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MASTER'S THESIS

Loosely-coupled user-friendly interface: a Window toward a better application of knowledge-based system in Architecture, Engineering and Construction

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Master's thesis in Construction Management and Engineering

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Dedicated to my father

for being the embodiment

of perfection in my life

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Abbreviations:

AEC:	*Architecture, Engineering and Construction*
BIM:	*Building Information Modeling*
HCI:	*Human Computer Interaction*
IT:	*Information Technology*
KM:	*Knowledge Management*
KMS:	*Knowledge Management System*
O-O paradigm:	*Object-Oriented Paradigm*
SA&D:	*System Analysis and Development*

Executive Summery

Isn't the prospect of interacting with your computer in the same way you interact with your colleagues intriguing? Why should we get instructed and ruled by machines on how to work with them instead of making them capable of adapting themselves to our working culture? Why should we be enslaved by our own craft? Why can't we get the information we need right when we need? Why do multiple systems developed for various tasks usually fail to jointly serve for a new task?

The quest for finding an answer to the above questions led the author to the concept of loose coupling. This thesis explores the potentials of adopting loose-coupling concept in interface design of knowledge management systems for construction industry.

For this purpose a prototype was developed which enables users to access relevant information to their work without getting engaged in any extra activity to translate their needs into systems' languages. The prototype dynamically observes the progress of a note being written, independent of the writing platform, and at a certain point if the composer feels the need for some assistance the system browses the various databases at its disposal for the most relevant suggestion. Similarly, in future, the same system could look at a bidding document, extract necessary information and make rough or detailed cost estimation and suggest it to the user in form of an insertion in the document. It can be installed on a mobile device, and while looking at an under-construction building frame, it can query the back office to produce information about the bearing capacity of a column.

In the background of this study lies the need to improve knowledge management systems. Organizational knowledge is built-up in the

course of time as a novice employee evolves into a senior member. The need to maintain, capture and reuse this knowledge within the organization in order to make its effective use in the long term and in order to avoid costly and time-consuming relearning; has led to a profound branch of specialty in the management disciplines referred to as knowledge management. Since the introduction of IT to knowledge management the term knowledge management system (KMS) in a broader use refers to ICT systems particularly devoted to the creating, retrieving, storing and distributing knowledge in an organization.

Despite its wide use in Architecture, Engineering and construction industry (AEC), KMS remains far from integrating into mainstream AEC practices for several reasons. One obstacle is the lack of interoperability between various systems developed. Another barrier, from a psychological point of view is training aversion amongst employees who are most often reluctant to go through training process. Lack of user-friendliness and complexity of interfaces are other major restrictions which have to be heeded.

The Idea of loosely coupled interface is derived from the abovementioned problems. Normative specifications for a good interface design are usually discussed under the topic of usability engineering. It defines qualities such as learnability, flexibility, recoverability, satisfactoriness and precision as the main indicators of usability and usefulness of interface design.

To fulfill the usability requirements, a solution based on high-level paradigm shift could be envisioned. Loose coupling, as opposed to tight coupling, implies a connection between sub-systems that are functionally rather independent and therefore create room for enhanced extensibility. A loosely-coupled interface has to be able to provide a means for the user to communicate with the system with minimal dictated rules. In other words, the more hardcore the rules are, the tighter the connection is. One of the best ways to achieve loose coupling is through giving human characteristics to systems. However, unlike tight-coupling, a loosely-coupled system needs intelligence embedded in the interactive device to boost the accuracy of the outcome. This is a particular quality that is used by human for the purpose of communicating with the surroundings. However, it has to be conceded that the prioritization between loose-coupling and tight-coupling is a matter of one of the extensibility or accuracy taking precedence over the other by the designer and the project's scope.

Loose coupling reinforces the industry through making easy communication with data-bases and timely knowledge capture and retrieval possible. If we extend interactive methods with back-end systems and bring more human character to HCI, it is likely that the need for training and huge capital investment for new technologies will be minimized. It will also provide a solution for the absence of interoperability as the same data could be presented to the system through diverse methods and the embedded intelligence in the interface will be able to suggest the most likely back-end system while processing the required data translation. Equally noteworthy is that loose-coupling makes interaction with computer much more natural and therefore user-friendly.

The concept is meant to provide a practical way to make an efficient use of existing knowledge bases in a user-friendly manner and intended solely to provide suggestions or advices in the area in which previous knowledge exists. Therefore, the misconception of looking at the proposed system as an omniscient knowledge holder has to be seriously avoided.

Ultimately, this has to be appreciated that if a humanized interface is desired for its palpable gains for interoperability, user-friendliness and timeliness, the essential human shortcomings have to be anticipated as the cost. Accuracy is an acquisitive quality and is built in the course of time. The interface resembling human way of communication should be observed in the face of the fact that accurate response will only be achieved when intelligence embedded in the interface is well trained and accustomed to context of the work and the users' mannerisms.

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Research Outline 1

1- Introduction:

This composition is to outline the scope of the research conducted as a prerequisite to completion of master's degree at the Technology University of Delft. The author is being majored in Construction Management and engineering, internally abbreviated as CME, as a specialization of Civil Engineering. Below would be a short introduction to the main domains this research is going to explore and address, further developing into a narrow description of research question, methodology and strategy.

1-1-1 Construction Management and Engineering

Construction Management is a comparatively novel specialty in Civil Engineering discipline whose core objectives are to sensitize project managers to sustainability, reduce project uncertainties, foster innovation in design, execution and maintenance and augment efficacy through establishing consensus among and minimizing conflicts between stakeholders and clients. The abovementioned objectives have led to a growing awareness about necessity of, and subsequent demand for, experts whose conventional technical know-how is fortified with managerial knowledge in order to create a common discourse between cost-time-oriented managers and technical engineers. TU Delft as one of the most prestigious and prominent technical universities worldwide, has grasp this need and addressed it through introduction of a new master track. CME, as an outcome of affiliated educational program between three major technical universities, 3TU, in the Netherlands, comprises five mandatory courses as cornerstones, namely, Legal and Governance, Process Management, Project Management, Collaborative Design and, finally, Integration and Orientation.

1-1-2 role of Knowledge in Construction Industry

Construction industry is characterised by its high fragmentation, one-of-a-kind project, volatility of working environment, pressure to complete, lack of incentive for post-mortem analysis and reflection and variety of expertise involved (Patal et.al , 2000). The totality of these features has led to the languishment of the industry particularly in terms of innovation (Robinson et.al, 2001). For innovation to be fostered in the industry, the need to lubricate knowledge creation and retrieval mechanism is irrefutable.

Additionally, in the wake of the presence of these characteristics, the industry is renowned as a knowledge-incentive organization (Anumba et.al., 2005) in which a huge proportion of expertise and professional know-how is tacit and therefore very susceptible to loss and disappearance. As a result of this tendency, the industry is fraught with examples of recurrent mistakes and failure in taking lessons from encountered problems. Consequently, knowledge plays an irreplaceable role in the industry and can be a determinant factor for the survival of an organization.

With the criticality of knowledge and its subsequent illusiveness clarified, it is of cardinal importance to mobilize required efforts to make effective use of knowledge in the industry. The major decipline concerned with the above objective is Knowledge Management or, otherwise, Organizational Knowledge Management.

1-1-3 Knowledge Management

Attributable to outrageous development of technology and, subsequently, the rising tide of complexity in project management the need for knowledge management is heightening. In a competitive market where cost-time-quality triangle domination is growing stronger, non-material assets are becoming a key factor for organizations' survival. With Knowledge being spotlighted as one of the most determinative and vital non-material assets, knowledge management has been the center of meticulous attention of scholars and academia for nearly two decades.

Knowledge Management is a discipline concerned with effective mobilizations of individual and collective knowledge for the best of the organization. Knowledge manifests itself in allegedly two main forms, namely, tacit and implicit knowledge. Knowledge management intends to bring into bear whatever it takes, be it new policies or technologies, to make a fluent circulation of information possible. It also aims at preempting very common disappearance of knowledge with departure of personnel.

It chiefly comprises four main realms of attention, namely knowledge creation, knowledge storage, knowledge retrieval and knowledge transfer. Knowledge Management has been the subject of extensive and meticulous research in various branches of organizational management.

1-1-4 Knowledge Management Systems and Construction Industry

In Construction management, also, the significance of fostering knowledge-oriented culture has been sensed for many years. It is contended that effective use of existing knowledge and stimulation of knowledge creating mentality amongst employees would contribute to enhancing fertility for innovation and creativity in the industry. Among legacies of KM application in AEC, improved performance, client satisfaction and better organization learning were highlighted (Zhang et al., 2009). Knowledge management systems (KMS) are ICT based tools that are used for the better accomplishment of KM principal objectives. Despite having been in use in the construction industry for a long time, KMSs have a long way before they are integrated into the mainstreams of the industry.

2- Problem Analysis:

As stated before, KMS, despite its relatively long history of implementation, is yet to become an integral part of organizational daily routine. In this research I will focus on the impression that interface may carry upon the acceptability of KMS in the discipline. The essential postulation of this research is that it has all possibilities to radically change the role of knowledge management in AEC provided a new approach is adopted with regard to human-system (human-computer) interaction.

In this research, I will try to outline the existing shortcomings of KMS in AEC and survey the possible enhancement that could be brought about through taking a more novel view of human-computer interface.

It will be more thoroughly discussed in the course of the second chapter that very often human impression of a system's usability and usefulness is considerably dominated by factors other than performance precision. These are factors that mainly revolve around the ease of use, ease of learning, ergonomics etc.

Another problem with KMS is that it seems to have failed to grow into a versatile and universal tool capable of adapting itself to the volatile contexts that is a common feature in a highly fragmented industry like that of AEC. Interoperability is a serious issue when it comes to KMS and we shall think of a solution through which KMS are becoming less dependent on the context.

This survey is dedicated to investigation of the possibility of boosting aforementioned criteria in KMS through deployment of a more user-friendly interface. Loose-coupling will be introduced as a concept a paradigm shift towards which contributes to achieving interoperability in KMS as well as securing user-friendliness. Below, very briefly, I will introduce user-friendliness and loose-coupling concepts as the main ingredients of this body of research.

2-1 User-friendliness in Knowledge-Management Systems (KMS)

Knowledge management systems have been under development and application for nearly two decades in a broad range of disciplines from organizational management to pharmacology and civil Engineering to medicine. However, surprisingly enough, KMS have, so far, failed to become mainstream in any employed context or industry. Multiple causes could be held responsible for such a tremendous fiasco among which high context-dependencies, low interoperability, unfriendly interfaces and laborious data feeding could be to name but a few. Combination of mentioned causes, amplified by many that were not, led to a persistent aversion against serious investment in KMS in various industries.

The urge for dynamic user interface and abilities to exchange information with commercial software packages are mentioned by Yang, Li and Skitmore (1996) as the major focal points in future development of expert systems in construction industry.

There is sensed a growing need for user-friendliness in KMS applications as to make them appealing to a wider spectrum of users and contribute to converting them to a mainstream in any expert domains.

There are many tools and technologies conceivable that can be efficiently utilized for the proliferation of user-friendliness. Speech recognition, text parsing, motion detection and pattern recognition are, among many others, some of the possible technologies whose integration into existing KMS may have tremendous virtues and benefits.

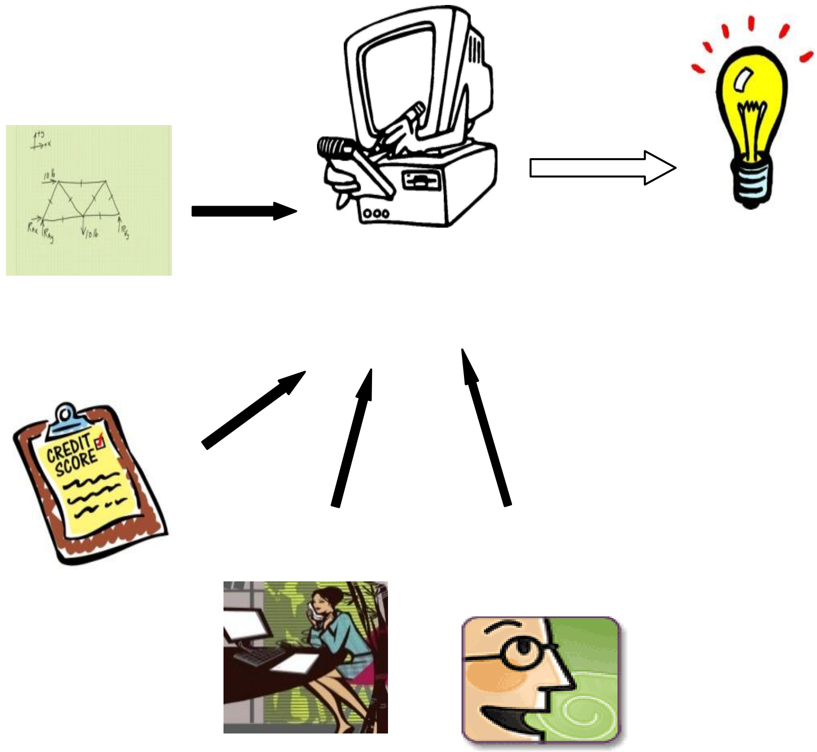


Figure 1.1

User-friendliness in KMS

Consequently, one of the main concerns of this survey would be investigation of the possible boosts in the extent to which knowledge-based applications are received by their target; this end is expected to be met through integrating more user-friendly interfaces.

2-2 Loosely coupled application

One of the main drawbacks of developed KMS solution in the industry has been the lack of extendibility and adaptability; meaning that usually the approaches leading to development of these applications are hugely ad hoc and problem-dependant. This has eventuated in massive reduction of reusability and versatility of developed applications. This problem is renowned, in academic terminology, as tight/strong coupling.

Since this research is expected to culminate in development of a prototype and given that this prototype is expected to be later developed in a wider scope of problems that are being or will be encountered, there is a need for the application to be as much extendable as possible. This necessitates the application to be developed as loosely coupled as possible.

Wikipedia writes under the issue of loose coupling:

> "*Coupling refers to the degree of direct knowledge that one class has of another. This is not meant to be interpreted as encapsulation vs. non-encapsulation. It is not a reference to one class's knowledge of another class's attributes or implementation, but rather knowledge of that other class itself*."

And further distinguishes loose from strong coupling by the following demarcation.

"Strong coupling occurs when a dependent class contains a pointer directly to a concrete class which provides the required behavior. Loose coupling occurs when the dependent class contains a pointer only to an interface, which can then be implemented by one or many concrete classes. Loose coupling provides extensibility to designs. A new concrete class can easily be added later that implements that same interface without ever having to modify and recompile the dependent class. Strong coupling does not allow this."

The potentials and disadvantages of loose coupling will be scrutinized and the gains of the concept being deployed will be depicted in the face of its possible costs and deficiencies. It is hoped that as a conclusion to this survey, a clear picture of loose coupling could be given to designers and developers so that they can make an informed decision on the selection between tight and loose coupling.

3- Research Questions:

Derived from above problem descriptions, the below could be considered as the central research question of this thesis. To provide a systematic guideline for reaching to a fulfilling result, the research question will be decomposed into sub-questions each of which will be addressed in a separate chapter.

❖ *How could loose-coupling concept lead to a better application of KMS in AEC?*

As stated before, the effort will be made to probe and illustrate the benefits and gains of loose-coupling concept for better knowledge management systems. Since the proposed method urges for a drastic adjustment of design mentality, and the fact that the pertinent technologies are yet at their infancy, it will be best tried to remain utterly discrete with regard to drawn picture so as to avoid deviation from scientific precision and accuracy. The above question is decomposed into below sub-question so that the devolvement of the argument is better outlined.

1

What are the existing problems and barriers for KMS use in the industry?

I will do an extensive literature study to discover the barriers against the pervasive use of KMS in AEC. This has to be done in the light of the proper understanding of the scope and objectives of knowledge management and knowledge management systems. As a result, chapter two will be allocated to investigation of the advantages and drawbacks of KMS.

2

If a new approach is to be taken towards KMS design, what essential criteria does it have to meet?

Once a set of relevant barriers were identified, I will concentrate on the criteria which determine the success of KMS in an organization, particularly those with regard to user-friendliness. On the premise of these criteria, I will develop a design framework for interface development in which human-centric design concerns will be incorporated in computer-human interface design. Additionally, loose coupling and tight coupling will be introduced and the advantages as well as disadvantages of each will be investigated. Departing from there, I will try to justify the applicability of loose-coupling in interface development particularly to improve systems interoperability, adaptability and extensibility.

3

Is loose-coupling a solution to the existing barriers and does it meet established criteria for a decent design?

The concept of loose coupling will be introduced and its benefits will be discussed, mainly in the view of its difference with tight-coupling. To study the extent to which the anticipated gains are realistic and achievable, a prototype will be developed.

4

How will an application based upon loose coupling operate and may address a sample problem? (Prototype development)

A huge proportion of this survey will be apportioned to the development of an application. This part of the work would be an applied synthesis of previous theoretical work which is expected to be consummated with a prototype application capable of demonstrating the expected gains and advantages.

5

How would Loosely-coupled interface contribute to AEC industry?

Once the notion of loosely-coupled interface is introduced and justified, there seems to be a need for pragmatic depiction of the concept's applicability in AEC industry. This question will be approached via drawing some down-to-earth scenarios wherein the concept could bring about some changes.

The general outline of the thesis would be as below. The report will progress in step-by-step coverage of the above sub-question and will, hopefully, consummate in a set of conclusions on the basis of conducted research and experiment.

Figure 1.2

Research Outline

4- The prototype at a glance:

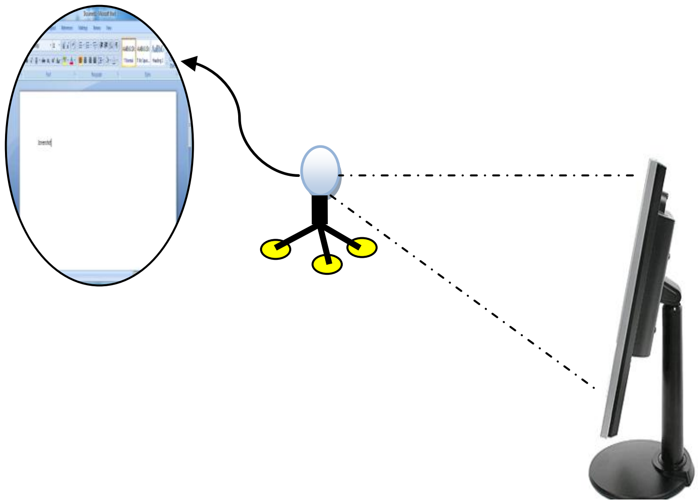
In this part, an initial sketch of the prototype is drawn and its underlying philosophy is scantly introduced.

