensional Trademarks are representational brands. They are composed of a design, e.g. the shape of the product and its package [16].

When registering a 3D brand name it has to be considered that the form distinguishes by special aesthetic features from others and, secondly, that it is not only required to reach a technical effect but as well an aesthetical. Lego, for example, did not succeed by arguing that the clamping effect of toy bricks could as well be reached by a different construction and design of the coupling elements (nubs) without qualitative, technical, functional or economical benefit against those having been built differently [17]. In contrast, the classical Cola bottle or Toblerone chocolat are registered 3D Trademarks.

Next to patent and trademark regulations, in the run-up to a cooperation with external partners, certified elements and legal aspects should be considered: How reliable is a partner, wich certification has he and which legal system does he come under. With a partner certified according to ISO 9001 and 27001, one can expect an according compliance of certain basic rules. Furthermore, the above mentioned aspects should always be agreed upon by contract. Here, one should consider: The content of a bilaterally written contract is of little use if a company has no chance to enforce it. Then, the contract isn't worth the paper it has been written on.

3. Our Approach: Secure Process Chains for Additive Manufacturing

Owing to the special features in additive manufacturing, in particular 3D Printing, currently a „Chain of Trust“ is in discussion widely. The idea is to reduce risks to a minimum by using the according technologies. At present, there are different, primarily cryptografic approaches to secure the authenticity of printing data and prevent unauthorized use of it [4].

Encoding and licensing of data by using Blockchain Technology provides an opportunity. The relevant data are encoded and the identification of the print template and the licensing of the printing process is done by means of Blockchain Technology. So far, this is mainly known from the finance world. It is a chryptografic procedure to proof the authenticity of financial transactions at digital payment. A specific Blockchain Application, for example, is the cryptocurrency Bitcoin. Blockchain Technology, however, may basically be used as well for the application of transactions in terms of franchising. Instead of Bitcoins, the license allows to print a certain number of a component.

Figure 1 displays how to represent the transaction „Alice authorizes Bob to print four copies of a certain product“ in a Blockchain. A so called Smart Contract files the license information in the Blockchain and secures that only Alice and Bob are able to read it. Later, Bob‘s printer verifies the license before starting to print. Additionally, the serial numbers of the separately printed components can be displayed in the Blockchain to proof type and quantity having been printed in accordance with the license terms [4].

To completely close the Chain of Trust, the machine and automation suppliers have to be taken into account. Similar concepts as those of manufacturing copiers can be realized. Like copying money is being prevented, by the installation of so called Secure Elements into machines for Additive Manufacturing, trusted printers communicating with the Blockchain are realized. Thereon, you can build up a complete Chain of Trust from copyright holder to service provider [18][19]. Other ways to lay Trademark Protection one level up are certified partners and the use of trusted printers (“Block-Chain Ready”) [4].

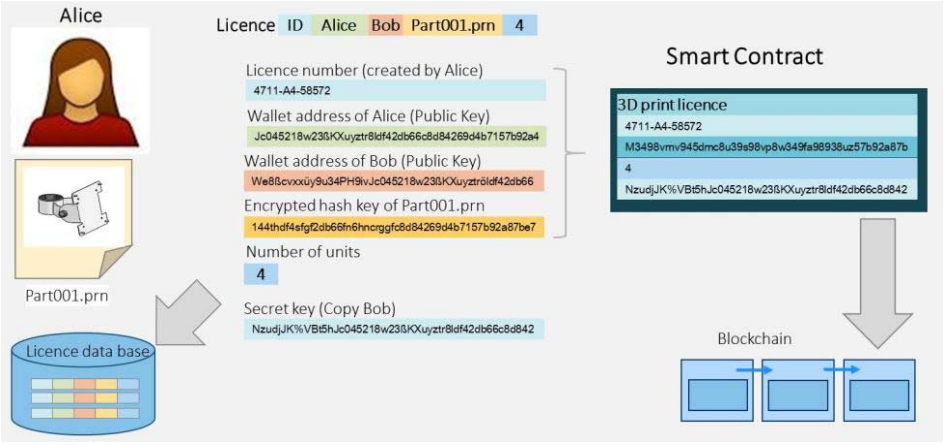


Figure 1. Licence Information pictured by means of Blockchain-Technology.

The project Secure Additive Manufacturing Platform (SAMPL) aims at developing consistent Chains of Trust for Additive Manufacturing Procedures for a commercial purpose. The entire process is seen – from development of digital 3D Printing Data via the exchange with a service provider of 3D Printers trusted by specific Secure Elements up to labelling of printed components by means of RFID-Chips. In addition to the available encoding mechanisms, a digital license management based on Blockchain Technology will be integrated into the data exchange solution OpenDXM GlobalX of PROSTEP AG. The interface for the exchange of certification and license data between copyright holder and receiver is Industry 4.0 Standard OPC-UA. Figure 2 illustrates the System Architecture [4].

The approaches pursued by the demonstrated system architecture aim to develop concrete potential uses for a number of stakeholders based on recent regulation by law [20]:

- Printer manufacturers: Distinguishing Feature „trusted“ 3D Printer, Integration of a module for copyright protection enables hedge for service provider and user [21].
- Author: IP protection, prevention from pirate copies, make rights enforceable, traceability of use, pricing dependant on usability [2].
- Original Equipment Manufacturer (OEM): secure on-demand-production, reduction of storage and transport costs, lower capital binding, quality guarantee, optimized spare parts distribution [22].
- Printing Service Provider: reduced transaction costs by using trusted 3D Printers, support services on quality control, legal security and competitive advantage [2][23].
- Final Customer: verifiable authenticity, protection against design manipulation, precise and secure billing, confidence in the work, advantages with guarantee claims [2][23].

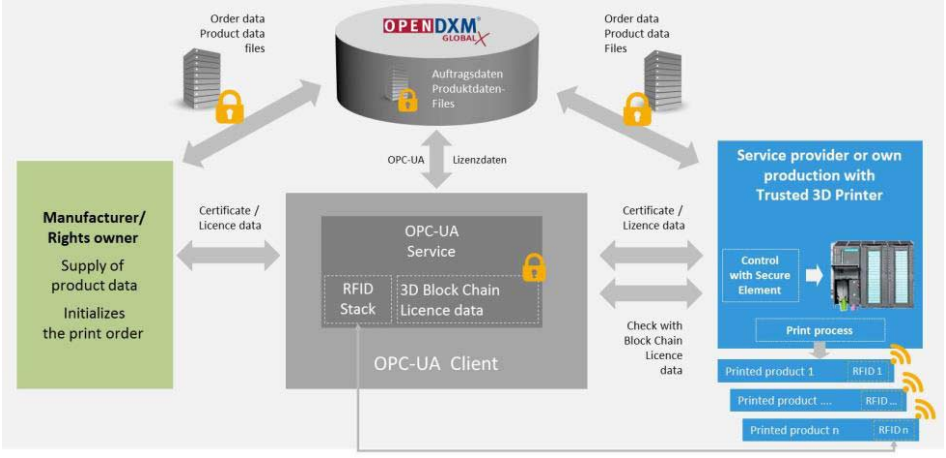


Figure 2. SAMPL System Architecture.

4. Conclusions and Outlook

In digital transformation, in the range of Additive Manufacturing, a lot of research is done on the topics of process management, technologies and methods [7]. Extensive research concepts on information security, license management, copyright protection and proof of authenticity, however, are still strongly underrepresented [18][24]. In digitalization and networking, products and production have to be granted a dominant role with regard to the security of the entire system and the risk management [25][26].

At present, there is no platform allowing to digitally and treaceably administrate data relevant for 3D printing taking into account digital licenses. In particular, digital product data have to be linked to license data. This lack is planned to be solved by an integration of the SAMPL Platform and a 3D Blockchain.

Saving and administrating digital licenses requires a database ensuring the stability of its entries. However, saving new license transactions such as updates of digital versions or changes in ownership are to be made possible. Having proven highest demands in terms of reliability and security with its first big implementation as a basis for the Cryptocurrency Bitcoin since having been started in the beginnings of 2009, Blockchain-Technology offers that kind of register.

The enlargement of the Chain-of-Trust via the 3D printer control into the printed product, e.g. via integration of RFID Chips, represents an interesting option for the organization of future business models culminating in the connection of any product with a digital product memory [27][28][29]. Thus, all 3D printed and RFID-tagged components could be smart products throughout the lifecycle. For example, the evaluation of product use, the analysis of typical damage patterns or repair requirements could lead to a targeted development and improvement. The control circuit, nowadays not closed at many products, could be closed across the product life cycle and, thus, allow new innovations [30][31].

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Part 14

Design Automation

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Transdisciplinary Engineering: A Paradigm Shift
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Construction and Application of Functional Requirement Model of the Urban Intelligent Lighting Appliance (UILA) Based on the Users' Need

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Abstract. The multi-functional Urban intelligent lighting Appliance(UILA) has become the important technology terminal to realize the construction of our smart city for future. By far, one of the most urgent problems which need to be solved is the way to apply those new functions to the UILAs effectively according to the users' need.This article takes Shanghai(China) as an example, analyzing and summarizing the functional demands of the future UILA from perspectives of functions, environment, aesthetics and energy-efficiency in the way of experts interview and bibliographic retrieval. By applying the theory of Kansei Engineering, we collect the data of the urban-dwellers' perceptual demand for the UILA's functions in different areas through questionnaires, specify the intention of the needing of the UILA's functions by combing Kansei engineering design with factor analysis, and set up the model to evaluate this application.The result of the research will provide the strong evidence for the relevant UILA design and make a big contribution to the future smart city construction.

Keywords. Urban intelligent lighting appliance(UILA), User demand, Functional intention, Design evaluation, Smart city

Introduction

The concept of "smart city" was initially proposed by IBM in 2008. By far, over 1200 cities in the world have joined in smart city construction [1]. China started the smart city construction in 2012. As the earliest smart city construction in China, Shanghai has formed the basic framework of being a smart city characterized by digitalization, networking and intelligentization after carrying out the 2011-2013 action plan of "smart city" construction. Smart city construction is an effective means to improve the core competitiveness of cities in the future, and it is seen as a development trend for cities in the future world.

By taking urban street lamps as the carrier and integrating multi-function hardware such as solar photovoltaic, LED lighting, micro nodes, video monitors, multimedia screens, information interaction screens, card readers, loudspeakers, and sensors, UILA

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aim to carry out localized development and share of government affairs, people's livelihood, commerce, culture, tourism, and traffic in smart cities on the basis of the information application system platform. Through hardware implantation, software superposition, and application expansion, organic integration of CityPad is to be realized and extensively applied to different scenes of cities, such as business areas, communities, parks, scenic spots and roadway lighting. Thus, it becomes a physical information system of smart cities.

Multi-functional UILA looks set to be an important technical terminal of smart city construction in the future. Via the multidimensional social collaborative design, existing street lamps will be upgraded, and the information perception network that covers sufficiently wide scope will be established soon, thus realizing the basic network platform of internet in smart cities, facilitating ultimate function and goal of improving people's life quality, and playing a key role in urban management, process and image. Therefore, it is of great importance to study the functional requirement of intelligent lighting devices in different areas of cities [2].

1. Design theories related to user needs

An important part of the "people-oriented" design idea is the study on user needs which refers to some physiological or psychological need of users in accordance with their specific enviornment [3]. According to Maslow's Hierarchy of Needs, user needs can be divided into the availability requirement from the phsyical and functional hierarchy, the applicability and validity requirement from the physiological and psychological hierarchy, and the human needs from the subjective feeling hierarchy [4].

Currently, design theories related to user needs in the product design and development process mainly include Kansei Engineering, emotional design, and engineering aesthetics [5]. Kansei Engineering is to carry out tests for physiological inforamtion of users such as their brain wave, electromyographic signal, sight trace, expression capture, and behavior record by means of application engineering technology, so as to quantify emotional needs of users, establish the relationship model between users' need space and product characteristic space, and provide scientific basis for product design and development. Emotional design is a design theory based on users' emotional needs, and it is to carry out design and development from the instinct, behaviors and reflection of users' emotion. Engineering aesthetics is a new discipline proposed by Liu Y L [6] who introduced ergonomics to the aesthetics field and advocated to use systematic and scientific engieneering and technology ways for aesthetic design and evaluation.

2. Design of the functional requirement research scheme of urban intelligent lighting devices based on user needs

Through research ways related to user needs, the functional requirement intention of intelligent lighting devices in different areas of cities will be determined in four steps, and the functional evaluation correlation model of intelligent lighting devices will be established [7].

2.1. Main functions of urban intelligent lighting devices in the future will be determined via expert interviews

Through the literature review of intelligent functional requirement of urban street lamps in the future, plus the interview with 39 experts from 18 enterprises specialized in R&D, production and manufacturing of intelligent lighting such as Moma Industry Design Group, Huawei Technologies Co., Ltd., and China Telecom, main functions of urban intelligent lighting devices in the future are summarized: photovoltaic system, LED lighting, intelligent sensing, micro node, rich-media ad, emergency call, city monitor system, charging pile, electronic signpost, weather monitoring, handy service for the public, and green conservation.

2.2. Questionnaire design about the functional requirement of intelligent lighting devices

Via literature review, it is found that urban functional zones are usually divided into the administration zone, residential mix zone, residential zone, greenbelt zone of scenic cities, central business zone, institute and college zone, high-tech zone, industrial zone, and suburbs. Different zones and 12 functions of cities are given with different numbres, and the semantic difference scale about the functional requirement of intelligent lighting devices in different zones of cities is established. The reliability and validity of the scale should be controlled in order to ensure the accuracy of the survey.

Table 1. Main functional requirements of urban intelligent lighting devices.

Number	**Y1**	**Y2**	**Y3**	**Y4**	**Y5**	**Y6**
Function	Photovoltaic system	LED lighting	Intelligent sensing	Micro node	Rich-media ad	Emergency call
Number	**Y7**	**Y8**	**Y9**	**Y10**	**Y11**	**Y12**
Function	City monitor system	Charging pile	Electronic signpost	Weather monitoring	Handy service for the public	Green conservation

2.3. Evaluation and analysis of functional requirements of intelligent lighting devices by users from different zones of cities

Through the questionnaire, evaluation of functional requirements of intelligent lighting devices in different zones of cities is provided by users, thereby obtaining the perceptual cognizance of functional requirements of intelligent lighting devices by users.

2.4. Establishing the functional requirement correlation model of different urban zones and intelligent lighting devices and make conclusions

Main functional requirements of different urban zones are determined, the corresponding relations between different urban zones and intelligent lighting devices are summarized, and functional requirement construction ways of urban intelligent lighting devices based on user needs are concluded.

3. Result

Due to the limited length of the paper, according to the research design plan, this paper focuses on the analysis of urban landscape green area, Central Business District and high-tech area.

3.1. High - tech area

The data were subjected to KMO dome test before factor analysis.P=0.776>0.5and sig.=0.000<0.05,the test results are in accordance with the analysis conditions.As shown in Table 2, the rotation component matrix is obtained by maximizing the orthogonal rotation of the initial component load matrix.It can be seen that the variables with high load on the first common factor are Y9, Y10, Y11, which are summarized as the interaction factor.Y6 is a high load on the second common factor, defined as safety factor.Y2, Y7 are the high load variables on the third common factor, defined as the lighting factor.Y12 is a high load on the fourth common factor, defined as greening factor. Which sums up the semantic core behind the 12 functional requirements and excavates the potential factors.

Table 2. High - tech area common factor data table.

Common factor	Sensual vocabulary	Factor load	Characteristic value	Variance contribution rate/%	Cumulative contribution rate/%
X11 (interaction factor)	Y9	.748	3.120	35.996	35.996
	Y10	.749			
	Y11	.879			
X12 (safety factor)	Y6	- .687	1.813	15.110	41.106
X13 (lighting factor)	Y2	.752	1.623	13.522	54.629
	Y7	.649			
X14 (greening factor)	Y12	.827	1.285	10.710	65.339

The component score coefficient matrix was obtained according to the Thomson regression method, the model of functional evaluation of UILA in the establishment of High - tech area is as follows:

Interaction factor X11= 0.043Y1 - 0.018Y2 - 0.042Y3 - 0.173Y4 + 0.174Y5 + 0.136Y6 + 0.085Y7 + 0.183Y8 + 0.240Y9 + 0.240Y10 + 0.282Y11 + 0.050Y12

Safety factor X12= 0.285Y1 + 0.100Y2 + 0.328Y3 + 0.084Y4 + 0.242Y5 - 0.379Y6 - 0.295Y7 - 0.066Y8 + 0.173Y9 + 0.143Y10 - 0.035Y11 - 0.022Y12

Lighting factor X13= 0.186Y1 + 0.464Y2 + 0.182Y3 + 0.216Y4 + 0.111Y5 + 0.102Y6 + 0.400Y7 + 0.271Y8 - 0.102Y9 - 0.107Y10 + 0.063Y11 - 0.072Y12

Greening factor X14= -0.109Y1 - 0.238Y2 + 0.389Y3 + 0.050Y4 + 0.075Y5 + 0.149Y6 + 0.012Y7 + 0.161Y8 + 0.108Y9 - 0.238Y10 - 0.140Y11 + 0.643Y12

3.2. Landscape green area

The data were subjected to KMO dome test before factor analysis. P=0.719>0.5 and sig.=0.000<0.05,the test results are in accordance with the analysis conditions.As shown in Table 3, the rotation component matrix is obtained by maximizing the orthogonal rotation of the initial component load matrix.It can be seen that the variables on the first common factor are Y6, Y7, Y8, Y9, Y11 According to its meaning summarized as service factor.Y2, Y10 is a high load on the second common factor, defined as the basis factor.Y1 is the third largest factor on the high load of the variable, defined as environmental factor.Y5, Y12 is a high load on the fourth common factor, defined as greening factor.Which sums up the semantic core behind the 12 functional requirements and excavates the potential factors.

Table 3. Landscape Greening Area Common Factor Data Sheet.

Common factor	Sensual vocabulary	Factor load	Characteristic value	Variance contribution rate/%	Cumulative contribution rate/%
X21 (service factor)	Y6	.645	3.127	31.060	31.060
	Y7	.677			
	Y8	.680			
	Y9	.878			
	Y11	.646			
X22 (basis factor)	Y2	.688	2.038	16.982	43.042
	Y10	-.667			
X23 (environmental factor)	Y1	.607	1.577	13.143	56.185
X24 (greening factor)	Y5	-.647	1.319	10.992	67.177
	Y12	.807			

The component score coefficient matrix was obtained according to the Thomson regression method, the model of functional evaluation of UILA in the establishment of landscape green area is as follows:

Service factor X21= 0.081Y1 + 0.036Y2 + 0.144Y3 + 0.178Y4 + 0.076Y5 + 0.206Y6+0.217Y7 + 0.217Y8 + 0.249Y9 + 0.094Y10 + 0.207Y11 + 0.059Y12

Basis factor X22= -0.242Y1 + 0.338Y2 + 0.172Y3+ 0.232Y4 + 0.214Y5 - 0.001Y6+0.155Y7 -0.172Y8 -0.136Y9 - 0.327Y10 - 0.055Y11 + 0.083Y12

Environmental factor X23= 0.385Y1 + 0.150Y2 + 0.243Y3 + 0.073Y4 + 0.025Y5 - 0.281Y6 + 0.107Y7 - 0.224Y8 + 0.081Y9 + 0.313Y10 - 0.319Y11 + 0.228Y12

Greening factor X24= -0.227Y1 + 0.256Y2 - 0.096Y3 - 0.218Y4 - 0.490Y5 + 0.018Y6 + 0.156Y7 + 0.150Y8 - 0.067Y9 + 0.059Y10 + 0.041Y11 + 0.536Y12

3.3. Central Business District

The data were subjected to KMO dome test before factor analysis.P=0.758>0.5and sig.=0.000<0.05,the test results are in accordance with the analysis conditions.As shown in Table 4, the rotation component matrix is obtained by maximizing the orthogonal rotation of the initial component load matrix.It can be seen that the variables with high load on the first common factor are Y9, Y11, which are summarized as the interaction factor.Y4 is a high load on the second common factor, defined as safety factor.Y6 are the high load variables on the third common factor, defined as the safety factor.Y12 is a high load on the fourth common factor, defined as greening factor. Which sums up the semantic core behind the 12 functional requirements and excavates the potential factors.

Table 4. Central Business District common factor data table.

Common factor	Sensual vocabulary	Factor load	Characteristic value	Variance contribution rate/%	Cumulative contribution rate/%
X31 (interaction factor)	Y9 Y11	.633 .749	2.850	33.749	33.749
X32 (network factor)	Y4	.611	1.715	14.289	28.038
X33 (safety factor)	Y6	.654	1.436	11.966	50.004
X34 (greening factor)	Y12	- .717	1.170	9.750	59.754

The component score coefficient matrix was obtained according to the Thomson regression method, the model of functional evaluation of UILA in the establishment of Central Business District is as follows:

Interaction factor = 0.204Y1 + 0.157Y2 + 0.137Y3 - 0.020Y4 + 0.208Y5 + 0.055Y6 + 0.138Y7 + 0.167Y8 + 0.222Y9 + 0.196Y10 + 0.263Y11 + 0.126Y12

Network factor = -0.237Y1 + 0.209Y2 + 0.326Y3 + 0.356Y4 + 0.249Y5 - 0.269Y6 + 0.189Y7 - 0.016Y8 - 0.093Y9 - 0.259Y10 - 0.054Y11 + 0.025Y12

Safety factor = 0.135Y1 + 0.074Y2 + 0.139Y3 + 0.133Y4 - 0.294Y5 + 0.455Y6 + 0.234Y7 + 0.360Y8 - 0.309Y9 - 0.164Y10 - 0.113Y11 + 0.149Y12

Greening factor = -0.032Y1 + 0.391Y2 - 0.275Y3 + 0.073Y4 - 0.041Y5 + 0.119Y6 + 0.402Y7 - 0.142Y8 - 0.076Y9 + 0.198Y10 + 0.038Y11 - 0.613Y12

3.4. Summary of functional requirements in different regions of the city

According to the analysis results to further summarize the functional requirements, which is related to the function of the region required functional elements, negative correlation function refers to the region does not need functional elements, as shown in Figure 1.

	High-tech area	Landscape greening area	Central Business District	industrial area	Administrative area	suburbs	Living mixed area	Residential area	Cultural and educational district
Positive correlation function		Y1		Y1	Y1	Y1		Y1	
	Y2	Y2		Y2	Y2	Y2			
					Y3	Y3	Y3	Y3	
			Y4	Y4	Y4		Y4	Y4	Y4
						Y5	Y5	Y5	
		Y6	Y6			Y6	Y6		Y6
	Y7	Y7		Y7	Y7				
		Y8		Y8	Y8			Y8	Y8
	Y9	Y9	Y9	Y9	Y9		Y9		
	Y10			Y10	Y10	Y10	Y10	Y10	Y10
	Y11	Y11	Y11	Y11			Y11	Y11	Y11
	Y12	Y12						Y12	
Negative correlation function	Y6	Y5 Y10	Y12			Y8			Y3

Figure 1. Summary of functional requirements in different regions of the city.

4. Conclusion

Through literature review and expert interviews, the functional zoning and functional requirement intention of urban intelligent lighting devices are determined. By making use of the user need related design theories, the quantized value of functional requirements of UILA in different zones is found. With the integration of factor analysis, the functional core and potential factors behind functional requirements are summarized, functional requirement for UILA in different urban zones is explored, and the functional evaluation correlation model of UILA is estbalished, thus providing vigorous basis and reference to the design and development of intelligent lighting devices, and helping designers to design UILA meeting user needs.

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Automated Metal Laminate Printing in Rapid Tooling for Mass Customization

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Abstract. The consumer market is rapidly evolving which induces a burden in the manufacturing sector in order to meet the customised demands of customers. Therefore, utilising technologies like Three Dimensional (3D) printing to accelerate production by providing smart and innovative solution is pivotal to the survival of companies globally. In this paper a 3D Metal Laminate Printer based on Laminate Object Manufacturing (LOM) is presented as a low-cost alternative to address the mould demand for functional testing and small orders of injection moulded parts. A LOM process is discussed which utilizes Aluminium foil and high strength epoxies to produce a composite part that has the potential to be used in short to medium cycle injection and blow moulding for mass customization needs. Tensile tests of Aluminium foil and Aluminium sheet composites were conducted to assess the mechanical properties of the manufactured composites.

Keywords. Laminate object manufacturing, Mass customisation, Rapid tooling, Smart tooling.

Introduction

The proposed 3D laminate printing technology in this paper is based on Laminated Object Manufacturing (LOM) first commercialised by Helisys in 1991 [1]. The system is developed to bond aluminium foil using high strength epoxies. The use of aluminium and epoxy provides a more durable composite part which could potentially extend the application of such parts beyond the capabilities of parts produced by conventional LOM, Fused Deposition Modelling (FDM) and other similar 3D printing technologies. The parts produced by the proposed system is most suited to providing an alternative in the low volume for rapid tooling in the Tool, Die and Mould (TDM) market as the modern day consumer is increasingly aware of variety, which provides an opportunity for manufacturers to cater for customization and low volume needs [2]. However, the high costs currently associated with the tooling market hinders mass customisation as low volume needs cannot be justified by high tooling costs, hence an entire market for mass customization is under-served [3].

The opportunity identified in customer-driven manufacturing has prompted a viable solution to the tooling market that sufficiently addresses the need for mass customisation [4].

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1. Literature Review

1.1. The South African TDM Sector

The South African TDM industry is worth approximately 13 Billion ZAR per annum and the South African based manufacturers contribute less than 15% to this market as depicted in Fig. 1 [2]. In recent years due to underinvestment and poor business practices to adapt to the constantly evolving manufacturing sector, the South African TDM manufacturers have faced a steady decline despite the increased presence of international Overall Equipment Manufacturers (OEM's). This is due to the ability of the Europe and a growing Asian markets to adapt to change by employing the latest technology while maintaining reliability and quality [5].

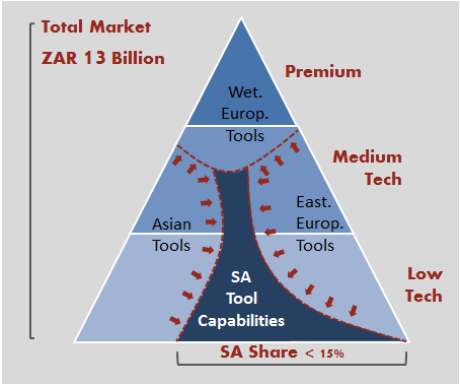


Figure 1. South African TDM Market [5].

The underlying cause for the decline in the South African TDM industry is the inability source large capital to fund the latest technology, which contributes to poor reliability hence deterring OEM's from utilizing local TDM manufacturers in favour of the Asian and European counterparts. The mould requirements from OEM's are generally large orders that are used for thousands of cycles due to the standardized, mass production of products produced by these OEM's hence trusted suppliers are used and SMME's in South Africa suffer [5].

Due to the evolving manufacturing sector, a market for mass customization is becoming increasingly prevalent [6]. Low volume of parts is required due to variation required by the customer [7]. This is a produce-to-order market that provides an opportunity for South African TDM manufacturers to distance itself from the conventional TDM manufacturing strategies and processes in order to explore 3D printing as a method of producing TDM for mass customization and step ahead of the curve as the world becomes drawn to variety in products.

1.2. Current TDM Manufacturing Technologies

The latest machining and simulation technology is vital to efficiently meet client demands. The production of mould for the injection and blow moulding industry is manufactured primarily using Computer Numerical Controlled (CNC) milling machines and Electrical Discharge Machining (EDM) for hard and soft tooling [8]. These manufacturing technologies are state of the art, industry standard to produce high

quality complex moulds for thousands of cycles which offsets the high prices to manufacture the moulds. Lead time can range from weeks to months for soft and hard tooling moulds respectively [9]. Polyjet 3D printed moulding developed by Stratasys is providing a low cost solution for the production of moulds for low volume production (typically 10-100 parts) using digital ABS plastic with high toughness and temperature resistance. Figure 2 shows a typical 3D printed mould using the Stratasys Objet500 connex for a functional design test at Unilever. Lead time and cost are significantly reduced when compared to the current industry standard, however the average time per part produced is generally longer as the molten plastic in the mould requires more time to solidify due to the inability of digital ABS to dissipate heat as effectively as soft or hard tool moulds [9].



Figure 2. Stratasys 3D printed mould [10].

This provides an avenue for Aluminum-Epoxy composite moulds to be explored as the moulds can be engineered to perform better through the use of application specific epoxies with thermal expansions and heat conductivity similar to the matrix material and the ability to manufacture conformal cooling channels to assist in better heat dissipation, hence resulting in reduced cycle times and better part quality.

2. Automated Metal Laminate Printer Design

The market gap identified in the injection and blow moulding industry has prompted a solution to produce low volume customized parts without steep cost implications. A potential solution using a system based on LOM is presented in Fig. 3 and Figs. 4 and 5.

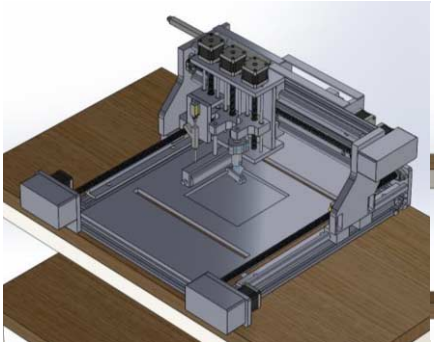


Figure 3. Isometric CAD Model.

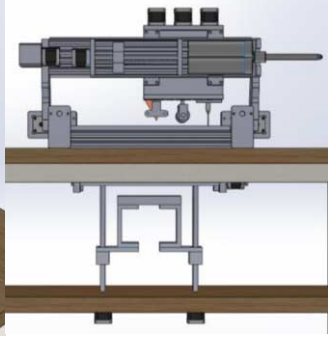


Figure 4. Back view of CAD Model.

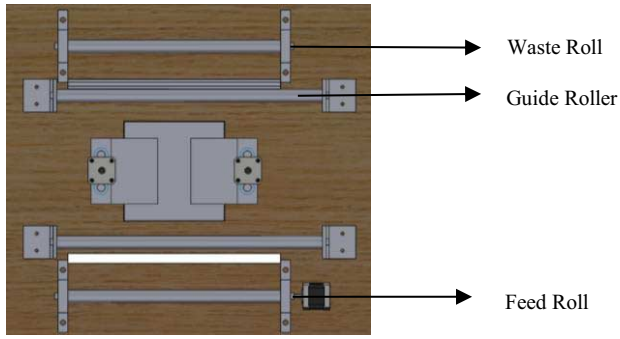


Figure 5. Bottom View of CAD Model.

2.1. Computer Aided Manufacturing (CAM) Preparation

The 3D Metal Laminate Printer will adopt a similar CAM preparation procedure as conventional 3D printing machines in order to maintain and promote an industry standard for rapid prototyping.

Fig. 6. outlines the fundamental steps taken to process a Computer Aided Drawing (CAD) model and produce a finished part [11].

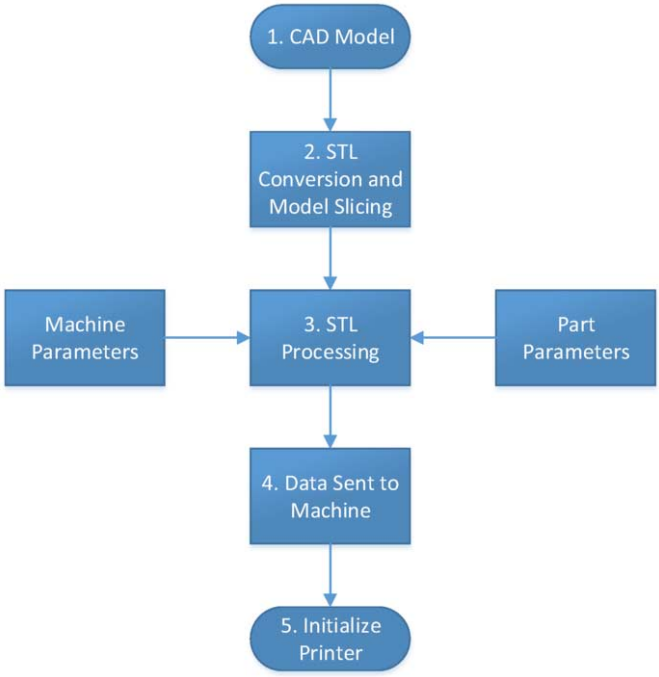


Figure 6. CAM Preparation.

The process is initiated by introducing a pre-existing 3D CAD model which then converts the model into a stereolithography (STL) file which represents the geometry as a series of triangles that is divided into multiple layers.

Step 3 involves processing the STL geometry by optimizing the layers according the thickness of foil that is loaded, as well as accounting for the approximate thickness

of the epoxy layer. Depending on the contours, curvature and user defined tolerances, this stage may decide to add pre-cut material of larger thicknesses to accelerate the build in areas of low curvature through the use of an optional pick and place arm. This stage will also involve verifying and updating the machine and part parameters, for instance, specifying a pause interval at required build heights to insert any sensors that may be used to monitor the structural health of the built part in real-time.

In the event of printing a mould for injection moulding, a temperature sensor can be embedded into the mould to provide a real-time update of the mould in operation. This allows the operator or computer, to manually or automatically adjust the flow rate of coolant through the mould thus improving the quality of the part produced and avoiding wastage through defected parts. Once the STL processing is complete, the machine and part parameters are sent to the printer which will then initialize the printer to begin manufacturing of the part.

2.2. 3D Metal Laminate Printing Process

The laminate printing process involves and series of sequential steps as described by Fig. 7.