Visual-based interface; visual on-screen pattern recognition:

The prototype will represent a vision-based interface which could be a constructive step towards popularization of KMS application. The prototype is expected to demonstrate that a written word on the screen could be recognized by the computer and further required action, for instance inserting a representing picture, is automatically effectuated.

Figure 1.3

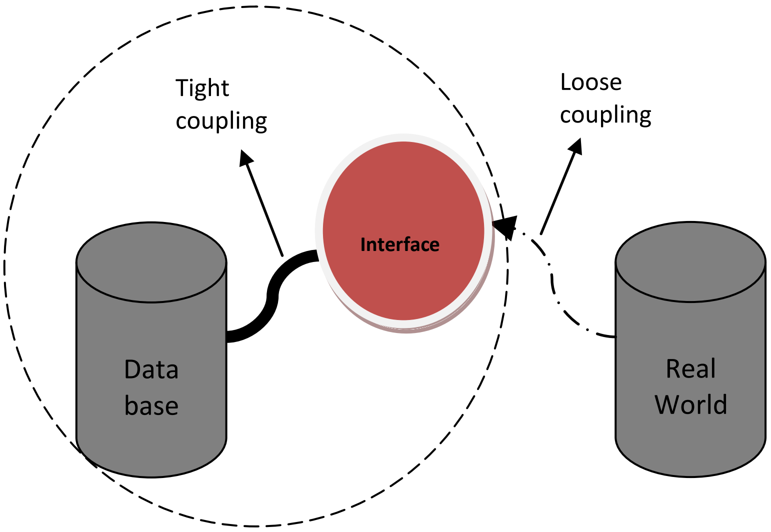
Visual pattern recognition as an interface



The above system is ideally required to be loosely coupled in the sense that instead of being a mere interface as a part of an embedded subset, it could be connected to a variety of databases among which it is capable of rummaging and finding the best matched solution. Yet, this decoupling is set out side of the scope of the prototype, for time is pressing, and the prototype will be tightly coupled to a knowledge-based.

Figure 1.4

Tightly coupled system



In the above picture, interface is actually part of the total system. The system has the knowledge embedded in itself and although that could be updated and accumulated, it is a try towards creating an omniscient, know-all system which cannot ultimately lead to a context-free application. Application of this nature would become contextually sensitized and trained to the environment they are being deployed in.

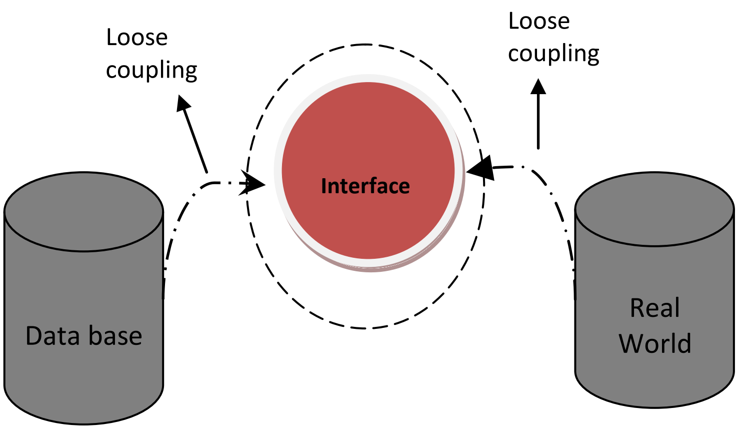


Figure 1.2

Loosely- coupled system

A surrogate method would be loosely coupled system. As illustrated above, interface will become an independent system which connects any real-world object of investigation and observation to any possible source of information as the database. In fact a loosely coupled system will ideally be able to search in the same fashion as human among variegated sources of information. .

5- Research methodology:

The main constituent of the first half of this survey would be literature study. To provide academic ammunitions for the prototype development, there is an exigency for reviewing literatures and articles on a wide spectrum of topics spanning over ICT application, Knowledge-based solutions, knowledge representations, usability engineering, ing etc.

Upon acquisition of sufficient information regarding KMS, user friendliness and loose coupling, the research will establish upon choosing appropriate criteria which determines the achievement of the goals being pursued.

This will be, further, followed by conceptual development of the prototype. All theories explored and identified as applicable will be integrated in one uniform body of concept to set the grounding for the actual development of the prototype.

Subsequently, the prototype will be developed. This phase will comprise several rounds of trial and error through which possible bugs will be removed. It is expected that with the appreciation of limitations caused by available tools some concession and scope-redefinitions would be inevitable.

The last step before presentation and report composition would be valuation of the prototype. This will be done through measuring the extent to which the developed application will satisfy the previously settled evaluation criteria. Then, some examples of the concept of the interface being implemented in AEC context will be given.

The research is expected to come to fruition with a report and presentation composed and prepared on the topic of research.

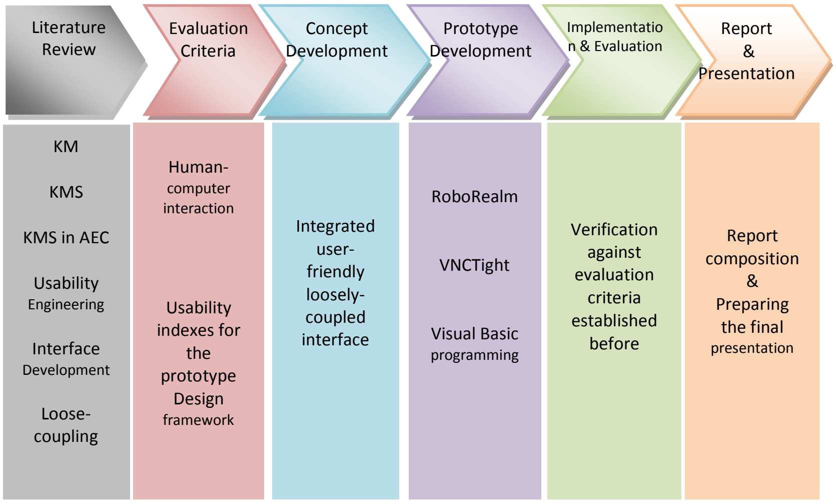


Figure 1.6

Research methodology

Knowledge Management and IT in AEC 2

"Why *is knowledge management important to AEC industry? What is Knowledge management system? In this chapter, answers to the above questions will be pursued. This is the intention of this chapter to clarify and probe the existing shortcomings with regard to existing KMS in the industry. However, a brief review of the basic definitions including knowledge and its various forms would be of a good assistance to bring coherence and cohesion to the discussion"*

2-1 Introduction:

Knowledge Management (KM) has grown into one of the most attended subject in the entire continuum of management studies, particularly that of Organizational Management. Attributable to outrageous development of technology and, subsequently, the rising tide of complexity in project management the need for knowledge management is heightening. In a competitive market where cost-time-quality triangle domination is growing stronger, non-material assets are becoming a key factor for organizations' survival. With Knowledge being spotlighted as the most determinative and vital non-material asset, knowledge management has been the center of meticulous attention of scholars and academicians for nearly two decades.

The main intention of this chapter is to introduce the advantages and potentials of knowledge management and enabling IT technologies in AEC industry.

For this very purpose, immediately following this introduction would be a brief terminological investigation of the term “knowledge”. Upon completion of this part, the chapter will proceed to drawing distinguishing lines between Knowledge, Information and Data. After a quick introduction of KM and IT and their interrelations, their implementations in the AEC industry will be scrutinized. However, knowing that KM implementation has not been as smooth as one may have expected, I shall, in the next section, browse the literature to determine what barriers and inhibitions could be held accountable.

Finally, consummation of this chapter would follow in form of recommendations and conclusions in the course of which a potential solution will be proposed to remove some of the existing barriers. The proposed solutions, forming the central focus of this dissertation, will be developed, validated and verified in succeeding chapters.

2- 2 Research Question Reformulation

The commencement of this chapter would be elucidation on the below research question:

What are the existing problems and barriers for KMS use in the industry?

To address the above question, it needs to be split into below sub-questions each of which will be answered in its particular section.

1

What is Knowledge?

A succinct review of knowledge definition and how the term differs from information and date

2

What is Knowledge Management and how it differs from IT?

Elaboration on domain of knowledge management and knowledge management systems

3

What are the uses of KMS in AEC industry and what barrier impedes its use?

Particularly attuned design methodology for human-centric interface design will be scrutinized.

2- 3 Knowledge definitions

Conventional definition posited by epistemologists suggests that knowledge is “justified true belief” which, however, has not been accorded incontrovertibly. Alternatively some believe knowledge without context is just information and, therefore, it is context-specific and spatio-temporal phenomenon (Noaka, Toyama and Konno, 2000). Further delineation of philosophical inquires and debates on definition of knowledge and evaluation of veracity of interpreting knowledge as “universal truth” is beyond the scope of this thesis since the abstract discussion more detailed than above would not carry any palpable implications on implementation of knowledge management and knowledge management systems in organizations and, therefore, would not be an added value.

Conclusions:

Hence, in this paper, knowledge, without substantial epistemological justification, will be considered to be a socially constructed phenomenon that can only be verified through investigation of semantic and logical consistency of co-location and co-existence of language elements such as verbs, nouns, adjectives etc., in the representing propositions within the context from which it stems, separately performed by individuals. In other words, knowledge is contextually verified information against what is paradigmatically and socially known as 'truth'.

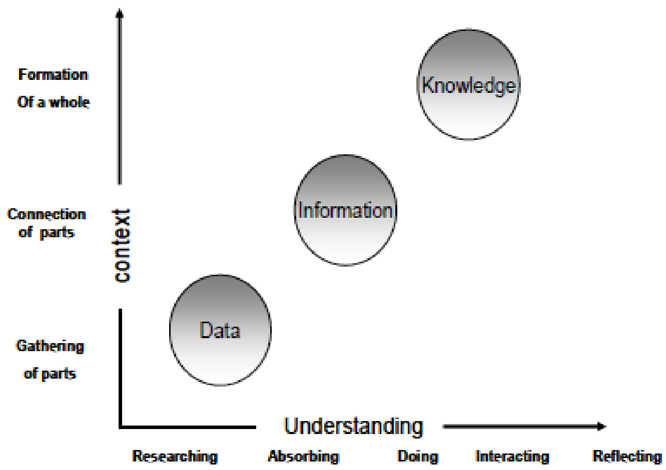
What is bearing more relevant to the direction of this study is distinguishing knowledge, information and data as well as appreciation of tacit vs. explicit taxonomy of knowledge.

2- 4 Knowledge, Information and Data

For one to thoroughly grasp the notion of Knowledge Management, appreciation of demarcating lines between data, information and knowledge is imperative. Subtle discrepancies in phrasing notwithstanding, aforementioned terms are unanimously said to differ at the level of structuredness. Data is known as independently meaningless figures and raw objective facts. Ensued from a process of structuralization, information will be formed from raw data. For knowledge to be formed, information will be valued, validated, verified and filtered so as to fit within a certain context (Alavi and Leidner, 2001, Beckman, 1999, Bhatt, 2001).

Figure 2-1

Data, Information and Knowledge (celevland,1982)



In above figure, understanding axis stands for the extent to which understanding of a certain matter at hand will be formed through an array of activities from researching to reflecting.

Differentiating line between data and information is relatively patent and undisputed since data is characterized by utter meaninglessness and rawness, whereas information is intelligible *per se* with a clear message. Dissimilarly, the line between information and knowledge is confusingly subtle and imperceptible. This is particularly so on the basis of various meaning attached to the term "*knowledge*" from wide gamut of epistemological traditions. A browse through knowledge management articles reveals that universal understanding of the terms is enormously lacking and, despite lifespan of over three decades, internal academic cohesion with regard to application of the terms has not been formed yet. Kogut and Zander, for example, put forth that "*information is knowledge that can be transmitted without loss of integrity*" (Kogut and Zander, 1992). Nonaka (2000) maintains that without being put into a context, it is just information, not knowledge.

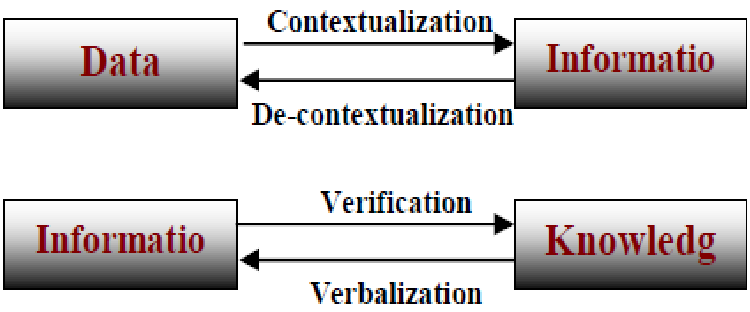
The taxonomy is, yet, patterned differently by Stenmark (2002) who maintains that information and data are two opposite ends on a continuum. He refers to information as focal knowledge that can be articulated and furnished with words and further contends that only when it is too decontextualized and distant form knowledge required for interpretation, will information become date. It is argued that the nature of difference between data and information is evolutionary structuredness while information varies from knowledge in that knowledge in interpreted information (Bhatt, 2001).

Conclusions:

The author is very much inclined to express his consensus with the latter classifications. To his speculation, knowledge is merely body of interpreted and verified information without any processing. In disagreement with Nonaka, information cannot be further contextualized as it is already structured and contextualized data. What in fact mentioned as contextualization, by Bhatt, Stenmark and Nonaka, between information and knowledge is, to my mind, only appraising the absorbed information against inventory of knowledge and is, consequently, drastically different in nature from contextualization required for transformation of data into information. Therefore, I suggest below diagram as an indication of interconnection between knowledge, information and data.

Figure 2-2

Data, Information and Knowledge



2- 5 Tacit VS. Explicit Knowledge

With regard to knowledge, there is an alleged distinction between *tacit knowledge* and *explicit knowledge*. While the latter implies knowledge which is articulated, codified and formalized, the earlier represents experience-driven knowledge residing in one's mind whose expression and transfer is an onerous and occasionally impossible task (Wong and Aspinwall, 2005). Stenmark (2002), however, posits that tacit knowledge, which is, to him, omnipresent, taken-for-granted and subconscious form of knowledge, is what knowledge in fact is; and he further contends that explicit knowledge is in reality just information.

According to Bergson, the very core of the dichotomization of knowledge into tacit and explicit is the problem of representation which invalidates existence of that what cannot be represented. Despite his rejection of the trueness of this categorization, Bergson contends that knowledge is an assemblage consisting of various cognitive capabilities (Styhre, 2004). For some philosophers of mind and epistemologists, among whom Bergson is the most eminent, knowledge cannot be *as such* and has a strong element of temporality involved.

The author distinguishs knowledge from skill in that knowledge is that what can be expressed and transformed into propositions that reflect the state of the affair. Knowledge and skill are unilaterally transformable. Skill is ineffable quality attributed to knowledge of a lesser degree. Take bicycle riding, one has the knowledge that pedals must be spun and pushed for the bicycle to move forward. This is knowledge since it can be represented and conveyed. However, maintaining balance on the bicycle is a skill and is, in fact, the quality that one gains through reaching a certain level of dexterity with regard to applying the gained knowledge. At no moment during a riding course is the cyclist aware of physiology of mussels and their interactions that made balancing possible. Transformation of skill to knowledge follows the moment a skill area is subject to conscious reflection. Skill as a higher degree of knowledge, in the world of practice and performance, can always be transformed into knowledge while the reverse is nonsensical. Skill is only formed as a result of acquisition of dexterity in the realm of a given or learnt knowledge in a degree which stands higher in the level of detailedness and elaboration, if it is to turn into knowledge, to the knowledge that initially contributed to its existence.

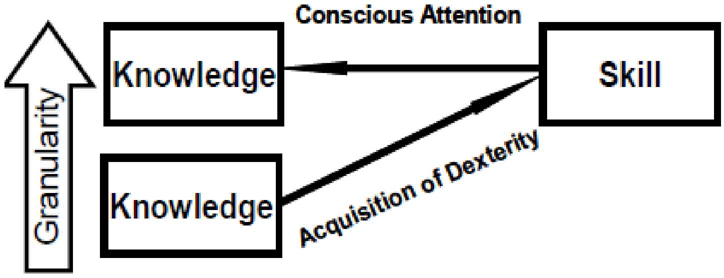


Figure 2-3

Knowledge-skill interaction

Thus, it is concluded that tacit knowledge or “know how” is a gained quality in the province of practicing a lower-degree explicit knowledge without being consciously directed to its existence.

Tacit knowledge would be non-existent as soon as the agent or do-er is conscious of its significance and becomes directed to its existence. Although the term “Tacit Knowledge” strikes as an epistemologically inconsistence phrase whose tacitness and inexpressibility is not logically in conformity with represenatbility of “Knowledge”, in this research, for practical purposes, the term will be deployed refereeing to undocumented, yet absolutely documentable and representable, knowledge.

Conclusions:

To bind the conclusions of the last two sections, The author shall hold that, in the light of the classification of figure 2.2, what could be created, stored, retrieved and disseminated is in fact only information. And for this information to be able to be processed, the knower should be conscious of its existence. What has to be the central endeavors of information management, or, to maintain consistency with prevailing terminology, knowledge management is to sensitize employees and workers to the significance of what they tend to perform subconsciously as skills and to encourage them to help express and document this information.

To maintain terminological consistency of this work with prevailing notion of Knowledge Management, I will keep deploying the term as a substitute to Information Management.

2- 6 Knowledge Management And Information Technology

With the comprehensive and universal definition of KM lacking, IT and KM definitions and practices are susceptible to conceptual confusion (Egbu and Botterill, 2002). For this very reason and to avoid further ambiguities, it is required to thoroughly appreciate the practical and semantic domain of each exclusively.

KM is much broader than IT, in the sense that IT could be best perceived as a set of electronic tools that could be exploited to facilitate KM practices.

The main exigency conduced to emergence of knowledge management was ever-growing competitiveness, in scope and pace, of the market (Metaxiotis et al. 2002). KM primarily aims at minimization, if not eradication, of recurrent mistakes. Malhotra (2000) describes the emergence of the demand for information processing, knowledge creation and informational-renewal as a response to environmental changes.

The major potential benefits of KM are enumerated as below (Wong & Aspinwall, 2005):

1- *enhance decision-making through just-in-time intelligence*
2- *improve work efficiency and productivity*
3- *increase innovation of products, services and operations*
4- *improve competency and competitiveness*
5- *enable rapid generation of technical solutions to clients' problems*
6- *increase responsiveness to customers*

KM is, also, believed to result in revenue growth, shorter design and production times, customers and staff satisfaction and market leadership (carrillo & Chinowsky, 2006).

Basically, among majority of authors there is consensus on categorizing knowledge management activities under four process, namely, creating, storing/retrieving, transferring and applying knowledge (Alavi and Leidner, 2001; Egbu and Botterill, 2002).

2-6-1 Knowledge Management Systems

Capturing, retrieving and disseminating knowledge cannot simply be realized through formal codification and documentation. Formal codification would only serve to inventorize and record what about which conscious knowing is already present. Through provision of dynamic interfaces between experts, managers would be capable of minimizing the detriment of misunderstanding, maximizing contrivance of innovative solutions and raising consciousness on subconsciously adopted solutions for typical problems. This will contribute to a sharper interpretation of circulating information as well as emergence of new insight into problems at hand.

Knowledge needs to be effectively captured and brought to bear for the knowledge management cycle to complete. This is so, because it seems evident (Udeaja et al. , 2008; Alavi and Leidner, 2001) enough that created knowledge is very susceptible to individual as well as organizational oblivion. Effective capturing mechanisms will safeguard and facilitate efficient exploitation of past information in any new contexts. Knowledge inventorization and retrieval is, conceivably, the most relevant area to IT applications.

Another constituent phase of knowledge management is knowledge distribution through which efforts will be made to publicize the captured knowledge and bring it to the public attention of the organization. Information should be fluently shared between different members of the organization for, at the very least, two fundamental reasons. First, information will only become knowledge once it is embedded and imprinted in the minds of individual; for this is the case, information should be inevitably shared if it is to be esteemed as knowledge instead of bureaucratic and hierarchic command. Second reason is that for knowledge to be verified on the organization scale the doomed practice is to furnish equal opportunity for members of the organization to reflect on the veracity and authenticity of the information.

One of the most significant and heeded provinces that has attracted enormous attention during recent years is application of Information Technology (IT) tools. Knowledge-orienting IT-based systems designed and implemented for managing organizational knowledge are mostly termed as “Knowledge Management Systems”. Finding an expert or a recorded source of knowledge using online directories and searching database, sharing knowledge and collaborating in a virtual team, accessing information on past projects and learning about costumer needs and behavior by analyzing transaction data are only a handful among myriad of examples of knowledge-oriented IT deployment(alavi and Leidner, 2001).

IT applications will help not only to effectively categorize and store explicit knowledge but also provide possibilities to make use of tacit knowledge embedded in first-hand experiences of individuals and embodied in their working cultures and troubleshooting strategies.
KMS, According to Maier (2007), is*” an ICT system in the sense of an application system or an ICT Platform that combines and integrates functions for the contextualized handling of both explicit and tacit*

knowledge throughout the organization or that part of organization that is targeted by a KM Initiative."

KMS differs from mainstream IT applications in that while IT merely deals with storage and retrieval mechanisms for fruitful use of information, KMS, through recontextualization, fosters and boosts knowledge sharing environment between target users (Alavi and Leinder, 2001).

Contextualization is an activity done on the premises of context of knowledge being two-dimensional. In this survey the term "back-end context", as opposed to front-end context, is used to refer to the context within which knowledge is created and stored. Yet, any information transferred, as aptly elucidated before, needs to be interpreted within a new context. This context, within which the transferred information is interpreted and, thus, transformed into knowledge is, hereafter, termed as "front-end context". Any advanced KMS, capable of recontextualization, has to be able to store information embedded in front-end context and locate and transfer it to the user in the front-end context.

KMS could be deployed, individually and integrally, for all aspect of knowledge management, creation, storage, retrieval and transfer, and, consequently, can lead to a better fulfillment of KM central objectives. Perusal of KMS applications and tools in aforementioned area abounds across literature of the domain. For instance, Saito et al. (2007) illustrate various technologies and their application domains in KM (figure 2.5 & 2.6).

Collaboration **Group support** **Project management** **Community support**	*Discovery* **Decision support** **Discovery & data mining** **Search & organization**
Dissemination **Enterprise portals** **Learning management** **Expertise management**	*Repository* **Document management** **Content management** **Process management**

Figure2- 5

KMs applications
(saito et al., 2007)

Collaboration **Connectivity** **Communication** **Authoring** **Collaboration** **Community** **Creativity** **Workflow**	*Discovery* **Storage** **Search** **Analytics** **Data mining** **Text mining** **Web mining** **Visualization**
Dissemination **Connectivity** **Communication** **Authoring** **Distribution** **E-learning** **Collaboration** **Community**	*Repository* **Connectivity** **Storage** **Authoring** **Search** **Workflow** **Organization** **Reasoning**

Figure 2-6

KMs component
Technologies
(saito et al., 2007)

Conclusions:

Nevertheless, IT application in knowledge management, or otherwise KMS, has to be particularly aimed at addressing below challenges and provide robust mechanism for boosts in these areas.

1. ***accessibility:*** *to increase convenience and speed of pinpointing required knowledge*
2. ***representation:*** *to provide an efficient means to represent knowledge to the end users*
3. ***validity:*** *to immunize the system against propagation of invalid and unauthentic knowledge*
4. ***scalability:*** *to extrapolate and interpolate information for any given scales and settings*
5. ***dynamism:*** *to develop technologies that safeguard and adjust to the dynamism of knowledge*

2- 7 KMS in AEC

Ostensibly, in the last few years nothing has impacted and revolutionized the Architecture, Engineering and Construction (AEC) industry more significantly than Information Technology. Information evolved into a strategic resource whose effective deployment has become the matter of maintaining the competitive position in the market and, in long term, financial survival (Harris and MacCaffer, 2006).

Construction projects, as no exception to other manufacturing projects, are best described as being governed by scope, cost and time constraints. Construction projects, however, differ radically from other types of manufacturing projects at several levels and frontiers. Competitiveness, low profit margin, tight deadlines, complex execution, high cost pressure and uniqueness (Carrillo & Chinowsky, 2006) are just handful among abundance of reasons that urge for the construction industry to be central to exclusive attentions and investigations.

An extensive survey in UK (Robinson et al., 2001) revealed that there are at the very least six chief momentums behind the demand upsurge for KM in construction industry which are arrayed in order of precedence below:

· *Need to encourage continuous improvement*
· *To share valuable tacit knowledge*
· *To disseminate best practice*
· *To respond to customers quickly*
· *To reduce rework*
· *To develop new products and services*

Aspinwall and Wong (2001) contend that in a competitive market environment, physical resources will have an emasculated value owing to the fact that they can be easy imitated and acquired on an equal basis. In the wake of this phenomenon, technical knowledge embedded in the organizations and amongst employees will become the prominent force and determinative factor for an advantaged market and superior stance.

The most solid ground for emergence of the KM in construction industry was the growing need for innovation and improved business performance (Kamara et al., 2002; Senratne & Sexton, 2008), which is directly driven from the clients' demand for creativity and originality with respect to aesthetics and increased benefit (value – cost) regarding the finance of the project(Ahmad & Russell, 1995; sarshar & Christiansson, 2004). Conversion form current static structure of building industry to a more dynamic environment is also acknowledged as an impetus behind ICT development in AEC (van Rees, 2007). Low speed of communication, physical distances in modern collaborative environment (Harris and MacCaffer, 2006), unique work settings, high fragmentation of the industry (Rezgui et al. 2010; Udeaja et al., 2008) lack of proper storing/retrieval mechanisms for knowledge imparted and gained in projects (Egbue et al., 2002) are also identified as characteristics presence of which pushes the urge for ICT development with an ever-increasing momentum.

Final Verdict:

Despite abovementioned organizational, economical and technological impetus behind ICT development in the area of knowledge management, it is patently revealed that construction industry has lagged behind many counterpart industries in this regard (sarshar & Christiansson, 2004; Stewart et al., 2004). For this very reason and in the light of the result of a literature review on the existing and lurking problems and shortcoming of KMS in AEC, which will immediately follow this section, the author shall reformulated the research question and propose a potential solution for a small part of the problems.

2- 8 KMS and its barriers in AEC

There are several hindrances involved with regard to application of knowledge management techniques heretofore. Problems associated with the current fashion of managing and mobilizing information can be bundled in five main categories, *Mobility*, *Convenience*, *Traceability*, *Structure* and *Reusability* (Hinkelmann and Probst, 2004). From abovementioned categories, *Mobility* refers to the availability of information where and when it is the most needed. User-friendliness, which falls under the category of *Convenience*, is another concern for managers who, when asked why developed tools failed to attract their attentions, voiced their discontent about laborious data-feeding processes and lengthy scroll-down menus. Another area of complaint was *Traceability* where the need for transparency of information for a lubricant communication is spotlighted. Closely intertwined with Convenience, *Structure* is the area where efficient and smooth access to information through well-established structure is addressed. Finally, ostensibly the paramount importance is placed upon the issue of *Reusability* which aims at eradication of recurrent mistakes inherent in certain types of projects through provision of learnt lessons from similar previous projects for project manager.

Stewart (2004) has proposed a three-level taxonomy for barriers on the basis of realms from which they stem. Industry, organization and project, they postulate, are three levels under which problems of variegated nature could be categorized. A holistic view of the top-down effect of IT implementation barriers is illustrated in Figure 2-7.
Although some non-IT and strategic solutions were proposed to address some of the identified problems, of the particular interest of this project is to effectively remove some of obstacles through IT-

oriented methods and systems. For this very purpose, identification of some of the lurking barriers of KMS deployment in AEC industry as more contributory and, also, more readily soluble through state-of-the-art IT applications has to be carried out. The problems will be selected from all three levels of KMS barriers and will be elaborately introduced in the order of precedence and relevance.

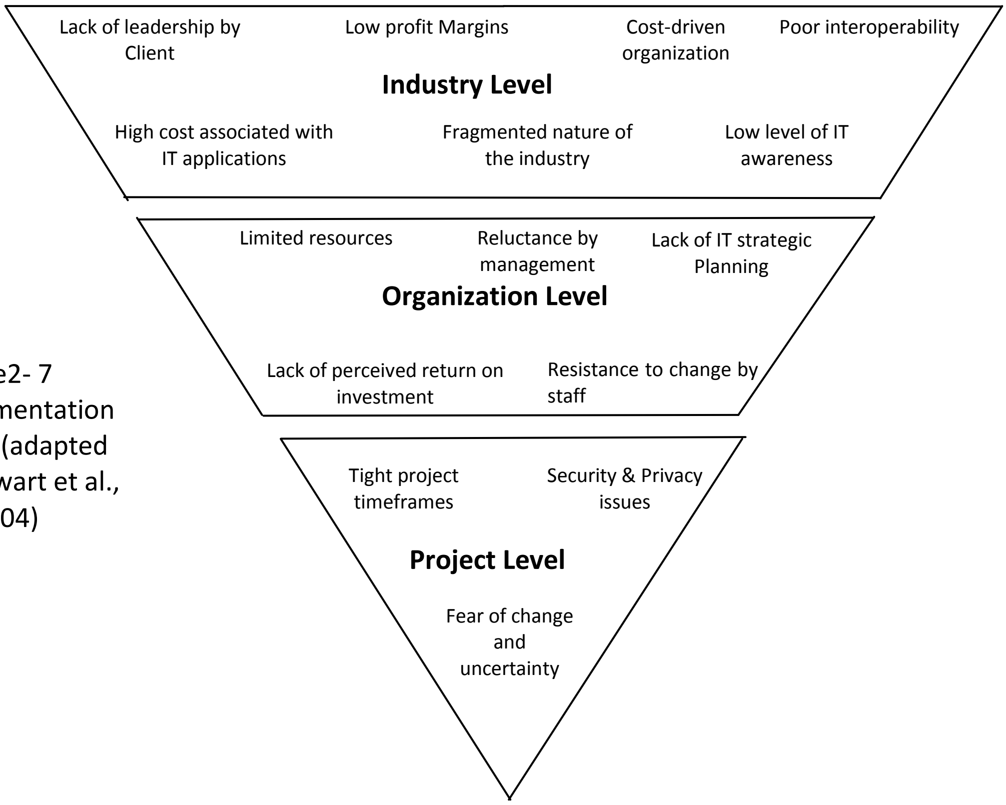


Figure2- 7
IT Implementation barriers (adapted from Stewart et al., 2004)

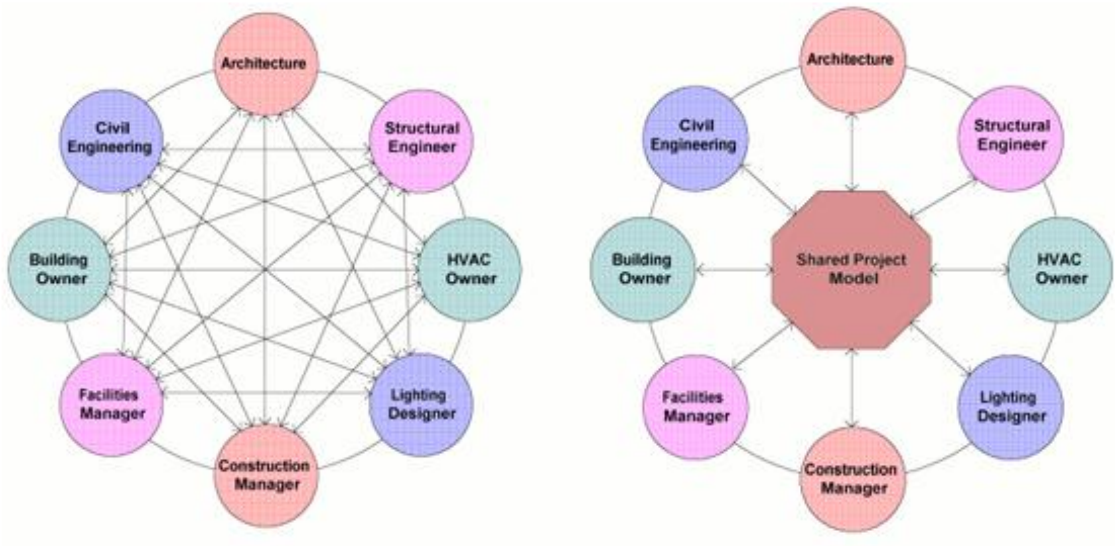
Interoperability (Industry Level)

Stewart (2004) imputes inter-operability problems between different computer applications as one of the major barriers of IT implementations in AEC. Interoperability, in the context of this research, denotes capability of various computer applications to fluently exchange and interpret data. Outrageous overflow of application, many of which are exclusively attuned and tailored to cope with intra-organizational problems, have eventuated in compatibility issue with regard to generated information.

According to Rezgui et al. (2009), the first wave of paradigm shift and therefore the second generation of KMS is a direct legacy of this very issue having been tangibly sensed. Urge for a centralized and unified information codification have resulted in emergence of ontology and product-modeling concept. The significance of the problem and universal awareness raised in the wake of it has led to formation of international alliance for interoperability (IAI) whose main objective has been set on creation, development and standardization of an object-oriented file format with a data model.

Figure 2- 8:

Interoperability with and without a centralized model (Kalny, 2007)



Absence of implementation incentives (Organization Level)

It is evident that training aversion and associated costs are one of the main deterrents of KMS (Lam et al., 2010; Egbu and Botterill, 2002; Stewart et al., 2004; Rivard, 2000). Know-how required for any IT applications intensifies technophobia among employees who tend to perceive training as much waste of time as it is an unsettling threat destabilizing their professional status and undermining their career. At the other end of spectrum, employers find training as a costly process for which they need very strong financial justifications. This poses a tremendous difficulty for IT developers as they have to invest a great amount of effort and time convincing people of applicability and seamlessness of their developments. This very phenomenon will also deprive IT designers of enough latitude required for practical experiment of their undertakings.

Figure 2- 9

Training Aversion (White, 2010)

User-friendliness (Organization Level)

User acceptance of any IT and KM system is an issue many authors have placed accent upon (Damodaran & Olphert, 2000; Hinkelmann & Probst, 2004; Geertman & Stillwell, 2009; Dishaw et al., 2002; Xu & Quaddus, 2005). Complexity of use is diagnosed as one of the major wherefores leading to underutilization of many potentially instrumental IT systems. Lack of user-friendliness as a result of inferior design of user interface is perceived as the most conspicuous barrier to KMS implementation (Damodaran & Olphert, 2000). Hinkelman and Probst (2004), putting user-friendliness under the category of Convenience, posit that while long scroll-down menus are cumbersome, easy interfaces supporting natural texts, graphics, forms and speech can tremendously conduce to successful implementation of KMS. It is believed that the main incentive of investment in KMS for managers is the perceived usefulness.

Subsequently, it is argued that nothing but user-friendly interfaces can inveigle and lure managers and investors into implementation of KMS (Xu & Quaddus, 2004).

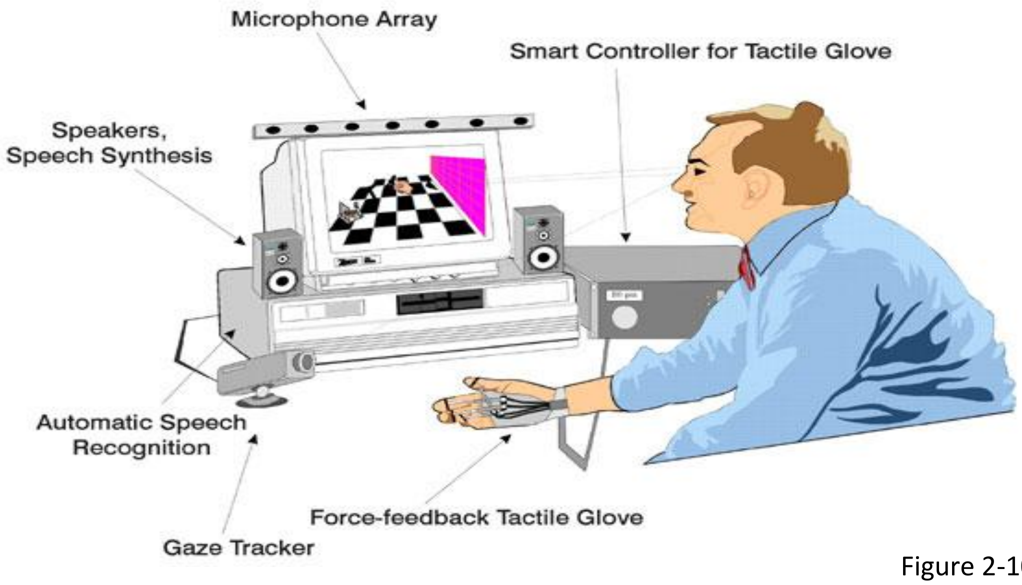


Figure 2-10

An example of advanced user-friendly interface

Just in-time capture and delivery (Project Level)

Another highly cited problem with regard to KMS is lack of dynamism and proper presentation formats. There are evidences that the tendency to postpone knowledge work and knowledge capturing after completion of a project leads to massive looses as many undocumented expertise surfaced ephemerally in the course of project lifecycle has vanished by that time (sarshar and Chiristiansson, 2004). Besides, it is of paramount significance to capture knowledge in the context of its elicitation. Thus, knowledge capture should be instantaneous and contextualized.