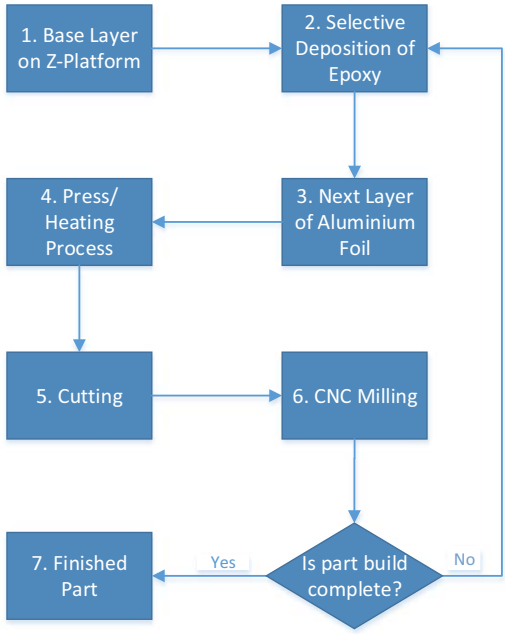


Figure 7. Flow diagram of laminate printing process

The initial stage of the part manufacture involves placing a base layer on the build platform indicated in Fig. 4. The epoxy cartridge is activated which dispenses the mixed epoxy through the dispensing nozzle. The dispensing nozzle releases epoxy paste on the aluminum substrate with a bead height of approximately 2 millimeters. The epoxy is selectively deposited on the aluminum substrate – a high density of epoxy on the area that forms part of the component and a low density on areas that is built to support the component. This is controlled by a linear solenoid which actuates the

closing and opening of the dispensing nozzle. Once the deposition of the epoxy is completed, the build platform indicated in Fig. 4 will be lowered so the roller can more a new layer of foil over the build area. At this stage, either a new layer of foil or a pre-cut sheet can be placed depending on the parameters set in the CAM preparation. This is particularly useful in layers of low/no curvature.

The roller noted in Fig. 4 and stage 4 of Fig.7 is lowered to sufficiently wet the part build area and ensure proper adhesion between the layers of material. The epoxy used in this process is a rapid curing epoxy which provides handling strength within seconds, hence a heating stage is not necessary. However, in the event of using a slow to medium curing epoxy, the build platform or roller can be heated to assist the curing process and provide handling strength without adversely affecting the part quality by warping due to a high temperature gradient associated with a soldering or welding material joining process. To provide complex parts of varying contours, a cutting process is needed at each layer. This is achieved through the use of a drag knife which can efficiently cut aluminum foil. An optional CNC mill is available to machine detail as required by the CAM pre-processing. The CNC mill stage is required to improve surface finish on the part. In the case of printing a mould with conformal cooling channels that assist in heat dissipation in the mould, the CNC mill stage is necessary to remove the excess material in the channels which results in minimal/no post processing required before the mould is put in operation.The process is repeated from stage 2 until the part is built according the input CAD Model.

There is not a commercially available printer using epoxy and aluminium to produce composite parts, however the Mcor has a commercialised a LOM paper printer called Iris which costs upwards 500,000 ZAR [12]. Initial estimates note that the Metal Laminate Printer would cost 200,000 ZAR.

3. Aluminum-Epoxy Laminate Manufacture

Composite samples were manufactured using Aluminum Foil, as well as 0.5mm Aluminum sheet, bonded with epoxy. Table 1 shows the mechanical properties of each substrate.

Table 1. Mechanical Properties of Substrate.

Property	Epoxy (Araldite 2011)	0.5mm Aluminum 1050-H14
Elastic Modulus (E), (GPa)	1.9041	69
UTS (MPa)	37	110
Poisson's Ratio	0.3	0.33

A theoretical laminate performance was derived using the theory of mixtures and shown in Table 2.

Table 2. Theoretical Mechanical Properties of Laminate.

Property	Theoretical
E (GPa)	59.61
UTS (MPa)	99.78
Poisson's Ratio	0.326

4. Results

The graph shown in Figure 8 represents the stress-strain relationship of the 6-ply Aluminum-Epoxy laminate. The average tensile modulus of elasticity ($E_{laminate}$) and Ultimate Tensile Strength (UTS) was found to be 7.053 GPa and 109.284 MPa.

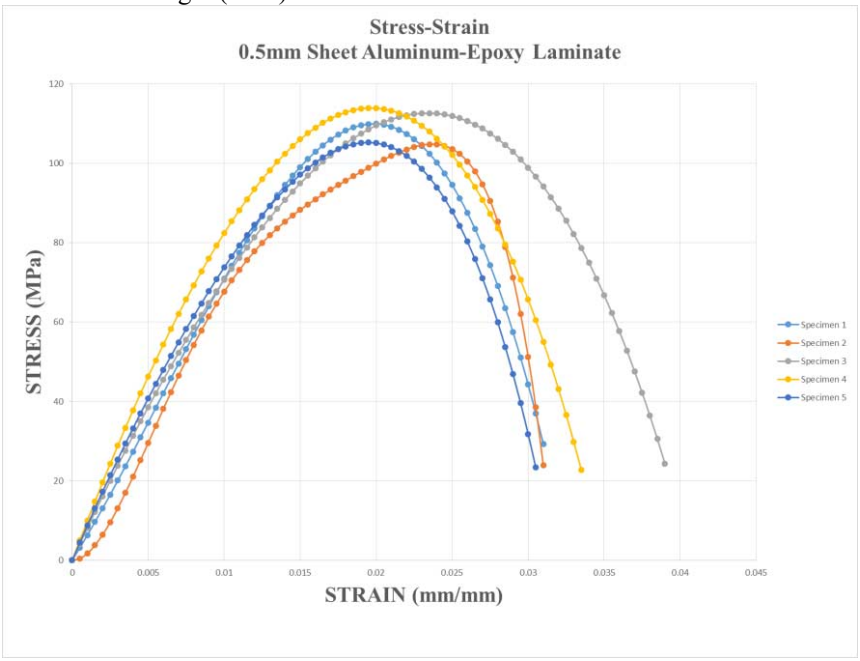


Figure 8. Stress-Strain diagram of sheet Aluminum-Epoxy Laminate.

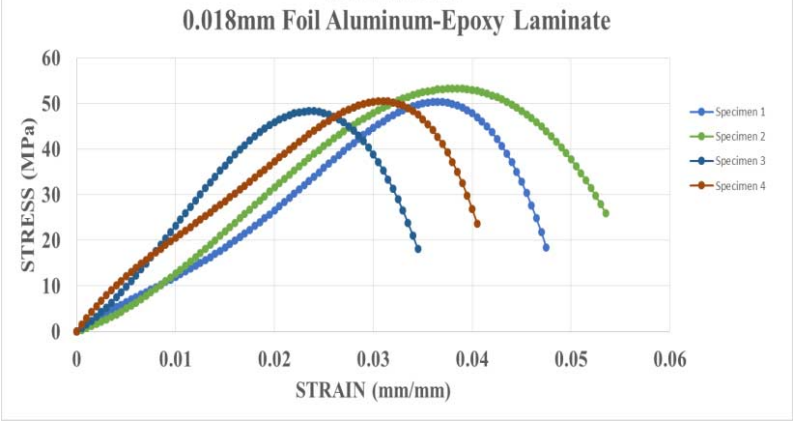


Figure 9. Stress-Strain diagram of foil Aluminum-Epoxy Laminate.

The stress-strain relationship of an Aluminum-Epoxy laminate manufactured from aluminum foil is displayed in Fig.9. Using domestic grade Aluminum foil, the Elaminate and UTS was determined to be 1.755GPa and 50.628 MPa.

5. Conclusion

A proposed model for a laminate printer was described. The printer's application described as an alternative for the production of moulds for low volume injection moulded parts. The printing process is clearly noted. Laminate samples using aluminum and epoxy were manufactured and subjected to tensile testing. The results of the experiment are recorded and suggest that this area of research, using aluminum and epoxy to produce short life production moulds is promising.

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Towards Interoperability Semantic Model to Support Design for Dental Implant Decision-Making

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Abstract. Information sharing led to a wide range of new complex applications in the Web environment, requiring a new way to formally represent knowledge and define a common vocabulary. Ontologies have recently been developed to provide a machine reasonable semantics of information sources that can be shared. The popularity of ontology development has increasing: it provides an information representation that supports enabling content-based access, knowledge modeling, interoperability, communications, and providing qualitatively new levels of knowledge representation in the form of the Semantic Web. Therefore, ontology can help professionals with a knowledge basis containing a proper semantic and validation rules. The oral rehabilitation has a directly impact of the patient life quality. Dental Implant treatment is complex and multivariable once diverse information must be proper shared and interpreted. A large number of dental implants failures due to an inappropriate definition. In this way, Dental Implant field has been continuously improved by the use of different techniques, methods and technologies in order to define the most efficient and effective diagnostic to the patient rehabilitation. The efficient and effective can be reached by enabling suitable decision-making in a shortest period of time, based on completed and updated information about the diagnostics. In this way, this research proposes a conceptual approach for making-decision using ontology concept and Multi-Criteria Decision Making/Analysis (MCDM/A) to support the dental implant definition. As results, the research presented a better picture of decision-making support in the Dental Implant field associate to engineering design. It is important the standardization and unification of knowledge by models that can be integrated, optimized and used as a referential for good practices.

Keywords. Design for Dental Implant; Semantic Interoperability; Multiple-Criteria Decision-Making/Analysis (MCDM/A); Decision-Making.

Introduction

Edentulism is a major health problem worldwide and has influence on life quality and well-being. Accordingly to The World Health Organization [1], 30% of the population whose age is between 65 and 74 are likely to lose some of their natural teeth, and severe periodontal (gum) disease, which may result in tooth loss, is found in 15-20% of

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middle-aged (35-44 years) adults. Those numbers make clear the high demand on dental implant surgeries around the world.

For some decades, dental implants have been used to support dental prostheses. They become a way to enhance appearance and improve oral health, since it emerged as a solution for teeth loss replacement. Currently, it is considered a well conceptualized method, however, this treatment is intricate and very particular for each patient, thus, on the last decades, several cases of implant failures and complications were related to inappropriate definition.

Dental implant treatment is complex since it evolve large amounts of variables that must be taken in account for treatment decision making. It requires information to be proper shared and interpreted in order to provide sufficing data for choosing procedures, pre and post-surgical care and implant characteristics.

This research proposes a conceptual approach for making-decision using ontology concept and Multi-Criteria Decision Making/Analysis (MCDM/A) to support the dental implant definition. In this context, it can help to enhance products and assist dental surgeons to achieve success on dental implant procedures, which stands for better health condition for patients since it increases reliability and avoid pre and post-surgical complications. As results, the research presented a better picture of decision-making support in the dental implant field associate to engineering design. It is important the standardization and unification of knowledge by models that can be integrated, optimized and used as a referential for good practices.

This paper is presented as follow: in Section 1, a problem statement is given regarding interoperability, dental implant and MCDM/A; Section 2 presents related works that gives support to this research; in Section 3 is shown the discussion and the contribution to the academic world; finally, Section 4 is dedicated to the conclusion of this paper and some suggestions for future works.

1. Problem Statement

A dental implant insertion as other health treatments, starts by an analytical process carried from a professional. After it is decided to perform an implantation, all health conditions are checked in order to verify the feasibility of the procedure. It includes habits, systematic changes, allergic history and bone analysis. Each patient has a different condition, some may not fit a dental implant procedure regarding their health conditions, while others may present some conditions of concern that requires extended attention, however, does not impossibilities the implantation.

Dental Implant treatment is complex and multivariable once diverse information must be proper shared and interpreted. Implantation has a lot of specifics and each detail can cause great effect when it comes to choose procedures, pre and post-surgical care, material of coating, shape, size, length, width and so forth. If a wrong decision is made, the implant survival will be compromised. MCDM/A can aid when there is more than one reasonable option, when no option has a clear advantage in terms of health outcomes, and when each option has benefits and harms that may be valued differently from a health professional perspective.

Proper decision-making is among the critical factors in implant dentistry and using a conceptual approach for making-decision via ontology concept and MCDM/A methods shows several benefits. An ontology representation, in addition to serving as guide of concepts, reduces ambiguities and increases reliability through the

standardization and unification of formal knowledge, while MCDM/A by quantitative means of structuring and working through the information, mitigates the risks involved on decision making; thus increasing the success rate and improving the reliability of dental rehabilitation process.

2. Related Works

The related works were structured according to the main domains related to this research: (i) Dental imaging; (ii) Implant design; (iii) Dental implant coating materials; (iv) Factors that affect dental implantation, and (v) Multi Criteria Decision Making/Analysis applied to dentistry.

2.1. Dental imaging

Proper planning and placement are among the critical factors in implant dentistry [2]. Medical imaging techniques are very important for dental surgeons, since it is the main approach for extracting information related to osseous conditions.

Traditionally, x-ray is the most common method used due to its versatility, however, according to [3], it is limited on structures representation because it can just represent two dimensions and can only relate information about height or mesial distal width.

Thereby, more advanced technologies have been used, such as CT (Computed Tomography) and CBCT (Cone-Beam Computed Tomography). [4] says that dental CT is the best method for the morphological, quantitative and qualitative assessment of the available. This technology captures large data quantities and in tandem with appropriate software, can produce tridimensional (3D) images. [5] says that planning on 3D results in a better implant position associated with bone quality and quantity, biomechanics and esthetics. The more advanced and precise are the images, more reliable and accurate is the dental implant placement planning, eliminating complications regarding mandibular nerve damage, sinus perforations, fenestrations, or dehiscence.

2.2. Implant design

Implant design play an important role, it can determine the success or failure on a dental implant application. According to [6], long-term bone stability depends directly on load transfer and distribution around dental implants, thus implant design is the key for balancing bone quality and mechanical load, by dimensioning diameter, length, treads, tapper angle and so forth.

Finite elements method has been widely used to analyze the mechanical stress distribution around the implants [7]. The patient's jaws are modeled on CAD (Computer Aided Design) in order to simulate the osseous conditions and mechanical loads. This method stands for shape optimization [8].

2.3. Dental implant coating materials

Thanks to Branemark's studies in the 1960s, the biological properties of titanium were discovered. Since then, titanium has been largely used due to his osseointegration and chemical properties.

Nowadays, most implant bodies are made from titanium, however, they differentiate from each other by their surface coating technology. New materials added to the titanium surface can accelerate osseointegration, therefore, anchoring the implant to the bone. For example, on [9] it is presented a gold surface incrustation which, according to the authors, should speed up the osseointegration process, likewise [10], presents a paper that shows results for a coating of titanium + (titanium + hydroxyapatite) + hydroxyapatite, the authors claim that the bio-ceramic material not only allows for good fixture in the bone but also dissipate loads involved on the chew process.

2.4. Factors that affect dental implantation

There are several factors that might influence dental implantation, some rest on patient health conditions, while others on surgeon expertise and technology of the implant itself.

In [11], was presented some patient health factors that could contraindicate a surgery for implant placement, such as, a history of heart attack, heart failure, valvular heart diseases, developed cancer, hemophilia, anemia, osteoporosis, diabetes, pregnancy and AIDS. In addition, not only historic of illness should be taken in consideration, habits also have to be considered, such as alcoholism, drug use and severe smoking as could be verified on [11], [12], and [13] papers.

Even though titanium is well accepted as a non-allergic material, there are some cases of allergic reactions to implants. [14] shows a case which a patient exhibited allergic symptoms that only disappeared completely after the dental implant extraction. The studies in [15], revealed cellular inflammatory reactions around bone anchored titanium implants, indicating an immunological response to the implant material. This response has also been reported to stimulate bone resorption, thus contributing to loosening of dental implants. The [16] research, indicates that the allergic symptoms are not caused by titanium itself, but by the impurities presence, such as, beryllium (Be), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), nickel (Ni), and palladium (Pa). Therefore, those elements would be triggering allergic reactions in patients. [17] suggests a patch-test reagent for titanium (tetrachloride 0.1%), however, due to variation on titanium`s impurities, this test might not be completely sufficient to infer whether or not a patient would present an allergic reaction.

In source [18], a study is presented to evaluate continuous and simultaneous variations of dental implant diameter and length, and to identify their relatively optimal ranges in the posterior mandible. The authors found that considering a poor bone quality, both implant diameter and length have influences, however, implant diameter has more effect on cortical bone stress, enhancing implant stability, while implant length is more effective reducing cancellous bone stress. They also suggest optimal sizes, dental implants which diameter exceeds 4.0 mm and 12.0 mm in length are a relatively optimal selection for a screwed dental implant in the posterior mandible with poor bone quality.

In source [6] is presented a research regarding bone stability around dental implants relating treatment factors, such as, dental implant design, augmentation technique, treatment protocol, surgical procedure, and systemic factors. The authors concluded that bone stability around dental implants depends on treatment-related factors that can be influenced by the implantologist (e.g., the implant design, implant surface coating, size and so forth). They also say that, small diameter and short implants are good possible options for treating patients with limited bone volume, because those implants can be loaded immediately, but the amount of occlusal loading must be controlled, however, immediate loading is contra indicated for short implants. [6] infers that the abutment design on an implant success are directly related to the loading, not only that, but, the treatment protocols should be adequately chosen, according to the clinical indication and patient`s bone quality. In case of a poor bone quality, augmentation can be necessary, thus, the material must be properly chosen according to the situation and indication of each individual case.

2.5. Multi Criteria Decision Making/Analysis applied to dentistry

Multiple Criteria Decision Making/Analysis refers to methods used to assist taking decisions considering multiple criteria. They are mathematical tools that helps finding weights of relevance for each criteria in order to evaluate given options and find the optimal alternative.

In source [19], a decision-making system for selection of dental implant abutments based on the fuzzy cognitive map was proposed. The system assists on taking implant types by analyzing fuzzy membership through fuzzy inference in order to find an optimized abutment structure based on knowledge of the implant surgeon and the domain of implant manufacturers. Even though this paper presents results regarding dental implant, it is limited only for a small part (abutment selection) of the entire process, furthermore, selecting the best abutment will only allow for better load transfer, which also is high dependent on fixture parameters, making it restricted and not practical when it comes to decision making regarding the entire dental implant process.

Thereby, source [20] published a paper which proposed a shared decision support system on dental restoration. The authors used a SDM (Shared Decision Making) approach in which doctor and patient contribute to decision-making based on available evidence and patient preferences. This paper presents a functional SDM system, however, its range is restricted to dental restoration, and in addition, it is more based on preferences, such as convenience, esthetics and financial constraints, rather than constraints regarding oral health, restoration life span, patient life quality and well-being.

3. Discussion

This research works toward evidences, which demonstrate issues regarding semantic interoperability and multi criteria decision making on dental implantation field. These issues provided sustenance to the proposal of an interoperability semantic model to support design for dental implant decision-making, moreover, the model aims to specification of dental implant conceptualizations in order to extract relevant information to be fed into a suitable MCDM/A method.

Related works exposed the complexity of dental implant treatments, and demonstrated that correct implantation requires proper consideration on several factors regarding medical science and production development process of implants. They are particular domains that have to be combined as an interoperable system.

In order to be interoperable, a system must be able to change data in such way that it can be interpreted and understood by users in different ends, therefore, communication must have standards, controlled vocabularies, terminologies. Since dental implants process evolve heterogeneous domains, it can lead to risks of misunderstandings due to semantic faults, which also drastically affect decision making.

Source [21] presents a study regarding the existing Decision Support Systems in Dental Decision Making. The study gives insights about Decision Support Systems (DSS) and Clinical Decision-Support Systems (CDSSs). The study shows that most DSS and CDSSs have problems dealing with knowledge acquisition and knowledge maintenance to their sustainability, therefore, highlighting current problems with interoperability among the existing systems.

In source [22], it is presented a work regarding decision making on periodontally involved teeth and implant therapy indications as well as possible modifying factors. Their results suggests that dentists' decision making are based on external evidence, such as clinician's expertise and patient's desires and concerns. [22] points to the need for establishing international guidelines to help the clinician identify themost suitable treatment option. The proposed model in this paper in tandem with ontology can help this issue, by creating a knowledge basis containing proper semantic and validation rules in order to formally develop a guideline for dental treatments.

The study [23] looks into evidence-based and decision-analysis approaches in order to synthesize the data and test it in a clinical context. Their study points to decision analysis method. According to [23], it would contribute by quantitatively comparing alternative treatment strategies by calculating expected values of the resulting outcomes, therefore, going along with the idea of this paper on choosing a MCDM/A method to enhance decision making on dental treatments.

Researches [19] and [20] treated small parts of the dental implant and dental restoration process regarding decision making, however, it is important to address all issues simultaneously, since they are interconnected. Therefore, it is necessary to explore or develop strategies to support the multivariable complexity of dental implant field while dealing with multi domain semantic interoperability.By combining domains, requirements and process steps along dental implant treatment, the authors come up with a model which represent the necessary cross information interoperability as can be seen on Figure 1.

The model, presented in Figure 1, could be used for an engineering design conceptualization basis for dental implants, since nowadays the product development engineering have to adapt to customer needs.

4. Conclusion

In this paper, was presented a research that lead to an interoperability semantic model to support the complex decision-making evolved on dental implantation. This area is in continuous development, and requires a suitable knowledge representation basis in order to enhance reliability on decision making process.

The authors presented a research, and the overall related works points to the need for an interoperable approach to represent the expertise of dental surgeons through formalization and standardization, thus avoiding misinterpretation. It is also suggested that a semantic interoperable model through standardization of controlled vocabularies and terminologies would serve as a guide for good practices enabling dental implant expertise to reach further away, as well enhancing reliability on dental rehabilitation process. In addition, a better knowledge representation gives proper criteria to be fed into a suitable MCDM/A method in order to improve decision making on dental implant field. Furthermore, the proposed model can solve issues regarding multi domain crossing when it comes to design engineering conceptualization process which needs to be carried out to in sync with dental implant advances.

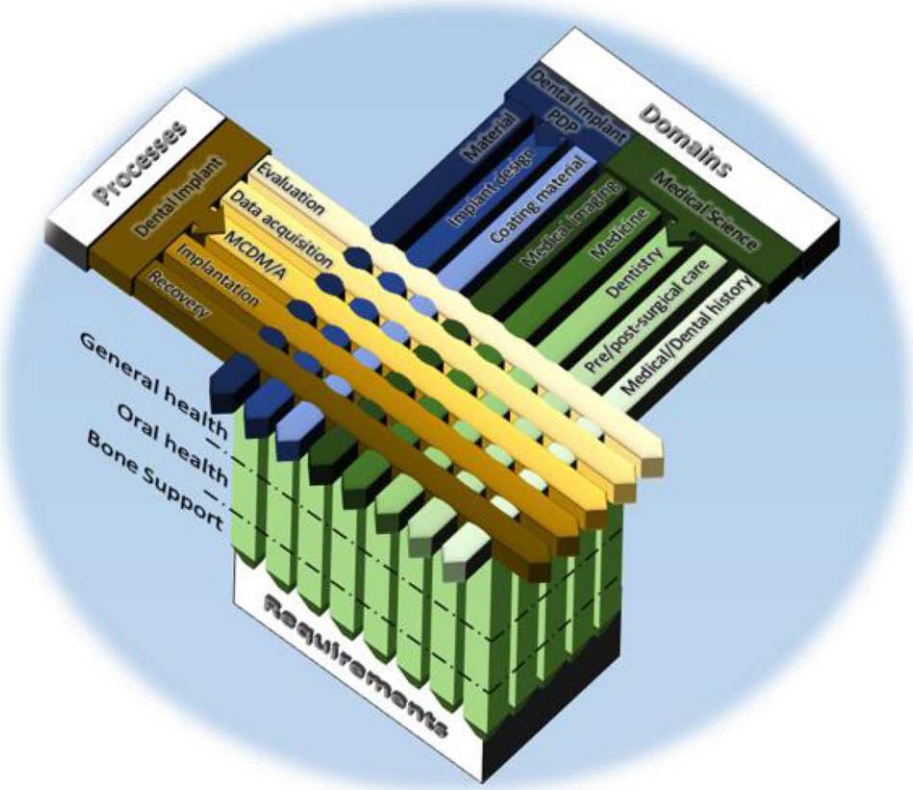


Figure 1. Crossing Domains, Processes and Requirements.

In order to give continuity to this research, several subjects are proposed for future works. Research the steps of dental implant process and the current available ontology basis for dental implant and merging methods as well. Survey dental implant surgeons in order to define relevant criteria and their relevance, as well compare to knowledge presented on current ontologies. Research and define a MCDM/A method that best fits into the dental implant process. Research implant product development and medical science domain towards existing sematic interoperable common ground.

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Utilizing Text Mining and Kansei Engineering to Support Data-Driven Design Automation

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Abstract. With the rapid expansion of Web 2.0, more and more people express their views and comments about products online. To understand and satisfy customer requirements, designers need to find out helpful information from online reviews and design a new one as fast as possible. It's an important phase to identify customer requirements in product development process. However, popular products can get hundreds of reviews, designers often spend a lot of time on identifying customer needs. Therefore, to meet customer requirements and speed up product development process, this research proposes a data-driven design method which combines text mining and Kansei engineering. Text mining is dedicated to capture and analyze the key words from customer reviews. Kansei engineering aims to translate customer needs into the product development domain. According to the result of Kansei Engineering, a CAD model will be generated to visualize prototype. Moreover, a case study of bike is provided to demonstrate the practical viability of proposed method. Under the trend of data-driven design, this is the first study that integrates text mining and Kansei engineering in product development process.

Keywords. Text Mining, Kansei Engineering, Product Development Process, Design Automation, Data-driven Design

Introduction

Recently, product development has emphasized on user-oriented design and the user experience. In order to find solutions for existing problems and meet customer needs, companies or designers nowadays must make clear understanding and insight of the actual needs of customers. Kansei Engineering (KE) was founded about 20 years ago. [1] defined KE as "translating the customer's Kansei into the product design domain." The Kansei means the customers' physical and psychological responses to the properties and characteristics of a product. To make customers be more satisfied with the new product, designers should consider customers' feelings in new product development. Thus, the success rate of new product development is expected to be increased.

With the rapid expansion of Web 2.0, more and more people express their opinions and comments to various products on the Web. Online reviews are generated from time to time and presented in various forms. Such opinion information reveals the evaluation

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of a product from netizens. Online reviews are not only useful for potential customers to make a decision but also critical for designers to develop a new product or a next generation of existing product. In the procedure of next-generation product development, designers have to extract current customer preferences from online reviews to satisfy customer needs accurately. Therefore, this study aims to propose a method to analyze customer reviews and extract customer requirements by integrating text mining and Kansei engineering for data-driven design. Text mining is dedicated to capture and analyze the key concepts from customer reviews. Kansei engineering intends to translate customer semantic meaning into the subsequent product design. Based on the Kansei engineering, a CAD model is generated to visualize the prototype.

1. Literature Review

1.1. Text Mining

Source [2] firstly introduced text mining is a technique for knowledge discovery from unstructured texts, especially social media data are usually large, noisy and unstructured [3]. Due to the increasing accessibility of textual data, the algorithms of text mining are developed and contribute in different fields. Source [4] proposed a heuristic two-phase model for authority and authentication sequence determination of technical documents via keyword extraction and document categorization. Source [5] applied K-means clustering and support vector machine classification to develop the text mining algorithm which effectively detected online hotspot forums. This technique has become mature and available due to scholars' effort and hard work.

With the help of text mining, many scholars have engaged in analyzing product reviews, which possess critical information with regard to customers' opinions and their experience with the product [6]. Enterprises always want to find customer opinions about their products and services. Potential customers also want to know the opinions from existing users before they pay for a service or a product [7]. Source [8] proposed a method for mining and summarizing online product reviews from Amazon. Each word is identified as part-of-speech and semantic orientation to decide customer preferences. The procedure of text mining is (1) mining product features that have been commented on by customers; (2) identifying opinion sentences in each review and deciding whether each opinion sentence is positive or negative; (3) summarizing the results. According to this method, customers enable to make an informed decision from a lot of reviews, which are long and only contain a few decisive sentence. Source [9] performed a competitive analysis through text mining approach with a case of pizza industry to obtain essential information for marketing and competitiveness comparison. The process includes pre-processing, applying text mining, and evaluating the mining results and recognize actionable. Moreover, SPSS Clementine text mining tool were used to facilitate the mining and analysis for the data on Twitter and Facebook. A system for summarizing product reviews and customer opinions is usually proposed with different methods [10-15]. According to the above literatures, previous researchers have applied text mining to understand the consumer behavior and addressed the challenge of huge reviews overload facing product designers.

To sum up, previous studies employed text mining to deal with natural language in various fields. However, previous studies almost proposed a method for potential customers to speed-up their decision process. Text mining is seldom utilized to support

product development process. Therefore, this paper uses text mining to collect customer reviews of products and try to find customers' potential needs.

1.2. Data-driven Design (D3)

With the trend of Internet of Thing (IoT) is come, the massive data generated by human and machine can create the opportunity in advancing the application of Data-driven Design (D3) for product, system and service [16]. Traditionally, researchers utilized questionnaire survey or focus group interviews to collect customer needs in the initial procedure of product design. However, these tools are costly and time consuming, and the size of available data is usually small scale[17]. Therefore, D3 for product design is proposed to collect extensive and realistic customer data, to interpret the relationship between customer data, and to guide new product design process. Source [18] presented a design method that significantly enhances the product portfolio design process, especially in the search of all possible product concepts. By using data-driven decision tree classification, a set of product concepts is generated and the feasibility is validated by multilevel optimization techniques. From a data-driven perspective, trend mining can address the challenges of capturing changes in consumer preferences that enable design engineers to forecast next generation product features [19]. Many D3 methods have been developed for identification of current customer requirements from online reviews. According to the collected and analyzed customers' product reviews, we are able to obtain current customer requirement. Then, based on the customer requirement and image, the new product development can accurately satisfy customer's demand. Source [20] translated customers' reviews into engineering characteristics in quality function deployment, which clearly understand how customer need is utilized by designers. Moreover, source [21] developed a framework to deal with big consumer data for market-driven product design. To help designers to understand the changes of customer requirements and their competitive advantages, the product features and sentiment polarities are employed to forecast the customer requirement. Source [22] proposed a method for enterprises to quickly understand customer-preferred product functions and features that are derived for product redesign and improvement.

1.3. Kansei Engineering

Source [23] developed Kansei Engineering as a consumer-oriented method for new product development in 1995. It is defined as a "translating technology of a consumer's feeling and image for a product into design elements". "Kansei" is a Japanese word which means a consumer's psychological feeling regarding a product. KE has be introduced in various distinct fields, such as automotive industry, construction, electric home appliance, office machine, etc. Several studies in the literature have utilized KE on the development of new product design. KE supports designer to develop a new product based on the consumer's feeling. Source [24] provided a design element analysis to extract important parameters such as color and shape that support the detailed design. The design element analysis is drilled down from the concept which is decided by initial concept classification. Source [25] apply KE in styling and design the speedometer and steering wheel of car interiors. Subjective evaluations were carried out by semantic differential scale and analyzed by multivariate analysis. Source [26] presented a decision support framework for an optimal design of bottle. Source [27] has reported an ergonomic toilet design which considering elderly people's needs. The

new toilet was tilted forward for elderly people's standing-up behaviors. Source [28] examined the relationships between appearances of watch and consumers' emotions to demonstrate that the product appearance would influence consumer involvement, emotion and even purchase intention.

Based on the existing literature, KE can be developed to serve as an elemental design support tool for a new product or an improvement for existing product. In the KE process, questionnaire is usually used to catch customer requirement. However, previous studies seldom applied text mining for online review to realize data-driven design.

2. Methodology

With the rapid expansion of e-commerce and online forums, more and more consumers buy products on shopping sites, discuss their personal experiences in forums, and comment products online. While customers want to buy a bike, it's reasonable that they would browse bike forums and related reviews before buying a bike. According to reading customer reviews, not only the customer evaluations of current product enable to be understood, but also the customer experiences and requirements can be captured. However, manually browsing through these reviews one by one requires a lot of time. Therefore, to investigate and analyze customer reviews original from the E-commerce Web site, the leading tool in text mining technique, SPSS Modeler, is conducted to facilitate the mining and analysis. After text mining, the KE is applied to translate customer reviews into design elements. Finally, a new product is designed based on the concept of design automation and data-driven design. Figure 1 expresses the architecture of this study. There are three major parts in the architecture: text pro-processing, text analysis and Kansei engineering. These parts are discussed step-by-step with the following contents.

2.1. Text Pre-processing

To make the results of text mining make be more representative of the population, the number of collected customer reviews should be as many as possible. Therefore, there are some pre-processing before text analysis. First, after selecting the target product, this study widely browses through shopping sites to collect representative product samples. Generally, a popular merchandise can get hundreds of reviews. Therefore, if the amount of the comments on the product is more than 100, then the product is considered as the candidate in this study. A customer review can be an article, a short comment, a discussion, or an experience to the similar products. To make the result of text mining reflect customers' Kansei image, this study only focuses on the text contents, exclusive the information of user name, date, rating and image of items. The customer reviews from shopping sites are manually collected as input information for subsequent analysis.

Second, raw data is a complete review which may contain the positive and negative comments. However, these raw data shouldn't be directly analyzed by SPSS Modeler, which mix the positive and negative comments in the same review would lead the mean of original reviews distorted. Therefore, to let each review indicate purely positive or purely negative comments, the next step is to transform complete review into several

sentences as input information. Moreover, the URL, video and other information that may impact the result of text mining are removed in this step.

Third, to discover and invent all the possible solutions for new product development, the analysis of the product design elements is conducted by morphological analysis, which is a method developed by source [29] to classify the target in each design element and help the designers recognize significant opportunities. To expand the area of possible solution, morphological analysis divides the research object into several design elements, and deal with these elements individually to form the overall solution. Morphological analysis aims to find the possible solutions from existing product that may generate a variety of solutions. Therefore, based on customer reviews, we expect to scale down the number of solutions and find the final design.

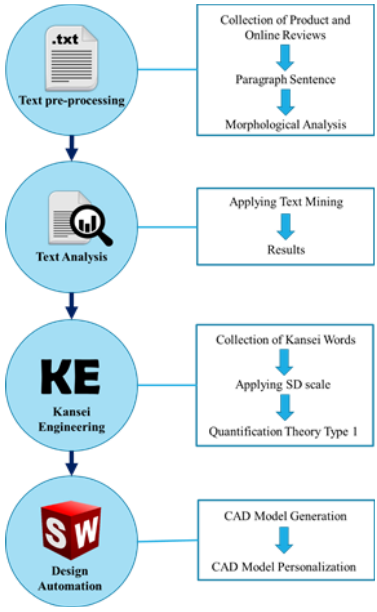


Figure 1. Research Architecture.

2.2. Text Analysis

This study applied SPSS Modeler's text analysis methods to extract key concepts from product reviews, generate categories which are composed of the extracted concepts, and help to gain insights from the unstructured text data. By following the four steps, we are able to identify popular product attributes and consumers' images of product from the collected reviews.

Step 1. Converting source data to a standard format.

The collected reviews is converted into a standard format that can be used for subsequent analysis. This conversion is conducted internally and does not change the original textual data.

Step 2. Analyzing converted data with the linguistic resources.