Mobility requirement mentioned by Hinkelmann & Probst (2004) falls under this category. Nature of common work in AEC is such that access to knowledge has to be ubiquitous, in the sense that a structural engineer in need of information when performing his regular on-site inspection has to be provided with the information instantaneously if negative consequence of forgetfulness is to be avoided. Furthermore, volatility of contexts within which knowledge needs to be imparted in AEC industry urges for a system capable of in-time interpretation of any context and further re-contextualization and effective knowledge retrieval.

2- 9 Discussion Overview

In this chapter, a quick review of knowledge management was made through introduction of various views towards the meaning of knowledge and resulting dichotomizations. Subsequent to elucidation of Data-information-knowledge paradigm, prevailing notion of Tacit versus Explicit knowledge was critically discerned.

It has been tried to remove any possible ambiguity in the comprehension of knowledge management and Information Technology domains and interrelations. Exploration of the KM process encapsulated within which is the entire gamut of knowledge-intensive practices was next addressed topic. With ICT being at the center of this thesis attention and interest, knowledge management systems were dissected.

Complementary to previous topics was literature review on the historical role and application of KMS in Architecture, Engineering and Construction. In order to pave the way for introduction of a novel solution to KMS relatively poor acceptance in the industry, examination of chronic deterrents of KMS deployment has constitute a considerable proportion of this chapter.

2- 10 Conclusions

Deficiencies of Knowledge Management Systems necessitate proper attention of designers and managers. When the enumerated problem areas are reviewed it becomes clear that a considerable rate of the problems pertain to data collection/presentation pattern of knowledge management systems. Complaint on the issue of user-friendliness directly implies lack of satisfactory attention to aesthetics, ergonomics and target users' cognitive preferences. As a result of sub-optimal consideration for user-friendliness a designed system will be victimized by target users' apathy which, most commonly, surfaces in form of training aversion and resistance against application. Most significantly, interoperability is an issue regarding data presentation and storage format and subsequent compatibility problems. It is the hypothesis of this research that to present a generic solution, not a case-specific troubleshooting, for these shortcomings a new approach towards user interface could be a possibility.

The above problems have been targeted and tackled from diverse solution area, yet seeking a solution in computer-user interface is relatively recent and poorly documented. To open the door for further exploration of the advantages, costs, opportunities and threats of this new approach, a background literature review on the subject of Human-computer interface (HCI) design is required. Owing to this, and responding to this need, next chapter will be allocated to investigation of HCI principles and relevant design methodologies.

User-friendly Interface Design 3

"A good interface has to fulfil certain requirements that are spanned over a wide variety of concerns from technological specifications to psychological needs of target users. These requirements are categorized under four classes, namely, ergonomics, cognitive, usefulness and affective. For a system to succeed and flourish in the targeted market area, considerations of the above factors are irreplaceably important. It is also noteworthy that human-centric design requires its exclusively attuned design methodology which varies from conventional system design methodologies."

3-1 Introduction:

In this chapter, and following previously mentioned barriers in KMS, the focal point is identification of design requirements of a solution capable of effectively addressing discovered KMS barriers. With this as the main objective, the chapter begins with reformulation of formerly broad research questions. Later, it will be tried to provide strong enough scientific ammunition for considering an enhanced human-machine interface as a topic of great value in KMS design.

User-friendliness, as one the major concerns of ICT users, will be subject to a comprehensive probe in the next phase. Potentials of highly accredited solutions for enhanced user-friendliness will be reviewed and the possibility of their integration into the interface will be investigated.

3-2 Research Question Reformulation:

Now that KMS shortcomings are identified in light of the preceding chapter it is time to investigate design features and specification for a good knowledge management system. For this purpose the research question, as mentioned before, will be reshaped into the below narrowed form:

If a new approach is to be taken towards KMS design, what essential criteria does it have to meet?

To address the above question, it will be split into below sub-questions each of which will be answered in its particular section.

1

What is human-computer interaction?

Under this section a brief review of human-computer interaction and its importance to successful system and application will be illustrated

2

What are the determinant factors for a good interface?

Usability engineering will be introduced as a principle which takes into account a wider range of concerns when designing a system.

3

How does human-centric interface design process differ from conventional design methodologies?

Particularly attuned design methodology for human-centric interface design will be scrutinized.

3-3 Human-Computer interaction

Human-computer interaction (HCI) is a rather recently heeded topic which spans over a wide spectrum of disciplines ranging from psychology and cognitive science to graphic design and computer science. The indispensability of the subject is well highlighted in the literature. Claim that interface can simply determine success or failure of any designed systems seems to be well devoid of exaggeration (Cho et al. 2009; Te'eni et al., 2007). Target users are initially exposed to interface lay-out and impressed by ease of input feeding and comprehensibility and relevance of presented data. The commercial governing rule of the first impression notwithstanding, there seems to be strong psychological impulsions for one to simply discard, or feel strong indisposition toward, any systems with poor interface.

Figure 3.1

User-friendliness in System Design (from www.CartoonStock .com)

"It's a very user-friendly model."

Shneiderman (1998) draws attention to fragility of users' trust and concludes that a failed experience of system operation or inaccurate results may erode their willingness to give the same system a new try for a long time. 50 to 70 percent of the system development effort is claimed to have been devoted to building the human-computer interfaces (Te'eni et al., 2007).

Having discussed the importance of HCI, I believe time is ripe to embark upon crystallization of the meaning of and, subsequently, involved domains in HCI. HCI is believed to be in quest for enhanced interaction between users and computers through escalation of user-friendliness and receptiveness to users' needs (Cho et al. 2009). With the abundance of meaning proposed for HCI, the below explanation by Encyclopedia of Human-computer interactions (2006), is believed to serve as the most elaborate and all-encompassing outline:

- **Conclusions:**

  "Human-computer interaction is a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use in a social context, and with the study of major phenomena surrounding them."

3-4 Usability Engineering and Human-centric Design

With appreciation of the significance of HCI design as a determinative factor of projects' overall success, Usability Engineering emerged as early as 1970s. Usability engineering refers to the effort to integrated factors leading to a more efficient and pleasant user interface into system development lifecycle. Since its birth, the usability engineering took many different turns and evolved into an independent, stand-alone and comprehensive topic on which numerous books and articles were composed.

At the highest level of abstraction, usability is defined as a quality of a system mainly ascertained by ease of use, ease of learning and user satisfaction (Rosson & Carrol, 2002; Mayhew, 1999; Leventhal & Barnes, 2008). Accordingly, usability engineering is a discipline in the course of which more concrete measurable indexes of usability will be introduced and structured methodologies to integrate usability into system design lifecycle are proposed.

The U.S Military Standard for Human Engineering Design Criteria suggested a four-dimension standard criterion for a decent HCI design (schneiderman, 1998).

- *Achieve required performance by operator, control, and maintenance personnel*
- *Minimize skill and personnel requirement and training time*
- *Achieve required reliability of person-computer combinations(reliability, availability, security, and data integrity)*
- *Foster design standardization within and among systems (integration, consistency, portability)*

Amid diverse models of usability measurement, Nielsen (1993) puts forth a methodology based on the consideration that usability, along with utility, are two main components of usefulness criterion which, in turn, is deployed as a means to appraise system acceptability. While utility refers to the extent to which a designed system commits to fulfilling the underlying expectations and precisely targeting the problems in question, usability index indicates the extent to which desired utility is performed effectively, efficiently and, most notably, satisfactorily. His methodology is represented best through the below system acceptability factors decomposition (Leventhal & Barnes, 2008):

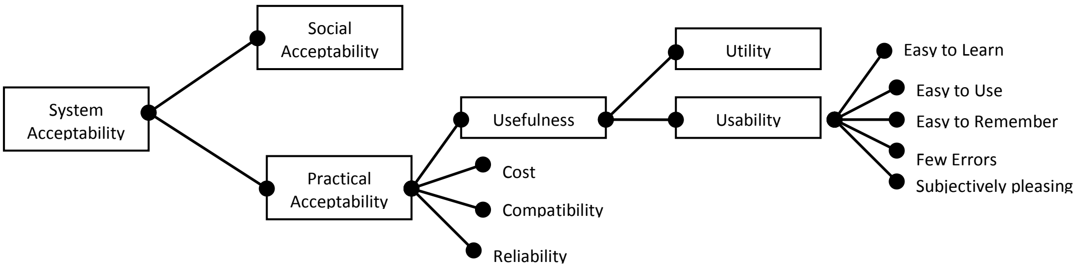


Figure 3.2

*Nielsen's Model of System Acceptability Attributes (*Leventhal & Barnes, 2008*)*

Nielsen methodology has viewed usability as a subset of a broader context of software engineering concerns. In this sense, it is conceivable that the significance of usability factors is overshadowed by the larger issue of systems acceptability (Leventhal & Barnes, 2008).

From a more technological perspective Sommerville (2001), in his book on software engineering, introduced usability attributes as being:

- ***Learnability**: time required for a new user to become productive with the system*
- ***Speed of Operation**: time required for delivery of the matched system response to the user's work practice*
- ***Robustness** : level of tolerance against user errors*
- ***Recoverability:** capability of system to recover from user error*
- ***Adaptability**: strength of the system ties to a single model of work*

Usability-sensitive design paradigm has been into various terminological guises. Castigating the notion of user-centric design for it failing to incorporate users' affective reactions and their holistic experience with technology, some authors, with the intention to adopt a broader view of human interaction with technologies, named the paradigm human-centric (zhang et al. 2004).

Condensing human-centric concerns under the encompassing and broad category of subjective satisfaction, schneiderman (1998) identified below measurable human factors to be as much concise evaluation basis as they are precise.

- ***Time to learn** : time required for acquaintance with the system*
- ***Speed of performance** : amount of time the system takes to return the output*
- ***Rate of errors by users**: the number and kind of mistakes the users are prone to make*
- ***Retention over time**: according to presentation of the results, the length of time users are capable of maintaining the acquired knowledge*
- ***Subjective Satisfaction** : the extent to which users gratification is achieved*

Nevertheless, to expound and draw a more apt and tangible picture of subjective satisfaction, a passing glance at potentially relevant disciplines to HCI design would be of a considerable assistance.

In order to better fathom the entire gamut of disciplines engaged in HCI design Zhang & Li (2004) developed an extensive framework (figure 3.2).

Zhang & Li (2004) perceived HCI as comprising two poles, namely, Human and Technology, which are being governed by the context of use and targeted area of applicability (task/job). As illustrated, at the human end, subjects such as ergonomics, demographics, cognitive sciences and emotional studies are well relevant. Similarly, at the technology side, issues such as hardware, software, applications, data information and knowledge are heeded. The interface, in above figure, is represented by the vertical arrow which bridge human to technology (Zhang & Li, 2004).

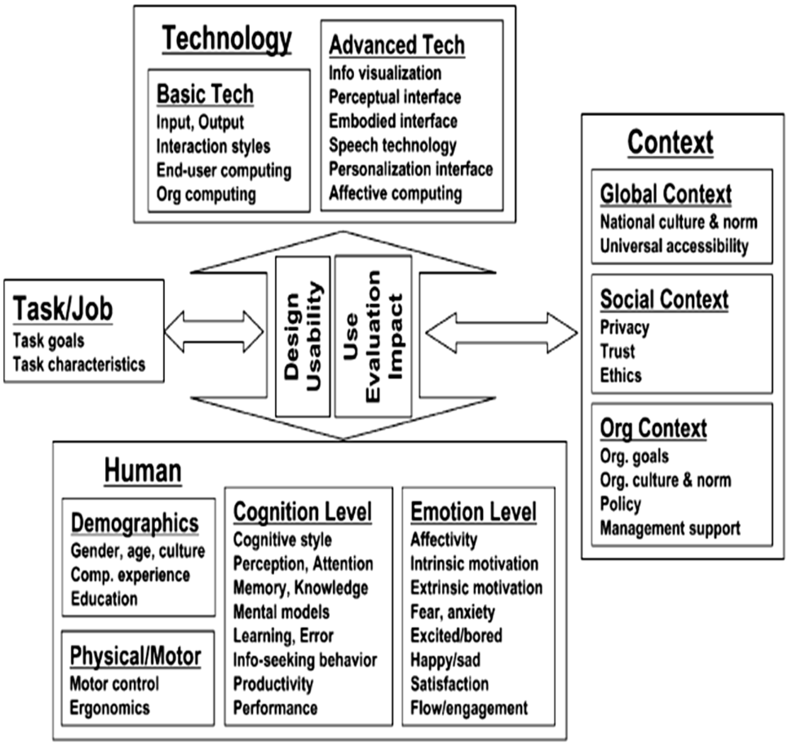


Figure 3.3

Broad HCI Issues and concerns (zhang & Li, 2004)

Identifying the conventional usability attributes as inadequate and incomprehensive and deducing from the broad picture of involved disciplines, Zhang et al. (2005) generate a more holistic view of design concerns and tabulate them as below:

Table 3.1

Human-Computer interaction Concerns (Zhang et al., 2005)

HCI Concern	Description	Sample Measure Items
Physical (ergonomics)	System fits our physical strengths and limitations and does not harm our health	Legible Audible Safe to use
Cognitive (usability)	System fits our cognitive strength and limitations and functions as the cognitive extension of our brain	Fewer errors and easy recovery Easy to use Easy to remember how to use Easy to learn
Affective, Emotional and intrinsically Motivational (pleasing and enjoyable)	System satisfies our aesthetic and emotional needs, and is attractive for its own sake	Aesthetically pleasing Engaging Trustworthy Satisfying Enjoyable Entertaining Fun
Extrinsically Motivational (usefulness)	Using the system would provide rewording consequence	Support individual's tasks Can do some tasks that would not so without system Extend one's capacity Rewarding

The above evaluation yardsticks seems to serve to the advantage of HCI design as it adopts a wider scope of usability and usefulness by heeding human pole of HCI to the same degree as technology pole.

With the design criteria clarified and discussed, time seems to be ripe to draw the discussion to the realm of design process and examine the possible similarities and dissimilarities of HCI design with general system design methodologies.

- **Conclusions:**

The author argues that for a system to be decently designed and well-received by target users, design specification should surpass far beyond merely fulfilling functional and technical requirements. It is contented that physical, affective and cognitive requirements of final users are as important as functional expectation from the system. Therefore, if a system is to survive, a proper design methodology has to be conceived to safeguard inclusion of multiple criteria.

3-5 HCI design process

Frameworks for system design and/or software engineering are manifold. However, detailed elaboration and examination of these frameworks is far beyond the scope and limitations of this research. Therefore, a simple evolutionary development approach towards system engineering, from architect perspective, proposed by Sommerville (2001), as a representative of the most generic characteristics of software design process, will be discussed.

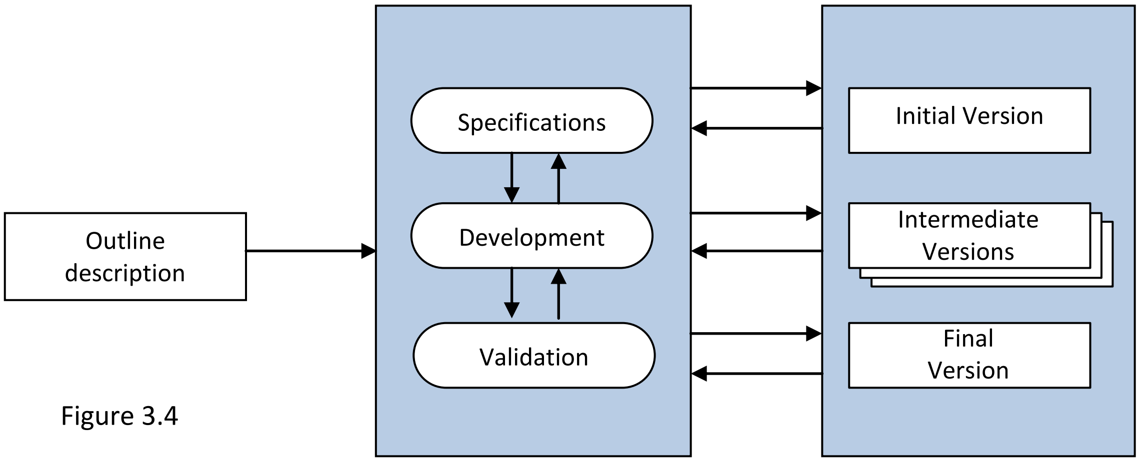


Figure 3.4

Evolutionary Developments (Sommerville, 2001)

Evolutionary design paradigm is grounded on the notion of iterative development and refinement. The paradigm requires many versions to be developed, implemented and exposed to target users and reflection on their feedbacks until an acceptable level of adequacy is reached. Central to this paradigm is that specification, development and validation activities are carried out concurrently with rapid feedback across them. Each activity can further be decomposed into a process. For example, software specification is the outcome of a process encompassing feasibility study, feasibility report, requirement elicitation and analysis, system models, requirement specification, user and system requirements, requirement validation and requirement document. As stated before, elaborate process design approach of HCI design is beyond the scope of this research.

With the above process as one of the most generic design paradigm given, time is to scrutinize HCI design methodologies, which are more or less nothing but contextualized and particularized general design principle.

Te'eni et.al (2007) propose a development methodology which is the outcome of their exhaustive literature review. They argued that conventional design methodologies have failed to properly address HCI concerns throughout it lifecycle. In modern System Analysis and Design (SA&D) books, interface is viewed as a component in the entire design process; and in the wake of such perception, HCI concerns and factors are not adequately ingrained into design process (zhang et al., 2005, Te'eni et.al ,2007) . Typical Software design methodologies are following the below generic structures.