In this step, we utilizes the linguistic resources to extract concept terms and generate categories. The linguistic resources are core and internal components of the extraction engine in SPSS Modeler. They exist in the form of templates, libraries, and compiled resources. During the concept extraction, the linguistic resources are used every time to identify concept terms. The result of concept extraction contains the number of review sentence in which the concept appears, the number of occurrences of this concept, and the type to which the concept is assigned.

Step 3. Identifying equivalence classes and integration of synonyms.

After concepts are identified, the software uses a normalization dictionary to identify equivalence classes. An equivalence class is a base form of a phrase or a single form of two variants of the same phrase. The purpose of assigning phrases to equivalence classes is to ensure different synonyms are not treated as two concepts. For example, "Excellent" and "Perfect" are treated as one concept.

Step 4. Assigning category.
Next, category are assigned to extracted concepts. A category is a semantic grouping of concepts. Categories would include components, positive and negative words, opinion words, and more. Linguistic systems are knowledge sensitive that means the more information contained in the dictionaries, the higher the quality of the results. Modification of the dictionary content, such as synonym definitions and assigned category, can simplify the resulting information.

2.3. Kansei Engineering and Quantification Theory Type 1

After text mining, we are able to determine the Kansei words according to the frequency of all the words in relation to the overall online reviews. A word which frequently appear in customer reviews can express most consumers' image of product. Thus, this study captures the frequent opinion words as Kansei words. Semantic differential (SD) scale is a type of a rating scale to measure the semantic meaning of products. Visual-Analogue Scale (VAS), one of SD scales, is accustomed to handle a psychometric response scale which is used in questionnaires. According to the result of quantifying the semantic meaning for each sample, we can construct the matrix of design element and semantic evaluation. The relationship between the representative Kansei words and the design elements is found by the Quantification Theory Type 1 (QT1) which is usually applied in Kansei engineering.

The purpose of QT1 is to establish mathematical relation between Kansei words and design elements. Product designers usually implement QT1 in questionnaire analysis or customer needs analysis to determine the importance of each design element. QT1 is a multivariate regression analysis for categorical data with one dependent variable (quantitative) and several independent variables (qualitative). The quantitative variables determines what factor affect the importance. The qualitative variables are dummy variables that take the value 0 or 1 to indicate the absence or presence of some categorical effect. Each qualitative item is composed of several categories. A product sample must contain each item, and selects one category from each item. This concept is similar the morphological analysis (Table 1). Based on these data, a multiple regression table can be established in Excel to calculate partial correlation coefficient for each item and category score. Moreover, a regression equation is able to forecast the dependent variable depend on particulars of each design element.

2.4. Design Automation

The research proposes a way to visualize the new product by the CAD model of Solidworks based on the result of QT1. There are two major phases of design automation [30]. First, a prototype is generated according to the standard specifications [31]. This prototype is the as-is model to the specific product and the to-be model will be generated in next step [32]. Second, the to-be CAD model is generated by modifying each design element which is determined based on the result of QT1. For instance, the prototype of the product is made in steel. Nevertheless, according to the analysis, it is indicated that aluminium is preferred by the customers. Thus, the material is modified from steel to aluminium in to-be model.

3. Case Study

3.1. Text Pre-processing

In this research, customer reviews are mainly collected from Amazon.com which is the most popular E-commerce Web site and represent a large sample of online customers. Moreover, only the customers who have purchased specific products at Amazon can leave comments to the products. This research selects several types of road bike as a specific products in the case study. The reviews pages in each website which sells specific bike are used as the textual data for analysis. In the reviews pages, the research manually captures the opinion text content, exclusive of user name, date, rating and image of item, to make the result of text mining reflect customers' Kansei image. In the preliminary research, we collect 331 customer reviews of Takara Kabuto Single Speed Road Bike which written on Amazon.com. All textual rata are exported to txt-file for subsequent text mining. Moreover, to accurately obtain customers' opinion, the reviews which contain the positive and negative comments are paragraphed into several sentences, and the contents include URL, video and picture, are removed to avoid the error of text mining. After conducting above steps, original 331 reviews are transformed into 2,623 sentence as the input data of text mining.After collecting the reviews of different road bikes, to discover all the possible solutions for new product development, the design elements of bicycle is discovered by morphological analysis. As shown in Table 1, the design element can be divided into 5 category, and each category has several type. These differences is selected based on the survey of road bikes.

Table 1. Morphological analysis of bike.

Item	**Category**		
Handlebar (d_1)	Flat (d_{11})	Drop (d_{12})	Bullhorn (d_{13})
Frame material (d_2)	Steel (d_{21})	Carbon (d_{22})	Aluminum(d_{23})
Saddle (d_3)	Thin (d_{31})	Middle(d_{32})	Wide(d_{33})
Wheels (d_4)	Aluminum(d_{41})	Alloy(d_{42})	
Derailleur (d_5)	Single Speed (d_{51})	21 Speed(d_{52})	

3.2. Text Analysis and Kansei Engineering

In the preliminary research, we take the sample No.1 as an example. The result of text mining can capture the frequency of each word in customer reviews. We extract the adjectives which often are used to express customers' opinion, and the bipolar adjectives are also extracted for subsequent Kansei engineering.

Table 2. Kansei semantic set.

Kansei semantic set	**Similar Kansei words**
Overall Impression	Excellent (296), Good (255), Like(130), Bad (85), Dislike (34)
Usability	Easy (59), Difficult (51)
Riding Experience	Comfortable (46), Not comfortable (14)
Weight	Heavy(62), Light (22)

According to the result of text mining, we select 11 adjectives which frequently appear in customer reviews as Kansei words that express most consumers' image of product. These Kansei words can be divided into 4 semantic sets, include overall impression, usability, riding experience and weight (Table 2). The overall impression indicates the comprehensive evaluation of customers to this bike. The usability represents the difficulty of the customer in assembling the bike. The riding experience often means the feeling when customer riding this bike. The weight obviously mentions the weight of this bike. The right column records the times of appearance of each bipolar adjective. In the preliminary research, we only collect one sample to test the result of combining text mining and Kansei engineering. According to the morphological analysis and the calculation of VAS, the result can be summarized into the Table 3.

Table 3. Matrix of design element and semantic evaluation.

Sample	Design element					Kansei Image Evaluation Value			
	d_1	d_2	d_3	d_4	d_5	Bad-Good	Difficult-Easy	Not comfortable - Comfortable	Heavy-Light
No.1	2	1	2	2	1	0.8224	0.5364	0.7667	0.2619

3.3. Design Automation

On the basis of the selected design element, several design elements are shown in Figure 2. The design elements are visualized by Solidworks that can assemble different components and the parameter of component is adjusted by designers. Based on the analysis of Kansei engineering, the handlebar is drop style, the frame is made of steel, and the wheel is made of alloy. Overall, the CAD models are not the final design scheme, but are the design propositions that considering customer requirements for designer to subsequent adjust [33]. According to these propositions, the new product will be conformed to consumers' requirements.



Figure 2. CAD model of handlebar, frame and wheel.

4. Conclusion

This study proposed a data-driven design method that combine text mining and kansei engineering. A case study of bike is applied to demonstrate the feasibility of this method. Text mining is dedicated to extract the feeling of existing products from customer reviews in Amazon. Kansei engineering intends to determine customer requirements and quantify customer's semantic feeling by using QT1. According to the result of Kansei engineering, the score of each design element is calculated for

determining the final appearance. Finally, each design element is visualized by solidworks to realize design automation. The result is the preliminary design in order to save designer's time to analyze customer requirements. The quality of text mining and Kansei engineering will be increased by gathering more samples and customer reviews for future work.

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Systematic Approach in Determining Workspace Area and Manufacturing Throughput Time for Configuring Robot Work Cell

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Abstract. This paper delineates the development process of a systematic approach in determining the workspace area, and manufacturing throughput time, of robot work cell. The primary goal of this work is to provide a fast and easy configuration model with minimal cost, human involvement, trial and errors adjustments. The configuration model is constituted based on the variant-shaped configuration concept with its mathematical model. Robot work cell configuration concept with its mathematical models are deliberated in this paper where integration of these findings will be able to provide a framework in modeling the graphical user interface (GUI) of the configuration model. This work utilizes the CATIA V5 software where it involves the CATIA VBA and macro tool. The completion of this work could provide a basis for future investigation in developing high quality configuration model of the multiple robot work cells.

Keywords. Robot work cells, configuration model, workspace area, manufacturing throughput time, CATIAVBA, CATIA macro

Introduction

Outlining optimal layout of robot work cell have turned out to be intensive challenge among analysts who are intrigued by the sector of configuration. This is due to the fact, it devours high cost venture [1], long outlining time, high expert comprehension and loads of human investment in designing the optimal layout [2][3][4]. In addition, it is many-sided to actualize in light of the fact that it wishes to account about the safety constituent [1][5]. Expecting to deal partially the issues, a configuration model was proposed for determining the robot workspace area, A_W with its manufacturing throughput time, MTT according the input data set by user.

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An underlying work on [1][5] were taken as reference for dealing with the safety constituent. The illustration of two-dimensional robot work cell with its safety measure as shown in Figure 1 was used to model the safety measure for multi-robot work cells.

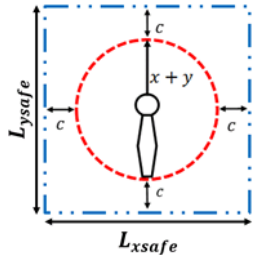


Figure 1. Illustration of 2D Robot Work Cell with Safety Clearance [1][5].

$$A_{safe} = L_{xsafe} \times L_{ysafe} = 2(x + y + c) \times 2(x + y + c) \tag{1}$$

Where,

- x : Length of robot arm (mm)
- y : Length of the robot tooling and work piece (mm)
- c : Clearance for the worker movement in a work cell taken as 650mm

With the development of safety constituents before, a variant-shaped configuration was formed which it could locate the near-optimal robot work cell layout. The variant-shaped configuration was constructed by joining along with at least one proportional squares next to each other according to the amount of robot used. The configuration was built by excluding the corner, half facing, diagonal and mix arrangement without considering rigid transformation condition (translation, rotation, reflection or glide reflection) [6]. Afterwards, the variant-shaped configuration was optimized through columns configuration and certain mathematical models was evolved where it is the key element to the invention of this configuration model.

The configuration concept with its mathematical model have been presented in this work where it provides a framework for developing the GUI of the configuration model. Then, a configuration model was invented by using the CATIA software where recently, it was utilized rapidly in designing of an automatic and intelligent system i.e. in [7] which proved that with the system, it able to reduce the development time, minimizing the errors and introduce technologies faster to the market [11][12]. At last, the robot workspace area, A_W and manufacturing throughput time, MTT of robot work cell are determined depends on the selection of configuration type. The outcomes of this work will enhance the way of configuring the robot work cell in future and the human-robot cooperation and additionally ease the setup cost and time in future.

1. Robot Work Cell Configuration

Certain works on configuration of optimal robot work cell were reviewed to analyse the raised issues which could be a great strategy in developing this model. A review [16] exhibited the optimal position for the depicted duties within the robotic manipulator

workspace. This work used the response surface approach for the both path translation and rotation. In view of the approach, a robotic optimisation tool as the add-in to the RobotStudio has been produced. The approach was checked appropriately by optimising the positioning of the industrial robots with its path in 4 different showcases for achieving a negligible process duration. In spite of, this review just centered around single robot, though in the real application, one or numerous robots could be available in the work cell. Moreover, another review [17] presented an enhancement work for laying out multi-robot work cells in a vertical area plane where accentuation to produce the outer surface of a large fuselage panel. This work expects to boost the covered workspace among two robots without crash between both robots and workpieces. This work fit to accomplish a design that yielded sensible positions by tried on an existing layout. Anyhow, this work must be utilized for two robot as it were.

Another review [18] provides a system with its method for optimising of the position of the distinctive workstations in the industrial robot work cell. The created system and its technique include one or many tasks and the industrial robot for carrying out these tasks. This work plans to upgrade the execution of the robot and in addition improve the efficiency of the automated work cell. In any case, the review was not material in the cases which utilized more than one robots. Additionally, an innovative layout approach was advanced [19]. The created approach depends on the Differential Evolution (DE) where it is used for solving the Facility Layout Planning (FLP). Robotic work cell layout was one FLP example hat was portrayed in this work. The mathematical FLP model incorporates couple of limitations and optimisation objective was proposed and a computerized design improvement was created for fulfilling the 3-D representation exhibit for the optimal layout. Yet, this work requires highly skilled and experienced worker for comprehension the approach.

Furthermore, an optimal robot positioning for tasks execution was presented [3]. This work expects to enhance the base position of an industrial robot to reach all predefined tasks and in addition limit the cycle time. Apart from that, this work integrated the robot inverse kinematics and collision avoidance with a derivative-free optimisation algorithm. The results of this work had effectively given a plausible arrangement in upgrading the cycle time for a robot station by placing the robot in optimal position. Be that as it may, future work would be centered around the improvement of the positions for a few robots, and on the programmed formation of the optimization approach. Another configuration review [1] shows an approach for effectively arranging different robots work cell. This motivation behind this review is to furnish quick design approach with less human inclusion at zero further speculation. In this review, the variant-shaped configuration was optimized by grouping the number of configuration into the columns configuration. As the outcome, the probable optimal robot work cell layout has been settled. Nevertheless, this work requires further investigation in determining the optimal layout for configuring various robot work cell and in addition making the PC based setup.

All the prior reviews demonstrate that there have been numerous techniques for the configuration of the robot work cell. Yet, there are many issues that emerge in view of the vulnerability interest for an optimised configuration system. Consequently, this work expects to settle the partially raised issue by proposing a systematic approach in developing a configuration model where it includes a safety and diverse arrangements for up to ten numbers of robots. Likewise, this work intends to make an innovative configuration model with minimal the configuration cost, human contribution at low venture and additionally fulfill the user necessities.

2. Development Process of the Configuration Model

2.1. Capture Conceptual Design of Configuration

In this activity, a configuration concept is determined where it begins with identifying and later optimizing the variant-shaped configuration wherein probable optimal robot work cells with its pattern in the form of mathematical model is exhibited. The mathematical model is extracted with the help of the MATLAB software. Later, workspace area, A_W and manufacturing throughput time, MTT equations were derived for each of the probable optimal robot work cell.

2.2. Design GUI of the Configuration Model

A completed GUI of the configuration model is generated by using the CATIA VBA and macro. Four levels of user form will be designed where each of the level will running their own specific tasks. The previous configuration concept with the derived mathematical models were utilized and the procedure of generating the GUI is eloborated through this activity.

2.3. Verify the Proposed GUI

The completed GUI of the configuration model is verified by executing a set of user data based on the selection of conguration types (normal configuration, configuration with minimum workspace area, configuration with minimum throughput time and configuration with both minimum workspace area and throughput time). The outcomes of the verification is presented and discussed through this activity.

3. The Proposed Configuration Model

A GUI of the configuration model is invented wherein it comprises of four different levels of user interface. First level user interface is used to begin the configuration process. Once user click the "Start" button, the next level of user interface will appear automatically (Figure 2).

In the second level user interface as shown in Figure 3, user is asked to select the "Number of Robot" based on the quantity of robot used and the configuration types.

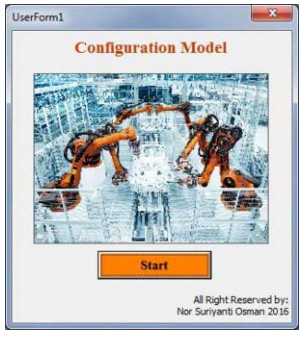


Figure 2. First Level User Interface.

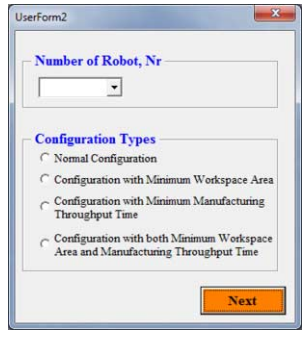


Figure 3. Second Level User Interface.

Thereafter, the procedure of identifying the optimal layout of robot work cell would be started. The current program of this level contains the following concept:

The concept of variant-shaped configuration was utilized and optimized by grouping the number of configuration into the columns configuration. It was grouped according to the same total number of robot in the references line at the horizontal plane. Additionally, the columns configuration must avoiding the rigid transformation and diversity position. The diversity position refers to the robot work cells which have the same number of robot in every horizontal line but diverse in position where they are considered as one or same optimal layout. In addition, this configuration involves a simple arrangement condition wherein the configuration with the corner, half facing, diagonal and mix arrangement was prevented [6]. As the results, the probable optimal robot work cell layout has been finalized and the data has been tabulated as shown in Table 1.

Table 1. Probable Ideal Robot Work Cell Layout [6].

Number of Robot, Nr	1	2	3	4	5	6	7	8	9	10
Number of Probable Optimal Configuration of Robot Work Cell, Nc	1	1	2	3	4	6	8	12	16	22

Next, the configuration pattern was successfully developed using MATLAB as shown in equation (2) (Figure 4 and 5). This equation will assist in determining the number of possible configuration, N_C according to the number of robot, N_r.

$$Nc = 0.0328Nr^3 - 0.229Nr^2 + 1.277Nr - 0.595 \tag{2}$$

Third level user interface (Figure 6) is utilized to calculate the workspace area, A_W and manufacturing througput time, MTT of the robot work cell. In this level, user need to input the robot information such as the robot arm length (mm) and the robot tooling and workpiece length (mm). Also, the manufacturing throughput time data such as the inspection time, t_i, process time, t_p, move time, t_m and queue time, t_q. Based on the previous study [1][5][11], new workspace area, A_W and manufacturing throughput time, MTT equations were derived. The derived workspace area, A_w equation is as follow:

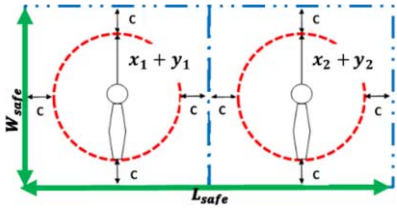


Figure 4. Illustration of Safe Multiple Robot Work Cell.

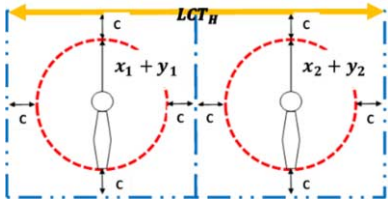


Figure 5. Illustration of Manufacturing Throughput Time for Multiple Robot Work Cell.

$$A_w = L_{safe} \times W_{safe} \tag{3}$$

$$L_{safe} = \max \sum_i^n [2((x_i + y_i) \ldots + (x_n + y_n) + (n \times c))] \tag{4}$$

$$W_{safe} = \max \sum_{i}^{n} [2((x_i + y_i) \ldots + (x_n + y_n) + (n \times c))] \tag{5}$$

$$1 \le i \le \infty \text{ and } 1 \le n \le \infty \tag{6}$$

To provide a reliable solution to this formula, dimension for both L_{safe} and W_{safe} must be in the maximum dimension. Meanwhile, the derived manufacturing throughput time, MTT equation is as follow:

$$MTT = \sum_{i}^{n} (RCT)_n + \sum_{i}^{n} (RCT)_n \tag{7}$$

Where;

$$MTT = LCT_H + LCT_V \tag{8}$$

$$LCT_H = LCT_V = \sum_{i}^{n} (RCT)_n \tag{9}$$

$$RCT = T_m \tag{10}$$

$$T_m = t_p + t_i + t_m + t_q \tag{11}$$

The equation was modelled through the summation of the robot cycle time, RCT in the horizontal and vertical manufacturing line cycle time, LCT_H & LCT_V where both of LCT must be the maximum dimension. For the LCT_V, the first horizontal line is excluded.

Finally, the fourth level user interface as in Figure 7 is presented where the final robot workspace area, A_W and manufacturing throughput time, MTT with the proposed optimal layout are displayed.

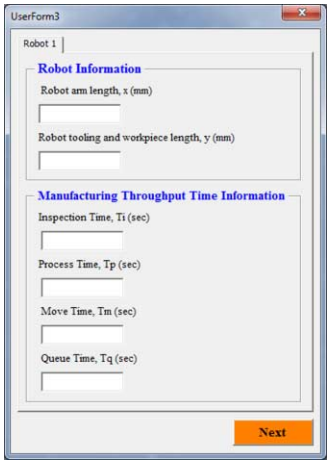


Figure 6. Third Level User Interface.

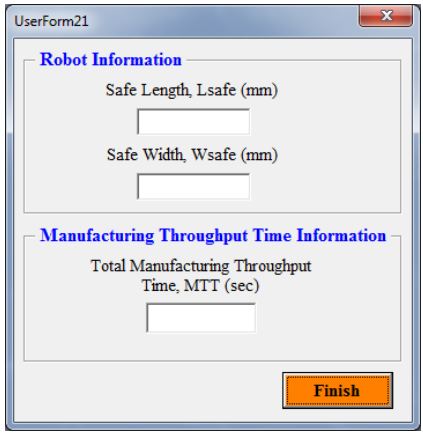


Figure 7. Fourth Level User Interface.

4. Verification of the Proposed Configuration Model

For the verification activity, one number of robot and configuration with both minimum workspace area and manufacturing througput time are elected to represent the outcome as shown in the second level of user interface (Figure 8). Then, by clicking the "next" button, the third level user interface will be displayed as in Figure 9.

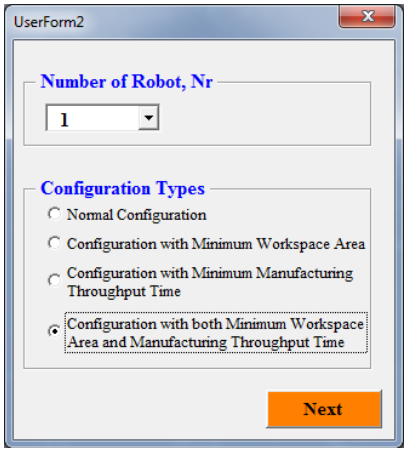


Figure 8. Second Level User Interface.

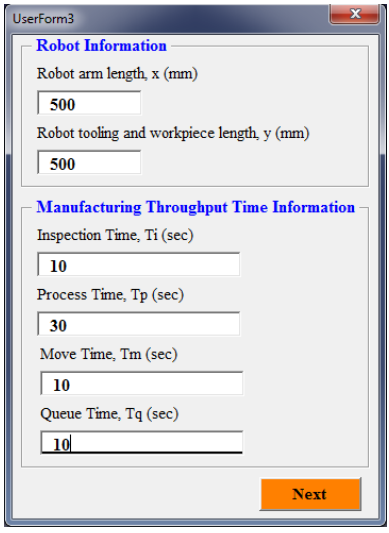


Figure 9. Third Level User Interface.

A set of data as in the third level user interface are required to be input in this user interface. Then, next level user interface as shown in Figure 10 will pop out by clicking again the next button. In the next level, the workspace area, A_W and manufacturing throughput time, MTT of robot work cell is calculated and presented with the proposed optimal layout. The "Finish" button in this user interface will exit the developed GUI of the configuration model as well as the CATIA drawing.

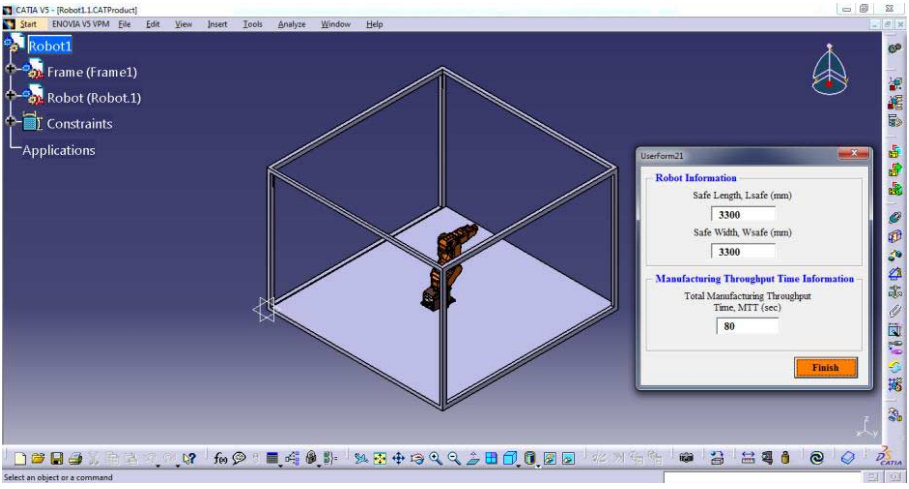


Figure 10. Fifth Level User Interface.

5. Conclusion and Future Work

A configuration model has been invented where the configuration concept, mathematical model with its GUI are presented. The fundamental motivation behind this work was giving a superior comprehension in the designing and developing of the configuration system. Besides, this work intended to give the quick and simple model for design engineers with the present of the significant data in regards to the robot work cell configuration system. In future, we will concentrate on the improvement of the configuration model which includes other complex user requirements.

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Part 15

Artificial Intelligence and Data Analytics

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Transdisciplinary Engineering: A Paradigm Shift
C. Chen et al. (Eds.)

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Estimating Cost of New Products Using Fuzzy Case-Based Reasoning and Fuzzy Analytic Hierarchy Process

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Abstract. Cost estimation is one of the influencial requirements for the current manufacturers when new products are introduced. This paper aims to propose a decision support system (DSS) that retrieves historical cases/products, which have the most similar cost estimates to the current case. This helps users to estimate the costs of new products at early stages of product development. The proposed DSS combines case-based reasoning (CBR), the analytic hierarchy process (AHP) and fuzzy set theory. Cases are represented using an object-oriented (OO) approach to characterize them in *n*-dimensional Euclidean vector space. A numerical example is illustrated to show the applicability of the proposed DSS

Keywords. New product development, cost estimation, decision support systems, case-based reasoning, analytic hierarchy process, fuzzy set theory.

Introduction

As new products are introduced into manufacturing systems, one of the complex issues is estimating the costs of these new products. In order to compete in dynamically changing situations, an appropriate cost estimation approach is required at the early stages of product development processes. Research findings have approved that although these early stage processes contribute to only 10-15% of the total product development costs, the 70-80% of development costs are committed at these stages [1, 2]. Additionally, customers usually demand high quality products with decreased prices. In order to meet these substantial challenges, manufacturers have to predict effectively the costs of the proposed new products. This is because cost estimation determines the overall performances of product development processes [3]. Stjepandić et al. [4] stressed that product development knowledge should be systematically considered at the early stage of product development.

This paper aims to propose a DSS that retrieves prior cases, which are expected to have the most similar cost estimates to the current problem, using case similarity measures. The proposed DSS combines fuzzy CBR and fuzzy AHP in the case retrieval

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process. This kind of combination has not been adequately studied in the past to articulate the problems of new products cost estimation.

The remainder of this paper is organized as follows: Section 1 reviews the literature. Section 2 describes the proposed DSS. In Section 3, a numerical example is illustrated. Finally, conclusions and future works are forwarded in Section 4.

1. Review of litrature

1.1 Related works

Several product cost estimation methods were proposed in the past. They are broadly classified into qualitative and quantitative approaches [5-7]. These approaches are sub-divided in different ways. For example, in Niazi et al. [5], qualitative approaches incorporated intuitive and analogical techniques; and quantitative approaches included parametric and analytical methods. However, in Caputo and Pelagagge [6], expert judgment and heuristic rules were categorized under qualitative; and quantitative approaches incorporated statistical (parametric and neural networks), analogous and generative/analytical methods. The advantages and limitations of the proposed methods were studied in Duverlie and Castelain [1], Rush and Roy [2], Cavalieri et al. [3], Caputo and Pelagagge [6] and Layer et al. [7].

Recently, AI techniques have been widely utilized for product costs estimation. For example, artificial neural networks (ANNs) were applied in Zhang et al. [8], Smith and Mason [9], Cavalieri et al. [3] and Caputo and Pelagagge [6] in different problem domains. CBR has also been utilized in product cost estimation problems. Duverlie and Castelain [1] compared a parametric and CBR method to estimate the costs of pistons. Kim et al. [10] compared multiple regression, ANNs and CBR to estimate the costs of construction projects. In An et al. [11], a CBR cost estimation model combined with the AHP to weight the attributes of construction projects. The findings showed that CBR is a promising approach in this problem domain.

1.2 Combining CBR, AHP and fuzzy set theory

CBR is an analogical reasoning approach, which draws inferences of a new problem depending upon experiences learned from previously solved problems [12]. Problem solving by retrieving successful experiences is a powerful and frequently applied approach in human thought and decision-making process. Human reasoners usually prefer to reuse and/or adapt their past similar situations to the current problem instead of starting from scratch every time. Remembering previously solved problems can be difficult to human users however computers are best to do so [12]. In this aspect, CBR systems seem more consistent with the natural reasoning process of people [13]. This is the major reason that findings from cognitive psychology have approved the psychological plausibility of CBR [12, 14], [15]. Aamodt and Plaza [14] described their general CBR cycle in terms of four 'Re's, which is usually called R^4 model.

1. *Retrieve* the most similar prior case to the current problem.
2. *Reuse* the knowledge in the retrieved case.
3. *Revise* the retrieved prior case in order adapt to the new case.
4. *Retain* the final solution as the learned case for future retrieval.

In real situations, knowledge can be reasonably expressed in terms of fuzzy sets whose descriptions are imprecise and vague. In such uncertain situations, fuzzy set theory is useful to grade the degree of membership of objects within [0,1] [16]. A case is an object that can be represented in terms of its several features. A case is said to be fuzzy if at least one of its features is described using fuzzy linguistic terms [17]. Usually, some features of an object can be suitably represented using fuzzy linguistic terms rather than crisp values. In addition, the weights of case features can be rated in terms of linguistic terms instead of using sharp numerical values.

Evaluating the weight of case features is one of the crucial challenges in CBR. It requires domain knowledge elicitation to make effective the reasoning process. In this study, fuzzy AHP is proposed to weight case features. The AHP is a systematic approach to elicit and represent experts' domain knowledge for prioritizing case features [18, 19]. Using pairwise comparison, the preference of one attribute over the other is expressed in terms of linguistic terms like "equally preferred", "moderately preferred", "strongly preferred", etc. These terms are purely subjective to define their boundaries due to human judgement. The conventional AHP was extended into fuzzy AHP to articulate this substantial problem in real-life decision-making [20, 21].

2. Proposed system

Figure 1 presents the flow diagram of the proposed DSS. In the proposed system, it is assumed that similar products are anticipated to have similar cost estimates.

2.1 Case feature selection and case representation

Identifying important case features, which can influence the costs of products, is the primary crucial work at an early stage of product development. In this study, machining rotating shafts is taken into account. First, three major product features are identified, namely, workpiece related, finished product quality and types of operations. Then these primary features are hierarchically branched into sub-features as presented in Section 3.

The identified case features are expressed in terms of numerical values, nominal values and fuzzy linguistic terms. The combination of these features is used to represent the cases in n-dimensional vector space. The cases are represented with the help of an OO approach using the Java programming language. The OO case representation approach is popular and widely accepted by software developers because of its comprehensiveness, flexibility, reusability and easiness to understand.

2.2 Weighting case features

The weights of features are evaluated using fuzzy AHP as stated before. Table 1 presents the relationships among the fuzzy AHP-based linguistic terms, their equivalent fuzzy numbers and their standard forms within [0, 1]. The fuzzy numbers and their reciprocals are converted into their corresponding standard fuzzy numbers by dividing them with the maximum value of the universe of discourse, which is 10 in this case [22]. The standardized fuzzy numbers are transformed into their corresponding crisp values by adopting a fuzzy ranking approach recently proposed by Chen and Chen [22]. Equation (1) is applied to defuzzify the required fuzzy numbers. This approach is simple; it avoids the limitations of other methods; and prefers the most precise fuzzy numbers when different fuzzy numbers have an identical mean value. After

determining the crisp score of any trapezoidal/triangular fuzzy number, A_{cs}, the classical AHP approach is applied for prioritizing case features.

$$A_{cs} = \frac{A_{mean}}{1+A_{std}} \quad (1)$$

Where A_{mean} and A_{std} are the mean and standard deviation of a standardized fuzzy number respectively.

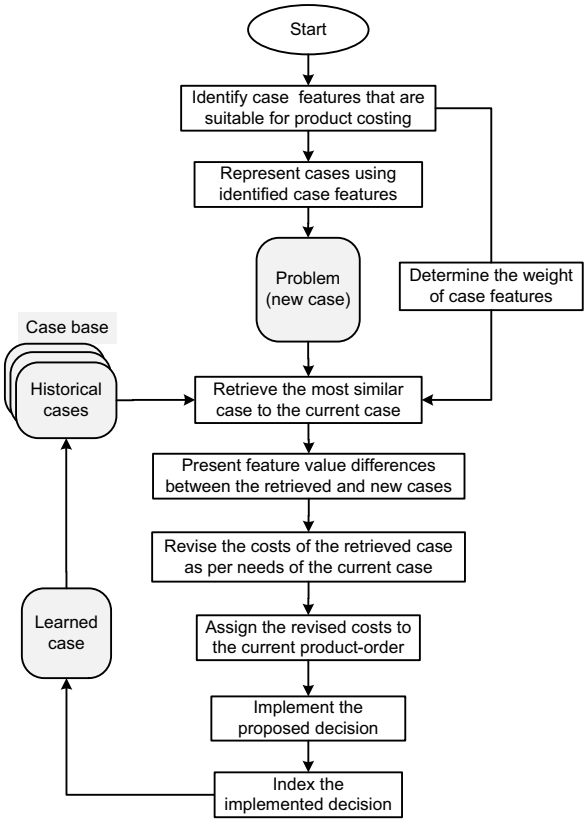


Figure 1. Flow diagram of the proposed DSS

Table 1. Linguistic terms, their equivalent fuzzy numbers and standardized fuzzy numbers.

AHP-based fuzzy linguistic terms	Equivalent		Standardized	
	Fuzzy number	Fuzzy reciprocal	Fuzzy number	Fuzzy reciprocal
Exactly equal	(1, 1, 1)	(1, 1, 1)	(0.1, 0.1, 0.1)	(1/10, 1/10, 1/10)
Equally preferred	(1, 1, 2)	(1/2, 1, 1)	(0.1, 0.1, 0.2)	(1/20, 1/10, 1/10)
Intermediate	(1, 2, 3)	(1/3, 1/2, 1)	(0.1, 0.2, 0.3)	(1/30, 1/20, 1/10)
Moderately preferred	(2, 3, 4)	(1/4, 1/3, 1/2)	(0.2, 0.3, 0.4)	(1/40, 1/30, 1/20)
Intermediate	(3, 4, 5)	(1/5, 1/4, 1/3)	(0.3, 0.4, 0.5)	(1/50, 1/40, 1/30)
Strongly preferred	(4, 5, 6)	(1/6, 1/5, 1/4)	(0.4, 0.5, 0.6)	(1/60, 1/50, 1/40)
Intermediate	(5, 6, 7)	(1/7, 1/6, 1/5)	(0.5, 0.6, 0.7)	(1/70, 1/60, 1/50)
Very strongly preferred	(6, 7, 8)	(1/8, 1/7, 1/6)	(0.6, 0.7, 0.8)	(1/80, 1/70, 1/60)
Intermediate	(7, 8, 9)	(1/9, 1/8, 1/7)	(0.7, 0.8, 0.9)	(1/90, 1/80, 1/70)
Extremely preferred	(8, 9, 10)	(1/10, 1/9, 1/8)	(0.8, 0.9, 1.0)	(1/100, 1/90, 1/80)

Additionally, fuzzy case features, which are described in terms of linguistic terms, are converted into fuzzy numbers in [0, 1] using eleven conversion scales (Figure 2) by referring to Chen and Hwang [23]. The variable x is any real number in [0, 1] and $\mu(x)$ is the degree of membership of x to the linguistic terms.

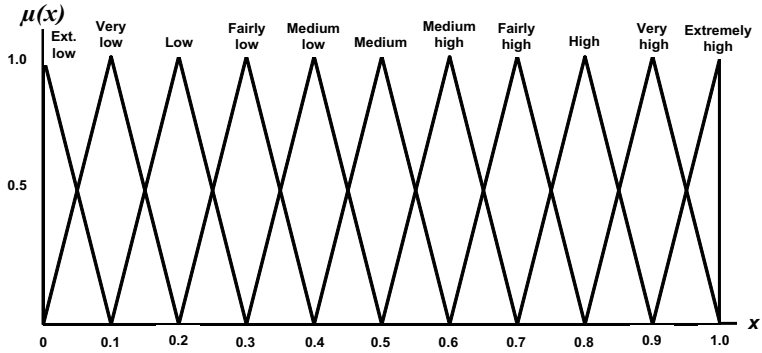


Figure 2. Conversion of linguistic case features into fuzzy numbers

2.3 Case retrieval and revision

This study uses the nearest neighbor (NN) matching function, which is popular and simple, to measure case similarities. This similarity measure is based on the inverse of the Euclidean distance between any two cases. The Euclidean distance between a new case p and a prior case q, $dist(p,q)$ can be calculated:

$$dist(p,q) = \sqrt{\sum_{i=1}^{n}[w_i * dist(a_i^p, a_i^q)]^2},\ dist\left(a_i^p, a_i^q\right) \in [0,1] \tag{2}$$

Where n is the number of case features; w_i is the normalized weight of the ith attribute; and a_i^p and a_i^q are the values of the ith attribute for cases p and q respectively.

From Equation (2), the distance between the individual features of two cases, $dist\left(a_i^p, a_i^q\right)$, can be determined as follows.

In the case of discrete and continuous numerical features:

$$dist\left(a_i^p, a_i^q\right) = \frac{|a_i^p - a_i^q|}{a_{i,max} - a_{i,min}},\ a_i^p \,\&\, a_i^q \in [a_{i,min}, a_{i,max}] \tag{3}$$

Where $a_{i,min}$ and $a_{i,max}$ are the minimum and maximum value of the ith attribute respectively.

For categorical attributes:

$$dist\left(a_i^p, a_i^q\right) = \left|a_i^p - a_i^q\right| = \begin{cases} 1\ if\ a_i^p \neq a_i^q \\ 0\ if\ a_i^p = a_i^q \end{cases} \tag{4}$$

In the case of fuzzy features, the authors consider trapezoidal fuzzy numbers and Equation (5) is adopted from Wei and Chen [24]. Their proposed method combines the concepts of geometric distance, the perimeter and the height of a trapezoidal fuzzy

number. In this case, the value height is 1. When trapezoidal fuzzy numbers are in a standard form $a_i^p = \left(a_{i,1}^p,\ a_{i,2}^p,\ a_{i,3}^p,\ a_{i,4}^p\right)$ and $a_i^q = \left(a_{i,1}^q,\ a_{i,2}^q,\ a_{i,3}^q,\ a_{i,4}^q\right)$; and $0 \leq a_{i,1}^p \leq a_{i,2}^p \leq a_{i,3}^p \leq a_{i,4}^p \leq 1$ and $0 \leq a_{i,1}^q \leq a_{i,2}^q \leq a_{i,3}^q \leq a_{i,4}^q \leq 1$.

$$dist\left(a_i^p, a_i^q\right) = 1 - \left[\left(1 - \sum_{k=1}^{4} \frac{|a_{i,k}^p - a_{i,k}^q|}{4}\right) * \frac{min\left(per\left(a_i^p\right), per\left(a_i^q\right)\right)+1}{max\left(per\left(a_i^p\right), per\left(a_i^q\right)\right)+1}\right] \quad (5)$$

Where $per\left(a_i^p\right)$ and $per\left(a_i^q\right)$ are the perimeters of trapezoidal fuzzy attributes of cases p and q respectively.

Referring to Equation (2), the values of $dist\left(a_i^p, a_i^q\right)$ are within [0, 1]. The maximum Euclidean distance, $dist_{max}(p,q)$, is found when all the values of $dist\left(a_i^p, a_i^q\right) = 1$; and the minimum Euclidean distance, $dist_{min}(p,q)$, is found when all the values of $dist\left(a_i^p, a_i^q\right) = 0$ i.e. when $p = q$. Referring Equation (2), the $dist_{max}(p,q)$ and $dist_{min}(p,q)$ values can be determined as $dist_{max}(p,q) = \sqrt{\sum_{i=1}^{n} w_i^2}$ and $dist_{min}(p,q) = 0$

Because distance and similarity are inversely related, the similarity between two cases p and q, $sim(p,q)$, can be found as follows [25]:

$$sim(p,q) = 1 - dist(p,q) \quad (6)$$

The minimum similarity measure, $sim_{min}(p,q) = 1 - \sqrt{\sum_{i=1}^{n} w_i^2}$ and using the same approach, the maximum similarity between any two parts, $sim_{max}(p,q) = 1$, and $sim(p,q) \in [sim_{min}(p,q), 1.0]$. Using these relationships, any retrieved case with a higher similarity value to the current problem is selected for reuse and adaptation.

The proposed DSS not only measures case similarities for case retrieval but also presents the difference in each case attribute for case revision. Then the case revision can be done by human experts using any other cost estimation approaches.

3. Numerical example

This numerical example is illustrated using a lathe-machining center. Suppose the machining center produces a number rotating shafts for different purposes. To represent cases using an OO method, twelve product features are proposed. The features are structured hierarchically as indicated in Table 2 to prioritize these proposed case features. The hierarchy incorporates three major attributes: (1) workpiece related; (2) required operations types; and (3) product quality requirements. These three major features are sub-divided into their corresponding sub-features. The normalized weights of the major features and sub-features (under their preceding features) at their specific levels are evaluated using fuzzy AHP. To do this evaluation, the concepts from Table 1 and Equation (1) are applied. The normalized weights of the twelve case features are proportionally calculated as indicated in the fourth column of Table 2.

The twelve product features are represented using numerical, nominal and fuzzy data (see Table 3). Length (L) and diameter (D) are represented using numerical values in millimeter. Material type (Ma) is represented using linguistic terms to describe the expensiveness of construction materials. Similarly, tolerance limit (Tl), surface smoothness (Ss) and durability (Du) are described in terms of linguistic terms and the

terms are converted into fuzzy numbers referring to Figure 2. Machining operation types such as turning (Tu), facing (F), thread-cutting (Th), drilling (Dr), boring (B) and tapping (Ta) are expressed using nominal values of {0,1}. Additionally Table 3 indicates three product-orders (P1-P3) as new cases and two training samples (T1 and T2) as prior cases. Assume CC1 and CC2 are costs assigned initially to T1 and T2 respectively and CC3 is the revision of CC2 as P1 is retrieved as a prior case (Table 4).

Table 2. Hierarchy of case features and their normalized weights

Major feature	Middle feature	End feature	Normalized weight calculation	Normalized weight (w_i)
Workpiece (0.475)	-	Length (0.278)	0.475x0.278	0.132
		Diameter (0.248)	0.475x0.248	0.118
		Material (0.475)	0.475x0.475	0.226
Operation types (0.277)	External (0.541)	Turning (0.519)	0.277x0.541x0.519	0.078
		Facing (0.176)	0.277x0.541x0.176	0.026
		Threading (0.306)	0.277x0.541x0.306	0.046
	Internal (0.459)	Drilling (0.475)	0.277x0.459x0.475	0.060
		Boring (0.277)	0.277x0.459x0.277	0.035
		Tapping (0.248)	0.277x0.459x0.248	0.031
Quality (0.248)	-	Tolerance (0.439)	0.248x0.439	0.109
		Surface (0.296)	0.248x0.296	0.073
		Durability (0.265)	0.248x0.265	0.066

Table 3. Structured features of cases/products

P	L	D	Ma	Tl	Ss	Du	Tu	F	Th	Dr	B	T
P1	500	180	0.7,0.8,0.9	0.4,0.5,0.6	0.8,0.9,1.0	0.7,0.8,0.9	1	0	1	1	1	0
P2	820	330	0.3,0.4,0.5	0.6,0.7,0.8	0.4,0.5,0.6	0.6,0.7,0.8	1	1	0	1	0	1
P3	520	200	0.7,0.8,0.9	0.4,0.5,0.6	0.7,0.8,0.9	0.8,0.9,1.0	1	0	0	1	1	1
T1	850	350	0.3,0.4,0.5	0.7,0.8,0.9	0.4,0.5,0.6	0.5,0.6,0.7	1	0	1	1	0	1
T2	450	150	0.7,0.8,0.9	0.3,0.4,0.5	0.8,0.9,1.0	0.7,0.8,0.9	1	1	1	1	0	0

The similarity between the new cases and training samples is calculated using Equations (2) - (6). The results are compiled in Table 4.

Table 4. Summarized results of the proposed DSS

Product	Most similar case	Similarity-value	Cost to be revised	No. of cases in case-base
P1	T2	0.952	CC2	2
P2	T1	0.944	CC1	3
P3	P1 (new case)	0.939	CC3 (revised CC2)	4

4. Conclusions and future works

In the past, a combination of fuzzy CBR and AHP was not applied to estimate the costs of new products. In this study, a novel and promising DSS is proposed to articulate this problem situation. The DSS is capable to retrieve the most similar prior cases to the current case and update its case base as new cases enter to the system (Table 4). The retrieved case is expected to have similar cost estimates to the new order. This DSS recommends the case revision to be done by human experts using other cost estimation methods. This is because the aim of the DSS is not to replace the tasks of experts; however, it should be to assist them in complex situations. Searching the most similar previous cost estimate is the most cumbersome work for human reasoners at the early stages of new product development processes.

In the proposed DSS, fuzzy cases have been represented using the combination of numerical values, nominal values and fuzzy linguistic terms. This kind of unified representation emulates human thought to process imprecise and vague information in

the real world. Although the numerical example has been illustrated using a few new cases and training samples, the proposed DSS can address any number of product-orders scheduled, training samples and case features. Because in real manufacturing situations, products mix variation is very high.

In the future, the proposed DSS will be tested using realistic historical data in order to validate its accuracy.

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An Ontology-Based Product Affective Properties Identification Approach

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Abstract. Precisely understanding the value and perception of consumers has long been recognized as essential elements of every market-oriented company's core business strategy. For this reason, customers' affection, as the basis for the formation of human values and judgment, should be considered carefully to strengthen the product quality and competitiveness. However, conventional product design places more attention to functional attributes and requires survey process to collect customers' evaluations, neglecting the in-depth study of the underlying associations between design properties and consumers' emotions based on the abundant online consumer response resources. To improve the deficiency, this study was proposed to develop a product affective properties identification approach. Particularly, data mining techniques (e.g. web mining, text mining) are applied to capture online product review resources. Considering the characteristics of user/consumer responses and evaluations, ontology is utilized to assist in the semantic analysis. With the help of product knowledge hierarchy and electronic lexical database, product properties, which can evoke consumers' affect, can be identified. Furthermore, the identified product affective properties are prioritized to provide designers with important reference for future improvement on the product. To illustrate the proposed approach, a pilot study based on iPhone 7 was conducted, in which the influential affective properties have been identified, and a ranking of them has been mapped out.

Keywords. Product affective property, ontology, data mining, product knowledge hierarchy, prioritization

Introduction

Nowadays, the increasingly competitive market has elicited an urgent need to develop a successful product which can satisfy the increasing consumer expectations and demands to the most. Apart from basic functions and economic considerations, affective aspects of products are also heavily concerned by consumers. Design attributes, such as color and form, can provoke feelings, and influence the overall perception of a product. Therefore, affective product design was proposed and advocated to develop products that satisfy customer feelings as an aspect of product quality. In this regard, previous relevant literatures have indicated that products with deliberate affective design can help improve consumer satisfaction and further promote product success. Therefore, good affective features could sharpen the competitive edge of products, and a precise understanding of product affective properties appears particularly important and deserves an in-depth investigation.

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1. Background Review

In today's competitive world, the optimization of customer satisfaction is essential in product design. A plenty of studies have been devoted to product affective design from different perspectives. Considering the basic assumption for product affective design that there exists a cause-and-effect relationship between consumers' affective responses and product features, existing studies can be generally classified into three categories:

- Identification and classification of consumers' affection; the semantic deferential method (SD) is frequently used to investigate customers' perception on products [1]. By studying product semantics, customers' subjective feelings about a product can be discerned and quantized on a Likert-type scale. Other assessment of emotion can be seen in the use of Conjoint analysis and Quality Function Deployment (QFD). Considering the ambiguity and subjectivity of consumers' affect, the selection methods for Kansei words (or emotional adjectives) are always a research hotspot. K-means clustering and affinity diagram have been used to achieve this purpose [2, 3].
- Modelling the quantitative relationship between affective responses and design attributes; in this regard, Kansei engineering is a notable way of translating consumers' psychological feelings about a product into perceptual design attributes [4]. A number of Kansei models have been developed to improve the association accuracy or applicability of Kansei approaches. For example, fuzzy logic and rough set theory are widely applied to cope with the uncertainty and ambiguity of affective responses [5, 6]. In addition, statistical methods, especially regression algorithms, and artificial intelligence techniques, such as neural network, rule mining and genetic algorithm, are also widely studied to model the relationship between affective responses and specific design attributes [7, 8]. Recently emerging studies place more attention to tackle the nonlinearity problem of the relationships.
- Assessment and prediction of product design attributes [9]; it relates to the estimation of customer satisfaction based on affective responses, so as to assist in the specification and prediction of design attributes. Factor analysis and hypothesis-testing approach are often used to reveal the affective performance of design attributes [10]. In this respect, pre-purchase affect are more focused to identify the affection which can influence the purchase decision [11].

For the above studies, the common and necessary operations include the selection of design attributes and Kansei words (or emotional adjectives), based on which survey and questionnaire will be conducted to collect rating scores (i.e. affective responses) from users/consumers. It indicates that the design attributes are specified by the survey assigners, rather than consumers, as well as the Kansei words. Subjects could only assess the given features using the given adjectives. It, in effect, extremely restricts consumers' freedom to express their feelings and opinions on any design attribute using more preferable words.

Moreover, research focus is mainly placed on pre-purchase affect, namely, customers' affective needs and preference elicited by the product, especially by the product form. In existing studies, the widely adopted practice is to present different product appearances to participants, then collect their evaluation scores. However, form design is just one concern of product design. The core considerations, such as the functionality, usability or safety, cannot be perceived from product form before real use.

Therefore, post-purchase or post-use affect should be more important and deserve more research attention.

Based on the analysis of existing studies, it can be concluded that: 1) current studies mostly require survey or questionnaires to collect user evaluations, which restricts users' choices to comment on other attributes; 2) affective design is often considered for product form design based on pre-purchase affect; 3) research focus is on the selection of adjectives and the advancement of mathematical relationships between emotional evaluations and design attributes, neglecting the further prioritization and re-construction of affective design properties which can provide more helpful reference for design practices.

To tackle the abovementioned research problems, this work aims to develop a product affective properties identification approach which can discover important affective properties from abundant online product review resources (where free comments including pre- and post-use experience can be obtained) and further prioritize them in terms of their affective performance so as to benefit designers with important reference for further product improvement.

2. Research Methodology

The overall framework of research methodology is outlined in Figure 1. Generally, it can be divided into three stages. Stage 1 is to capture product review data from online resources and perform basic text processing to extract useful textual tokens. At Stage 2, the textual tokens are examined to identify product affective properties. For this purpose, ontology is utilized to provide semantic analysis, and product knowledge hierarchy is constructed to provide design considerations. At Stage 3, a prioritization process is deployed to estimate the importance of different affective design properties. Hence, affective design properties can be ranked in a hierarchical structure to provide reference for designers.

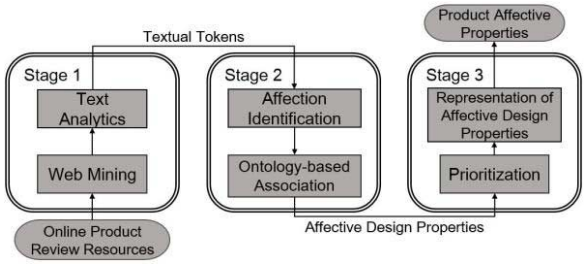


Figure 1. Overall Framework of Research Methodology.

2.1. Stage 1: Extraction of Online Consumer Responses

With the rapid development of the Internet, there are more and more online platforms and convenient accesses for consumers to offer their understandings and impressions on products. Customers/users can give any comments on any design aspects which can evoke their interests. Therefore, customer responses can be captured from a wide range of sources such as pervasive sensor networks, internet services and social media, especially online product review websites, which actually contain abundant consumer responses.

Step 1: *Content Extraction*. Web mining is applied to crawl on web logs of product review websites or social media to extract meaningful contents (i.e. consumer responses/comments). Extracted contents will be collected as response documents.

Step 2: Text Processing. Text mining is applied to tokenize textual responses, discover textual patterns and further pre-process the textual data in a quantitative manner (e.g. TF-IDF, correlation, similarity). Considering the further processing at Stage 2 to identify affective design properties, n-gram generation is needed to capture the semantically meaningful phrases.

2.2. Stage 2: Identification of Product Affective Properties

The extracted word tokens are examined from perspectives of design and affect. In particular, tokens representing product attributes or specifications are identified as design property tokens. Tokens implying affect, such as adjectives, are identified as affective tokens. Through establishing the relationships between affective tokens and design property tokens, product affective properties can be identified.

Step 3: *Establishment of PKH*. Product knowledge hierarchy (PKH) is outlined to assist in the identification of design-related tokens. As shown in Figure 2, product information can be layered in a hierarchical structure from the holistic view of product to product properties and sub-properties. For different products, main product properties should be specified accordingly. With the help of PKH, tokens representing product properties can be identified.

Step 4: Affection Identification. For affective tokens, an electronic lexical database is deployed to select adjectives out. Particularly, emotional adjectives are treated as the evidence of affect.

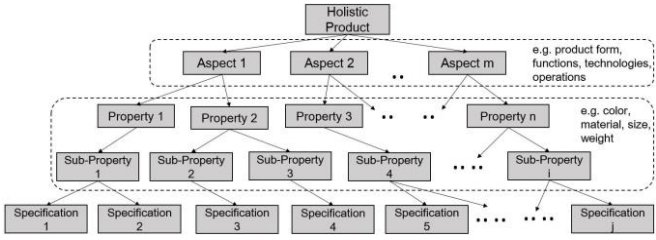


Figure 2. Product Knowledge Hierarchy.

Step 5: Establishment of Associations between Design Properties and Affect. Ontology is leveraged to provide semantic relations to associate affective tokens (AT) and product property tokens (DT). A relationship set U is generated based on ontology to bridge affective tokens $at_i \in AT$, $\mathrm{AT} = \{at_i | i = 1, \dots, I\}$ and design property tokens $dt_j \in DT$, $\mathrm{DT} = \{dt_j | j = 1, \dots, J\}$. As shown in Figure 3, the elements in AT will be related to DT based on U, and an association matrix can be thusly obtained. If an association relationship exists in a proper semantic context, the dt with associated at will be regarded as an affective product property.

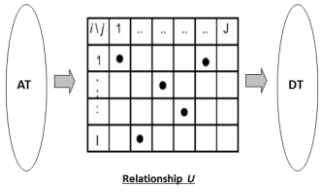


Figure 3. Association relationships between AT and DT.

2.3. Stage 3: Prioritization of Product Affective Properties

The identified product affective properties will be further prioritized according to their design importance and affective intensity. Based on the priority, product affective properties can be re-organized and represented in a rank.

Step 6: Prioritization. The priority of the product affective properties will be estimated from two perspectives: design and affect. Design importance will be calculated based on the total occurrence (i.e., TO_{dt_i}), term frequency–inverse document frequency ($TF-IDF_{dt_i}$, see Equation 1) and *PKH* priority (i.e., priority subject to *PKH*, $\mathrm{f}(h_{PKH})_{dt_i}$, see Equation 2) of design property tokens. Therefore, design importance *DI* can be calculated using Equation 3. Likewise, affective intensity will be estimated based on the polarity (i.e., p_{at_j}, if positive, then $p_{at_j}=+1$; if negative, then $p_{at_j}=-1$), occurrence of affective tokens (i.e., TO_{at_j}), $TF-IDF_{at_j}$ (see Equation 4) and semantic intensity (i.e., the intensity of the adjective, SI_{at_j}, an AHP process is designed to index the semantic intensity into three classes: 1 represents Weak, 2 represents Medium, and 3 represents Strong). Thus, affective intensity *AI* can be calculated using Equation 5. A weighted calculation is introduced to integrate *DI* and *AI* in order to achieve the overall priority (i.e., the priority of design property *i* with affect *j*, $OP_{i,j}$, Equation 6). Considering the length of this paper, not all equations are presented here, such as the normalization and aggregation equations.

$$TF-IDF_{dt_i}=tf(dt_i,d)\cdot idf(dt_i,D)=(0.5+0.5\frac{f_{dt_i,d}}{\max_{dt_i} f_{dt_i,d}})\cdot\log\frac{N}{n_{dt_i}} \tag{1}$$

where $f_{dt_i,d}$ is the number of times that design token *dt* occurs in document *d*, *N* is total number of documents in the corpus, n_t is the number of documents where the design token *dt* appears.

$$f(h_{PKH})_{dt_i}=\frac{e^{\beta h_{PKH}}-e^{-\beta h_{PKH}}}{e^{\beta h_{PKH}}+e^{-\beta h_{PKH}}};\beta>0 \tag{2}$$

where h_{PKH} is the depth to the root level in PKH, β is a smoothing factor, $\beta>0$.

$$DI_{dt_i}=TO_{dt_i}\cdot(1-TF-IDF_{dt_i})\cdot f(h_{PKH})_{dt_i} \tag{3}$$

$$TF-IDF_{at_j}=tf(at_j,d)\cdot idf(at_j,D)=(0.5+0.5\frac{f_{at_j,d}}{\max_{at_j} f_{at_j,d}})\cdot\log\frac{N}{n_{at_j}} \tag{4}$$

where $f_{at_j,d}$ is the number of times that affective token *at* occurs in document *d*, *N* is total number of documents in the corpus, n_t is the number of documents where the design token *at* appears.

$$AI_{at_j}=p_{at_j}\cdot TO_{at_j}(1-TF-IDF_{at_j})\cdot SI_{at_j} \tag{5}$$

$$OP_{i,j}=\omega_d DI_{dt_i}+\omega_a\left|AI_{at_j}\right| \tag{6}$$

where w_d is the weight of design importance, w_a is the weight of affective intensity; |AI| is considered, since no matter positive or negative responses, the more the absolute value, the more it is concerned by consumers.

Step 7: Product Affective Property Representation. Every product affective property can be denoted as "design property (*DI*, *AI, OP*)". For *AI*>0, it represents the product properties with positive consumer affect; therefore, such properties are the strength of this design. On the contrary, for *AI*<0, it indicates the product properties cannot satisfy consumers and may be the weakness of the product. The higher *OP* means higher integrated priority, thus more attention should be paid. Therefore, product properties can be re-organized and ranked in three dimensions. Strength and weakness can be easily recognized, and valuable reference on which properties to what degree should be improved could be achieved.

3. A Pilot Study

A pilot study based on iPhone 7 was conducted. Amazon and CNET are two important product review platforms and selected as online product review resources. A web mining and text mining software *RapidMiner* is used to capture the content of the review webpages and perform basic text processing. The complete content of one review webpage will be treated as one document. In this preliminary study, 50 documents are captured in total. The collection of all documents will be treated as the corpus.

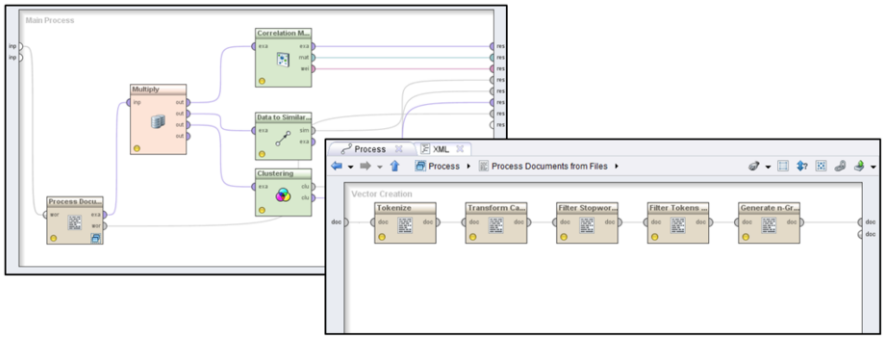


Figure 4. Extraction of Online Consumer Responses with Rapid Miner.

1. Stage 1: As shown in Figure 4, main processes consist of *Process Documents from Files*, *Multiply*, *Correlation Matrix*, *Data to Similarity* and *Clustering*. In particular, *Process Documents from Files* is executed by sub-processes, i.e., *Tokenize*, *Transform Cases*, *Filter Stopwords (English)*, *Filter Tokens (by length)* and *Generate n-Grams (terms)* to separate extracted content into individual word tokens and specify Stopwords and length to control the tokenization process. To retain the original semantic meaning, n-grams (in this work, n is set as 3) are defined to generate semantically meaningful short terms. *Correlation Matrix*, *Data to Similarity* and *Clustering* are also considered to provide simple analysis of the captured documents. In result, 13953 attributes (including single words, 2-gram terms and 3-gram terms) were obtained.

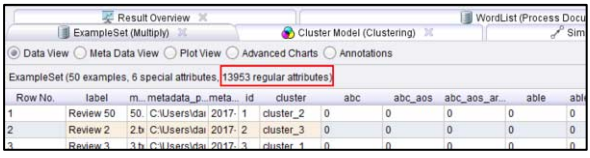


Figure 5. *RapidMiner* extraction results.

2. Stage 2: PKH is developed for Smartphone. A set of proper semantic relations is selected based on ontology to narrow the connections down to certain relations with relatively higher importance. Referring to previous ontology-related studies, "*synonymous*", "*Meronym*" (a part of) and "*Hypernym*" (a kind of) are frequently analyzed and also taken into account in this work. With the help of the semantic relations, tokens, which can be associated to PKH, are identified as design property tokens. Moreover, *WordNet* (an electronic lexical database) is introduced to provide lexical reference. By the use of *WordNet*, emotional adjectives can be distinguished as affective tokens. Afterwards, the relationships between design tokens and affective

tokens are established with joint consideration of semantic relations and lexical reference, and the design tokens which are successfully associated with affective tokens are regarded as product affective properties. As results, nearly 400 product affective properties have been identified. Some examples are presented in Table 1.

Table 1. Examples of Identified Product Affective Properties.

Product Affective Property Examples		
amazed_smoothness	beautiful_designed_products	cheap_headphone
amazed_smoothness_controls	beautiful_device	cheap_water_resistance
amazing_cpu	beautiful_device_look	cheaper_amoled_screen
amazing_cpu_wasted	bigger_battery	chip_powerful
amolded_screen_icing	bigger_battery_play	connector_expandable
amolded_display_pleasing	bigger_battery_speaker	decent_cell_phone
battery_heavy_use	bigger_screen	decent_headphone
battery_issue_timed	buds_excellent	device_simpler
battery_life_excellent	buds_excellent_durable	device_simpler_frustrating
battery_life_great	camera_fantastic	device_audiophile_old
battery_life_lower	camera_fantastic_work	disappointed_fast_charging
battery_life_shorter	camera_faster	dish_pretty_good
battery_life_terrible	camera_faster_processor	display_pleasing
etc…	etc…	etc…

3. Stage 3: *DI* and *AI* of each product affective property are calculated using Equations 1-5, and overall priority of product affective properties can be computed using Equation 6 (in this study, *DI* and *AI* are assigned with the same weights, namely, 0.5). Considering the large number of product affective properties, the properties with higher priorities are listed in Table 2 below.

Table 2. Product Affective Properties with Higher Priority.

Product Affective Properties	**DI**	**AI**	**OP**
Battery (-)	0.565	0.579	0.572
Camera (++)	0.511	0.469	0.490
Headphone, headphone-jack, headphones (+)	0.762	0.209	0.485
Sound, sounds (++)	0.462	0.385	0.424
Plug (++)	0.415	0.417	0.416
Screen (++)	0.532	0.273	0.403
Charging, charge, charged, charger (--)	0.562	0.227	0.394
Bluetooth (N)	0.413	0.320	0.366
Music (+)	0.504	0.200	0.352
Adapter, adapters (--)	0.428	0.222	0.325
Lightning (-)	0.421	0.188	0.304
Look, looks (++)	0.283	0.318	0.300
Size (+)	0.259	0.300	0.280
Tech, technologies, technology (+)	0.248	0.214	0.231
Software (N)	0.217	0.154	0.185

*+ means there are more positive responses than negative ones for the property; - means there are more negative responses for the property; the number of + and – implies how much this affect is stronger than the other.

According to the results, it can be found that the battery and charging-related issues are the main pain points of iPhone 7. It can be understood that the battery problem of iPhone 6 is widely complained and discussed among consumers, so the battery and charging performance for iPhone 7 is also questioned by consumers. For adapters, it should be considered jointly with "*Lightning*" which is also negative, since a new change for iPhone 7 is the "*Lightning to Headphone Jack Adapter*". The new change brings consumers with some inconvenience, since they need one more adapter and cannot charge and use headphones simultaneously. On the other hand, the camera,

screen, appearance and technology, to name a few, are the advantages of iPhone 7 and should be maintained in future generations.

4. Discussion and Conclusion

In summary, this work aims to develop a product affective property identification approach. For this purpose, a web- and text-mining process is deployed to take use of online product review resources, capture useful consumer responses and perform textual analysis. Afterwards, ontology and electronic lexical database are utilized provide semantic relations and lexical reference to identify design-related and affect-related word tokens and moreover, assist in the association between design tokens and lexical tokens. The design tokens which are related with affective tokens will be regarded as affective design properties. Finally, the importance and affective intensity of the affective properties will be estimated, and overall priority of these properties can be accordingly achieved.

However, there are still some limitations of this work. For example, for the same product property, positive and negative responses co-exist. How to calculate the final affect should be carefully considered. Moreover, how to fully take the context into account and improve the accuracy of information detection will still be studied in future research.

Generally, this study explores a product affective properties identification approach based on ontology and data mining and is promising to contribute to the discovery of important affective design properties from rich online consumer responses.

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Mining the Customer's Voice and Patent Data for Strategic Product Quality Function Deployment

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Abstract. The goal of research and development for new product and service development is to satisfy customers. A company that satisfies customers with short life cycle products like smartphones that match or exceed expectations builds brand equity and a global competitive advantage. Companies are challenged with the task of identifying the market demand that evolves with technological innovations. Since many of the short product life cycle communications products are continuously changing, capturing and measuring the satisfaction of customers is increasingly difficult. One approach to accurately identify market demand and customer satisfaction with the functions of products is to listen to what is said among social networks. The Internet has empowered customers to express their opinions, attitudes, beliefs, and purchase intentions about products using community platforms, social media, customer blogs, and other networks. The words, expressed on these platforms, represent the voice of customers and provide collective and dynamic intelligence about the users' purchase intentions as well as experience using the products. Patent documents disclose the technological evolutions of a domain, and contribute to the features and characteristics of products that differentiate between brands and build customer expectations and loyalty. This research proposes a systematic methodology to combine collective intelligence using Internet web crawling and text mining to access the voice of customers. Patent information (retrieved from global patent search engines and analytic function mining of the patent content) provides critical information for planning strategic product repositioning and improvements that match the voice of customers and increase brand loyalty. The systematic extended QFD approach provides intelligent and dynamic demand-compliant strategies for developing new products and services.

Keywords. Patent analysis, Web-mining, Quality Function Deployment (QFD)

Introduction

For short life cycle products (e.g., smartphones), market demand is constantly changing with the rapid development of technology. Global enterprises face increasingly fierce competition and successful research and development strategies are critical. The goals of R&D for new products and services is to satisfy the customers and increase brand

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loyalty. Customer demand is dynamic and elusive, and the means to identify the wants and needs of costumer requires new methods of insight.

The number of Internet users accounts for over 40 percent of the world's population [1]. E-business offers many different electronic commercial websites for customers to purchase products or services. The Internet enables customers to express their opinions, attitudes, beliefs, and purchase intentions about products through different community platforms, social media, customer blogs, and social networks. The comments expressed by customers on these platforms provide collective and dynamic intelligence about the customers' purchase intentions and experience using the products, and serve as an important reference for strategic business development.

The world is entering the era of a knowledge-based economy where innovation oriented enterprises that own and utilize intellectual property are more competitive than production oriented companies. Patent documents reveal the technological evolutions of a specific domain and describe the features and characteristics of products that differentiate between brands and build customer expectations and loyalty. Quality function deployment is useful for product design and uses the voice of customers to determine the characteristics of products through market research. The method allows a company to identify the most important product features and improve products according to the needs of customers.