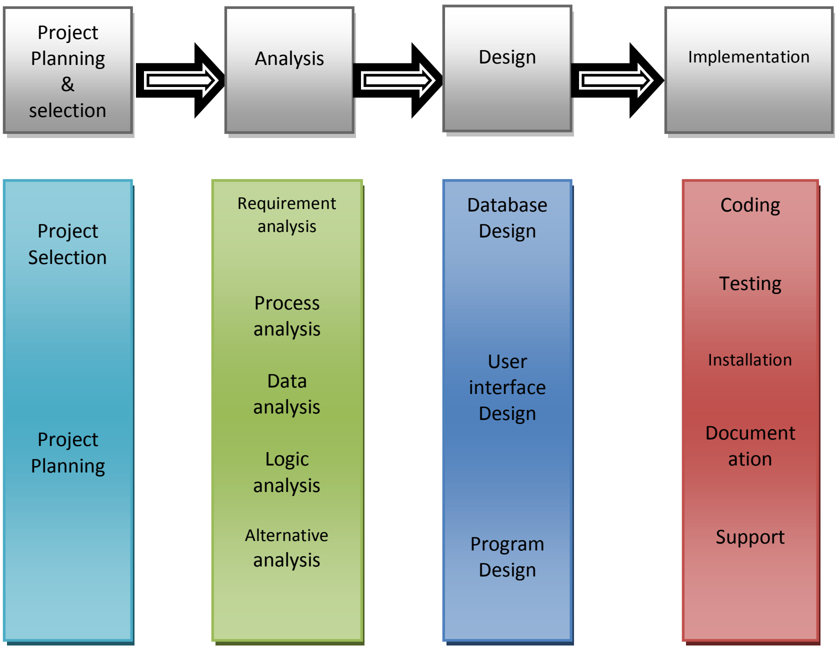


Figure 3.5

Modern System Analysis & Design (Adapted from zhang et al., 2005)

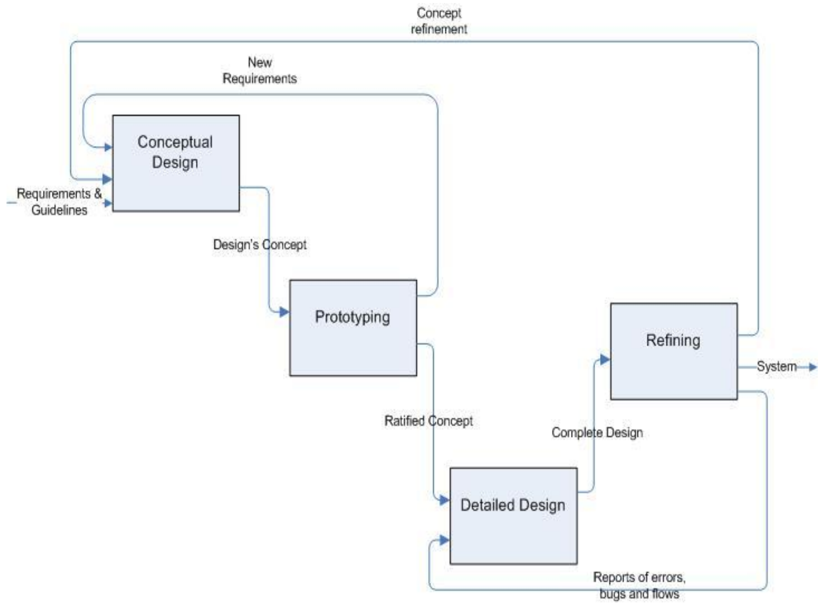
In the above figure, design phase can be split into (1) conceptual design and prototyping and (2) Iterative detailed design and refinement.

As illustrated in figure 3.5, while conceptual design and prototyping requires minimal iteration, ultimate design cannot come to fruition unless it is subject to several rounds of feedbacks and troubleshooting.

Nevertheless, zhang et al. (zhang et al., 2005, Te'eni et.al ,2007) propos a more human-centric design methodology to safeguard a more dominant role for HCI concerns throughout the design lifecycle. Their methodology, figure 3.6, is an extension to the Modern SA&D.

Figure 3.6

generic interface design process



This methodology differs from modern SA&D in that it embraces HCI concern in its very core and stretches over the usability indexes throughout its development. This is in palpable contention with modern SA&D approach in which interface design, and therefore usability engineering, would only constitute a phase in the entire process.

The vertical line schematically demarcates HCI and SA&D design emphasis by setting them on the right and left side respectively. The boxes intersected by the line are common activities in both paradigms.

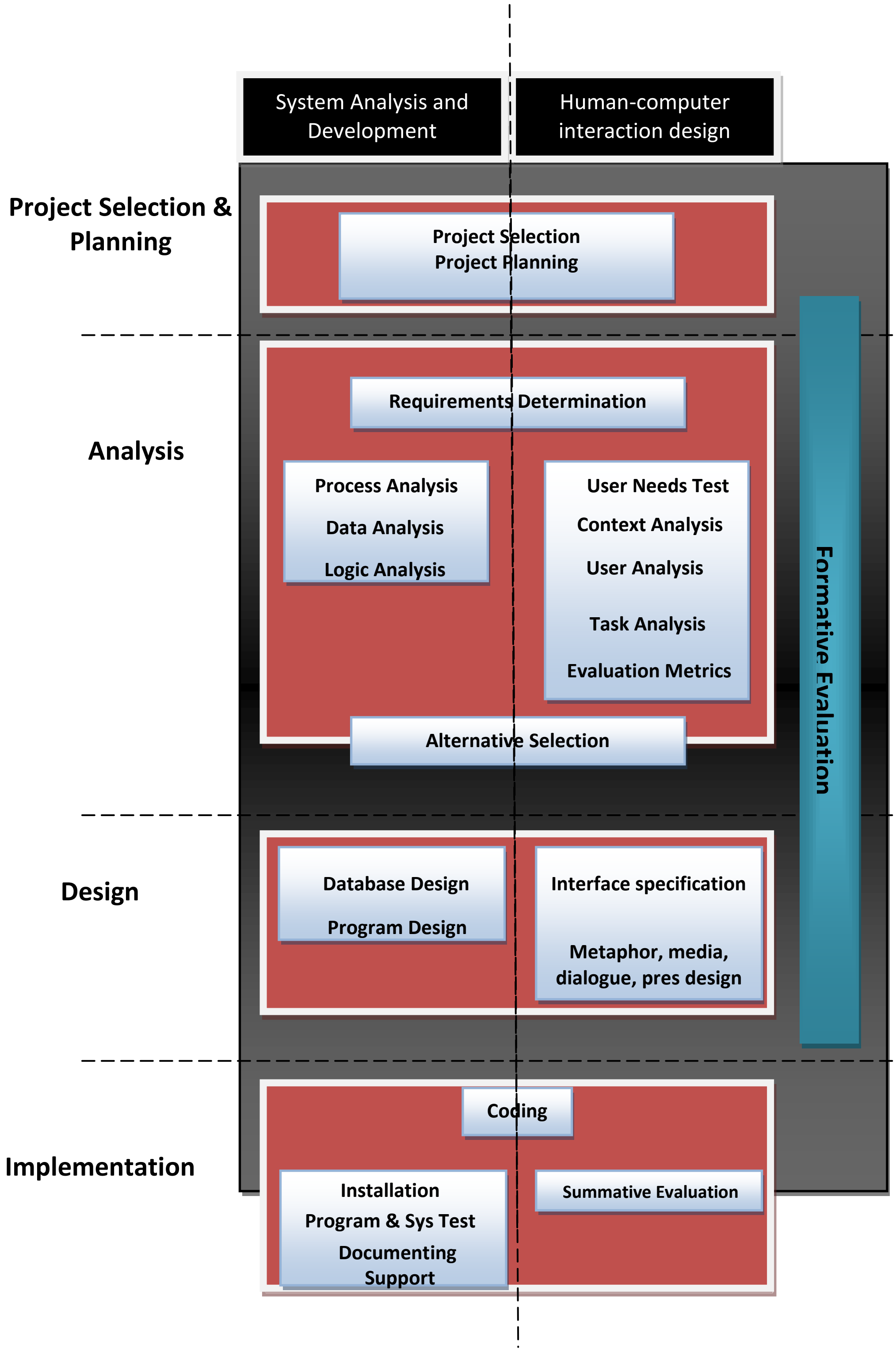


Figure 3.7

Human-centered Systems Development (adapted from zhang et al., 2005)

Iteration embedded in the above methodology will offer a greater potential for fitness of the application to the client's expectations and requirements. In addition, parallel development will ensure better integration of HCI concerns throughout the development lifecycle.

Conclusions:

It is contended that a proper interface design process is the one which incorporates human-centric concern from the early stage of the total system design. Yet, since the basic hypothesis of this research is to develop independent, stand alone interface as an agent, from the above design process only the below half will be taken into account. Hereafter, the research will follow the design methodology proposed above to structure the loosely-coupled interface.

3-5-1 Context, User and Task Analysis

The context analysis means determination of factors such as task's frequency, rigidness and situational constraints as well as users' expertise and motivation.

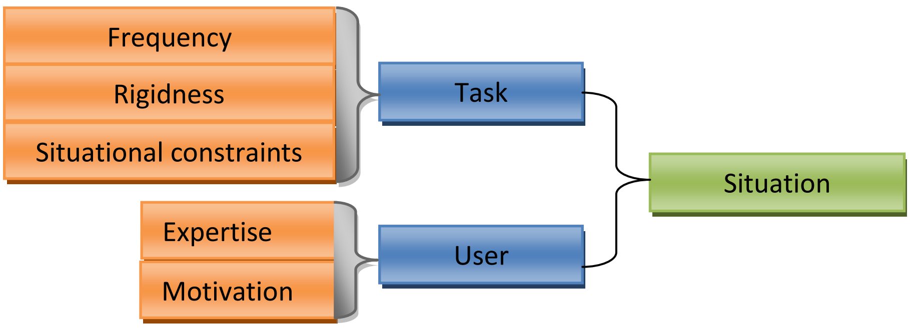


Figure 3.8
A comprehensive method of usability (adapted from Leventhal & Barnes , 2008)

In situational variables, and under task-oriented concerns, *Frequency* of task is recognized as influential in the design. The more frequent the task is, the better the system should be at handling the sequence of actions. Clarity and simplicity of the sequence of actions eventuating to a certain result will have a paramount criticality in highly frequent tasks.

Rigidness represents the extent to which the task could be performed through options. Needless to say that less rigidity means the increased number of paths through the task and also greater number of options along the path through the task. In this sense, less rigidity means more complexity and obscurity of the sequence of the task and, consequently, less usability.

With respect to *Situational Constraints,* whatever variables that might be of significance for the particular nature of the task have to be taken into account. Response to below questions could illustrate the nature of concerns that will fall under this very category *(*Leventhal & Barnes, 2008*)*.

- Is the task ever done collaboratively?
- Is the task done for entertainment?
- Does the task have any security restrictions?

The *expertise* of users will impact the usability to a considerable degree. The more expert user is expected to have a better mental picture of the task and expected to be in need of more extended latitude to apply their own mental model of the solution while novice users expect the more guided process through the task completion.

Motivated users are anticipated to be more prepared to invest time and energy in completion of the task and, therefore, less complexityaverse. For this very reason conjecture of target users and their likely *motivation* and patience in task accomplishment has to be of paramount concern to designers.

3-6 Discussion Overview:

This chapter included a brief perusal of usability engineering as a way to integrate design specifications that could lead to more user-friendly human computer. The research delved into literatures on the subject and discovered that a user-friendly interface need more than simply serving the required functionality. It has to give the same level of attention to ergonomic, cognitive and affective aspect of systems during design phase. Subsequent to this, design methodologies which are flexible enough to cover human-centric design specification from the early stage were discussed and explored.

3-7 Conclusions

As stated in the previous chapter, the need for enhanced HCI in KMS can be logically driven from highlighted problem areas. Of four problem area addressed by this research, all, namely absence of implementation incentives, just-in time capture and delivery, user-friendliness and interoperability, would directly fall under the category of HCI concerns. This will complete the conceptual linkage between problem areas and potential solution that will be proposed and developed hereafter.

In the illustration, figure 3.9, possible areas of concern for each identified problem are shown. For instance, while user-friendliness is perceived as a problem driven from improper attention to combined area of cognition, affection and ergonomics, Interoperability problems are only associated with usefulness. This indicates, and is believed, that all identified problems could be resolved if all HCI concerns are properly effectuated in system design. On this ground, the solution will be sought in enhanced interface design. The research will, hereafter, examine the fitness and potentials of loose-coupling concept as a way to safeguard human-centric HCI design while offering systems' flexibility and extensibility. It is also worth mentioning that the loose-coupling concept is not a temporary solution tailored for a particular context of use; but alternatively it is a high level strategic shift of design mentality and paradigm in the hope that it could lead to a better utility for KMS in AEC industry irrespective of where it is to be used.

Not only these criteria are important to justify the need for boosted user-friendliness with regard to knowledge management systems, but also the mentioned specification will be used as evaluation metrics for the concept of loosely-coupled interface and its prototype.

Having drawn a clear image of the importance of HCI for the successful implementation of KMS and delineated the concerns and criteria of human-centric design basis for User interface, the research, will carry on to introduce loose-coupling, as a concept, and computer vision, as a tool, as a promising solution for the targeted problems identified in the second chapter.

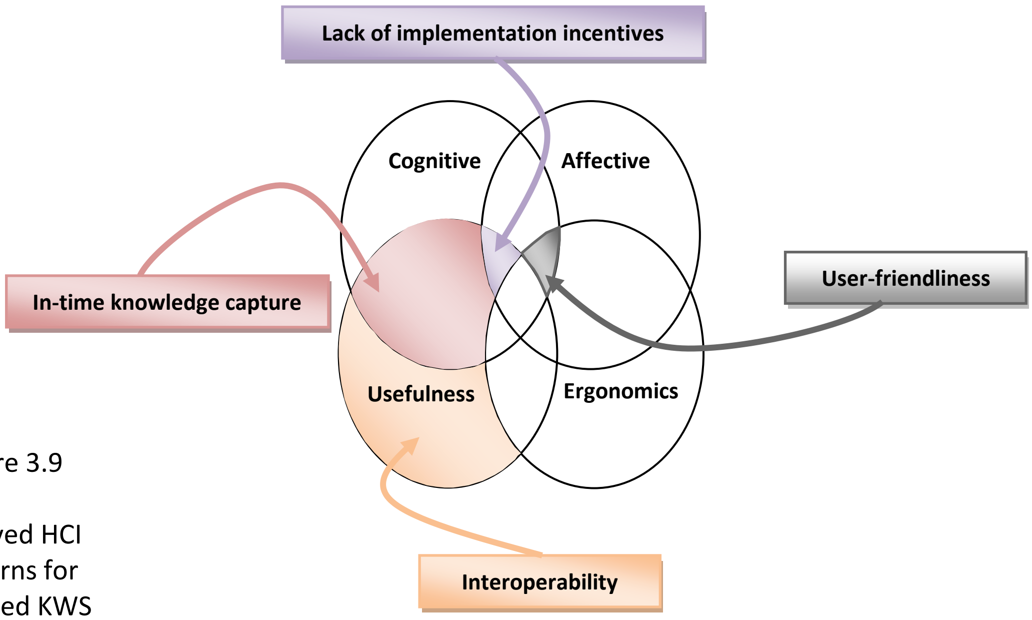


Figure 3.9

Involved HCI concerns for identified KWS problems

4

Loose Coupling as a Solution

"Loose-coupling concept, as a massive paradigm shift with regard to systems designs, would remarkably contribute to establishing Human-centric design parameters into overall design process. Not only this, but loose coupling also serve for the good of KMS through offering better opportunity to tackle some of the relevant shortcomings identified in previous chapter"

4-1 Introduction

Loose-coupling as to system engineering presents a novel view towards the structure of the system. For many years systems where being design on the premises of tight-coupling concept in which the connection between various components and sub-systems are rigidly defined. However, loose-coupling urges for an altered structure in which components are designed to serve certain function as independently as possible to other components. This will offer a greater room for extensibility and flexibility.

In this chapter, the author proposes this new concept to be implemented in knowledge management systems that are being used in AEC industry. This is hoped that this radical paradigm shift regarding systems' structure would contribute to resolve some of the persistent problems of KMS application in the industry.

The chapter will commence with research question reformulation which is the report's initial question narrowed and decomposed in the light of preceding discussions and conclusions. Thereafter, the discussion will advance in line with the resulted sub-questions.

4-2 Research Question Reformulation:

As illustrated to this point, KMS has some underlying shortcomings which deter its integration into AEC mainstream tools. Among several problems, lack of interoperability, untimely information capture and presentation, sub-optimal user-friendliness and absence of implementation incentives are found to be the most crucial. Later, it is argued that an enhanced interface could be a solution as usability engineering safeguard consideration of areas under which KMS barriers fall, namely ergonomics, subjective satisfaction, usefulness and cognitive analysis. For this purpose, a design methodology was developed which will incorporate HCI concerns into system design.
Consequently, proposing loose-coupling concept as a novel perception towards system design and particularly interface design, the author will investigating the validity of this hypothesis through responding to below sub-questions.

Is loose-coupling a solution to the KMS barriers and does it meet established criteria for a decent HCI design?

This broad question will be split into below sub-question questions answers which could collectively provide a justifiable answer.

1

What is loose Coupling and how does it differ from tight coupling?

The loose coupling concept will be elucidated and its differences from tight-coupling will be delineated

2

What are the Advantages and Disadvantages of loose-coupling?

The advantages and disadvantages of loose-coupling will be scrutinized and identified

3

Why could loosely-coupled interface be seen as a solution?

The reasons for hypothesizing loose-coupling as a solution will be justified

4

How would a loosely coupled interface look like?

Conceptual development of a loosely-coupled interface framework

4-3 Loose Coupling and Tight coupling

Tight and loose coupling is recognized in terms of the extent to which constituent components of a system are capable of functioning independently. The less independency will result in a tighter coupling and vice versa. In line with above definition Lugu and mihalache (2010) define loose coupling merely as independence of subsystems. Hussain (2007) puts it as evolution of various components without any effect of integration. Encapsulating the core objective of loose coupling in their exhaustive definition, Tann and Shaw (2007) propose that loose coupling intends not only to provide stand-alone implementation of applications on different platforms and operation system but also to readily adopt the implementations without the interface being affected.

In tight coupling, conversely, subsystems are being perceived as components of one single entity whose functionality depends on seamless integration of all subsystems. In this sense, subsystems in a tightly-coupled system are majorly not capable of serving their functionality independent of other subsystems. However, It shall be stated that this does not mean that stand-alone subsystems could not or, otherwise, are not being used in a tightly coupled systems, as there are always some very low level subsystems that are independent modules that can be used in other systems as well, e.g. a routine to calculate square root, replace a portion of a text etc. Therefore, tightly coupled systems are does whose components are rigidly intertwined without possible replacement if the system is not to be rebuilt or modified. However, in loosely coupled systems, majority of components could be replaced as they are designed to serve their functionality independent of back-end and front-end sub-systems.