R&D efforts often fail to achieve short term results since they are often slower than the many new product lifecycles. This research proposes a systematic methodology to combine collective intelligence using Internet web crawling and text mining to access the voice of customers. Analytic function mining of patent content provides critical information for strategic product repositioning and improvements that increase brand loyalty. The extended QFD methodology provides intelligent and dynamic demand compliant strategies for developing new products and services and shortens the R&D product development cycle.

1. Literature Review

In this section, the literature related to patent analysis, customer perception, latent semantic analysis, and quality function deployment are discussed. Patent analysis is used in the research methodology to understand the technical focus of a company. Studying the customer's perception and buying behavior (e.g., satisfaction and dissatisfaction) helps to establish whether the company's marketing and product positioning is consistent with the customers' preferences. Latent semantic analysis is used to calculate the correlation between the voice of customers and the engineering functions which are derived from an analysis of the trade literature and patents. Finally, quality function deployment visualizes the combined research analysis results.

1.1. Patent analysis

According to World Intellectual Property Organization (WIPO), patent documentation is rich in technical knowledge which record 90% to 95% of the world's commercial products' research and development results. By analyzing and studying patent documents, the time and cost of research and development can be reduced by almost 40%. Patents helps companies make decisions for the product, technology, and service development, and avoid infringement. Many scholars use patent analysis methods to

gain insight into market opportunities. Li et al. use technology roadmaps and patent analysis to explore Cisco's business ecosystem [2]. Suh and Park propose a patent and service oriented technology roadmap to assist research and innovation [3]. Ernst and Omland propose two innovative patent metrics, degree of market coverage and technology relevance. Market coverage considers the worldwide sales of products protected by patents, and the degree of technical relevance considers the number of patents cited as the benchmark index of the patent. The two indicators can be used to quantify the value of patent assets [4]. Trappey et al. propose a model of patent quality assessment by using principal component analysis (PCA) method to extract patent indicators [5]. Further, innovations and IPs are often driven by market demands. Their correlations are analyzed by researchers [6].

1.2. Customer perception

Customer perception is an important issue to consider in market strategy development [7]. Customer perception can be influenced through the process of identifying needs, finding solutions to satisfy these needs, making purchasing decisions, interpreting advertising messages, and taking actions to make a purchase. Customer perception can be divided into three stages, exposure, attention, and comprehension. The exposure stage describes humans react to an external stimulus in the environment. Vision, under different environments, cultures, and ages will cause different interpretations. Different products with sounds or music can deepen the impression of customers. The sense of touch allows customers to feel the texture of products. The attention stage refers to the customer's reaction to various stimuli. The customer's comprehension of the message provides meaning to the received information. After information processing, customers will remember their experiences and subsequentially influence their future decision making [8].

Horn and Salvendy [9] note that customer perception can be significantly influenced if the product innovation conveys a meaning of importance and novelty. Lee et al. develop an ontology-based intelligent system for automatically classifying customer complaints. Using a case study of restaurant service provision, a customer complaint handling system was created. The system identifies the similarity among customer complaints so that managers are better able to link the causes to the history of operations including sources of supply and staff management [10].

1.3. Latent semantic analysis

LSA assumes that the meaning of a word is determined by other words that appear simultaneously in the document, rather than from the literal meaning of the word. Using this algorithm, the semantic or conceptual relationships within a document are expressed by the frequencies of words within documents. LSA does not consider the grammatical structure or pre-defined lexical meaning which reduces the bias caused by human interpretation [11].

Foltz uses LSA to map the semantic relevance of vocabularies to the text in a document with good results [12]. Kireyev et al. and Ozsoy also use LSA in a similar manner to define semantic spaces. The results show that LSA is more effective than traditional indicators [13]-[14]. Luh et al. develop a ranking algorithm for estimating search engine efficiency based on LSA and genetic algorithms [15].

1.4. Quality function deployment

The QFD methodology is used to develop a product or design a service by transforming the customer's needs into technology breakthroughs or service innovations. QFD combines the voice of customers (VoC) and the concept of quality control design innovative products, processes, or services. The applications of QFD are extensive and have been applied across many industry sectors. Improved QFD methods have been developed by using fuzzy theory, analytical hierarchy processes, and multivariable analysis. Liu suggests that when developing new products, QFD may be combined with the Kano model so that costs and materials may be chosen according to demand. The relative importance between elements can also be defined, which improves the production process [16]. Singh et al. note that QFD can be used to improve the technical aspects of management. Researchers must pay attention to the changes of customer preferences to match the market trends [17]. Sularto and Yunitasari apply the QFD approach to study the point-of-sale (POS) system of a restaurant to analyze customer demand and explore the metrics which influence the speed of processing orders and payment methods to attract customers and develop strategies [18].

2. Methodology and case demonstration

The methods used in the research are provided in this section. This research applies patent analysis, web data mining and latent semantic analysis to analyze online reviews of a target product. There are four procedures used in this research including patent analysis, secondary data collection of previous product analysis research and reports, latent semantic analysis, and the construction of a quality function deployment matrix.

Patent analysis is an effective way to define the technical focus of a company. The technical data of this research is collected from previous studies and trade literature related to the selected product. Latent semantic analysis is used to calculate the correlations between the voice of customers and the engineering functions. Quality function deployment visualizes the results of the combined research processes.

2.1. Patent analysis

This research selects the ASUS ZenFone2 (type: ZE551ML) smartphone as a target case study product. The scope of the patent search focuses on AsusTek Computer Inc., an international computer hardware and electronics provider. The global patent database search result shows that ASUS has a total of 239 patent families distributed in China, Taiwan, US, Europe, and WIPO. The largest number of product relevant patents are registered in China. Table 1 shows the result of the top International Patent Classifications (IPCs). ASUS holds significant numbers of patents in the following classifications: constructional details or arrangements, related to display configuration, internal electronic components and camera lens modules. Patent group 2 and 3 are related to temperature control. Patent group 4 and 5 are related to the assembly structure.

Table 1. Top IPCs

Patent group	IPC	Definition	Patent family count
	G06F	Electric digital data processing	
1	G06F/116	Constructional details or arrangements	29
2	G06F/120	Cooling means	9
	H05K	Printed circuits; casings or constructional details of electric apparatus; manufacture of assemblages of electrical components	
3	H05K/720	Modifications to facilitate cooling, ventilating, or heating	14
4	H05K/716	On hinges or pivots	10
	H04M	Telephonic communication	
5	H04M/102	Constructional features of telephone sets	11

2.2. Data collection

The customer comments for the ZenFone 2 were retrieved from Amazon.com, the most popular e-commerce platform during August, 2016. Four hundred and eighty-three sets of negative reviews (e.g., one star to three stars out of five stars) were collected and text mining was used to extract the key terms with the highest frequency of occurrence [19]. After the secondary customer dissatisfaction data were collected, this research sets up two rules to select key terms. First, a comparison is made between the proportion of key terms appearing in the positive and negative comments. If a given key term appears more in positive comments, then the term is excluded. Second, if a key term appears in over fifty comments as part of a negative statement, the term is included in the data set. As Table 2 shows, the result are divided into hardware and software. Hardware contains components such as the power system, screen, camera, and RAM. Software involves applications (Apps), bloatware, and the performance of the product.

Table 2. Top frequency key terms of negative reviews

Type	Category	Key terms
Hardware	Power system	drain, battery, battery life, charge, power, remove battery
	Signal and connection	connect, text, call, message, sim, bluetooth, internet, miss, lost
	Camera	camera, light
	Display	flicker, glass, screen, touch, shatter
	Design	button, vibrate
	Memory	ram
	Sound and audio	voice
Software	Software	softwar, app, bloatware
	Performance	slow, fast, perform

QFD requires that the engineering functions be well defined. This research constructs an ontology of the selected product. Figure 1 highlights the functions of a smartphone which consists of a screen, outer casing, battery, speaker, antennas, and printed circuit board. There are 12 key functions defined in this study. The function of the motion sensing chip signals the direction and movement of the handset to provide somatosensory operations. The power management Integrated Circuit (IC) and battery management IC deal with the distribution of most the power supply resources, and control the voltage, temperature to ensure safety and service life. The camera lens module contains CCD/CMOS, filter, and transparent lens, the transparent lens focuses the light on the CCD/CMOS via the filter, then processes the light from the rear end.

The transceiver IC converts the analog and digital signals. The power amplifier IC amplifies and sends out the signal so cell sites can receive the phone signal. The brightness sensor adjusts the screen brightness according to the environment. The wireless signal IC is used to handle digital and analog signal conversion. The G-sensor and E-compass capture the acceleration caused by external force and control the built-in compass. The application processor integrates the CPU, GPU, RAM, USB, and the SD card are the core elements enabling the mobile phone to function. The speech codec IC codes and decodes received sound and converts the digital signal to drive the speaker or headphones. The touch sensing IC measures actions using the changes of voltage. The related literature and reports of each functions are collected for the construction of the QFD matrix.

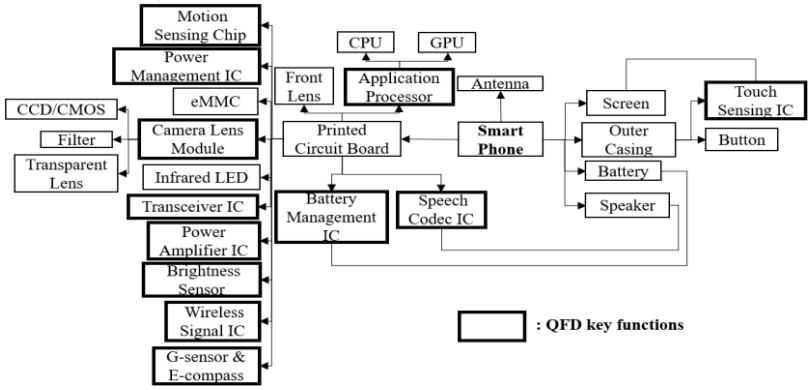


Figure 1. Ontology of smartphone

2.3. Latent semantic analysis

The first step of LSA is to establish a symbiosis matrix (word by document). The two-dimensional matrix models the relationship between the vocabularies and the documents. The elements in the matrix represent the count of vocabularies appear in the documents. Since this is usually a high-dimensional sparse matrix, the matrix contains many null values (0). Singular value decomposition is applied to reduce the dimension of the symbiosis matrix and map the high dimension space to the low dimension vector space. The cosine similarity between the vocabularies and the documents is calculated.

2.4. Construction of QFD

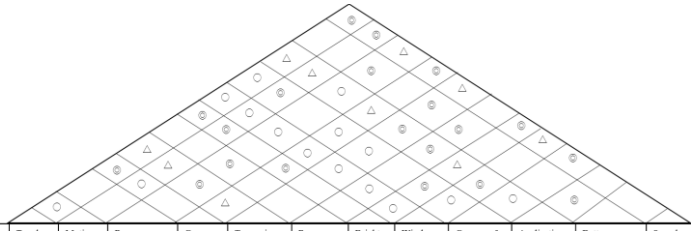
The matrix model for the voice of customers and the engineering functions are defined during the data collection stage. The similarity between these two axes is calculated using the latent semantic analysis method whereas the key terms of VoC are compared with the collected functional literature. The QFD roof shows the correlation between engineering functions. The similarity values are sorted by sequence and the VoC-function relationships (strong ◎, fair ○, or weak △) are assigned according to the percentile distributions (≧75%, 50-75%, or 25-50%).

Normalized Term Frequency-Inverse Document Frequency (NTF-IDF) evaluates the importance of a term for a set of documents. The methodology filters out common

words and keeps important ones by considering term frequencies and document length simultaneously [20]. The average NTF-IDF value of each category is collected and by using the weights of each category, the terms are ranked. The rule for ranking the engineering functions is to sum up the weighting. The QFD matrix is shown in Figure 2.

The highest ranked priority for improvement is the camera category and the most relevant functions are touch sensing, lens module, and brightness sensing. These functions require additional development to better satisfy the customers. The second highest ranked priority for improvement is the memory category. Almost every instruction requires memory to process, which in turn is strongly related to power, battery, and amplifier functions. The signal and connection category ranks third in priority. This category is related to the cellular network and involves the signal of a call, message transmission, and image resolution. The most relevant functions are touch sensing, lens module functioning, and brightness sensing.

This study adds a patent dimension at the bottom of QFD to map the distribution of key functions to the case company's patents. The patent groups were defined in section 2.1. The case company's patents are less focused on the most important functions (e.g., top importance rating functions) defined by this research. Most of the patent groups are related to the application processor which defines the configuration and cooling methods.



Function / Category	Avg. NTF-IDF	Touch Sensing	Motion Sensing	Power Management	Camera Lens Module	Transceiver	Power Amplifier	Bright-ness Sensor	Wireless Signal	G-sensor & E-compass	Application Processor	Battery Management	Speech Codec	Total Score	**Improve Priority**
Power system	71.48		△	◎		○	◎		○	△	○	◎	△	1929.96	9
Signal and connection	109.75	◎	○		◎	△		◎	△	○	△		○	2963.25	**3**
Camera	154.06	◎	○		◎			◎	△	○	△		○	4005.56	**1**
Display	117.55	◎	○		◎			◎	△	△			○	2703.65	4
Design	109.52	◎	○		◎			◎	△	△			○	2518.96	7
Memory	142.14		△	◎		○	◎		○	△	○	◎	△	3837.78	**2**
Sound and audio	88.35		△	◎		○	◎		○	△	○	◎		2297.1	8
Software	95.78	◎	○		◎	△		◎	△	○	△		○	2586.06	6
Performance	99.27		△	◎		○	◎		○	△	○	◎	△	2680.29	5
	Total score	25	19	20	25	14	20	25	17	15	15	20	18		
	Importance Rating	**1**	**3**	**2**	**1**	7	**2**	**1**	5	6	6	**2**	4	**Patent family count**	
	Patent group 1			√	√				√		√		√	29	
	Patent group 2										√	√		9	
	Patent group 3				√						√	√		14	
	Patent group 4							√			√			10	
	Patent group 5					√			√				√	11	

Figure 2. Quality function deployment

3. Conclusion and Future Research

In the era of demand-driven marketplace, rapid product deployment based on the dynamic needs of customers is critical. The combined voice-over-the-web and patent mining for QFD can efficiently and precisely identify correlations between the voice of customers, the demand-driven technical functions, and the patented innovations of the

enterprise. The multi-dimensional mapping of customer demands, engineering functions, and company's patented IPs is helpful when developing R&D strategies for new product development and deployment. A company can find future directions of product improvement reflecting the market needs to enhance its global competitiveness. In the future, competitor analysis will be taken into further consideration. Also, the selected product deployment can be applied to the similar products (or product lines) using the similar IPs with similar customer demands for further strengthening their global market position in the sector. The research hopes the proposed methodology can be designed as a computer-supported system platform for its extensive applications.

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Using Machine Learning to Forecast Patent Quality – Take "Vehicle Networking" Industry for Example

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Abstract. Machine learning has become a key development target globally in recent years. An increasing number of algorithms have been applied to solve practical issues. At the present stage, machine learning technologies have progressed from a pure research topic to tools employed for solving practical issues, becoming a key development direction of practical technologies and a prominent emerging discipline. Furthermore, current machine learning technologies have transformed from tools that supplement decision-making to methods that replace manual decision making when generating optimal decisions. This transformation fundamentally changes the tasks that required relatively long workhours in the past. In addition, this may even facilitate distinctive interpretations to effectively aid researchers and operators in addressing problems from a new perspective. Therefore, this study adopted a machine learning technology, namely artificial neural networks (ANNs), to examine relevant topics in patent quality. To verify the effect and identify the characteristics of machine learning in patent quality analysis, this study focused on the fast-changing internet of vehicles (IoV) industry. tailed analyses of key patents were also performed. Finally, a model of high-quality patents in this industry was developed to serve as a reference for other researchers.

Keywords. Machine learning, Patent quality, Vehicle Networking, internet of vehicles (IoV)

Introduction

Machine learning has become a key development target globally in recent years. An increasing number of algorithms have been applied to solve practical issues. At the present stage, machine learning technologies have progressed from a pure research topic to tools employed for solving practical issues, becoming a key development direction of practical technologies and a prominent emerging discipline. Furthermore, current machine learning technologies have transformed from tools that supplement

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decision-making to methods that replace manual decision making when generating optimal decisions. This transformation fundamentally changes the tasks that required relatively long workhours in the past. In addition, this may even facilitate distinctive interpretations to effectively aid researchers and operators in addressing problems from a new perspective.

Therefore, this study adopted a machine learning technology, namely artificial neural networks (ANNs), to examine relevant topics in patent quality. In patent quality determination, previous practice has mostly depended on experts giving appropriate interpretations on the basis of patent quality indices. However, obtaining expert perspectives and judgements is extremely time-consuming and entails higher personnel costs. Machine learning can effectively shorten the time for obtaining interpretations and thereby reduce the cost of making judgements. The tool is highly beneficial for the fast-paced emerging industry of high-tech applications. Fast determination of patent quality can provide research and development and related patent personnel with a rapid grasp of key conditions in the industry, further facilitating research and development personnel to produce specific strategies in response to their competitors' technology planning.

To verify the effect and identify the characteristics of machine learning in patent quality analysis, this study focused on the fast-changing internet of vehicles (IoV) industry. Analyses of the key influencing indices of patent quality in this industry were conducted using machine learning technologies. Detailed analyses of key patents were also performed. Finally, a model of high-quality patents in this industry was developed to serve as a reference for other researchers.

1. Literature Review

Patent quality has been a crucial research topic because improvement of patent quality is essential to industrial and research development. Current evaluations of patent quality are mostly based on patent-related indices or related data on past litigation cases, the latter of which is mainly analyzed through conventional methods. Numerous scholars have analyzed conventional patent-related indices. For example, [1] used social networks to compiled data regarding co-writing works**.** [2**]** adopted numerous factors such as patent family size, forward and backward citations, patent scope, claims, and patent inventors to develop a composite index according to the stability of individual factors for patent quality analysis. [3] performed an in-depth evaluation on the writing quality of patents from the perspective of patent inventors' thought processes. [4] performed an integrated analysis on patent indicators and product life cycles. [5] further researched patent-related indices such as citations, patent family size, patent inventors, and patent age to identify directions for strategic planning. In summary, conventional patent quality analysis mainly involves integrating key indices such as patent citations (forward and backward citations included), patent family size, number of patent claims, and patent inventors. These indicators typically indicate the explicit messages of patents. Employing such messages facilitates the rapid summarizing of patent conditions to produce an overview of patent quality, through which related problems can be identified and addressed. Indices can be regarded as the most prevalent and accessible criteria for patent quality evaluation.

In addition to indices-based analysis, another approach evaluates patent quality by evaluating patent legal status data, which has become a prominent branch of patent

quality evaluation; [6][7][8][9] have evaluated patent quality by using this approach. However, the exact methods used these scholars differed.[6] regarded litigation status as another variable that influences patent quality. By observing patent litigation, [6] assigned weight to this factor in a patent quality model. [7] studied German patent litigation cases from 1993 to 1995 to analyze the feasibility of high-quality patents. [8][9] investigated the effect of multiple variables on patent quality throughout the patent litigation process. The aforementioned five studies have revealed that patent legal statuses (i.e., whether a patent is involved in a lawsuit, patent payment status, and the overall status of patent maintenance) constitute another set of key criteria for patent quality evaluation.

The aforementioned two sets of criteria, namely patent indices and legal status data, remain the core criteria applied in current practices of patent quality judgement. In addition, such judgements are typically supported by conventional economic and quantity models. However, compared with machine learning technologies, these models require more time when making a judgement and involve more complicated conditions. One of the most representative machine learning technologies is ANNs, which were first developed by **[10]** Early ANNs featured a primitive structure and were modeled on the conditions of human neurons. A notable breakthrough in this technology was achieved by Rochester,[11] who created a perceptron network, a model identification-based algorithm that enables 2-layer computer learning using basic addition and subtraction operations. However, the maturation of this system should be attributed to[12] who developed the backpropogation algorithm for ANNs.

Rapid progress in networking-capacity enhancement and computing system expansion are occurring in ANN development. Such developments aim at facilitating more complicated and highly intensive judgements. Therefore, this study adopted a hybrid ANN to evaluate key patents in the IoV industry and attempted to effectively improve the capacity of ANNs for patent quality evaluation.

2. Research Methods

The To save considerable time in data interpretation, this study employed a hybrid ANN to interpret IoV-related patent data and identify corresponding high-quality patents.

This study comprised the following steps:

2.1. Searching for IoV-related patents:

The IoV has developed into a prominent industry in recent years. At present, the main development direction in this field is to realize automated driving. Therefore, smart vehicles connected to the IoV would not only be equipped with a driving system of their own, but also have the capacity to manage numerous connections, including vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), vehicle-to-pedestrian (V2P), vehicle-to-cloud (V2C), vehicle-to-home (V2H), and vehicle-to-handheld device (V2HD) connections and data exchanges. These factors are collectively referred to as vehicle-to-everything (V2X) interactions. In light of this concept, smart vehicles are expected to become the medium of a large system that connects the existing possibilities of convenience in transportation and daily-life. Hence, the development of this technology may contribute to upgrading the vehicle, household appliance, internet,

semiconductor, and traffic and transportation industries. This study investigated key patents related to the aforementioned trends of development in key databases worldwide, specifically using the patent data search tool developed by Thomson Innovation to search for patents registered in the United States Patent and Trademark Office. The main keywords used in the inquiries consisted of common terms in IoV research and relevant terms for smart vehicles and existing driver assistance systems (Table 1).

Table 1. Keywords used in patent search.

Key words
V2X (Vehicle To Everything)
V2V(Vehicle to Vehicle),
VANET(Vehicular ad hoc network)
V2P (Vehicle to Pedestrian),
V2I (Vehicle to Infrastructure),
V2C (Vehicle to Cloud)
V2H (Vehicle to Home)
M2M(Machine to Machine)
Automotive navigation system
WAVE, Wireless access for vehicular environment
Fleet telematics system
Intelligent vehicle technologies
DSRC, Dedicated short-range communications
IVI , In-vehicle information system
ADAS (Advanced Driver Assistance System)
Parking Assist(Aid) System
Backup parking aid system
Night vision system
LWDS, Lane departure warning system
Blind spot detection system
AFS, Adaptive front-lighting system)
ACC, Adaptive cruise control
CMS, Collision mitigation system
TPMS, Tire-pressure monitoring system

After related patent keywords were determined, the search scope and time were configured. Patents granted by the United States Patent and Trademark Office during 2005–2016 were searched to identify those containing the aforementioned keywords in their title, summary, or right claims. A total of 11,335 patents were filtered, from which patents related according to the INPADOC patent families were excluded (for patents with overlapping technologies, the INPADOC database groups them in families and

present only the most representative entry as a reference). Finally, 4,683 patents were retained as the analysis subject in this study.

Key patent indices that were employed to examine the aforementioned patent data in all sections were then integrated and are presented in Table 2.

Table 2. Key patent indices.

Index	Definition
Claim count	The claims describe the technologies related to a patent. Higher counts generally indicate greater level of innovation.
Assignee count	The assignee count calculates the number of patent owners. Higher assignee counts generally indicate that the patents are more likely to be the products of collaboration.
Inventor count	Inventor count calculates the number of inventors who coinvented a patent. Higher inventor counts indicate that more inventors were involved in the invention.
Application to grant day count	The index calculates the number of days between filing a patent application and receiving the patent grant. Fewer days means that the patents were granted at faster speeds.
Priority right to grant day count	The index calculates the number of days between gaining priority rights of a patent and receiving the patent grant. Priority right date specifies the date the first application of a patent is filed. Longer durations mean more comprehensive protection for the patents.
Forward citations	The number of citations the patent has received.
Backward citations	The number of other patents that the patent cited.
Citations to nonpatent literature	Citations to earlier patents and to nonpatent literature
Patent family count	This index analyzes the state of the patent family.
Country count where a specific patent family is granted	This index analyzes the countries where a patent family is granted.
Legal event count	This index analyzes the frequencies of legal events related to a patent, including maintenance fee payment, lawsuits involved, and patent ownership transference.

The key influencing parameters of patent quality were extracted through the aforementioned process of patent indices integration. The most influential parameter, namely legal event count, was then identified and adopted as the principal judging parameter in subsequent analysis.

2.2. Filtering key parameters

A stepwise regression model was adopted to analyze the key parameters identified in the previous step. In this model, the t value and its significance level α were used as referencing indices to determine whether a specific independent variable would be selected. If the $|t|$ test value of an independent regression coefficient was greater than the theoretical t value obtained from t-tables (or if α achieved significance), the

computer system automatically included this independent variable in regression equations; however, if the value did not achieve significance, the computer system automatically excluded this independent variable from regression equations. Analyses were performed on 11 indices, and those retained after the analyses were employed as conditions for developing the judgment equations in the next research step.

2.3. Analysis models

After model computation was completed, one machine learning models, namely self-organizing maps (SOMs; also known as a Kohonen map) were employed to group related data sets. SOMs is one kinds of grouping algorithm (unsupervised algorithm) based on an ANN. In contrast to other grouping algorithms, SOMs feature a topological map in which the distributions of all outputs (clusters) can be presented. Hence, SOMs present the original high-dimensional data visually in a low-dimensional space, effectively displaying the grouping results.

After the completion of data collection, SOM was used to examine the classification and grouping results of IoV data. Professional research personnel were then invited to analyze and summarize the patent classification results. Finally, an appropriate conclusion was reached.

2.4. Building quality evaluation models

After the aforementioned models were built and achieved stability, each patent was categorized in its corresponding quality class. A regression equation was developed for patents in each group to facilitate evaluating the achievements of all patents in the specific patent groups. Subsequently, the indices and their weights that were employed in individual group evaluations were integrated to assist experts with further interpretation.

2.5. Analysis results of IoV-related patent quality

After the patent quality-evaluating model for IoV-related patents was established, the model was analyzed. On the basis of analysis and research results, related possibilities were investigated and conclusions were drawn.

3. Experimential result

In this paper, we collected patent data (4683 items) on the Vehicle Networking industry from the patent database of Thomson Innovation (https://www.thomsoninnovation.com/login); we split these patent data into five parts. Four parts are the training data set and the other is the testing data set. In addition, each patent data includes 71 patent indicators, and we selected 11 patent quality indicators in our research, as shown in Table 2.

We used “Legal event count” to define the quality of the patent. The model considers the remaining indicators to be features of the patent. As mentioned in Section 2, patent litigation can be used to measure patent quality. Therefore, “Legal event count” is used to define the quality of patents in this research. We define a patent with the value of 'INPADOC Legal Status' from 0 to 1 as Low-Quality; from 2 to 4 as Medium-Quality; and larger than 5 as High-Quality.

Following SOM step (please see table 3), this research shows cluster 4 is the best result in experimential, and through this step , we can define that all this patent from 4groups, low quality patent , medium-low quality patent , medium quality patent , and high quality patent. All this item shown in Figure 1.

Table 3. SOM Cluster Result.

SOM Cluster Process
SOM mode : online
SOM type : numeric
Affectation type : standard
Grid : Self-Organizing Map structure
Features : topology : square x dimension : 10 y dimension : 10 distance type: euclidean Number of iterations : 23065 Number of intermediate backups : 5 Initializing prototypes method : random Data pre-processing type : unitvar Neighbourhood type : gaussian

Table 4. SOM Cluster Result.

Cluster 3			
Degrees of freedom : 2			
	F	pvalue	significativity
Inventor.Count	1.234	0.29126651	
App..Pub..Date..By.Day.Normal	2293.731	0.00000000	***
Pub..Earliest.Prior.By.Day.Norma	1563.595	0.00000000	***
Count.of.Citing.Patents	5.872	0.00283769	**
DWPI.Count.of.Family.Countries	4674.875	0.00000000	***
NPADOC.Legal.Status.Count	454.749	0.00000000	***

Cluster 4			
Degrees of freedom : 3			
	F	pvalue	significativity
Inventor.Count	0.960	0.41050056	

App..Pub..Date..By.Day.Normal	1724.729	0.00000000	***
Pub..Earliest.Prior.By.Day.Norma	2037.8125	0.00000000	***
Count.of.Citing.Patents	8.299	0.00001672	***
DWPI.Count.of.Family.Countries	5676.984	0.00000000	***
NPADOC.Legal.Status.Count	589.841	0.00000000	***

Cluster 5			
Degrees of freedom : 4			
	F	pvalue	significativity
Inventor.Count	1.228	0.29661496	
App..Pub..Date..By.Day.Normal	1446.085	0.00000000	***
Pub..Earliest.Prior.By.Day.Norma	1682.286	0.00000000	***
Count.of.Citing.Patents	6.795	0.00001893	***
DWPI.Count.of.Family.Countries	4257.989	0.00000000	***
NPADOC.Legal.Status.Count	447.992	0.00000000	***

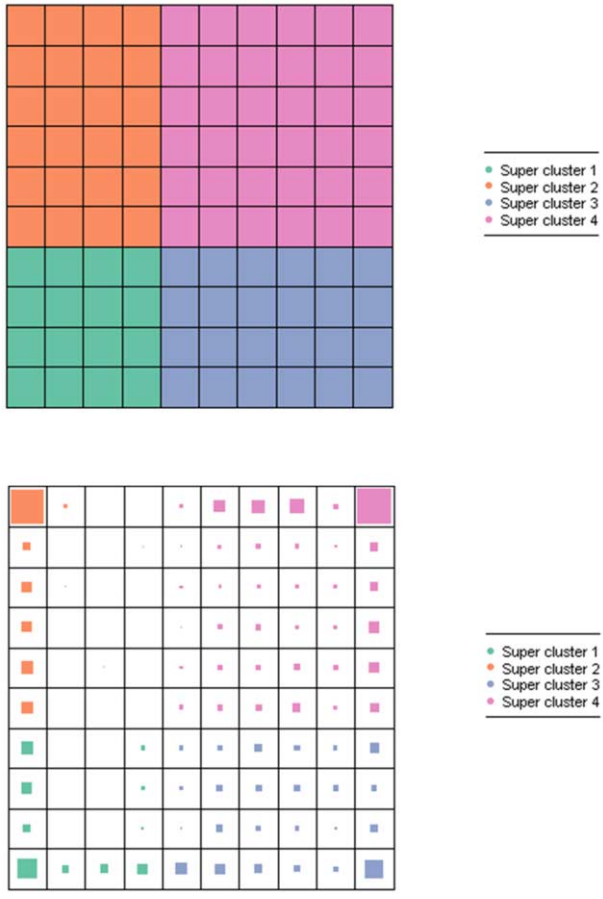


Figure 1. Clustering results.

Following research result, our research combine regression define 4 cluster situation,4683 samples saved at beginning state are used for testing the accuracy of resulting models at this point. The testing outcome are listed below.

1. Prediction function of mid-low value patents:

Y1=-5.003+0.3X1+0.7X2+0.93X3-0.97X4-0.1X5-0.772X6

In mid-low value patents, the significant indicators are the days from application to approval, number of IPC at the moment, the number of inventor, number of non-patent references, number of DWPI families. The rest indicators show no significance.

2. Prediction function of low value patent:

Y2=0.122+0.5X1+0.4X2+0.42X3+0.79X4-0.10X5+0.32X6

In low value patents, just like in mid-low value patents, days from application to approval, number of IPC at the moment, the number of inventor, number of non-patent references, number of DWPI families show significance but the rest are not.

3. Prediction function of mid-high value patents:

Y3=0.64+0.85X1+0.27X2-0.92X3-0.29X4-0.3X5+0.2X6

In mid-high value patents, number of patent inventor is the only significant indicator ,while others are not. Variation of this valuable has an impact on the prediction.

4. Prediction function of high value patent:

Y4=0.47+0.01X1+1.8X2-1.5X3-0.421X4-0. 59X5+0.265X6

In high-value patents, the three significant indicators are number of IPC at the moment, number of patent inventor, and number of CPC while the rest are not significant. That is, changing in these three valuables in the function varies the result most dramatically.

As a conclusion, the only significant valuable is the number of inventor in the high value patent prediction function, both number of non-patent references and number of patent family are important valuables in changing the result of the mid-high value patent prediction function, no significant valuable is find in mid-low patent prediction function, and number of CPC and constant can differ the result of the low value patent prediction function the most.

4. Conclusion

Patents involve complex data which include text, images and lots of metadata; in addition, patents change over time. Therefore, managing organizational knowledge scattered across diverse sources of information is necessary in handling vast data sets. In this research, we collected various patent quality indicators and adapted the SOM to derive these data to develop an automatic patent quality classification model. In this way, when the patent data are updated, the classification model can rapidly re-analyze the patent quality. As we known, patent creation must be publicly discovered in exchange for a time-limited monopoly on its creation. Thus, developing a system that can automatically provide responses when patent data are updated is an important task.

According to the experimental results, the proposed model can obtain the key information from the patent quality indicators. Therefore, the results are very encouraging. It shows that the proposed model can efficiently predict the quality of patents.

Furthermore, further research can examine other data mining techniques for feature selection, such as information gain and principal component analysis to extract the patent quality indicators to enhance the prediction performance.

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Test Data Generation Based on Hybrid Tabu Annealing Genetic Algorithm

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Abstract. In this paper, we investigate the generation of path-covered test data for automated software testing. Testing plays the critical role in detecting bugs and ensure the quality of the software in the software development lifecycle. As an alternative to the manual testing of high cost, low efficiency and poor reliability, search based approaches have been applied in automated test data generation. We propose a hybrid algorithm to generate the test data by integrating the heuristic approaches of tabu, annealing, and genetic algorithm. We discuss the effects of parameters in the process of genetic operations. Several benchmark source code pieces are used to demonstrate the effectiveness of the proposed approach. The experiment results show that the proposed algorithm has lower time complexity and better performance in convergence compared with other existing algorithms.

Keywords. Automated test data generation, Tabu annealing genetic algorithm, Cascade coding

Introduction

As an important mechanism for software quality assurance, software testing plays a critical role in the software development life cycle. For the typical software development, software testing activities may account for more than 50% of the total cost [1]. And it is well accepted that the later software defects are found, the higher cost of bug removal will incur, while the hidden software defects may cause disastrous consequences after the the delivery to customers. Since manual testing are associated with many undesired problems, such as high cost, low efficiency and poor reliability, automated software testing has become a de facto alternative and been successfully deployed in industry. With the help of the recent development in artificial intelligence fields, traditional software engineering is evolving into intelligent software engineering, which is evidenced by the emergence of search-based software engineering[2]. Heuristic search algorithms are adapted to transform the traditional software engineering problems into search-based optimization ones by introducing proper fitness functions so as to efficiently search the optimal solution in the problem space.

In this paper, we investigate the problem of test data generation by pesenting a hybrid tabu annealing genetic algorithm to create the test data covering a particular path. First, we obtain the control flow charts of the source code using the specialized

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tools such as Code Visual. Then, based on the resulting control flow charts and the test requirements, we retrieve the target paths. And finally, we apply the proposed hybrid tabu annealing genetic algorithm to generate the test data of target paths. Our algorithm is based on the modified genetic algorithm, using cascade coding to construct the chromosomes and branch functions, and consequently set the fitness function. Since the genetic algorithm has its shortcomings: too fast convergence often leads to the local optimum, the simulated annealing is added to the crossover and mutation operations, so as to improve the climbing characteristics of the algorithm. In addition, tabu search can effectively reduce the roundabout search steps after the mutation operation, thus increasing the diversity of the population and accelerating the population iterations.

The rest of the paper is organized as follows: in Section 1, we discuss the related work in generating test data with heuristic search algorithms; in Section 2, we present our model to generate test data using hybrid tabu annealing genetic algorithm. The experiments are performed for several benchmark source projects and the results using different algorithms are compared in Section 3, showing the efficiency and effectiveness the proposed approach. And finally in Section 4 we conclude this paper by remarking the proposal and the future research.

1. Related work

Test data generation can be transfered into the the form of a search problem and hence the well established heuristic search algortihms inspired by certain natural phenomena and physical laws find their place to speed up the search process while preserving the desired performance of the solution. The application of genetic algorithm can be found in [3-5] to generate the test data of all the branches, to obtain multiple test data optimization algorithm, combined with graph theory to carry out genetic operations, and to solve multiple targets. Genetic algorithm has been combined with simulated annealing for the software test data generation [6]. In addition, colony algorithm[7], tabu search [8], particle swarm algorithm [9,10] are also used to generate data for software testing. Jiang et al proposed a reduced-particle algorithm to generate test data and improve the generation speed [10]. The improvement of genetic algorithm in testing has attracted many researchers, and some recently developments can be found in [11, 12]. Among these heuristic search approaches, we combine simulated anealing, genetic algorithm, and tabu search into an integrated framework.

2. Hybrid tabu annealing genetic algorithm

In general, the test data generation process consists of three main steps (see Figure 1): first, the static analysis of the program is performed to obtain the control flow diagram, and then the resulted control flow graph and test requirements are used to get the target path, and finally the genration algorithm is applied to produce the data on the target path.

To generate test data, we need to map the parameters of the solution space to the chromosomes, the basic units of genetic algorithm for the later processings. Instead of encoding single input data as individuals as in the traditional way, we denote the i-th

input in the group of as n test input data as x_i. To increase the efficiency of the evolution, we use cascade encoding to concatenate x_i: each variable is encoded as a binary string with fixed length m, $u_{i1}u_{i2}...u_{im}$, and then combine the variables into a single binary string with the length $n \times m$. The decoding process can be drived by break the $n \times m$ bits into n substrings.

The fitness index is used to evaluate the degree of an individual being able to survive in the iterative process. The branch decision expressions in the selection and loop statements determine which path will be executed. The branching condition to be satisfied is called a branch predicate. Let the branch predicates be represented by the expression e1 *op* e2, where e1 and e2 are expressions and *op* is a binary operator. Using $f_i(x_1, x_2, ..., x_n)$ to represent the branch function of *i-th* branch, x_i means the *i-th* inputs. The branch predicate can be transformed into a decision form with 0: F con 0, where F is called the branch function of the branch path (see Table 1).

Only when the value of a branch function is non-positive should the branch to be executed. Therefore the branch function indicates whether the test data choose a target path. If we intend to get the test data for the target path, the value of each branch function should be non-positive. This gives rise to the fitness function defined in (1). If a branch function is positive, the larger its value is, the bigger the path deviation will be. For n inputs and m branches, the fitness function is given as flows:

$$\text{fitness}(x_1, x_2, ..., x_n) = \sum_{i=1}^{m} \frac{1}{1 + f_i(x_1, x_2, ..., x_n)} \tag{1}$$

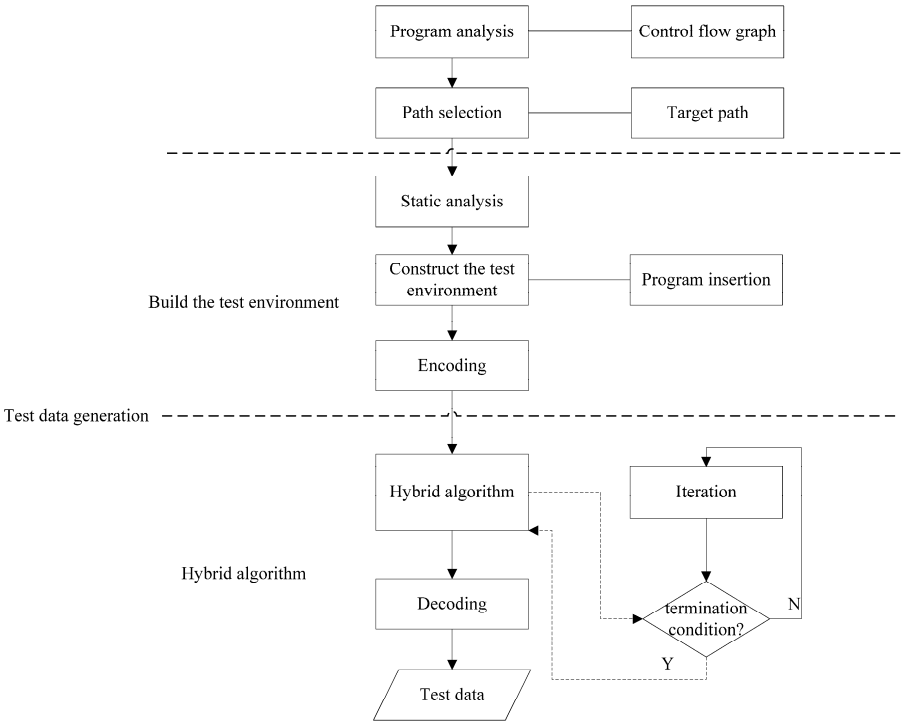


Figure 1. Test data generation process.

Table 1. The definition of branch function.

Branch type	Branch function f	Execution Criterion
e1>e2	$f_i(x_1, x_2, \ldots, x_n) = \begin{cases} e2 - e1, & \text{if } e2 \geq e1 \\ 0, & \text{otherwise} \end{cases}$	F=0
e1≥e2	$f_i(x_1, x_2, \ldots, x_n) = \begin{cases} e2 - e1 + \alpha, & \text{if } e2 > e1 \\ 0, & \text{otherwise} \end{cases}$	F=0
e1<e2	$f_i(x_1, x_2, \ldots, x_n) = \begin{cases} e1 - e2, & \text{if } e1 \geq e2 \\ 0, & \text{otherwise} \end{cases}$	F=0
e1≤e2	$f_i(x_1, x_2, \ldots, x_n) = \begin{cases} e1 - e2 + \alpha, & \text{if } e1 > e2 \\ 0, & \text{otherwise} \end{cases}$	F=0
e1=e2	$f_i(x_1, x_2, \ldots, x_n) = \lvert e2 - e1 \rvert$	F=0
e1≠e2	$f_i(x_1, x_2, \ldots, x_n) = \begin{cases} 0, & \text{if } e1 \neq e2 \\ 1000, & \text{otherwise} \end{cases}$	F=0

In the three genetic operations: selection, crossover and mutation operation, each may affect the efficiency of the algorithm. Applying the tournament selection, we select individuals to generate a new population, then find most viable individual in this population. The number of individuals in the new population is called tournament size. Also, considering good individuals may be lost in the evolution, the elite strategy is used, that is, the most viable individual in each generation is protected by genetic to next generation to accelerate the iterative process. In the crossover operation, we use multi-point uniform cross way to generate several points, the number of points is the same with the number of parameters. Then, assigning those points to each parameter randomly, the crossover probability of each parameter is the same. That is, using single point cross way on each parameter. In the mutation operation, with the evolution of the population, it is necessary to reduce the mutation rate to prevent population degradation. We compare the fitness of new individual after crossover operation with average fitness of parent population. If the fitness of new individual is higher, we reduce the mutation rate and the variation factor decreased with the increase of the number of iterations, otherwise, we increase the mutation rate.

In order to jump out of the local optimum when the mutation rate becomes low, the suboptimal solution is accepted with certain probability in the selection process, so the diversity of the population can be maintained. We combine the genetic algorithm with simulated annealing process to achieve this. First we compare the new individuals with the old ones, if the new individuals perform better, we accept them; otherwise, the individuals will be accepted with a decreasing probability by the Metropolis acceptance criteria. In this paper, the annealing process is added not only after the mutation, but also during the crossover process. So we can control the convergence of the population in the process of crossover to prevent the deterioration of individuals after crossover.

Tabu search helps improve the evolution process to avoid detour search with the help of a tabu list. First a state is set as the current optimal state, and then a new state is generated in its neighborhood. In this paper, the individual before mutation and the parent before crossing are recorded, and these individuals are used as a neighborhood of the individual which needs tabu search after mutation (see Table 2).

Table 2. The proposed test data generation algorithm.

Step 1	Analyze the source code to obtain the control flow chart/data flow chart
Step 2	Analyze the control flow chart to find all paths, and determine the target path $\text{Path}_{target}<b_1, b_2, \ldots, b_m>$ according to the demand, b_i denotess the *i-th* branch
Step 3	Mark the branch node on the target path as program plug. Calculate each branch function $f_i(x_1, x_2, \ldots, x_n)$. Set the fitness function
Step 4	Initialize parameters: the population, initial population size, selectivity rate, crossover rate, mutation rate, tabu table length, initial temperature, cooling coefficient, tabu search number and maximal iteration were randomly generated. Set the termination condition, the termination condition in this article is that all individuals are target output
Step 5	Determine whether the population to reach the termination conditions, if not then execute the following algorithm, otherwise, go to step7
Step 6	First, according to the stochastic league selection method, select individual1 and individual2, using *fitness1* to represent the larger fitness of them, and then cross them to get individual3 with *fitness3*, calculate $\Delta F = \text{fitness1} - \text{fitness3}$, if $\Delta F \geq 0$, individual3 will be accepted, otherwise individual3 will be accepted with the probability of $\exp(-\Delta F/kT)$, by Metropolis acceptance criteria, where *k* is the cooling coefficient, and *T* is the real-time temperature, and then the new individual is mutated. Also using Metropolis acceptance criteria to accept the individual4 after mutation. Since then, there are four individuals which can be the neighborhood, then using tabu search to choose the best individual. Return to step 5.
Step 7	Generate the results and decode the results. Return the results

3. Experiments and analysis

In the experiments, we tested different settings of parameters. All experiments were run independently 500 times, taking the average run time and the average number of iterations to avoid random factors. All programs are written in Java, run on Windows 7 (64-bit) operating systems, and the hardware is Intel (R) Core (TM) i7-4710MQ CPU @ 2.50GHz 2.50GHz processor, memory of 8.00GB. The selection of parameters have impacts on the performance of the proposed algorithm, as shown in Figure 2 and Figure 3, and the proper parameters can be chosen for the particular application of the proposed algorithm.

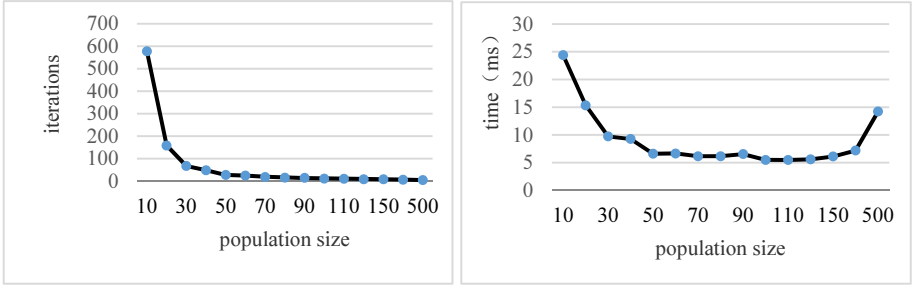


Figure 2. Effects of population size on experiment.

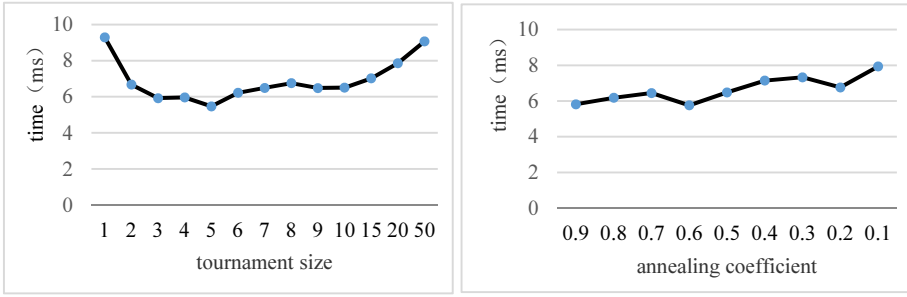


Figure 3. Effects of tournament sizes and annealing coefficients.

We compare our algorithm (TS-SA-GA for short) with the approaches in the current research, including Ahmed Algorithm [3], ST method [11], MPC method [5], BC-GA method [12], and FCWPSO method [13] to generate test data for some benchmark programs, namely, triangulation, three sorting and bubbling sorting processes, to verify the efficiency of the algorithm proposed in this paper. The results show that the proposed algorithm(TS-SA-GA) has advantage over the others in execution time (see Table 3).

Table 3. Convergence time of three program using different algorithms (seconds).

	Ahmed	**ST**	**MPC**	**BC-GA**	**FCWPSO**	**TS-SA-GA**
Triangles	0.294	0.438	0.097	0.352	0.051	**0.011**
Three Sorting	0.928	4.680	0.467	1.231	0.124	**0.002**
Bubbling Sorting	0.321	1.764	0.245	0.523	0.096	**0.094**

4. Conclusions

One of the many challenges that the automated software testing faces is to prepare the quality test data. Search based test data generation is used to explore the problem space in order to return the qualified solutions. In this paper, we attempt to improve the genetic algorithm based search by integrating simulated annealing and tabu search into the genetic operations. The proposed hybrid algorithm outperforms the traditional genetic algorithm in generating the test data, as demonstrated by the experiments. We shall investigate the application of the proposal to practical problems, as well as improving the algorithm in the following directions: optimization of the fitness function, new encoding scheme, and the inclusion of data driven search.

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Part 16

Smart Systems and Internet of Things

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Transdisciplinary Engineering: A Paradigm Shift
C. Chen et al. (Eds.)

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Internet of Things for Manufacturing in the Context of Industry 4.0

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Abstract. Internet of Things (IoT) can be defined as "a world where physical objects are seamlessly integrated into the information network, and where the physical objects can become active participants in business processes. Services are available to interact with these 'smart objects' over the Internet, query their state and any information associated with them, taking into account security and privacy issues." The Internet of Things itself is enabled by a few key technologies which have had extensive progressive in the last few years. As the well world-wide spread of Industry 4.0, IoT-enabled manufacturing plays an important role in supporting smart factory, intelligent automation, and real-time adaptive decision-makings. This paper comprehensively review related technologies and world-wide movements so that insights and lessons could be useful for academia and practitioners when contemplating IoT technologies for upgrading and transforming traditional manufacturing into a Industry 4.0 future.

Keywords. Internet of Things, Manufacturing, Industry 4.0, Technology.

1. Introduction

Industry 4.0, well-known as 'smart factory', was proposed in Germany with the modular structured smart factories, Internet of Things (IoT), and other technologies for creating a virtual version of the physical world so as to make decentalized decisions [1]. Industry 4.0 is referred as the 4th Industrial Revolution, with prior three industrial revolutions being mechanization powered by the introduction of mechanical production facilities using water and steam between 1784 and mid 19th century, the mass production based on the division of labor using electric energy from late 19th century to 1970s, and automation powered by computers since 1970s. Today, driven by information and communication technology (ICT) in particular the Internet and embedded systems technology, the seamless integration of the physical (real) and digital (virtual) worlds is made possible, giving rise to IoT. The widespread application of IoT marks the transition of industrial production to its fourth stage - Industry 4.0 [2]. Industry 4.0 thus enables companies to cope with the challenges of producing increasingly individualized products with a short time to market and ultimately enhances companies' competitiveness [3].

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IoT is the internetworking of physical devices, vehicles (also referred to as "connected devices" and "smart devices"), buildings, and other items—embedded with electronics, software, sensors, actuators, and network connectivity that enable these objects to collect and exchange data [4]. It allows objects to be sensed and/or controlled remotely across existing network infrastructure, creating opportunities for more direct integration of the physical world into computer-based systems, and resulting in improved efficiency, accuracy and economic benefit in addition to reduced human intervention [5-7]. Radio requency identification (RFID) technology as one key elements in IoT was initially prposed to iniquely identify interconnected objects through radio waves [8]. Due to its identification advantages, RFID has been widely used in various industries to supporting data collection and objects distinguishment [9-12].

IIoT (Industrial Internet of Things) is termed as the adoption of IoT technologies in industry [13]. IIoT integrates machine learning and Big Data Analytics for smart machining and advanced decision-makings. Decisions based on such data are prone to be errors, which may bring negative impacts on manufacturing efficiency and customer satisfaction [14]. Manufacturing industry has used RFID for data capturing for a decade [15]. For example, an affordable approach to shop floor performance improvement using RFID or auto-ID technology with wireless manufacturing was presented [16]. This paper attempts to firstly review the IoT technologies and world-wide movements so that insights and lessons could be useful for academia and practitioners when contemplating IoT technologies for upgrading and transforming traditional manufacturing into a Industry 4.0 future.

The rest of this paper is organized as follows. Section 1 presents related technologies such as RFID, Bar-code, and wireless communication standards. Section 2 shows the world-wide movements from North America, European Countires, and Asia Pacific Area. Section 3 highlights the insights and lessons from this research and indicates the future implementation. Section 4 concludes this paper.

2. Related Technologies

2.1 RFID

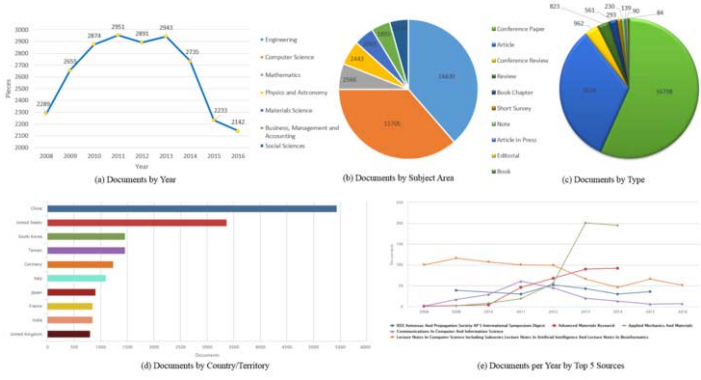


Figure 1. Statistics Analysis on RFID Research.

RFID technology uses electromagnetic fields to automatically identify and track tags attached to objects, which can stored electronic information [8][17][18]. Two types of tags are included: passive tags collect energy from a nearby RFID reader's interrogating radio waves and active tags have a local power source such as a battery and may operate at hundreds of meters from the RFID reader [19]. Unlike a barcode, the tags need not be within the line of sight of the reader, thus it could be embedded in the tracked object. RFID is one method for automatic identification and data capturing without any human intervenes so that it could be used widely in industry.

RFID research has been placed particular attention in recent years [9-11, 20-28]. From Figure 1 (a), it could be observed that, from the year of 2008 to 2016, the total documents published are 23,713 with the average of 2635 documents per year. The major subject areas are shown in Figure 1 (b) from where Engieering and Computer Science take up 39% and 36% respectively. From Figure 1 (c), most of the documents are from conference papers and articles. RFID books are quiet few (only 84) compared with other types such as notes and review. As shown in (d), the most active research countries/territories are China, United States, South Korea, Taiwan, and Germany where RFID research in terms of technologies and its applications are popular. (e) presents the top 5 sources about the keyword 'RFID'.

2.2 Bar-code

Bar-code technology is an optical and machine-readable data presentation by varying the widths and spacings of parallel lines [29]. It has one and two dimensional codes which use linear and rectangles, dots, hexagons and other geometric patterns in two dimensions [30]. Bar-code usage in industrial context was sponsored by the Association of American Railroads in the late 1960s when it was developed by General Telephone and Electronics (GTE) and called KarTrak ACI (Automatic Car Identification), which involved placing colored stripes in various combinations on steel plates which were affixed to the sides of railroad rolling stock. Then in 1981, it was used by the united States Department of Defense to labelling all the products sold to the military from where a logisitcs applications of automated marking and reading symbols has been used for a long time [31]. Figure 2 presents a statistics report in different views such as documents by year, by subjects, by type, etc, from Scopus database where keyword 'Bar-code' is used for obtaining the results between 2008 to 2016.

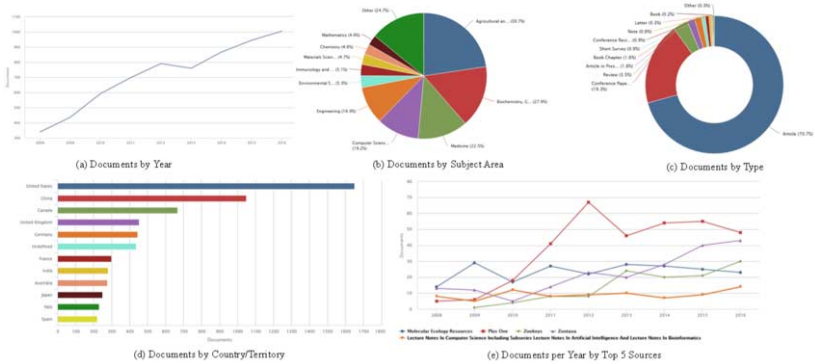


Figure 2. Statistics Analysis on Bar-code Research.

Figure 2 (a) presents the published documents related to this technology by yearly. It could be seen that around 350 documents were published in 2008 and over 1000 was

in 2016, which is three times more than the year 2008. And the numbers increase stably recently. From Figure 2 (b), the top subject areas used Bar-code are agricultural and biological science (39.7%), biochemistry, genetics and molecular biology (27.9%), medicine (22.5%), computer science (19.2%) and engineering (16.9%). These areas used Bar-code to identify various objects to through labelling a numbering code whatever linear lines or 2D shapes. Figure 2 (c) shows the types of documents most of which are articles that takes up of 70.7%. And then, conference papers rank at the top second with 19.3%. From the view of county/territory, United States, China, and Canada are the top three countires which used this technology most from Figure 2 (d). Over 1,600 documents are from United States that because it is firstly proposed in U.S. and now widely used in various industries. Figure 2 (e) shows top 5 resources for producing these documents.

2.3 Wireless communication standards

In IoT-enabled manufacturing, wireless communication standards are very important since all the manufacturing objects should be identified, connected and reacted. Wireless communication is a way to send data or information between two or more points which are not connected physically by any conductors such as cables or wires [32]. Wi-Fi is a wireless local area network that enables portable computing devices to connect easily with other devices, peripheries, and the Internet, which uses tandardized as IEEE 802.11 [33]. Wi-Fi approaches speeds of some types of wired Ethernet for accessing in manufacturing shopfloors, industry sites, and at public hotspots [34-36]. Wi-Fi wireless communication technology was used in a cyber-physical system in industry to process automation and control with some sensors [37-39].

Another wireless communication is cellular data service which offers coverage within a range of 10-15 miles from the nearest cell site whose speed have increased as technologies have evolved, from earlier technologies such as CDMA and GPRS, GSM, to 3G networks such as W-CDMA, EDGE or CDMA2000 [40]. Wireless sensor networks are responsible for sensing vibriations, interference, and activity in data collection networks for example in manufacturing stations or working machines. This allows the manufacturing system to detect relevant quantities, monitor and collect data, formulate clear user displays, and to perform decision-making functions [41]. Wireless data communications are used for spaning a distance beyond the capabilities of typical cabling in point-to-point communication [45].

Bluetooth, a well-known wireless communication method, is for exchanging data over short distances by making full use of short-wavelength UHF radio waves in the ISM band from 2.4 to 2.485 GHz from fixed and mobile devices and building personal area networks (PANs) [46]. Invented by telecom vendor Ericsson in 1994, this technology was conceived as a wireless alternative to RS-232 data cables which are able to connect up to seven devices, overcoming problems that older technologies had when attempting to connect to each other [47, 48]. It is managed by the Bluetooth Special Interest Group (SIG), which has more than 30,000 members in the areas of telecommunication, computing, networking, and consumer electronics, which are used in industry [49]. ZigBee is an IEEE 802.15.4-based specification for a suite of high-level communication protocols which are used for creating private area networks with small, low-power digital radios, such as for shop floor automation, manufacturing device data collection, and other low-power low-bandwidth needs [50]. It is specially designed for small scale projects which need wireless connection. The technology was

defined by the ZigBee specification which is intended to be simpler than other wireless personal area networks (WPANs), such as Bluetooth or Wi-Fi [51]. Its low power consumption limits transmission distances to 10–100 meters so that power output and environmental characteristics have great impacts on the technology [53].

2.4 Smart Sensors

Smart sensors play important roles in supporting the IoT-enabled manufacturing or IIoT. Sensors for capturing the temperature, humidity, force, vibration, etc have been widely used to get the real-time data [54]. For instance, vibrating fork level sensors are used due to its switch reliable, cost effective, and efficient principle. The tuning fork detecting components are planced into vibration by establishing motion in the sensing fork. So that the machine vibrations or moving objects could be detected and such information is important for decision-makings such as machine matainance.

When implementing different sensors in manufacturing, the integration of heterogeneous senors are crucial, especially in real-time basis. Thus, an online real-time quality monitoring system using heterogeneous sensors for additive manufacturing processes was reported [55]. These sensors have been deployed on various manufacturing objects such as machines, materials, shopfloor buffers, etc [56]. After that, the real-time data could be captured and collected for further decision-makings. More sensors technologies, implementations, and review could be observed from [57-59].

3. World-wide Movements

This section reviews the current world-wide movements of IoT-enabled manufacturing so that industry practitioners are able to get some ideas and insights from reading their successful cases or governmental policies which are going to promote this field under the Industry 4.0 era. United States is of course one of key countries in IoT-enabled manufacturing. US government launched several programs to improve manufacturing such as Advanced Manuafcturing Partnership Plan (2011) and Industrial Internet (2012). 35% of US manufacturers are currently collecting and using data generated by smart sensors to enhance manufacturing/operating processes. And 34% believe it is “extremely critical” that US manufacturers adopt an IoT strategy in their operations. 38% currently embed sensors in products that enable end-users/customers to collect sensor-generated data. GE in the US proposed the concept of Industrial Internet that aims to connect manufacturing facilities, people, and data analytics through IoT application in most of their companies in 2012 [60]. Three major parts of the Industrial Internet are smart facilities, smart systems, and smart decision-making.

In 2013, Germany introduced an Industry 4.0 program which covered one core, two topics, three dimensional integration, and eight plans. IoT is one of the key elements in this program. Industry 4.0 creates what has been called a smart factory where modular structured smart factories, cyber-physical systems monitor physical processes, a virtual copy of the physical world and decentralized decisions could be achieved [61]. Over the IoT, cyber-physical systems communicate and cooperate with each other and with humans in real time, and via the Internet of Services, both internal and cross-organizational services are offered and used by participants of the value chain [62]. There is a working group on Industry 4.0, aiming at implementing the

recommendations from German federal governemnt. This group members are the founding faterhs and driving force behind industry 4.0.

In China, a strategic plan called Made in China 2025 was proposed with the Guidance of the State Coucil on Promoting Internet + Action and 13th Five-year Plan on national Program for Science and Technology Innovation. Made in China 2025 has a clear goals, guidance and road map for 30 years. There are nine missions ten major development fields and give major programs [63]. Recently, Japanese government initialized an Industry 4.0 plan which aims to create standards for technology to connect factories and to combine efforts to internationalize industrial standards from Japan. Mitsubishi, Fujitsu and Panasonic, some of the initiative's founding members, plan and act global this initiative to make a difference. Nissan Motor is also a member, which looks for areas of collaboration instead of understanding this as a competing model to Industry 4.0.

4. Insights and Lessons

Several lessons could be obtained from the review investigation. Firstly, IoT key technologies like RFID, Bar-code, and wireless communication standards are quite mature in industry applications. However, their integrations such as technical and data integration are scarcely reported. That may result in isolated technology implementation in entire manufacturing sites. For example, parts being produced communicate with machines by means of a product code, which tells the machines their production requirements and which steps need to be taken next and all processes are optimized for IT control, resulting in a minimal failure rate.

Secondly, sucessful cases are seldom reported since most of the implementation of IoT-enabled manufacturing is till in the initiative stage. Best practices and case studies require more implementations of IoT technology in the industry so that manufacturing could be better transformed and upgraded [64].

Thirdly, the IoT-enabled manufacturing is till led by developed countries like US and Germany. For example, most of the top IoT technology providers are from these countries. Few of them are from developing countries like China and India. Developing countires like China are chasing with rapid step due to the government plans or programs. In the near future, these countries may be the biggest market for IoT technology and their applications.

Manufacturing worldwide is on the cusp of a revolution where new information technologies are suddenly offering not only to make the management of manufacturing more effective from early versions of plant and enterprise software, but the work itself smarter [64]. Technologies based on the Internet of Things have the potential to radically improve visibility in manufacturing to the point where each unit of production can be "seen" at each step in the production process. Batch-level visibility is being replaced by unit-level visibility. This is the dawn of IoT-enabled manufacturing which requires a healthy dose of technology to ensure machines work together, material flows visibly in real time, and teams of knowledge workers orchestrate the entire manufacturing process [66]. The IoT-based environment enables this possible, for example in plant floor applications, it can create a network linking a range of manufacturing assets from production equipment to parts being produced, from sensor-embedded automation controls to energy meters, from trucks to a warehouse's smart shelves [67].

With the IoT, manufacturers can give each of their physical assets a digital identity that enables them to know the exact location and condition of those assets in real time ubiquitously throughout the manufacturing sites or even the whole supply chain. Very importantly, IoT-enabled manufacturing also requires proactive and autonomic analytics capabilities, making manufacturing an intelligent and self-healing environment. With IoT-enabled manufacturing, companies can predictively meet business needs through intelligent and automated actions driven by previously inaccessible insights from the real world. It transforms manufacturing businesses into proactive, autonomic organizations that predict and fix potentially disruptive issues, evolve operations and delight customers, all while increasing the bottom line.

5. Conclusion

This paper reviews the current Internet of Things for manufacturing in the context of Industry 4.0 where IoT-enabled manufacturing is about creating an environment where all available information from within the plant floor is captured in real-time, made visible and turned into actionable insights. IoT-enabled manufacturing comprises all aspects of business, blurring the boundaries among plant operations, supply chain, product design and demand management. Enabling virtual tracking of capital assets, processes, resources and products, IoT-enabled manufacturing gives enterprises full visibility which in turn supports streamlining business processes and optimizing supply and demand.

Some key technologies and world-wide applications are reviewed so that some critical insights and lessons could be obtained. Such important insights could be used for guiding practitioners and academia in their applications and research in the near future due to the development of Industry 4.0.

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A Pattern Based Approach to Human Motion Control

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Abstract. Most researches on motion control are attempting to control motion from the outside. But as Bernstein pointed out in the case of human motion the number of the degrees of freedom is tremendously large, so it is extremely difficult to control motion from the outside. However, if we note how our bodies contribute to our cognition, there are approaches from the other way , i.e.,from the inside. Gallwey pointed out in his book "The Inner Game of Tennis" what an important role our bodies play in tennis. Our muscles are different from person to person, so to win a game, there is no explicit way, but we must fully utilize our embodied cognition. It is his message. This paper describes a pattern-based approach to motion control, which is based on our capability of embodied cognition.

Keywords. Motion Control, Skill Transfer, Pattern Based Approach, Mahalanobis Taguchi System, Embodied Cognition

Introduction

Polanyi [1] pointed out there are two kinds of knowledge; explicit and tacit. Motion Control is a typical tacit knowledge. Although there are many machines which control motion, how we can control human motion is still not clear Let us take a bicycle riding, for example. We learn to ride a bicycle by trial and error by ourselves.

Bernstein used cyclogram and pursued a human motion of hammering down. Near the object, his motion trajectories are almost identical, but far from it, his motion varies widely from time to time (Figure 1).



Figure 1. Cyclogram of hammering.

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Machines reproduce our motion near the goal. So it can be controlled rationally or explictly. This is possible, because the environment does not change. When the evironment changes, adaptive control may provide a solution. But even in such a case, there are objects that do not change with time. But in bicycle riding, situations are totally different. Everything changes with time.

Bernstein pointed out the difficulty of human motion control is due to its large degrees of freedom. Indeed it is, if we consider bicyle riding.

But the importance of human motion control is increasing. It is not only to transfer skills, but more to activate our cognitive capablities [2].

It is pointed out in this paper how important human motion is and a new approach which is pattern-based, and is based on our intrinsic cognitive capabilities is proposed to control it.

1. Human motion control: state of the art

Human motion control has been attracting wide attention, because it relates to many different fields, which include sports, assistive technology, etc. Another important point we have to remember is even if we control our machines, we need to control our motions, because most machines are not fully automated.

Most human motion control studies use motion capture or EMG (Electromyography). In motion capture studies, most of them observe the movements of our joints. They reproduce our successful movements, but they are insufficient for activating or developing our cognitive capabilities. There are many unsuccessful data, but they do not provide us with any clue to how we can control ourselves to move successfully. EMG is used primarily for observing the health of muscles.

What is becoming increasingly important today is fast adaptability. The environments and situations change very frequently and extensively. So we have to be adapable to cope with such changes. Human motion control is no exception. Yesterday, how we can transfer our skills was very important, but the skills needed today have changed. It becomes more important how adaptable we can be in controlling our motions. In this sense, the process of motion learning becomes more important. In other words, adaptable motion and bicyle riding have much in common.

To make it clear how we can tackle this problem, let us look back and understand how we expanded our controllability in engineering.

2. The world is changing

Yesterday, our world was closed with defnite boundaries. In a closed world, we can apply rational approaches. Changes were not frequent and even if there were, they were gentle. So they were mathematically differntiable and we could predict the future.