The concept could be better portrayed in terms of object-oriented (OO) paradigm. Tight coupling exists when dependant class in a system is directly linked to a concrete class with no, or very little, room for changes and substitution. Loose coupling, at the other end, the link between the dependant class and concrete class (es) is made through an intermediating interface (Wikipedia). UML models (figure 4.1 and 4.2) will illustrate the distinction through the example of a tester that is supposed to be operated by a relevant machine. In the loosely coupled system, figure 4.1, the tester contains a pointer only to the interface which is being implemented by several devices. The tester has no direct knowledge of the devices and provided a new device is invented in future it could be simply added without any modification to tester. In tight coupling, though, tester contains a pointer to the device which closes the path for future extension or modification (Wikipedia).

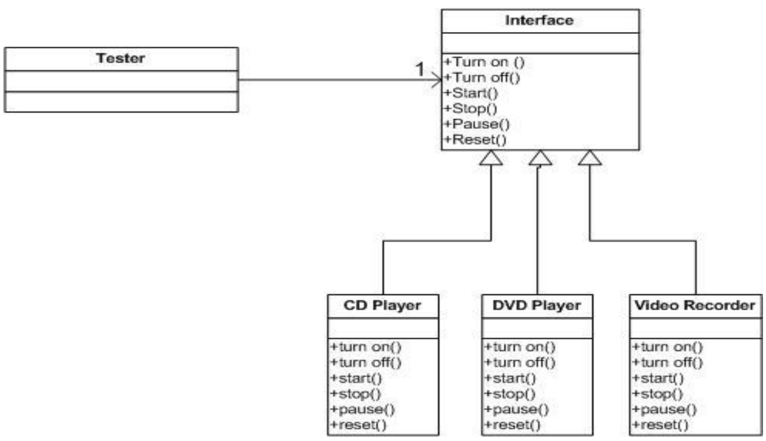
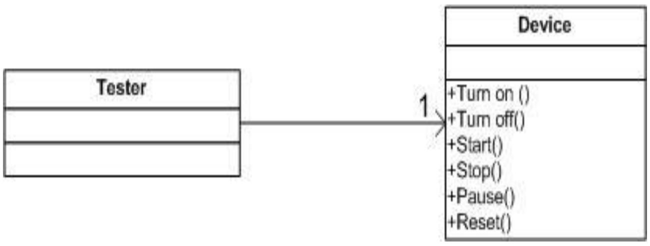


Figure 4.1
Example of loose coupling
(Wikipedia)

Figure 4.2
Example of Tight
coupling
(Wikipedia)



To better understand the notion of loose coupling, below examples could be helpful:

Example one: A computer operating system is tightly-coupled to interactive devices such as mouse as the connection is tightly established and the operating system requires a mouse to perform the defined function. A computer equipped with touch screen LCD, Electronic Pad and mouse provides a much looser instance of coupling. Now, if a the system is capable of acquiring X,Y coordinates of the destined point on the screen through computer-vision, the coupling would be extremely loose as the dependence upon a certain device is minimized.

Figure 4.3

Example of loose coupling

Example Two: A phonebook application on a cell phone or computer could be another example. If searching for one's phone number requires menu scrolling or typing then it is an instance of tight-coupling. However, if a voice recognition capability is brought to use so that user can simply call the name of the desired person, the system would be far looser.

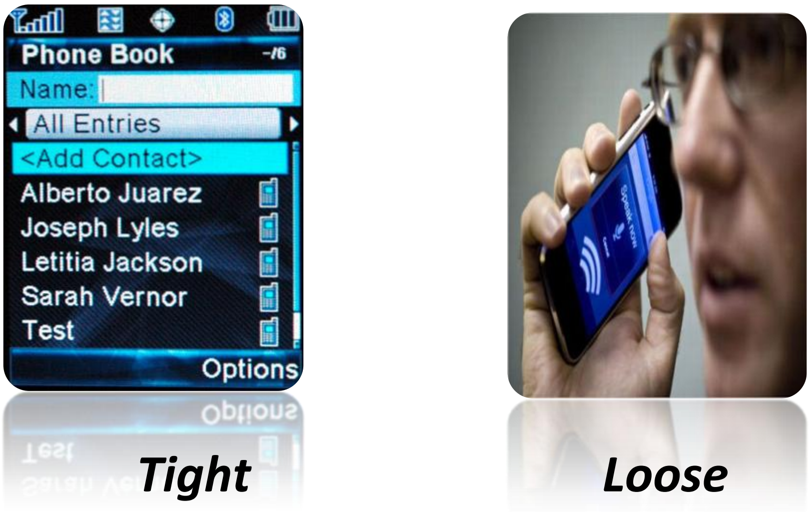


Figure 4.4

Example of loose coupling

Example three: let's take a more technical example. If structural calculation software requires the new building frame to be drawn in the software, this would be an extremely tightly coupled interface. Now, if the same software is capable of communicating with architecture design software, in which the building was previously designed, and proceed with the calculation, then the coupling is much looser. For looser coupling, it is conceivable that not only the software can communicate with other software for its required input, but also can interpret and read the hand-drawn sketchs on a piece of paper. Similarly, it could be well imagined that if the software is installed on a cell phone, which is equipped with a vision device, it can take a picture of an actual under-construction building and provide the relevant calculations to the desired part (this could be done through augmented reality based applications that are currently available for other purposes).

Tight

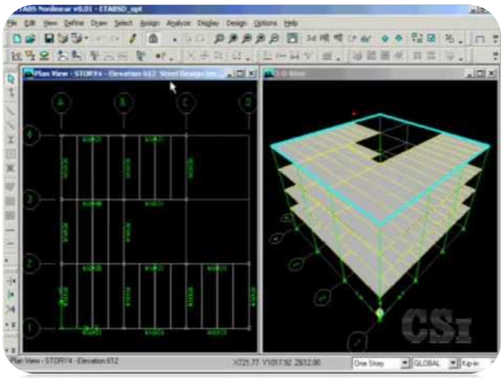
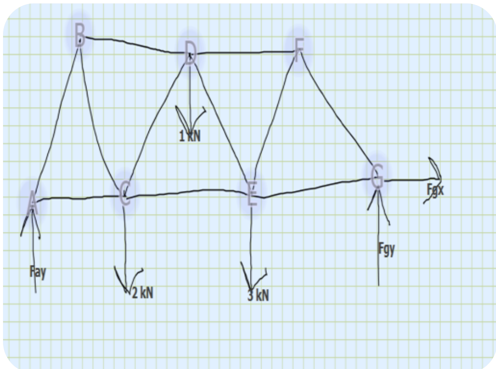


Figure 4.5

Example of loose coupling

Loose



As can be seen in above examples, loose coupling concept is established upon the idea to increase the adaptability and extensibility of systems through providing more extended and diverse trends of data gathering and decreasing the dependencies on particular format or sub-systems . Take the first example, the looseness increases as the range of acceptable data presentation increases insofar as in the case of computer vision, all previous methods could be used to transfer the X,Y coordinate to the computer. In this particular example, though, one has to be cautious that comparatively loose case could be instance of both loose and tight coupling depending on the underlying class definitions. If various devices were defined as particular objects compatible with the required function or service, then the coupling is tight. However, if the same devices were defined in terms of an interface instantiation, then it could be an example of loose coupling.

Conclusions:

Loose-coupling is the extent to which constituent subsets of a system are capable of functioning independently and flexibly. If the user feels he/she is bound to adapt to the system's behaviour, and the system is imposing its culture upon him/her then the system is likely to be tightly-coupled.

4-4 loose coupling; advantages and disadvantages

Discussion of advantages and disadvantages of loose coupling is a very delicate issue as the actual implementations of systems built up entirely on the concept of loose-coupling are of a rarity. However, as mentioned before, the central motivation behind loose-coupling is its potential for interoperability and extensibility. This advantage is resulted from the fact that the connection between two subsystems is usually defined through a mediator. The mediator or the interface functions as a convertor which transforms data format from the origin to the destined module. As the functions of subsystems in a loosely-coupled system are defined as independent as possible to each other, replaceability presents itself as another major advantage of systems of this nature. This, in turn, offers room for innovation, creativity and adaptability. Loosely-coupled systems are usually targeted at a much broader scope of problems as compared to tightly coupled ones. Additionally, loose-coupling is believed to require minimal expertise for development, particularly compared to tight-coupling (Castle, 2006).

Another noticeable gain of loose-coupling is easy debugging. If a newly assembled system is suffering from bugs and glitches, loose-coupling requires far less time-consuming and onerous troubleshooting. This is mainly due to reduction of so called ripple effects. Ripple effects represent the complexity of a system through implying the implication of a sub-system alternation on the entire system functionality. Again, as the loosely-coupled systems comprise relatively independent sub-systems in terms of functionality, modification of a sub-system will lead to minimal effect on the entire system.

Last but not least, loose coupling is comparatively cheaper regarding the initial costs (Brandmeyer and Karimi, 2000).

Nonetheless, loose-coupling is not devoid of disadvantages. The most considerable are low execution speed and lower accuracy. Tight-coupling is reported to be a far more robust concept with regard to accuracy of the results. As a result, it is conceivable that for tasks with low context volatility tightly coupled systems are much more appropriate.

The above analysis could be represented in term of loose vs. tight coupling comparison. The below table indicate how two concept perform against several criteria.

Table 4.1

Loose vs. Tight coupling comparison (adapted from Castle, 2006)

Criteria	Loose Coupling	Tight Coupling
Accuracy	Low	High
Scalability/ interoperability	Very High	Low
Adaptability	High	Low
Cost	Low	High
Debugging	Easy	Difficult
Execution speed	Slow	Fast
Programming Expertise	Low	High
Room for creativity	High	Low

Selection between loose or tight coupling in a system should be base on the requirement of the system and the possibilities and drawbacks of each method. Loose coupling serves to the great advantage of scalability, adoptability and flexibility. At the other end of the spectrum, tight coupling provides more ad hoc solution and efficient performance.

Consequently, in practice, traverse from tight to loose-coupling means moving from systems capable of answering to systems designed for suggestions. This is, again, due to the accuracy difference between the two concepts.

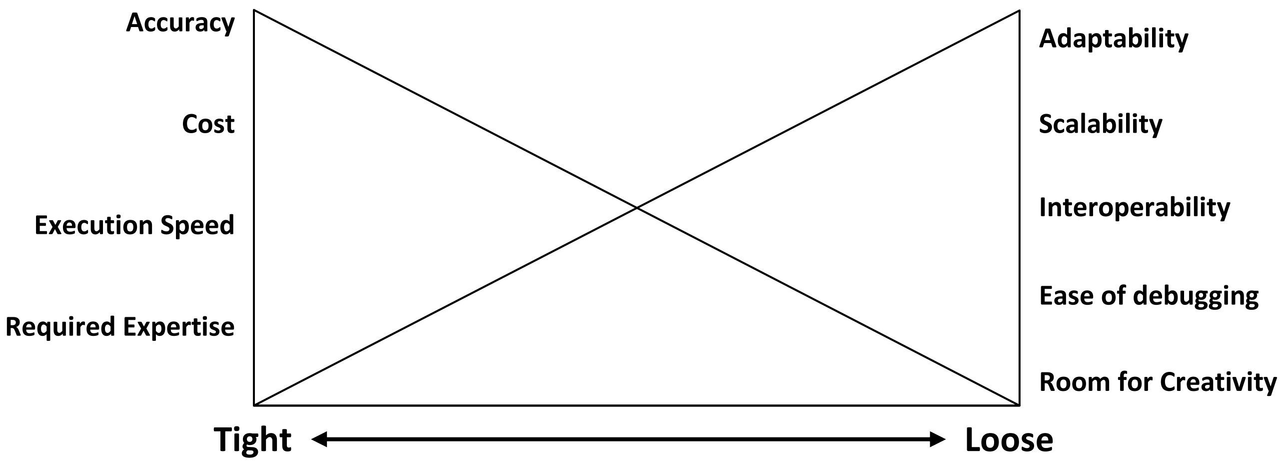


Figure 4.6

The effect of degree of looseness on the specifications of the KMS

Figure 4.6 illustrates the effect of moving in between tight and loose coupling on the features of the total system. As can be seen the thither coupling would mean increased accuracy, cost of implementation and maintenance, execution speed and required expertise while at the same time means diminished adaptability, scalability, interoperability, ease of debugging and room for creativity.

Conclusions:

The loose-coupling advantages have to be appreciated in the face of possible costs one may bore when forgoing tight-coupling concept. At the highest level, selection between the two concepts has to be based on the context-imposed prioritization between accuracy and extensibility. Loosely coupled systems, owing to their independent modules and subsystems, are very extensible and adaptable which makes them almost incontrovertibly suitable for fostering innovation and creativity in highly volatile contexts. Nevertheless, it has to be heeded that the looser the system is, the more the given outcome tends to be in form of suggestions rather than absolute answer to the problem at hand.

4-5 Loose-coupling as a solution

As shown above, loose-coupling fits better in highly volatile working contexts. In this section, the reasons to take loose-coupling concept as a potential solution to existing KMS problems will be discussed.

It was argued that human-centric interface design could lead to removal of some of the existing KMS barriers as it would safeguard various concerns whose incorporation into interface design will well address interoperability, user-friendliness, in-time knowledge capture and lack of implementation incentive.

The previous section illustrated that superiority of loose-coupling in terms of interoperability and scalability is well-documented in literature and is therefore beyond doubt. However, if it is shown that loose-coupling concept incorporates HCI design concerns, then it could be discerned as a potential solution to KMS barriers. Hence, this section will be devoted to indicating that loose-coupling will outperform tight-coupling in terms of functional (usefulness), cognitive, affective and ergonomics features.

Usefulness

The most delicate matter will be the functionality of a loosely-coupled system since it is overshadowed by tight-coupling regarding accuracy and precision of outcomes and performance. The first impression of this phenomenon could be that loose-coupling will fail to maintain superiority when it is down to usefulness. Yet, the argument may find a different complexion in accordance with the expectation from the system for particular tasks. If a system is designed to provide professionals with expert suggestions and advices, as opposed to definitive description, then loose coupling could no longer be undervalued. In addition, increased flexibility could strike many users as more important for some users, depending on the criticality of the task and their expectations. Nonetheless, the author believes that for AEC industry which is characterized by product uniqueness and task/context volatility, advise-giving, or otherwise suggestion-based, systems would better meet the expectation of the users. A tightly-coupled system may lead to a more dependable outcome if a certain project or context is considered; yet, looking in long term effect, loose-coupling will be better able to survive in the business as it could be manipulated and adopted inexpensively for various contexts.

Ergonomics

As shown in the case of loose-coupling examples, when the concept is applied to human-computer interface, it means the user should not feel bound to the imposed culture of the application. A loosely-coupled system will require the system to be compatible to various forms of data acquisition.

With the loose coupling implemented, the users will be limited to minimum possible behavioral constraint when working with the system. Take the mouse example, the vision-based application will allow the user to work with his mouse if he/she prefers to do so while posing no inhibition to use fingers, pen or any other object. From this perspective, the loosely-coupled system will score high in ergonomics feature of the interface as it will offer a wider range of acceptable behavioral pattern from the users.

Affective Quality

Similar to ergonomics, loose-coupling is expected to outdo tight-coupling when it comes to subjective satisfaction of the users. A look upon measuring indexes of affective desirability of an interface brings into surface the potentials of loose-coupling to lead to better results. Aesthetically speaking, loose-coupling, due to its inherent flexibility, is more readily designable for a more appealing look. Additionally, since loose-coupling at the front end requires humanization of human-computer interaction, it is well prognosticated that it would be less frustrating.

Cognitive Quality

Cognitive superiority of an interface is assessed through the error rates, recoverability, ease of use and learnability. Error rate seems to be more relevant to the quality of the system designed rather than underlying architecture and therefore is speculated not to be a point of difference between two concepts. Nevertheless, as discussed in previous chapter, debugging is much easier in a loosely coupled system as the function- or service-based modular structure make error identification noticeably faster. Learnability and ease of use will be maximized owing to minimization of need for training as one of the main goals of loose-coupling.

Final Verdict:

It is illustrated that loose-coupling has better potentials for human-centric interface design. With the right expectations and requirements, loosely coupled system could be as useful as tightly coupled one while offering a more long-term applicability. With regard to other HCI concerns, it is also argued that loose coupling has an upper hand mainly due to its inherent flexibility and scalability. , With loose-coupling being more adapted to human-centric design, it is believed that loose-coupling can serve best to remove KMS barriers.

4-6 conceptual development of loosely coupled interface

With the advantages and disadvantages of loose-coupling discussed and the relevance and appropriateness of the concept for KMS amelioration argued, time is to conceptually develop an interface based on the loose-coupling concept. In this section, the overall principal of an interface designed based on loosely coupled concept will be elaborated.

An interface is connected to two contexts, that is to say, back-end and front-end. Front-end is the context and environment surrounding the real world of which the user is a part. Back-end is the knowledge-based or data-bank from which the relevant information according to arisen need from the front-end is stored. Interface is a means to capture the input data required for the back-end system to perform information retrieval. Loose-coupling could be conceived and implemented at either or both ends. However, the methods to achieve loose coupling at each end vary in line with principal characteristics of each context. Below, a conceptual way to realize loose-coupling at each end will be scrutinized.

4-6-1 Loose coupling at the front-end system

First point to take into account is that KMSs predominantly delimits the users to a certain pattern of actions. For a system to operate, the user is expected to work with a mouse, write necessarily with a keyboard, follow the dictated procedure, get acquainted with the terminology and adopt expected perspective. This means relatively tight coupling at the front-end. One major task of the interface will be to loosen the coupling at the front-end.

The best way to loosen the coupling at the front end is to simulate human-human interaction in human-computer action. Basically, this is because or conception of independence from system-imposed action could not be possibly any further that human-human interactions. This could be achieved through embedding human sense into interface that are vision, hearing, touch, smell and taste. Yet, our professional interaction, as the main realm of KMS, would rarely happen beyond the combination of vision and hearing. This means that we are most often acquire our information through seeing and hearing. This means reversing the conventional interaction pattern. It is not the user which has to go the system and provide it with relevant data, but it is the system which acquires the needed data from the users while he is probably not even consciously directed towards the system.

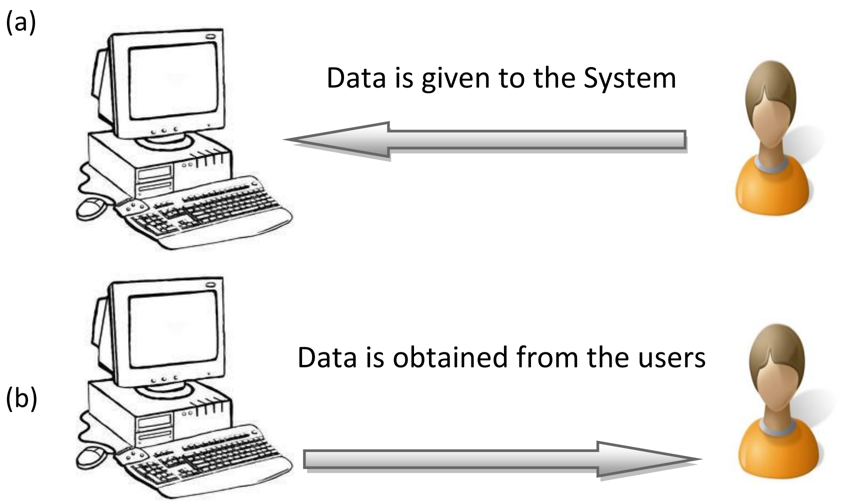


Figure 4.7

tight-coupling (a) and loose coupling (b) between user and interface

Computer vision makes possible designing an interface capable of data acquisition through relevant medium, webcam as an instance. Voice recognition, also, has been achieved in computer sciences for many years now. Together they can make interaction with computer much more pleasant and address KMS problems mainly through enhanced user-friendliness.

Through the simulation of interface-user interaction to human-human interaction, the particular problem of training aversion and managers' indisposition to invest in changing the systems will be best approached. As maintained before, an interface capable of seeing and hearing will require minimal training as it is particularly attuned to extract data from the environment without requiring the user to follow particular rules.

Interoperability will also be addressed not through the state-of-the-art standardization of formats and information presentation methods, but instead via making the system less dependent on the presentation format. It does not matter if your written note, for example, is written in Microsoft Word or any other counterpart platform since the note is subject to image processing and data extraction.

4-6-2 loose coupling at the back-end system

Majority of developed KMSs incorporate interface as embedded within the system. This embeddedness results in inevitable tight-coupling and therefore limited scalability and flexibility beyond the contexts for which the system is designed.

Figure 4.8
Conventional tight-coupling between systems and interface

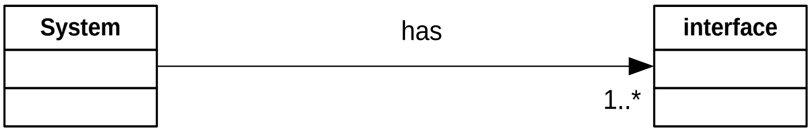
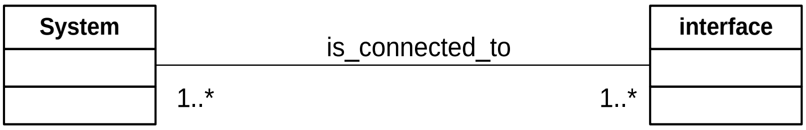


Figure 4.9

Targeted loose-coupling of interface and back-end system



The cardinal ingredient of data analysis is context recognition. As discussed, data needs to be contextualized for it to evolve into information. Consequently, an intelligent interface has to be able to have understanding of the context of the document. The recognition of the context of work at hand is the most crucial step needs to be taken for the proposed philosophy. There are different approaches and methods that could be integrated for this purpose. Text-mining methods could be used to provide an overall understanding of the context of the document. However, it has to be conceded that like human brain which uses certain a priori for interpretation and analysis, a certain level of abstract ontological data-base needs to be embedded in the interface, transforming it from being merely a bridging tool between two environment, namely real world and data base, to a stand-alone system. Yet this independence has to remain minimal to the extent required for embedding intelligence into the interface; and the ultimate data processing has to be left for the most appropriate knowledge base. In a very simple form, the interface could embrace a glossarial data bank and make a clustering of typical terms in diverse likely contexts. For instance, it could be given to the system that presence of the words “cost”, “bid”, “requirements” and “deadline” could possibly denote that the documents in hand is a biding document and accordingly a certain cost-estimation system could be used. It goes without saying that the above is only a very rough image instantiating the hypothesis and remains very crude and naive.

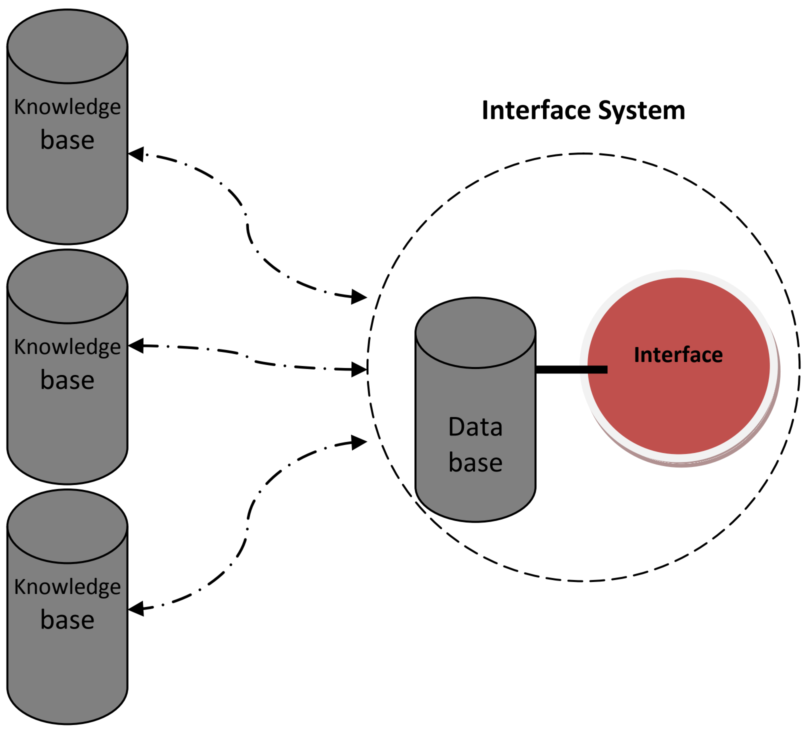


Fig 4-10

Minimal tight-coupling in the interface for enhanced loose-coupling at the back-end system

The advantage of the above hypothesis is that since the embedded data-base in the interface has to be kept at minimum possible level, it can deploy the advantages of the loose-coupling and tight-coupling at the same time. There are certain clear rules that can also be subject to automatic evolution provided a decent learning mechanism is used, which will increase the dependability of the responses.

Additionally, minimal tight-coupling will enable easy adaptability and addition of more possible back-end knowledge base if required.

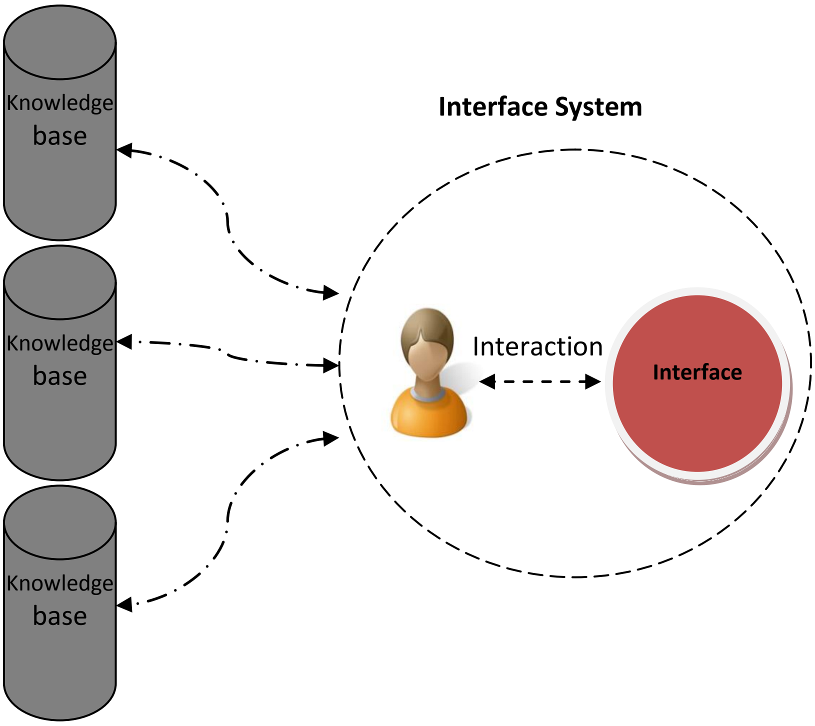
The main disadvantage is, however, that it will need all regular maintenance that a tightly-coupled system needs and that high level modifications will always necessitate major revision and updating of the interface system.

Another possible way to achieve loose-coupling at the back-end system is to leave the context recognition to the users of the system. A simple query mechanism could be defined through which the users will indicate their expected results and, therefore, narrow the selection of the appropriate

back-end system. This method will result in achievement of high level of loose-coupling at the back-end system at the cost of decreased automation and, subsequently, possible degeneration of friendliness.

Fig 4-11

User intervention for enhanced loose-coupling at the back-end system



However, if we analogize this philosophy to human brain, it is worth heeding that, similarly, for human the linkage and dependency to the exposed environment is far looser compared to its coupling with and reliance on their knowledge. While human can far more readily adapt to the changing environment and different contexts, it seems to be far more resistant against paradigmatic shift. Consequently, any alternative hypothesis and methodologies contrived for boosting the loose-coupling at the back-end system should be in the light of appreciation of the above fact.

- **Conclusions:**

Loose-coupling could be applied to either or both of back-end and front-end system. At the front-end it could be best achieved through humanization of human-computer interaction mainly through integrating computer vision and voice recognition. At the back end system, though, loose coupling achievement is a very complex matter. Two possible ways were thought of in this research. One way is to embed intelligence in the interface and look at it as a mediating agent passing and processing data transfer from the two ends. Second way is to utilize a query system which let the end user narrow the selection of the knowledge base according to his understanding of the situation.

4-7 Discussion Overview

The chapter commenced with research question reformulation based on the insight from the previous chapters. To sweep any possible ambiguity with regards to the meaning and differences of loose-coupling and tight-coupling, a section was devoted to distinguishing the two. Some examples were used to assist the reader in better comprehension of the inherent differentiating points between the two concepts. Following this section, advantages and disadvantages of loose coupling were discussed. Justification of adoption of loose-coupling as a potential solution to KMS shortcomings followed in the succeeding section and it was tried to depict the contribution of loose-coupling concept for the integration of human-centric interface design concerns into KMS design. Finally, a conceptual design of the interface was conducted so that the reader gets acquainted with the notion of loosely-coupled interface.

4-8 conclusions

It is argued that loose coupling possess a great potentials for being discerned as a solution to KMS drawbacks and shortcomings. Loose-coupling due to its intrinsic capability for enhanced interoperability, mobility and adaptability could well cover a wide area of problems that are currently impairing KMSs. It is presumed that loose-coupling inherence of human-human interaction method will conduce to remarkable boost for user-friendliness. It is observed to have superior compatibility with human-centric HCI design criteria, particularly in ergonomics, affective and cognitive categories. However, it has to be taken into account that lack of accuracy of loose coupling, in comparison to tight-coupling, makes this system more applicable for consultation and suggestion rather than ah-hoc solution seeking.

The concept could be of a particular use in AEC industry since various professionals involved in a project tend to have their usually segregated perspectives and approaches. Therefore, information transfer in this highly fragmented group requires flexibility and interoperability. This is probably the most significant strength point of loose-coupling. Another remarkable contribution of loose-coupling which could be of a significant interest in AEC industry is it mobility. As described above, it could be well imagined that the looser the coupling, the more versatile and mobile the system.

All in all, despite its relatively clear gains and room for improvement, loose-coupling is a pretty recent view towards KMS and therefore lacks referable well-known examples. This has led to the conclusion that for a better demonstration of the concept, a prototype is of a valuable assistance if not an exigency.

Prototype Development for the Interface 5

"The prototype indicates the user-friendliness and potentials of an interface designed based on loose-coupling concept. This interface will serve for the best of AEC industry particularly through enhanced interoperability and mobility"

5-1 Introduction

As mentioned earlier, an interface designed on the premise of loose-coupling is of a rarity in AEC industry. This chapter aims at demonstrating the potentials of the concept in AEC industry through elaboration of a prototype which was developed for this purpose. The author spent nearly four months developing this interface which required laborious programming and acquaintance with a robust yet affordable computer vision software.

This chapter includes the description of the prototypes goal and limitations. The design methodology which was extensively introduced in the fourth chapter will be followed to create the prototype.

As can be seen in the methodology, figure 5.1, subsequent to requirement determination, the context analysis will be carried out. Then, the interface framework will be drawn and discussed before the final programming and assembly is executed. Noteworthy is that, the basic evaluation metrics defined for a proper HCI design in the fourth chapter will be brought to bear to evaluate the prototype and it functionality at the end of this chapter.

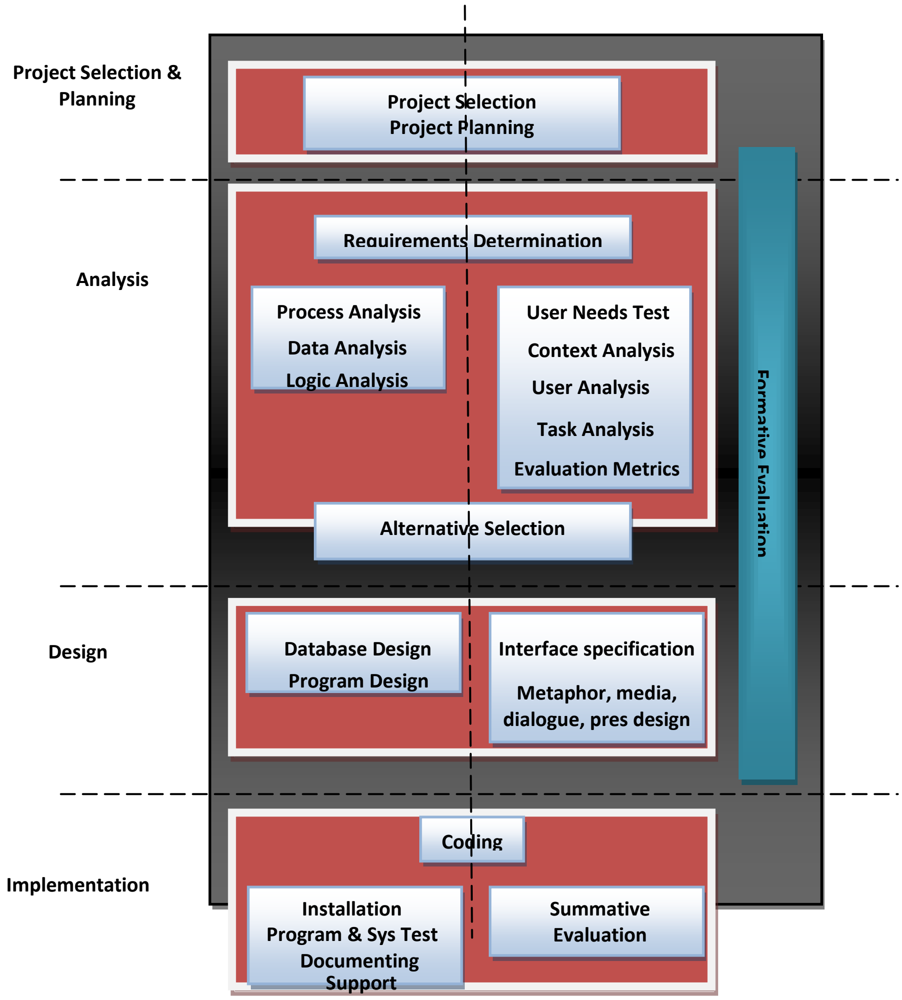


Figure 5.1

Human-centered Systems Development (adapted from zhang et al., 2005)

5-2 Research Question Reformulation

Following the preceding chapter, in which the potentials of loose coupling concept as an enhancement to KMS was discussed, in this chapter, an interface designed based on loose-coupling principle will be depicted through a prototype. The central research question which will be addressed in this chapter is as following:

How will an application based upon loose coupling operate and may address a sample problem? (Prototype development)

The above question is granulized as below:

1

What are the goals and limitations of the prototype?

The scope of the prototype will be drawn and its goals will be clarified

2

In which Context is the prototype expected to function?

A simple context analysis of the prototype will be conducted

3

How is the prototype designed?

Step-by-step journey through design process of the prototype

4

How does the prototype function in a test?

A complete run of the prototype will be sectioned and reviewed

5-3 Scope and Goals of the Prototype

The most noteworthy at the inception of drawing the framework for the prototype is to reiterate that the raison d'être of the prototype is to concretely represent the notion of loose-coupling in interface design and development and the implication it may carry upon enhanced friendliness, technical usefulness and other paramount shortcomings sufficiently discussed in previous chapters.

In the context of AEC industry, it is crucial to identify features an interface likely to boost the quality and experience of implementing KMSs has to be equipped with. One of the challenges being faced in the industry is volatile data, be it wishes, requirements, guidelines, policies or technology, and the need to translate this data into a presentable format to KMSs. This cost a great deal of time and creates hassles as the operator is expected to have precise understanding of the data context and technical know-how to effectively run the application. The procedure leads to massive friendliness reduction and interoperability problems.

With the conceptual framework, drawn in the previous chapter, and the specific problem above, the scope and goal of the prototype is defined as following: Application of computer-vision in interface development as a potential means to loosen the coupling to the front-end system. The prototype dispenses with actual demonstration of loose-coupling at the back-end system; for there remains insufficiency of theoretical backing for it and implementation of any hypothesis would cause tremendous complexity in programming and development. Nonetheless, the possible ways to obtain loose-coupling at the back-end system was brainstormed and discussed in previous chapter. The goal is defined as providing a concrete evidence for possibility, applicability and usefulness of applying vision-based loosely-coupled interface in KMS that are being particularly used in AEC.

Conclusions:

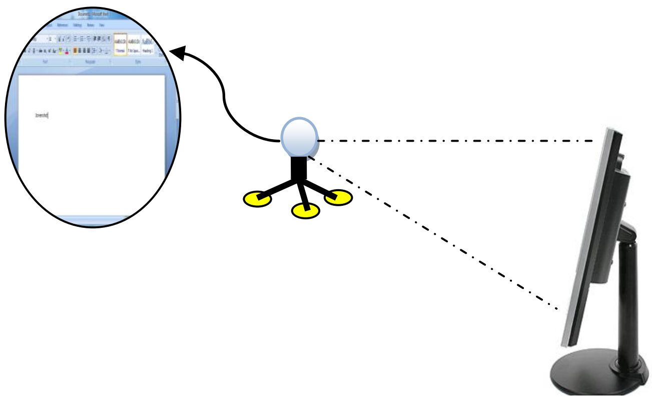
To demonstrate how an interface based on loose-coupling concept work, a prototype will be developed. The scope of this prototype is utilization of computer-vision, as a means to achieve utmost loose-coupling at the front-end, for a typical task in AEC industry. However, with the limited time and resources available, the prototype will not represent loose-coupling at the back-end system.