But today, our world is expanding very rapidly and extensively. It is an open world without boundaries. Changes are frequent and extensive and further they are angular. Therefore, they are not differentiable so that we cannot predict the future. We cannot apply rational approaches anymore. Simon [3] pointed out that our rationality is bounded. If the number of data becomes too large, such problems as computational complexity emerges. Therefore, we have to solve the problem by trial and error.

But to control, we have to secure reproducibility. We have to expand rational approaches beyond the world of rationality. Then, how do we do that?

3. System Identication

System identification is crucial in system dynamics to establish a mathematical model. But let us discuss system identification in a much broader sense.

Let us first consider the problem how we can identify the name of a river. A river is continuously flowing and changing. So if we look at the flow, we cannot identify the name of the river. Therefore, we look around and we find something that does not change with time, such as trees, mountains, etc. They serve as identification points.

In the field of control, the same idea works. Let us take arc for example. There are many researches on arc, but we cannot predict its behavior. Yet, arc is used in welding and arc welding is used extensively. We cannot predict its behavior rationally, so we look around the molten pool and we find points which behave rationally. Thus, we can control arc based upon these points. The idea is the same as we identify the name of a river.

Engineering expanded its world beyond the world of rationality by identifying proper controllable points.

But if we consider bicyle riding, there are no such controllable points around. The situation is the same as in swimming. We are in the flow.

Then, how can we control not from the outside, but from the inside?

4. Adaptable Modeling

Thus, what is needed for human motion control is adapable modeling. In system dynamics or software engineering, their concepts of adaptive modeling are how they can make their model adaptive to the changes. But in the case of human motion control, we do not have any models. We have to develop an *adaptable* model.

In other words, we need to develop a new approach which permits us to develop a model one after another in response to the changing situations. This is nothing other than learning. We learn to grow.

To be able to develop such an adaptable model, we must be situational aware or fully cognizant of the situation.

Then, how can we develop such a growing model or an adaptable model?

5. Detection of emotion from face: Our previous research

This challenge brought us back to our previous research. We used to work on detecting emotion from face. We tried many image processing techniques, but without success. After many failures, we realized that everybody can easily detect emotion from cartoon face. It is very simple and in black and white. This led us to change our policy. We changed from detection to recognition. Cartoon face is a pattern. We understand how a cartoon character is feeling based on a pattern. We compare face patterns and if the pattern we are looking at matches with the pattern of one emotion, for example, happy, then we know the character is happy.

We simplified face images into patterns and compared the pattern of simplified face image with the cartoon face model pattern as shown in Figure 2. This approach was very successful. We do not have to spend much time for processing and in addition, our faces vary from person to person and even one man's face varies from time to time, but such wide variations can be processed without any difficulty [4],[5].

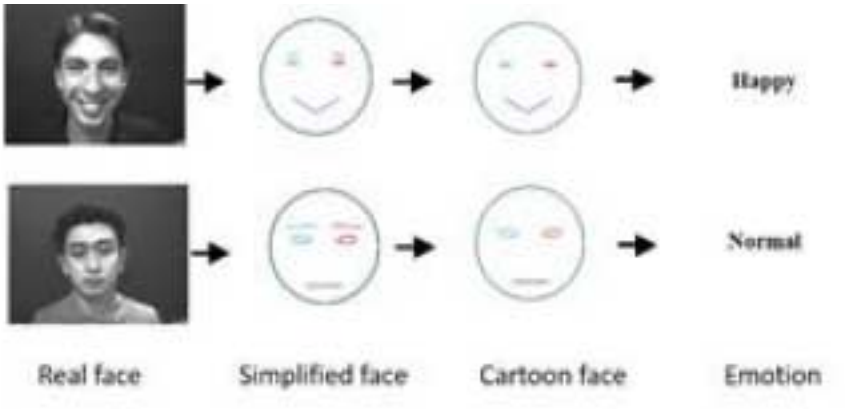


Figure 2. Detection of emotion from face using cartoon face model.

This experience taught us a lesson. We were trying to *detect* emotion, but if we try to *recognize* it, it is much easier. In other words, if we have a model of some kind, no matter how rough it may be, we can develop an adaptable model easily. Besides, if we introduce a pattern approach, we can process multi-dimensional information at once. In the case of other techniques, we have to apply it one after another.

Human motion is multi-dimensional, but if we introduce a pattern approach, we understand at once, if our motion is good or not. But how can we evaluate adaptability? In order to be adaptable, we have to know how much good or bad our motion is. If we can measure it, then, we can adapt our motion to the changing situation adequately.

6. Mahalanobis Taguchi System (MTS)

Mahalanobis Taguchi System or MTS [6],[7] is a very unique technique for pattern recognition. It introduces Mahalanobis Distance (MD), which reduces multi-dimensional information into one dimension and enables us to compare different patterns quantitatively with one single measure MD.

The basic idea of MTS is to define Unit Space and to compare a sample with this Unit Space using Mahalanobis Distance (MD). MD shows how much a sample pattern is different from the Unit Space (ideal pattern). A threshold MD is set up and if the MD of a sample pattern is smaller than this MD threshold, then a sample pattern is determined to belong to the Unit Space pattern (Figure 3).

For example, if we are going to recognize the image of a number, first we divide the image of numbers o, 1, 2,---, 9 into pixels. We collect these unit space samples and average them and obtain Unit Space for 0, 1, 2,---9 (Figure 4).

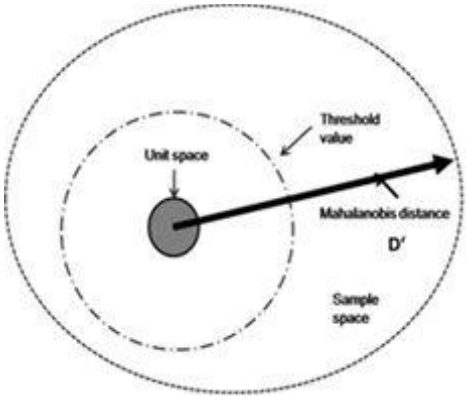


Figure 3. Mahalanobis Taguchi System.



Figure 4. How Unit Space is obtained.

7. Recognition Taguchi (RT) method

MTS developed from MT method to MTS method, and further to old MTA method, new MTA method, TS method, T method (1), T method (2) and then to RT method. RT method is the newest which was developed very recently. Recognition Taguchi (RT) method serves for the current purpose.

The procedures of RT method are as follows.

(1) Determine feature items to define a pattern
(2) Collect sample data to constitute Unit Space
(3) Define Unit Space
(4) Calculate Mean MD (MDmean) of Unit Space samples
(5) Determine Threshold MD (MDthreshold) based on MDmean.
(6) Calculate MDsample for a sample

When we come across the number image, we compare this image sample with these Unit Spaces and calculate their MDs. The smallest MD leads us to recognize what number it is.

The primary benefits of RT method are

(1) We can prepare a large number of unit spaces.
(2) They can be processed very rapidly.

For example, if we process numbers, we only need to prepare 10 (0 to 9) sample spaces. But in the case of body movements, we need to prepare a large number of sample spaces, but they can be accommodated and processed rapidly without any mathematical difficulty.

In fact, we can process 10s of thousands of unit sample spaces. This is very much different from other MTS methods. Most of them need to limit the number of unit sample spaces and their processing speed is slow.

It should be noted that original RT is developed for Recognition. Thus, it is named Recognition Taguchi. But, although the procedure is the same, we used it for cognition. So to be exact, the method used here should be called Cognitive Taguchi (CT) method.

8. Evolutionary Cognitive Taguchi (ECT) method

The regular RT method defines Unit Space after assembling many samples as shown in Figure 4. But to develop cognitive capabilities, we need to introduce a new way of defining Unit Space.

Instead of defining Unit Space after all repetitions, we update Unit Space after each success. After many successful repetitions, Unit Space will be the same as the one obtained by the regular procedures. But this process of updating provides us with information about how much we are improving and whether we are on the right track or not.

9. Intrinsic cognitive pattern

Most cognitive pattern approach are from outside. But what we are discussing here is a cognitive pattern approach from inside. It will satisfy our intrinsic motivation and our needs for growth, as described next.

Gallwey pointed out in his book "The Inner Game of Tennis" what an important role our bodies play in tennis [8]. Our muscles are different from person to person, so to win a game, there is no explicit way, but we must fully utilize our embodied cognition. We have to learn from failures. That is his message. Intrinsic cognitive pattern approach shares the same idea.

Brain science, neuroscience, etc. are progressing rapidly so intrinsic cognitive pattern or network is expected to be made clear soon, but at present, we have to rely on such technologies as Motion Capture, Eye Tracking, EMG, etc. But no matter what technology may be used, we can define intrinsic cognitive pattern based on these data as described above.

10. Self-Determination Theory (SDT)

Deci and Ryan proposed Self-Determination Theory (SDT) [9][10][11]. They pointed out that there are two kinds of motivations; extrinsic and intrinsic. Extrinsic motivation is in economics term, a reward.

We feel happier, even if the job is the same, if we are motivated internally and do it. Traditional engineering has been making efforts to satisfy our extrinsic motivations. We made efforts on how we produce better quality and better functioning products. Although voice of customers has been emphasized, it is only considered within the framework of external motivation. We would like to make decisions ourselves. That is why Deci and Ryan called their theory SDT.

Another important point they pointed out is that we need to grow. Learning is growing. That is why we feel happy when we learn to ride a bicycle. But most machines today deprive us of such opportunities of self-determination or learning to grow. We have to re-consider our design as will be discussed next.

Intrinsic cognitive pattern approach is expected to be one of the solutions.

11. Tolerance

By introducing this intrinsic cognitive pattern approach, we can satisfy intrinsic motivations of users. We can provide a wide margin for users to decide and act in their own way. If such a wide margin is secured in design, then it is expected that man and machine can work more happily together and it is expected we can reduce human errors drastically as we did with technical failures.

Such AI technology as Deep Learning will help us to set such a margin. But current AI needs computer power, but RT is fast enough and needs far less computer capability. Thus, it is much easier to apply.

12. Sense of balance

Physiology has made clear that we balance our body using our deep sensation, or proprioception, which controls our position and movements. It is important to note that proprioception varies widely from person to person, as does skin sensation. In fact, proprioception comes from Latin proprius, meaning “one’s own”, “individual”. So, it is natural that our movements differ from person to person.

We should remember that our sense of balance integrate all information. It processes multidimensional inputs from our sensors and sends signals to our actuators such as arms. legs, etc. Intrinsic cognitive pattern approach is deeply associated with our sense of balance.

13. Connected Machines

IoT is connecting machines rapidly. Traditional engineering made efforts to develop individual products with better quality and better performance. But now we need to design and operate machines as a team. So, just like a human body, we need a sense of balance or sense of coordination to run these machine teams.

Knute Rockne, American football coach, pointed out that a best team cannot be formed with 11 best players, but can be with players who play for the team adaptively.

Franz Beckenbauer, German soccer coach, introduced Libero system to make their team more adaptable to the changing situations on the pitch.

In other words, the importance of communication is rapidly increasing to be fully adaptive to the changing situations. Engineering systems need to be re-designed to communicate better not only between machine and machine , but also between man and machine with ample tolerance for human errors..

Intrinsic cognitive pattern approach described here is expected to be very effective and will play an important role in this age of communication.

14. Summary

An intrinsic cognitive pattern approach to motion control is proposed, using revised version of Recognition Taguchi method, which is one of Mahalanobis Taguchi Systems. MTS). The greatest feature of MTS is to reduce multi-dimensional informatio to one

dimension. Thus, it can compare patterns quantitatively using Mahalanobis distance (MD).

As the problem we are tackling here is not to recognize patterns, but to realize how we can be successful in our motion, RT method is reframed as Cognitive Taguchi method and it helps us to learn motion more effectively by comparing motion pattern one after another. MD provides us with a quantitative measure so we can understand how we should improve our motion to be successful.

The uniqueness of our approach is while most cognitive approaches look at a system from outside and identify the system parameters to control motion, our approach look at a system from inside and entrust decisions to humans.

This is because the number of degrees of freedom in human motion is too large, we take note of the superb human sense of balance. This enables us to allow a much wider margin in design for humans, which permits our trials and errors. Thus, it will satisfy our desire to make decisions ourselves and our needs to grow.

Although this approach is developed to control our motion, it will also help to respond to the change IoT is bringing about, i.e., connected machines. Traditional engineering has been paying attention to an individual machine, but what is facing us now is a team of machines. It is expected our approach will also help to respond to such requirements, too.

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Utilizing Cyber Physical System to Achieve Intelligent Product Design: A Case Study of Transformer

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Abstract. Industry 4.0 is known as a powerful supportive system that enterprises can enhance their competitiveness. One of critical techniques of industry 4.0 is Cyber-Physical System (CPS). CPS is a mechanism which can control or monitor physical equipment in the front end and utilize the cloud computing in the back end to achieve intelligent production or services. Although the concept of CPS has been understood by industries, how to implement CPS and accomplish the goal of enterprises remains vogue. This study utilizes the framework of CPS to achieve intelligent product design. Based on the data collected from sensors of CPS, Principal Components Analysis (PCA) is firstly employed to figure out key factors. Next, A Artificial Neural Network (ANN) method is developed to build a forecast model to identify parameters which have better yield in the backend. CPS then modify these parameters improve the yield as well as future product design. As a result, the yield issue can be solved not only in the manufacturing but also in the product design stage.

Keywords. Industry 4.0, Artificial neural network, Cyber physical system, Intelligent Product Design

Introduction

Industry 4.0 is the current trend of automation and data exchange in manufacturing technologies. It includes cyber-physical systems, the Internet of things and cloud computing. Industry 4.0 creates what has been called a "smart factory". Within the modular structured smart factories, cyber-physical systems monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the Internet of Things, cyber-physical systems communicate and cooperate with each other and with humans in real time, and via the Internet of Services, both internal and cross-organizational services are offered and used by participants of the value chain.

Industry 4.0 is based on a concept that is as striking as it is fascinating: Cyber-Physical Systems (a fusion of the physical and the virtual worlds) CPS, the Internet of Things and the Internet of Services, will collectively have a disruptive impact on every aspect of manufacturing companies. The 4th industrial revolution, which unlike the previous revolutions, can be predicted, therefore allowing companies to take specific actions before it happens [1].

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The most important technique of industry 4.0 is cyber-physical system (CPS). Cyber-physical Systems (CPS) are simply physical objects with embedded software and computing power. In Industry 4.0, more manufactured products will be smart products, CPS. The Industry 4.0 describes a CPS oriented production system that integrates production facilities, warehousing systems, logistics, and even social requirements to establish the global value creation networks [2]. Based on connectivity and computing power, the main idea behind smart products is that they will incorporate self-management capabilities [1]. CPS is integrations of computation, networking, and physical processes. Embedded computers and networks monitor and control the physical processes, with feedback loops where physical processes affect computations and vice versa. The economic and societal potential of such systems is vastly greater than what has been realized, and major investments are being made worldwide to develop the technology. The technology builds on the older (but still very young) discipline of embedded systems, computers and software embedded in devices whose principle mission is not computation, such as cars, toys, medical devices, and scientific instruments. CPS integrates the dynamics of the physical processes with those of the software and networking, providing abstractions and modeling, design, and analysis techniques for the integrated whole.

In today's competitive business environment, companies are facing challenges in dealing with big data issues of rapid decision-making for improved productivity. Many manufacturing systems are not ready to manage big data due to the lack of smart analytic tools [3][4]. However, there are few studies discussing CPS in product design. Most studies apply CPS in information technology. Therefore, the aim of this study is to apply CPS in product design to achieve intelligence. This study utilizes the framework of CPS to achieve intelligent product design. Based on the data collected from sensors of CPS, Principal Components Analysis (PCA) is firstly employed to figure out key factors. Next, A Artificial Neural Network (ANN) method is developed to build a forecast model to identify parameters which have better yield in the backend. CPS then modify these parameters as to improve the yield as well as future product design. As a result, the yield issue can be solved not only in the manufacturing but also in the product design stage.

1. Literature review

1.1. Industry 4.0

Industry 4.0 is a strategic initiative of the German government that was adopted as part of the "High-Tech Strategy 2020 Action Plan" in 2011 [5]. In Germany, a major debate on Industry 4.0 has started, which in the meanwhile has also spread to other countries, like the US or Korea. The idea behind this term is that, the first three industrial revolutions came about as a result of mechanization, electricity and IT. Cyber-physical systems made up of connected systems of software, sensors, machines, workpieces, and communication technologies monitor physical processes, create a virtual copy of the physical world, and make decentralized decisions [6]. Now, the introduction of the IOT and CPS into the manufacturing environment is an ushering in 4th Industrial Revolution.

It was common knowledge that, in general, the engineering discipline followed technological trends. This was particularly true of industrial engineering (IE), which

was defined as "concerned with the design, improvement and installation of integrated systems of people, materials, information, equipment and energy..." [7].

In comparison to many other traditional manufacturing concepts like Advanced Manufacturing or Lean Production which had been widely established in the scientific literature, Industry 4.0 could be identified as a term which was mainly used in the popular science in different contexts [8]. Developed by the German Federal Government to promote its High-tech strategy, this multifaceted term comprised a variety of interdisciplinary concepts without a clear distinction. It had often been used as a synonym for the planned 4th Industrial Revolution by pointing out its huge technological potential, comparable to technical innovations which led to the first industrial revolutions: (1) the field of mechanization, (2) the use of electricity and (3) the beginning of digitization [9].

Industry 4.0 represents a smart manufacturing networking concept where machines and products interact with each other without human control. Smart factories Industry 4.0 on the basis of collaborative cyber-physical systems represents a future form of industrial networks [10]. central aspects of the Industry 4.0 can be further specified through three paradigms: the Smart Product, the Smart Machine and the Augmented Operator. The guiding idea of the Smart Product is to extend the role of the work piece to an active part of the system. The products receive a memory on which operational data and requirements are stored directly as an individual building plan. In this way, the product itself requests the required resources and orchestrates the production processes for its completion. This is a prerequisite to enable self-configuring processes in highly modular production systems [11].

1.2. Cyber physical systems

Cyber–physical systems (CPSs) are integrations of computation and physical processes. Embedded computers and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa. The design of such systems, therefore, requires understanding the joint dynamics of computers, software, networks, and physical processes [12].

The current state of CPSs could be described by capturing the values of its important process variables. Two kinds of important process or state variables in CPSs included (1) measured variables representing the sensor measurements and (2) control variables representing the control signals [13]. In CPSs, the distance between the values of process variables and the corresponding set points was calculated by controllers. After calculating this offset, the controllers using a complex set of equations, elaborated a local actuation strategy, and calculated a new actuating or control variable. The resulting manipulated value was sent to the suitable actuator to keep the process closer to the determined set point [14]. The controllers also sent the received measurements to main control servers and executed the issued commands from them. In CPSs, the operators of the system must be aware of the current state of the controlled objects. Since CPS is in the initial stage of development, it has to define the structure and methodology of CPS as guidelines for its implementation in industry clearly. To meet above demand, a unified system framework has been designed for general applications. In addition, corresponding algorithms and technologies at each system layer are also proposed to collaborate with the unified structure and realize the desired functionalities of the overall system for enhanced equipment efficiently, reliability and product quality [15].

1.3. Summary

Industry 4.0 is the trend ,but also is a direction of the automation industry. Understanding the meaning of CPS and traits of industry 4.0 based on internet ,personalized service, data decision ,energy-efficient respectively can provide real solution for clients in need. In order to identify parameters which have better yield in the backend, we utilize ANN to build a forecast model in section 3.

2. Methododology

The aim of this paper is to build a forecast model to identify parameters which have better yield in the backend via artificial neural network. Then, CPS can modify these parameters improve the yield as well as future product design. The methodology in this paper is divided into two parts. Phase I employ PCA to figure out key factors. Phase II utilize ANN o build a forecast model to identify parameters which have better yield in the backend via artificial neural network as Figure 1.

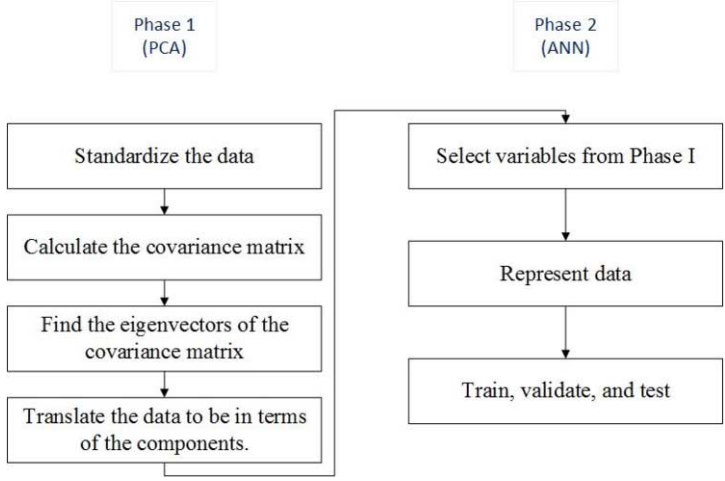


Figure 1. A process of the methodology.

2.1. Phase I: Employ PCA to figure out key factors

Principal component analysis (PCA) [16] is a well-established technique for dimensionality reduction, and a chapter on the subject may be found in numerous texts on multivariate analysis. Examples of its many applications include data compression, image processing, visualization, exploratory data analysis, pattern recognition and time series prediction.

PCA is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components. The number of principal components is less than or equal to the number of original variables. This transformation is defined in such a way that the first principal component has the largest possible variance (that is, accounts for as much of the variability in the data as possible), and each succeeding component in turn has the highest variance possible

under the constraint that it is orthogonal to the preceding components. The resulting vectors are an uncorrelated orthogonal basis set. PCA is sensitive to the relative scaling of the original variables.

Besides, PCA is a simple yet popular and useful linear transformation technique that is used in numerous applications, such as stock market predictions, the analysis of gene expression data, and many more. In this section, we will see that PCA is not just a "black box", and we are going to unravel its internals in 4 basic steps.

- Step1. Standardize the data
  Whether to standardize the data prior to a PCA on the covariance matrix depends on the measurement scales of the original features. Since PCA yields a feature subspace that maximizes the variance along the axes, it makes sense to standardize the data, especially, if it was measured on different scales.
- Step2. Calculate the covariance matrix
  The classic approach to PCA is to perform the eigendecomposition on the covariance matrix Σ, which is a d×d matrix where each element represents the covariance between two features. The covariance between two features is calculated as follows:

$$\sigma_{jk} = \frac{1}{n-1}\sum_{i=1}^{n}(X_{ij} - \bar{x}_j)(X_{ik} - \bar{x}_k) \tag{1}$$

We can summarize the calculation of the covariance matrix via the following matrix equation:

$$\Sigma = \frac{1}{n-1}((X - \bar{x})^T (X - \bar{x})) \tag{2}$$

where $\bar{x}$ is the mean vector

$$\bar{x} = \frac{1}{n-1}\sum_{k=1}^{n} X_i \tag{3}$$

- Step3. Find the eigenvectors of the covariance matrix
  To show that the eigenvectors are indeed identical whether we derived them from the scatter or the covariance matrix.
- Step4. Translate the data to be in terms of the components.
  In the last step, we computed to transform our samples onto the new subspace via simple matrix multiplication.

2.2. Phase II: utilize ANN o build a forecast model to identify parameters

Artificial neural networks (ANNs) may be defined as structures comprised of densely inter connected adaptive simple processing elements (called artificial neurons or nodes) that are capable of performing massively parallel computations for data processing and knowledge representation [17].

ANNs have been intensively studied during the last two decades and successfully applied to dynamic system modelling as well as fault detection and diagnosis. Neural

networks provide an interesting and valuable alternative to classical methods, because they can deal with the most complex situations which are not sufficiently defined for deterministic algorithms to execute. They are especially useful in situations when there is no mathematical model of the process considered, so the classical approaches such as observers or parameter estimation methods cannot be applied. Neural networks provide an excellent mathematical tool for dealing with non-linear problems.

An artificial neural network is an interconnected group of nodes, akin to the vast network of neurons in a brain. Here, each circular node represents an artificial neuron and an arrow represents a connection from the output of one neuron to the input of another as Figure 2.

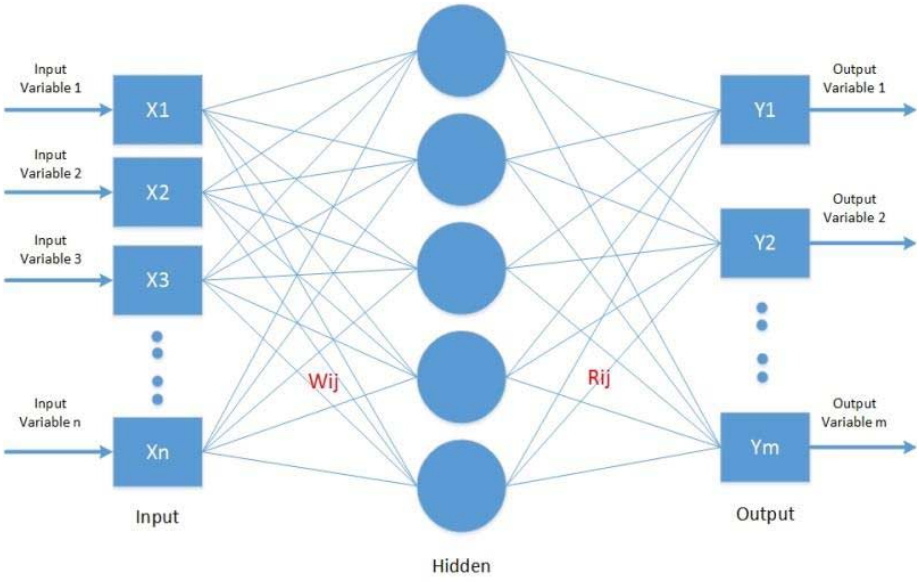


Figure 2. A framework of ANN.

- Step1. Select variables from Phase I
  Whether to standardize the data prior to a PCA on the covariance matrix depends on the measurement scales of the original features. Since PCA yields a feature subspace that maximizes the variance along the axes, it makes sense to standardize the data, especially, if it was measured on different scales.
- Step2. Represent data
  Raw data are rarely fed into neural networks without preprocessing/transformation. One of the common transformations is to take natural logarithm of the change in the variable value.
- Step3. Train, validate, and test
  We move forward in time and divide the whole historical data set into training, validation, and test set at a proportion of, say, 7 :2: 1. The advantage of having the validation set follow the training set is that these data contain the most up-to-date market trends.

The root-mean-square error (RMSE) represents the sample standard deviation of the differences between predicted values and observed values. These individual differences are called residuals when the calculations are performed over the data

sample that was used for estimation, and are called prediction errors when computed out-of-sample. The RMSE serves to aggregate the magnitudes of the errors in predictions for various times into a single measure of predictive power. RMSE is a good measure of accuracy, but only to compare forecasting errors of different models for a particular variable and not between variables, as it is scale-dependent.

We assume that we already have n samples of model errors ϵ calculated as (ei, i = 1,2,... , n). The uncertainties brought in by observation errors or the method used to compare model and observations are not considered here [18].

$$\text{RMSE}= \sqrt{\frac{1}{n}\sum_{i=1}^{n} {e_i}^2} \tag{4}$$

3. Case study

Power transformer is one of the main product of many electronic company in Taiwan. It provides usage not only to domestic enterprises but also foreign markets such as America, Canada and Japan…etc. However, although the manufacturing quality of transformer receives recognition, it meets the problem of overdesign inevitably in the process of product design and transformers come in below customer's requirement. Therefore, it will lead to lower customer satisfaction. The redesign and manufacture of transformers will also increase the company's unnecessary costs.

3.1. Principal component analysis

In the Figure 3, we can find silicon steel sheeting is highly correlated to the weight of radiator. Copper loss is highly correlated to impedance voltage, the weight of magnet core, and the weight of radiator. Iron loss is highly correlated to copper loss, impedance voltage, the weight of magnet core, and the weight of radiator. Temperature rise is almost negative correlated to others. Impedance voltage is highly correlated to copper loss, the weight of magnet core, and the weight of radiator. The weight of magnet core is highly correlated to copper loss, iron loss, and the weight of radiator. The weight of radiator is highly correlated to copper loss, iron loss, impedance voltage, and the weight of magnet core.

		silicon steel sheeting	copper loss	iron loss	temperature rise	impedance voltage	the weight of magnet core	the weight of radiator
Correlation	silicon steel sheeting	1	-0.691	-0.403	0.582	-0.67	-0.587	-0.805
	copper loss	-0.691	1	0.788	-0.269	0.94	0.805	0.921
	iron loss	-0.403	0.788	1	-0.147	0.712	0.958	0.725
	temperature rise	0.582	-0.269	-0.147	1	-0.354	-0.316	-0.578
	impedance voltage	-0.67	0.94	0.712	-0.354	1	0.727	0.866
	the weight of magnet core	-0.587	0.805	0.958	-0.316	0.727	1	0.819
	the weight of radiator	-0.805	0.921	0.725	-0.578	0.866	0.819	1

a. Determinant = 4.402E-6

Figure 3. Correlation Matrix.

In terms of communality, the weight of radiator contributes to factors up to 0.961, followed by copper loss and iron loss as Table 1.

Table 1. Communalities.

Component	Initial	Extraction
silicon steel sheeting	1.000	.804
copper loss	1.000	.920
iron loss	1.000	.904
temperature rise	1.000	.858
impedance voltage	1.000	.836
the weight of magnet core	1.000	.880
the weight of radiator	1.000	.961

According to the preset, abandoning the factor whose Eigenvalue<1 are less than one, and there are two factors remaining in this example. Extraction Sums of Squared Loadings, in other words, is Coefficient of determination. We find that the first principal component and the second component explain 88.056% of the total variation. as Figure 4.

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.038	71.965	71.965	5.038	71.965	71.965	4.073	58.185	58.185
2	1.126	16.090	88.056	1.126	16.090	88.056	2.091	29.871	88.056
3	.475	6.779	94.834						
4	.263	3.757	98.591						
5	.079	1.130	99.722						
6	.014	.197	99.919						
7	.006	.081	100.000						

Figure 4. Total Variance.

In the Figure 5, the scree plot shows that 2 of those factors explain most of the variability because the line starts to straighten after factor 2. The remaining factors explain a very small proportion of the variability and are likely unimportant.

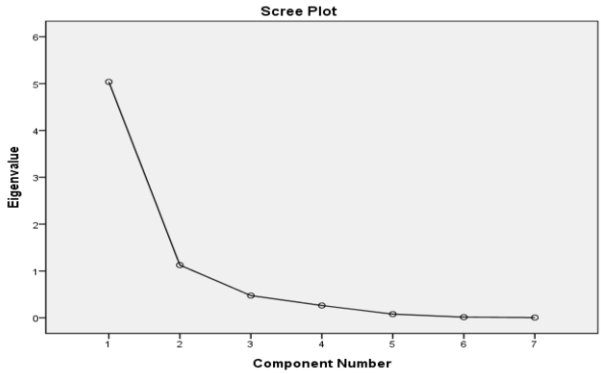


Figure 5. Scree Plot.

Table 2 presents the proportion of the two principal components including a variable, and we set up a new variable K1 for principal component 1, K2 for principal component 2

K_1 =0.971*the weight of radiator+0.944*copper loss+0.911*impedance voltage+0.9*the wright of magnet core+0.83*iron loss-0.792*silicon steel sheeting-0.497*temperature rise (5)

K_2 =-0.134*the weight of radiator+0.173*copper loss+0.263*the wright of magnet core-0.464*iron loss+0.421*silicon steel sheeting+0.782*temperature rise (6)

Table 2. Component Matrix

Component	Component	
	1	2
the weight of radiator	.971	-.134
copper loss	.944	.173
impedance voltage	.911	
the weight of magnet core	.900	.263
iron loss	.830	.464
silicon steel sheeting	-.792	.421
temperature rise	-.497	.782

3.2. Artificial neural networks

We can know from Figure 6 that root mean square error of training data is lower 22.89% than testing data. Besides, The misjudgment rate decreases and converges to 0.11.

3.3. Discussion

In previous study, discussing about the application of PCA and ANN in product design, which is related to return the optimal parameters feedback to product design. The amount of training samples is too little, which lead to the poor performance of ANN .So, we need to add more samples to achieve higher accuracy of the prediction. Employing PCA, we got critical parameters to avoid collinearity. Utilizing ANN, we can build a forecast model to improve the stage of product design.

4. Conclusion

CPS is a trend in response to industrialization. In fact, there is no case successfully improved. Now there is only a concept and we practice it in product design. This study is mainly using CPS to feedback the product design process of transformer in the backend. We reduce the dimensions of variants and get two new variants. Then, we use ANN to get the best parameters. The final result shows that these variables' learning are

effective because the misjudgment rate is convergent to 0.11,which is very low. For the future research directions, we would observe the variation of parameters in different learning rate and take more sample into consideration to achieve higher accuracy rate.

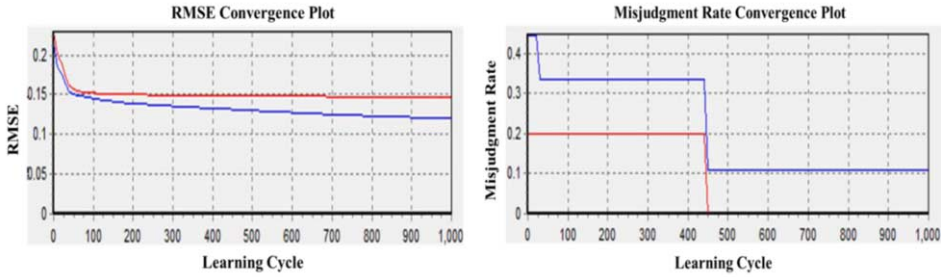


Figure 6. RMSE plot & Misjudgment Rate Plot.

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Automation of Designing Car Safety Belts

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Abstract. Designing seat belts for modern cars is largely a routine process. Supporting the design process by conventional CAD techniques despite many benefits does not shorten time-consuming design tasks as significantly as we would expect. Only the use of Generative Modeling method can considerably automate routine part of the design process of safety belts. The key to the development of Generative Model is to develop a basis for a seat belt retractor, which determines the whole structure of seat belt assembly. The paper describes in details the design of the Generative Model of the base of a seat belt retractor and the impact of its individual parts on the final form of the belt assembly. In addition, the base is equipped with a Poka-Yoke system, integrated into the Generative Model which ensures the elimination of assembly errors. To build the Generative Model, CATIA system and Knowledgeware tools were used. The paper also shows examples of CAD models of belts assemblies developed using elaborated Generative Models.

Keywords. Knowledge-based Engineering, safety belt, retractor base, poka-yoke, generative model

1. Introduction

Subassemblies used in modern cars have to meet new technical and economical requirements. Safety belt designed and produced by a specialized company can be a top example of such subassembly. Both a designer and a producer of a belt have to have means to design and manufacture it, where assured and safe technical solutions are used which can be easily adopted to the requirements of a customer. Therefore, the belt should comply with functionality list and technical limitations defined by an ordering party. Usually a designer is aware of maximum number of functionalities of a belt and its technical limitations and the chosen solution is an inteligent combination of selected functionalites and respective technological solutions integrated in the whole assembly of a seat belt.

Seat belt assembly must be adapted to specific requirements and limitations of casing in a car. The designing process, which relies on inteligent matching final solution with a long list of partial solutions and on adapting them to limitations of casing, is particularily suitable for aiding it with Generative Modeling (GM) techniques [1], [2], [3]. This method goes far beyond the simple parametrization although it uses it intensively. Such factors as routine designing process, matching parts of ready made

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technical solutions, adaptation to size and shape of elements and subassemblies according to given criteria and limitations, multiplicity of relations, especially geometrical ones, between collaborating elements predestine this aiding designing method to be used [4], [5]. Designer can do it without many tedious tasks and be sure that many errors can be avioded which result from temporary lack of focus.

The Generative Model (GM) is based on well identified methodology [2][6-9] which includes identification, record and processing of designing knowledge, integration of that knowledge to geometric model in CAD tool, testing and increasing functionality of GM. GM is an associative CAD model which adapts to input parameters, defined in various ways, beginning with common user editable parameters and up to environmantal features which are detected by the model e.g. identification of geometrical features of other parts of the structure. The ability to adapt to these parameters by change of form or size of elements of GM is a distinctive feature of such models [10-13].

One of the most important elements which reflect selected functionalities and limitations is safety belt retractor base. In this base functionalities and limitations are represented as integrated geometrical features. These identified and implemented parts in the base enable placing particular subassemblies which decide on these functionalities and limitations. It is crucial for making GM design in a proper way and use it as a base for choosing the form of the rest of parts. Such GM approch enables not only advanteges concerning design proces but has the important influence on final car parameters and also reduces mass and in consequence energy effciency of transportation operation [14], [15].

In the further part, two key tasks will be presented, connected with GM creation of safety belt and in particular safety belt retrector base. The key tasks are knowledge acquistion and GM creation in Knowledgeware environment of CATIA system.

2. Knowledge modeling

2.1. Ontology introduction

Ontology is a specific backbone for the knowledge gathering process. It contains the detailed structure by which knowledge will be introduced and which will allow it to be prioritized and ordered. It is also characterized by a series of implemented tools in the form of templates, which are the basic element to allow later work on the acquired knowledge. Ontology modeling implies both conceptualization and formalization of the applied domain.

These diagrams can also be divided into two categories in terms of the nature of knowledge that will be written in them:

- Declarative knowledge (also called descriptive) - can take the form of formal and informal knowledge. It mainly refers to the description of the state / situation of objects / activities and the concepts and relationships between them, and indicates what the problem is and what it is intended to solve, rather than what steps to take to achieve this. Examples of this form of knowledge are models and theories.
- Procedural knowledge (also referred to as operational) - indicates how to achieve the intended objectives, that is, the pledge of the procedures, functions or activities to achieve the intended results.

The delimitation of the nature of the knowledge stored in the database on declarative and procedural basis brings disproportionate benefits to the further stages of the use of the implemented knowledge. It allows you to preserve the order of management of the knowledge which is entered, its hierarchy, and also allows you to maintain an appropriate structure in the created database. It should be borne in mind, however, that such division is not intended to permanently separate the two types of knowledge. Although knowledge about instances and relationships between these elements is written in a separate part, and all the procedures and steps necessary to achieve the intended individual, the whole is not able to exist without each other. This form significantly improves the functionality of the knowledge base [10], [11]. It is a modern and practical solution that is an indispensable part of the design and construction process.

Table 1. Ontology basic structure.

	Methodology build	Methodology use
Acquisition of knowledge	Analysis of the field of application Design or adapt the ontology of the field Improving and developing ontology	Application of knowledge acquisition tools to acquire knowledge in the field of design, product and design process of CAD modeling
Formalization of knowledge	Develop rules for creating a formal model Construction of a formal model	Construction of a set of Generative Models in the given design and design class Storage of Generative Models
Implementation of knowledge	Develop alternative ways to create a Genarative Model Developing methods for transforming a formal model into a Genarative Model	Construction of a set of Generative Models in the given design and design class Storage of Generative Models

2.2. Ontology used to implement knowledge of seat belt retractor housing

Using the classic knowledge base is quite a hassle. The necessity to study the complementarity of the knowledge contained in the books, the constant return to the same information and their verification is not a convenient step for the user. In addition, when you encounter a problem, you need to find additional information to solve it. The next inconvenience arises when you want to re-run the process or need to use another user's knowledge base. Another problem is the lack of ability to overlap and emphasize certain information. This prevents the user from accessing the required data quickly. All these problems are eliminated using an ontology based knowledge base:

- No problem with the structure,
- No need to search for missing information,
- Anyone can use this database,
- The workload and time required to build the base entail unruly benefits, facilitating the designer / builder's work.

The graphical form of elements is predetermined, but it is possible for the user to interfere and adjust the appearance of the elements for his own needs, preferences or standards imposed on them for the realization of the process of acquiring knowledge. The KADM (Knowledge Aided Design Methodology) [2][5][10][11] ontology used in the natural knowledge construction work also had some necessary elements to build a correct knowledge base structure. These are the following diagrams for the informal model:

- activity diagram,
- activity diagram of the constraint entity,
- unit structure diagram and constraints
- and the structure view"

Structure and constraints diagram is designed to impose constraints on structural elements using the structure view diagram. This allows the user to impose certain constraints on a particular element of the structure, in detail in the form intended for that purpose, e.g. strength limitations resulting from certain construction calculations or dependency of certain related elements.

Activity diagram is intended to enable the structural diagram to be supplemented by detailed steps from forming and shaping a part to finished product. It allows user to save the technology used, the following steps during the manufacturing process, and the control rules. The knowledge stored here is a procedural knowledge that fully reflects the path of transition from idea to finished product using specific procedures. For building ontology and Knowledge Base constraction PCPAK environment was used [16].

3. Development of aiding tools for safety belt design

3.1. Standard solution

With a classic approach to modeling, in order to create a whole range of different types of enclosure construction, user needs to create around 70 different models. By using CATIA v5, you can do this in a single file with built-in knowledge base using the Knowledgeware module in the form of parameters, relationships and rules that control the display of the desired housing. Despite this, the model becomes "heavy" with so much data and is not working properly with it. Such a form can serve to build the base of existing constructs, but does not introduce the automation of this process.

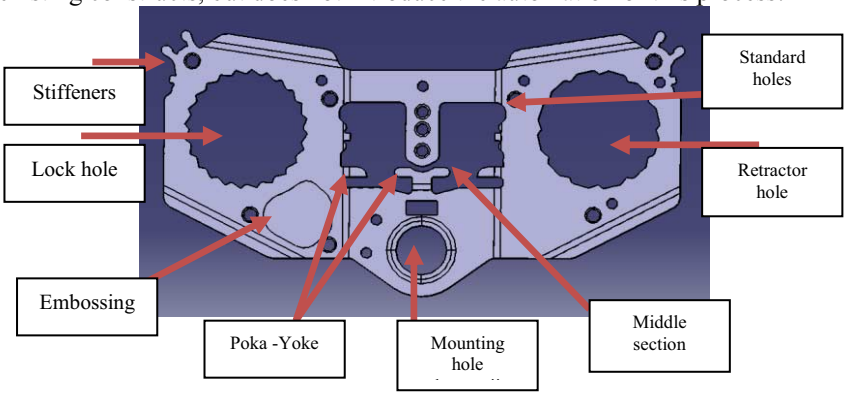


Figure 1. Structural design of the seat belt retractor housing.

3.2. Generetive Model (GM).

According to this concept, the created model was supposed to contain elements allowing to automate some of the activities contained in it. To do this, you must include

the entire construction in the necessary parameters and then use the previously mentioned Knowledgeware toolbox.

3.3. System for the design of the seat belt retractor housing.

The general approach to building a system to assist the construction of the seat belt retractor was to use the appropriate Power Copy, User Defined Feature, and Document Template. It was necessary to identify similar housing features for all models and save them in the right form.

The idea behind this model was to make a few simple steps to achieve the ultimate form of the seat belt retractor. In addition, the intention of the constructor was to insert individual design features in the form of the User Defined Feature knowledge template with the block access to the construction of the individual features for the third party, ie, the use of the Black Box Protected option.

3.3.1. Start building the system - Document Template.

Two Geometrical Set elements were inserted into the tree structure to preserve order and functionality, enabling them to incorporate the elements underlying the structure, that is, a group called Input Elements and Structural Elements containing the structure for the housing base.

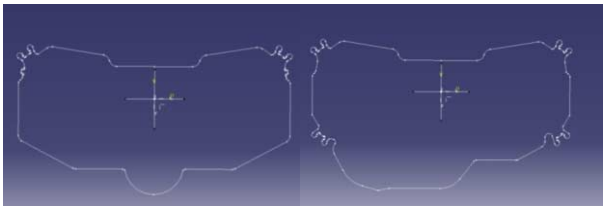


Figure 2. Different geometric shapes of the outer edge for the seat belt retractors.

Based on the sketches. a user is able to go on to create a three-dimensional structure. The essential feature of creating these components was to provide a common solid for all types of enclosures.

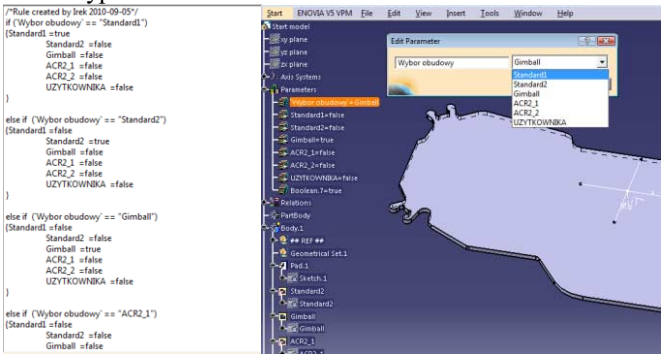


Figure 3. Rules used in the system [left]. Form of choosing a variant of the retractor housing [right].

The last step is to save the file as a knowledge Document Template. After this operation, when inserting this template into a new document, the user will automatically receive the correctly created base shell file structure.

3.3.2. Design features saved as User Defined Feature.

As for the process of constructing the base shape of the outer edge of the casing, it was necessary to prepare the work space by adding and renaming the two Geometrical Set sections. After this operation, a base element was required based on which the planned cutout was to be made and the earlier designation of the base elements of the structure.

A cuboid of 2mm thickness was drawn out of the rectangular sketch. To make sure that the later construction will not have any undesirable constraints, there is a need to extract the input elements from the resulting solid. This capability is provided by the Extract utility located in the Generative Shape Design module. In addition, the use of the Create Datum tool allows you to deprive the "parent" elements extracted.

The next steps are actions analogous to the outer edge, that is, drawing and positioning the sketches of the individual sections of the middle section placed in the Structural Elements group and their subsequent cutting using the Pocket tool. Ultimately, it is important to specify parameters and write rules that controls the display of the selected structure.

For other structural features saved as a User Defined Feature template, the creation process looks virtually identical, except that other spatial operations are used to obtain the desired feature (Hole tool). This is illustrated below (Figure 4).

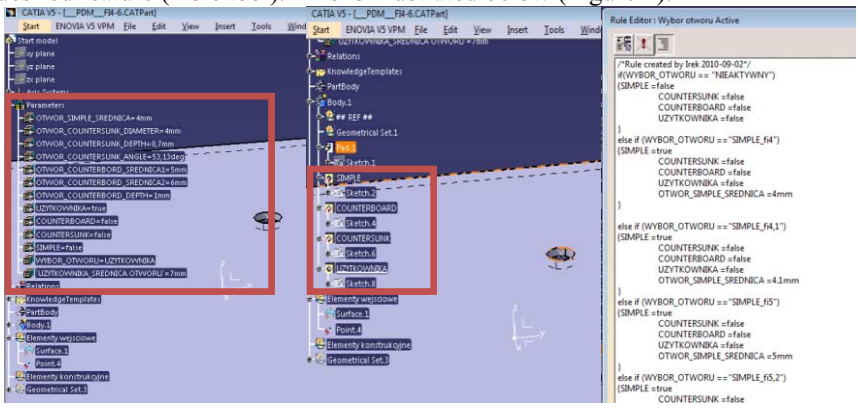


Figure 4. Tree with parameters implemented in the file [right]. Geometric operations [left].

3.3.3. Design features saved as a Power Copy template.

The last part of the system are sets of components used already after the transformation process into a sheet metal element in the Generate Sheetmetal Design module. They will be used to generate Stamp elements, position the insertion points, and define the fold lines for the final form of the casing.

The ready-made templates inserted into the file will copy the items written directly into the structure of the tree.

3.3.4. Templates insert.

This is the stage, which includes placing all previously described templates in the base file.

Consequently, the user automatically receives the external shape of the retractor housing. Now we can proceed to inserting the remaining templates. Finally, the design assumes the form shown in the figure below (Figure 5). When inserting each item, a

dialog box appears asking to indicate the characteristic input elements for insertion of these structural features.

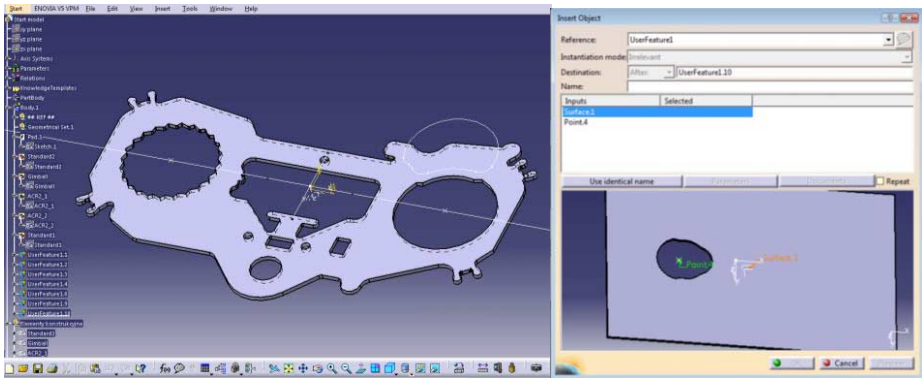


Figure 5. Final retractor model shape.

3.4. Overal system shape

The built-in system based on the implementation of knowledge base construction and advanced CAD system brings the user great benefits. The database can be extended with new product references and using it becomes fast and transparent (Figure 6).

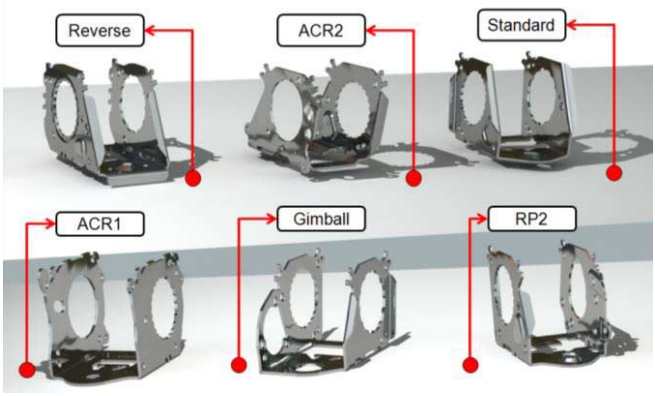


Figure 6. Alternative retractors housings as result models from Generative Model.

4. Conclusions

Safety belt is a typical example of specialized car subassembly. GM aids designing of such subassemblies greatly but these methods are not sufficiently popularized. Detailed description of the usage can be helpful in spreading the method in automotive industry. The main difficulty in planned and systematic use of the GM method is the lack of organized, deliberate and systematic actions connected with acqusition and recording of designing knowledge and systematic approach to GM creation. At the early stage it is important ot determine if models are to be made ad hoc or they are to become systematic base for majority of designign process. In the latter case it is necessary to plan the whole structure and conseqently create part of the final product as GMs.

The assumption that for the whole product GM will be made only once is difficult to meet and instead of expected results it can cause frustration and dissatisfaction of the applied method. The solution is to create GMs of smaller product fragments, preplanned sets which usually works better.

The use of GMs gives very good results as it not only reduces time devoted to routine tasks but first of all decreases the number of mistakes and thus improves CAD models quality which are realized in these routine tasks. It enables for analysing greater number of possible configurations and potential solutions, offering more comfort for a designer and allowing him/her to focus on conceptual and innovative tasks.

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Ubiquitous Cloud Object for Fine-Grained Resource Management in E-Commerce Logistics

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Abstract. Logistics resources are of great importance in E-commerce as the essential factors of production, basically including man, machine and material. Optimization for E-commerce logistics always relys on the real-time information of logistics resources. Actually, these resources are exchanging information continuously when they interacting with each other. Since the management granularity for logistics resources still remains at a coarse level, most of the interaction information between resources cannot be well recorded and organized. To achieve fine-grained management of logistics resources that could provide real-time resources visibility, traceability interoperability and availability is urgently needed. The booming of IoT technologies makes it feasible to realize fine-grained management. However, how to make resources smart to interact with other resources and construct a resources-oriented information network to serve enquiries from EISs has not been well studied. This paper presents a ubiquitous cloud object (UCO) framework for logistics resources to achieve fine-grained management. A ubiquitous cloud object model is proposed to abstractly virtualize heterogeneous logistics resources into cloud mappings. The concept of object cluster achieves the flexible resource granularity with a designed object gateway service (OGS) to construct information network. Aiming at facilitating the integration of UCOs with Enterprise Information Systems (EISs), object chain is used to organize UCOs to fulfill the specific workflows.

Keywords. Ubiquitous Cloud Object, Object Cluster, Object Gateway Service, Object Chain

Introduction

Benefiting from the prosperity of E-commerce, E-commerce logistics has developed by leaps and bounds in recent ten years [1]. As a typical resource-oriented industry, the resources scale has extremely expanded accordingly [2]. Now the increasing competitions prompt these E-commerce logistics companies to change from extensive growth to intensive growth. Hence, the effective disposition of various logistics resources has been treated as a core competence and prompted E-commerce logistics companies to improve resource utilization. Resource management in E-commerce

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logistics focuses more on the resource visibility, traceability, interactivity and interoperability so that the three most important kinds of resources, including man, machine and material could be coordinated and synchronized intelligently to fulfill the goods transportation according to customers' orders [3, 4]. However, the management granularity for resources still remains at a coarse level in reality, which falls behind and is different from that in manufacturing [5]. For example, the number of operators for a specific work is usually regraded as the input for task allocation, but individual differences such as specific statuses, operation preference and applied knowledge are not well recorded to support refined decision-making to improve resource utilization. Thus, to achieve fine-grained resource management has become essential.

The booming of IIoT(industrial internet-of-things) makes it possible to realize fine-grained resource management. Several IIoT prototype systems have been designed and developed for similar purposes [6, 7]. For example, the concept of cloud asset is proposed to solve the asset management problem in flood control [8]. However, more practical problems have puzzled the E-commerce logistics companies to apply IIoT technology to achieve fine-grained resource management. The fast integration of logistics with IIoT technology is one of the most serious problems. Three research questions exist that impede the settlement of this problem as follows:

Firstly, how to use a ubiquitous resource model to describe the physical logistics resources and IIoT resources with fine granularity? The IIoT resource could be seamlessly integrated with the physical resource. The emerging industrial wearables which combines sensing technologies with industrial wearable technologies are the most suitable forms of IIoT resource. So the IIoT resource could be attached on the host physical resources to enhance the functionalities and intelligence. Resource description framework (RDF) is proposed by W3C as a resource model to describe collections of formalized statements about a Web resource [9]. While the media role of IIoT is without consideration in its model so that it lacks of connectivity between physical resources and software mappings. Some agent-based smart object models are successful to warp smart devices into software agents only [10, 11], but they neglect other resource types especially the human resources and these agent-based model are generally lack of resource structure, granularity and interactivity. For example, the smart asset agent provides real-time visibility and controllability for a ordinary pump through a smart device attached on the pump [12]. In terms of resource management, this agent is actually the result of two resources superposition and either resource should be organized in an individual resource object. Thus, a ubiquitous resource model is essential to fulfill the following three requirements for the description of physical resources with fine granularity. Firstly, the atomicity of physical resources should be well expressed by this model. Secondly, the model should have the reconfigurable feature so that the cloud mappings of resource objects could be able to be compitable for different software environments. Thirdly, the model should enable the UPnP management for physical resources.

Secondly, how to achieve flexible granularity for managing resource objects? The fine granularity realizes the expression of each resource object in atomic level. But several resource objects will have strong relationship in terms of their physical distribution or application preference. Logistics resource objects and IIoT resource objects typically have strong relation. For example, an operator may wear a smart glass and a RFID glove, then the three objects are treated as a whole for the management. But how to rapidly construct the information network for the three relation-based objects are a practical problem in reality.

Thirdly, how to make resource objects easy-to-adapt and resource information simple-to-acquire? Resources are required to be organized and arranged based on the definite working logics of a specific logistics operations. While the working logics for the same operations may vary in different E-commerce companies. So how to make the resource objects to easily suit different working logics is important. Furthermore, the working statuses such as the opeartion results and the resources information are critical for EISs to make decisions, so the sharing of resource information is also required.

In order to solve the three problem, this paper proposed a ubiquitous cloud object (UCO) to virtualize physical resources into cloud agents based on the UCO model. Object cluster is designed to achieve the flexible granularity with the construction of local information network. To make resources easily adapt to different working scenarios, the object chain is used to facilitate the integration of resources with EISs. The rest of this paper is arranged as follows: An overall framework is demonstrated in chapter 1 to illustrate the concept of cloud object in fine-grained resource management. Chapter 2 describes the concept of UCO in detail together with its model. UCO cluster and UCO chain is discussed in Chapter 3 and conclusion are given in chapter 4 finally.

1. Overall framework

The overall framework has abstracted fine-grained logistics resource management into three layers and two kind of spaces, as shown in Figure 1.

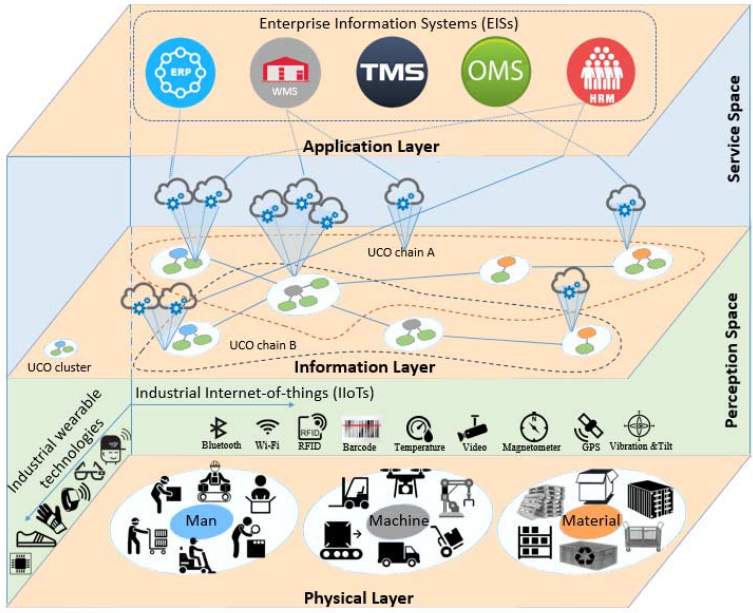


Figure 1. The conceptual framework for UCOs in fine-grained resource management.

- Physical layer

All the physical resources involved in E-commerce logistics operation belong to this layer. Fine-grained resource management aims at facilitating these resources

to seamlessly integrate with logistics operations. The fine-grained requirement is embodied in the granularity of resource objects. For human resource, each person is a resource object. While for machine, the granularity of resource object depends on the smallest controllable unit. For example, considering the automated conveyor with one controller, the controller can be treated as a resource object. The scope of machine is wide including infrastructure, facilities, equipment, tools, devices, vans and etc. Material is generally regarded as the passive resource that need to be tagged and recognized. Various kinds of carriers such as contains, boxes and pallets as well as goods are the typcial material resource objects.

- Perception space

The perception space is built upon the IIoT objects. Even though these objects are physically existed, their functions and applications are expressed in perception space. A variety of information technologies such as sensing technology, recognition technology and transmission technology are adopted to construct the preceprtion space. The rapid development of IC technology makes these information technologis easily to be integrated with traditional physical resources in the form of wearable or embedded system. So these resources could be able to be virtualized as cloud objects through the perception space.

- Information layer

The information layer focuses on the integration of fragmented data collected by resource objects into useful information. The types of information are converged in this layer. One is the expressed in the form of UCO cluster which represents the coupled relationship between UCOs. So the detailed information of a specfic logistics objects could be available for application. The other type is the working logics of UCOs or UCO clusters, which is described by UCO chain.

- Service space

Cloud service is the main form for resource sharing and applications. A UCO, UCO cluster or a UCO chain in information layer could be mapping into cloud services if they are shareable besides their fulfillments for operation. The service content is the embodiment of functionalities for its dependency. So a multi-functional resource object could be projected into several separate services. Then these services could be published, found and invoked by applications.

- Application layer

EISs and different domain systems locate in the application layer. These applications obtain resource services in the service space and bind or invoke them to fulfill application logics. So applications are the final users to use resources and the application scenarios make more requirements on service management such as the service pattern and service quality.

2. Ubiquitous cloud object

UCO is the software entity that represents physical resources in information systems. It maintains the direct or indirect connection with corresponding resource objects

including both physical resrouce objects and IIoT objects and is exposed as cloud service to be invoked by applications/EISs. So it works as the bond of physical resources and EISs. The ubiquity of the cloud object is also shown on two aspects. For the physical resource objects, the UCO should be able to virtualize, express and drive heterogeneous resources. For resource services, the UCO also should be ubiquitous for different service patterns and service modes.

The nature of UCO is agent. It encapsulates the resource objects as intelligent software agents. Zhang et al [11] has been adopted similar encapsulation using an agent-based model to wrap RFID readers into intelligent agents to be integrated with the execution systems. However, both ubiquity and sociability required in fine-grained management have not been considered in these agent-based models. So in this research we proposed the concept of UCO with its agent-based model.

The UCO model is an agent-based model that gives a conceptual framework for this kind of intelligent software agent. UCO will be created based on this model in the cloud and associated with physical resource object. A UCO consists of six core components, as shown in Figure 2. The functions of each component are briefly described as follows:

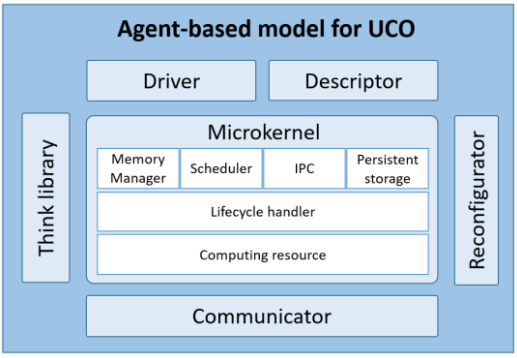


Figure 2. The agent-based model for UCO.

- Microkernel

The microkernel is near-minimum amount of software that realizes the most basic fuctions. It works as the brain of UCO to coordinate other components and enables five functions. The most important function is the lifecycle handler. It provides lifecycle management for UCOs considering the status of both physical resources and computing resources. The life status could directly influence the other four functions. The memory manager hosts the assigned memory resources and manages virtual memory according to the memory utilization and requirements. The scheduler is in charge of all the thread scheduling to perform specific tasks. IPC is required for the thread communication. Persistent storage is the file system that used to store necessary files such as configuration files.

- Descriptor

Descriptor is similar to the name card of UCO. Uniform resource identifier (URI) is used by descriptor to identify UCO and the descriptions are organized based on the resource description framework (RDF) data model. Descriptor is mainly in charge of updating the values for properties.

- Driver

Driver is an optional component which is used to drive the specific resource objects that owns the sensing ability actively. Through the driver, the microkernel establishes the physical link with corresponding resource object and realizes the remote control.

- Reconfigurator

The reconfigurator is designed to enhance the ubiquity of UCO for software running environment. So UCO could be capable to run on different systems. Reconfigurator will check the running environment for UCO and select the suitable cross-compiler to reconfigurate UCO.

- Think library

The think library realizes the intelligence of UCO. Based on the inputs given by microkernel, it could generate suggested decision parameters though rule-based intelligence. Two types of rule-based intelligence are provided. One is the rule-based expert system that rules are derived from the past experience or experts' suggestions. The other is autonomous learning-based rule which aims at learning, evolving rules practically.

- Communicator

The communicator is in charge of the external communication of UCO. Generally, agent communication language (ACL) is used for the communication between UCOs. While in most situations, the UCOs are required to communicate with external environments, for example, to exchange information with EISs. So the communicator also supports additional communication protocols via plug-in protocol modules. The specific formats of communication protocol could be configurated in the module templates.

3. Relationship network of UCO

3.1. UCO cluster

The UCO cluster refers to a set of UCOs that are physically connected together or in the closest relation. The flxible granularity of resource is enabled by UCO cluster through the flexible combination of UCOs. So the UCO cluster is similar to the UCO molecule that is comprised of multiple UCO atoms. The properties of a UCO cluster is the superposition of UCOs' properties. For example, a operator with his equipped wearable devices totally could be regarded as a UCO cluster. In additon, the UCO cluster facilitates the deployment of local network. Different from traditional computer networks, resource objects may have different communication or connection methods and their physical and logical relationships also have to be considerate in costructing this network.

Object gateway service (OGS) is then designed for the UCO cluster to build the information network autonomously. It works as the mobile device middleware that could be deployed on some UCOs which have advanced operting systems such as Android. Then these UCOs are served as the object gateways (OGs) which are capable

of managing other UCOs and sharing network services such as the 3G/4G/LTE/Wi-Fi network for them. The overall working process for OGS is shown in Figure 3.

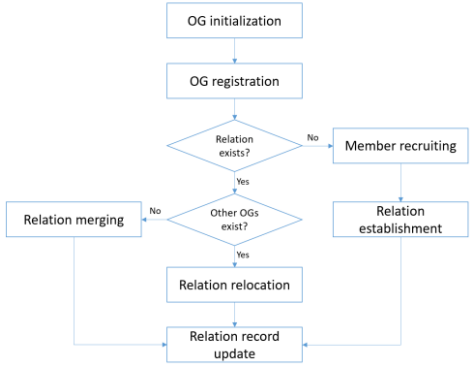


Figure 3. The OGS's working process.

3.2. UCO chain

The object chain emphasizes on integrating UCOs with operational working logics. Three steps are required for the generation of an object chain. Firstly, the definition of object chain should be made according to the specific workflow. Secondly, the UCOs or UCO clusters are required to be assigned to the nodes of the whole chain, as shown in Figure 4a. Finally, configurations should be made to ensure the data compatibility.

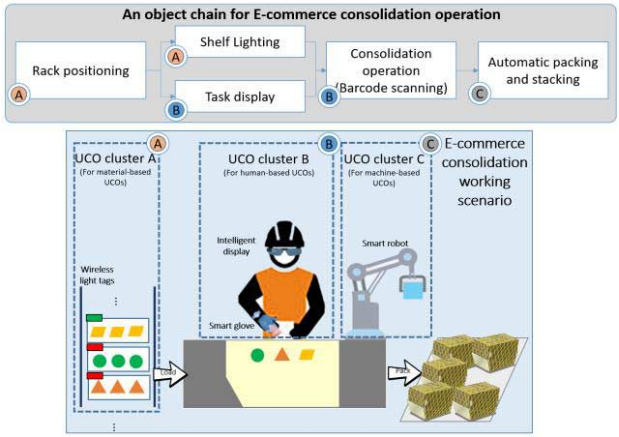


Figure 4. An object chain example for E-commerce consolidation operation.

```
func (*ResourceA) WorkNodeA(ResourceB, chFinishSignA, chFinishSignB) {
    A.RackPositioning()
    go b.WorkNodeB(chFinishSignA, chFinishSignB)
    A.ShelfLighting()
    chFinishSignA <- true
}
func (*ResourceB) WorkNodeB(chFinishSignA, chFinishSignB) {
    b.TaskDisplay()
    for {
        ch <- chFinishSignA
        if ch == true {
            break
        }
    }
    b.ConsolidationOperation()
    chFinishSignB <- true
}
```

Figure5a. The pseudocode for workflow script.

```
while(Interrupted()) {
    chFinishSignA := make(chan bool)
    chFinishSignB := make(chan bool)
    ResourceInit()
    a.WorkNodeA(b, chFinishSignA, chFinishSignB)
    for {
        ch <- chFinishSignB
        if ch == true {
            break
        }
    }
    c.AutomaticPacking()
}
```

Figure5b. The pseudocode for running script.

A workflow script will be generated according to the defined workflow as shown in Figure5a. The running script will be also generated and continued to execute if there is no interrupts as shown in Figure 5b.

4. Conclusion

The paper proposed the concept of UCO and its agent-based model to realize fine-grained resource management in E-commerce logistics. Three contributions have been made in this research. The first one is the proposion of agent-based UCO model, which virtualizes physical resource objects into UCOs. The UCOs bridge the gap between physical resource and EISs so that the physical resource objects could be easily and flexibly integrated, shared and controlled in EISs. The second contribution is introducing the UCO cluster, which achieves the flexible granularity of resources. An OGS is designed and adopted for the autonomous construction of information network. The third contribution is the concept of object chain that focuses on the integration of UCOs and UCO chains with EISs to make the easy accesses to real-time resource information.

This research could be extended in three aspects. Firstly, the optimization on OGS should be conducted considering quality and load of link in different scenarios. Secondly, a hybrid cloud platform is required to centrally manage and share UCOs in enterprise environment. Thirdly, the measurements for service quality should be proposed to evaluate the availability, reliability and sustainability for UCOs' services.

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