However, the conceptual methods to achieve loose coupling at the back-end system was discussed in the previous chapter.

5-4 Prototype Analysis

The task, correspondent to our defined goal and scope, is to make an action in Microsoft Word deploying computer vision, as a way to obtain loose coupling. A webcam is directed towards a screen while an operator is writing on the Microsoft Word. The webcam closely examines the screen while the writing is continuing. It has to be able to detect certain pre-defined words and proceed with relevant and similarly pre-defined actions. This simple description conveys the main expected functionality of the prototype.

Figure 5-2
A view of the prototype layout



Very briefly, the target user of this prototype is a typical employee who is constantly busy with translation of data from its actual context into computer-recognizable context. This typical employee would possibly urge for an enhanced performance of the system in accordance with human-centric HCI design concerns. He is likely to be willing to only work with a single data-gathering agent, or otherwise interface, which can carry the burden of inter-contextual data translation with minimal interference of the user.

The user is expected to have high motivation for working with the application as he might have limited choice of alternatives. This means the user is favorably tolerant of a certain level of sub-optimality and patient with working with the application.

The task is to insert a picture relevant to a certain word, when it is detected on the screen. It is expected to be a rather frequent task and it is important that the process handling is done accurately and smoothly. The task is fairly rigid owing to its straightforwardness. There are not much various alternative to perform the task and therefore it is less complex and leaves room for increased usability. The task could be done collaboratively therefore the interface should be increasingly adaptable. The particular task targeted by this prototype may not be restricted by any security measures which leads to easier planning for its development.

For the evaluation of the prototype, the same metrics that were introduced in the third chapter will be used. Below diagram summarizes these evaluation metrics and also indicates to which category of human-centric HCI design concern each belongs.

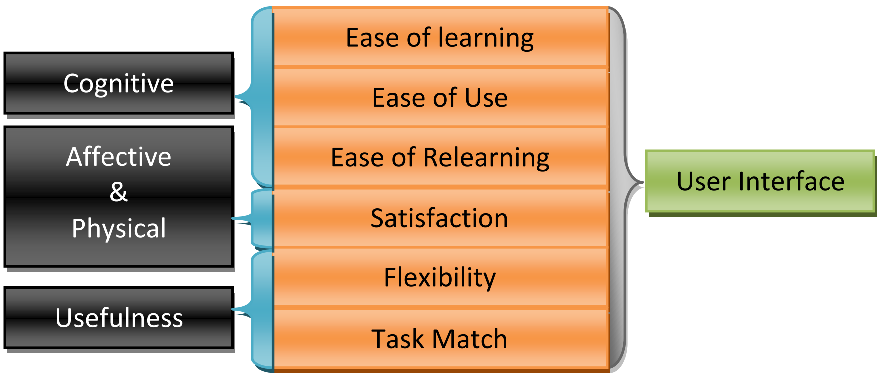


Figure 5-3

Evaluation metrics for HCI design

Conclusions:

The prototype is expected to detect certain words on the screen and proceed with picture insertion under the relevant part. The task is identified to be of a frequent nature, it is favorably rigid, it could be done collaboratively and has minimal security restriction. The target user is known to be well motivated and patient with the application and has good understanding of the nature of the work. Total context analysis reveals that the task and user do not impose any particular impediment upon design requirements and pave the way for boosted user-friendliness.

5-5 Prototype Design

In this section, the prototype structure, limitations, its components and constituent tools will be introduced. Also, the general functionality of the prototype will be browsed through a step-by-step dissection.

5-5-1 Design limitations

It goes without saying that abovementioned application will only serve as a means to represent the core concept on the basis of which it is created and, subsequently, is not expected to be ready for actual implementation.

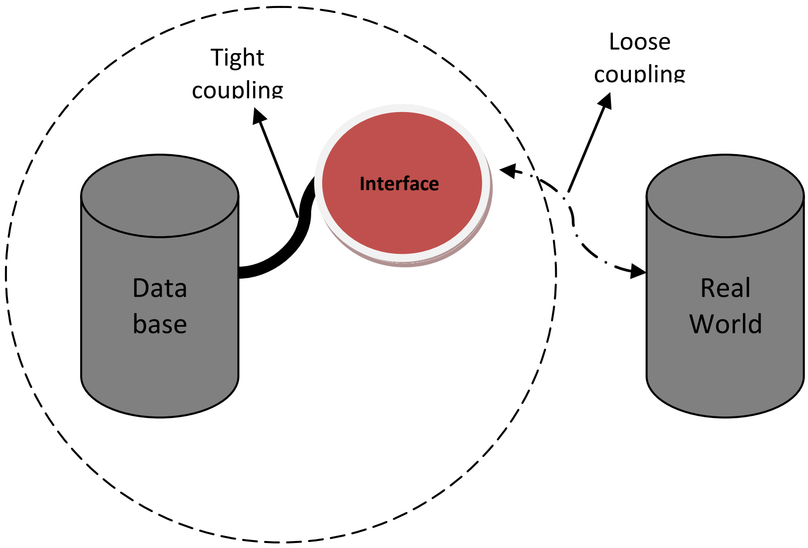
Prior to embarking upon detail description of tools and enablers of the application and relevance to the concept, it is of cardinal importance to discuss boundaries and limitations of the application.

As the first limitation, the application dependence upon the particular environment of Microsoft Word and a certain font is a cause of limited access to a more powerful image processing tool, a robust image capturing device and time limitation. The ideal interface has to be independent of the exposed environment and should be able to operate even on a handwritten document on the desk. This limitation is an external problem in the sense that it is a result of the lack of resource I could avail myself as a master student and has no relevance to the full functionality that the application can offer. With the proper resources available, the prototype could be easily improved to an interface independent of working station and environment.

The second and even more conspicuous limitation is the tight coupling at the back-end. Currently, the objective of the prototype is to detect certain predefined words, namely “Bridge”, “Book” and “Desk”, and manage to bridge the connection from the base computer, the one to which webcam is connected, to working station, the one on the screen of which the word is detected, through network connection and insert relevant pictures. Ideally, the interface has to be equipped with the capability to connect to diverse knowledge bases and serve various functionalities in accordance with the nature of the task and expected outcomes. Given the significance of this feature, although in the developed prototype it is only considered as a research limitation, I have discussed in theory how loose coupling to the back-end system could be achieved.

Figure 5-4

The prototype's target



As illustrated above, the prototype aims centrally at demonstrating the loose coupling at the front end, while remain tightly coupled to the back-end system or more precisely have some tight relations with embedded rules that ought not exist in the ultimate model of loosely-coupled interface. The interface should, ideally, target the layout shown in figure 5.4.

The last limitation, which is, in some respect, an off-shooting of the second limitation, is the picture insertion fashion of the prototype. The current structure of the program uses a predefined coordination and the sequence of exact points the cursor is expected to click on and follow to accomplish the task. To be more precise, in Microsoft Word the picture inserting action is through following **Insert>Picture>Directory**, each of which is spotted by the certain coordination in the screen. In the prototype, the (X,Y) coordination and the exact directory of data-bank, picture gallery, is pre-determined and fed to the application in the sense that when the word "Bridge", for example, is detected the cursor is commanded to follow a certain given path which leads to clicks on **Insert>Picture** and the exact location where the pictures are stored. Indubitably, this could not be the way in which a loosely-coupled interface is designed. In the conceptual design, the interface should identify the path according to various contexts and environments. It has to be able to browse the screen, in Microsoft Word as an instance, and find the word "Insert" and then lead the cursor to the very direction. Still this pattern could be further loosen by embedding artificial intelligence into the interface so that it is capable of initially making intelligent guess that clicking insert is the most likely path leading to the desired outcome. Upon the first successful run, this intelligent interface will be able to learn and follow the exact same path in the future tries.

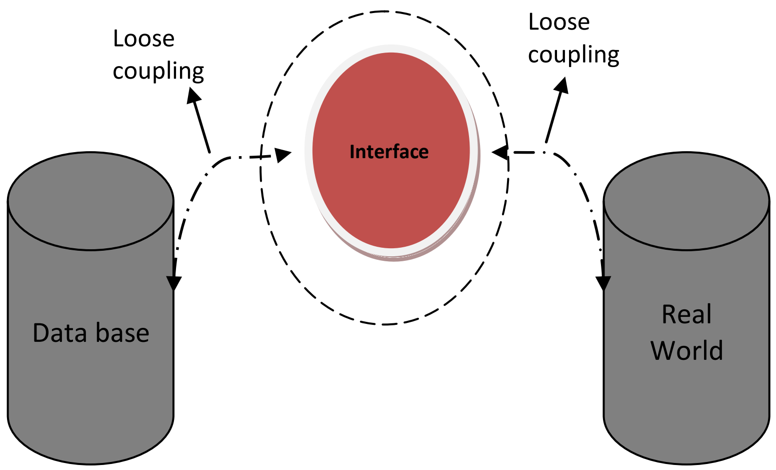


Figure 5-5

The ideal interface layout

With the clear image of the scope of the project and the objective of the prototype, time is to elaborate in detail how the above objective is pursued.

The first step was to opt for proper real-time image processing software which could offer a reliable edge detection and image matching functions. For this purpose, RoboRealm was found a strong tool. It is powerful vision software with a wide spectrum of use in computer robotics and image analysis.

5-5-2 Tools

This section is devoted to introduction of tools that enabled the development of the prototype. These tools include RoboRealm as robust open-source computer-vision software, VNC Tight as a mean to bridge two systems on the same network and, finally, Visual Basic at the programming language.

5-5-2-1 RoboRealm

RoboRealm is open-source computer vision software which enables real-time image processing.

The ease of use in the virtue of incomplex menu and easily spottable features contribute to making the software a very attractive choice for rapid prototyping for which advanced features and functions are not of a great necessity.

Among wide spectrum of modules offered those that were brought into bear in this research will be expounded more in details. The combination and following of the below modules, in order, is empirically proved to result in the most satisfactory outcome.

1- ***Adaptive Threshold***
2- ***Negative***
3- ***Population Threshold***
4- ***Close***
5- ***Blob Filter***
6- ***Shape Match***
7- ***Blob Replace***
8- ***VBScript Program***

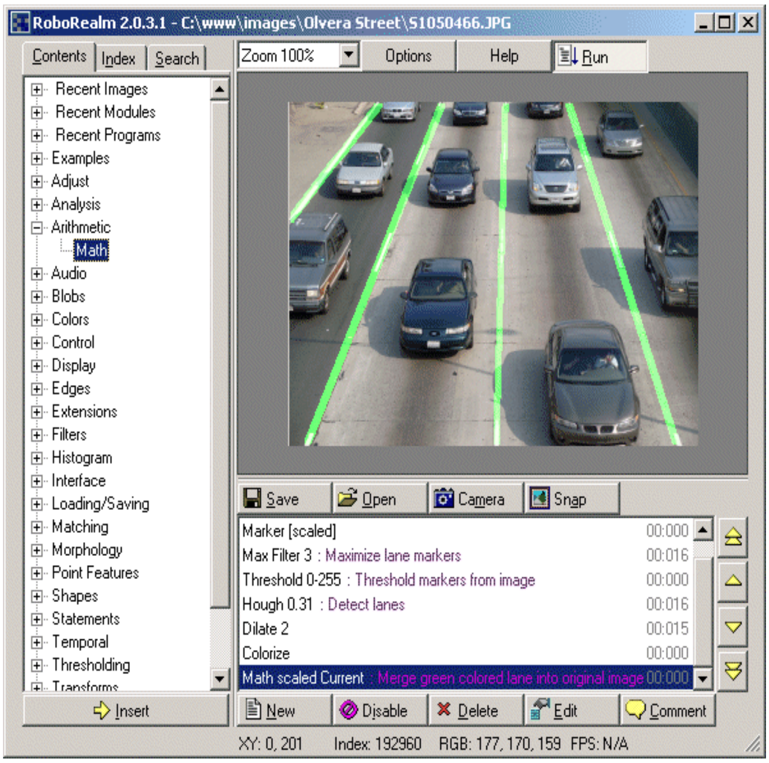


Figure 5-6

RoboRealm Environment

Adaptive Threshold

This will allow the segmentation of objects in uneven lighting conditions and, therefore, help obtain better contours for objects. The module serves its functionality through comparing the lighting of pixels in their respective vicinity and performs binary thresholding, rendering the original image black and white.

Figure 5-7

Before and after shot of Adaptive Threshold module

Negative

This module will invert all pixels values. If a pixel is black, this module will help convert it to white.

Figure 5-8

Before and after shot of Negative module

Population Threshold

In order to create a more uniformed with minimal details, Population Threshold will serve to determine if the non-black pixel lives in a neighbourhood whose population is greater than some specified threshold. If it does then the pixel is set to white, otherwise it is set to black.

Figure 5-9

Before and after shot of Population Threshold module

Close

The close module would perform dilation and erosion functions simultaneously to connect close objects. This function, as will be shown later, would enable unifying close separate letters to make a single word recognizable as such. Individual letters will be attaché together in such fashion that RoboRealm can identify a word as an independent word and prepare it for further image matching module.

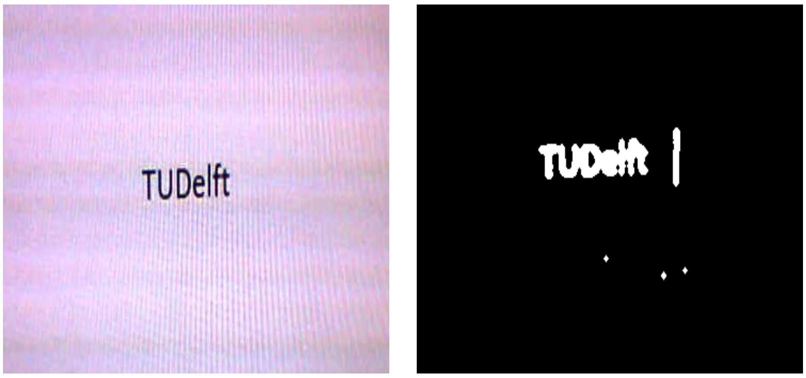


Figure 5-10

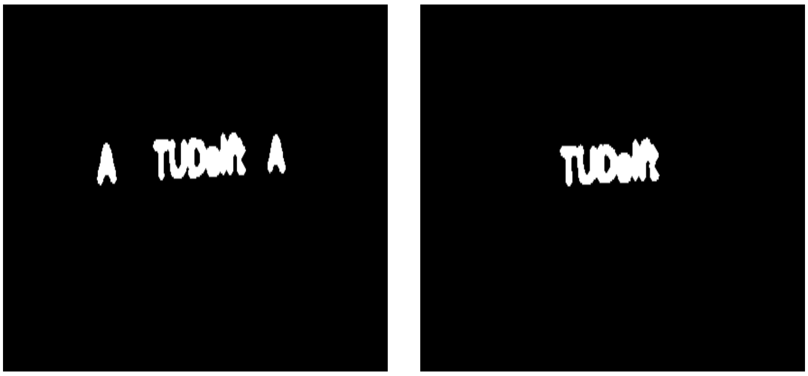
Before and after shot of Close

Blob Filter

This module will eliminate blobs of certain features and specifications. User-defined yardsticks will be used to ensure that only relevant blobs are identified and the rest of the noisy background is omitted. RoboRealm avail the users of a wide range of filtering parameters ranging from colour and texture to size and shape. The sole pre-condition for this module to run is that some sort of segmentation modules leading to grouping of pixels into blobs is used and the background is already set black.

Figure 5-11

Before and after shot of Blob Filter module



Shape Match

Shape matching, as the backbone of my application, makes a juxtaposition of a binary image with a known database of images. It performs a statistical calculation and returns a similarity extent in form of confidence percentage. The shape matching module remains independent of shape translation, size and orientation which is a great advantage for variable contexts.

Figure 5-12

Before and after shot of Shape Match module

Blob Replace

Blob Replace will exchange the white blobs in the present image with colors and patterns offered in the interface. In my project, this module is solely used to replace the previously whitened background with the actual background.

5-5-2-2 Visual Basic

As suggested by the name, RoboRealm has anticipated the need for customized operation. This need was addressed through VBScript module which enables the users to process image statistics and map.

5-5-2-3 TightVNC

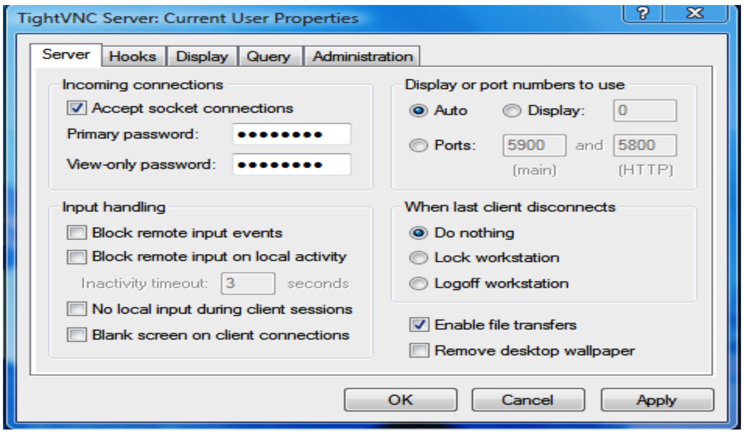
Another external tool used in the application is TightVNC. Prior to looking into the software, it is noteworthy that TightVNC is a temporary bypass measure taken to boost the similitude of the design prototype to the actual intended interface and has to be replaced with a more dependable, robust and ubiquitous method for the interface development. Alternative approach will be discussed at the conceptual level in conclusion and recommendation section more thoroughly.

TightVNC is an open source application particularly designated to the purpose of remote controlling of computer desktop. It enables the users to take over the mouse and keyboard of a remote computer and allow them to manipulate and change the desktop as though they are working with their own local machine.

In the prototype, TightVNC is used for the base computer to take over the machine on the screen of which detected words are located and proceed with the insertion of pictures. The chief limitations leading to abatement of loose-coupling in the prototype are the security password required for two machines to connect and the IP address of the target computer that needs to be preset in the program. However, these limitations do only exist in the face of the shortcomings of the deployed tool, namely TightVNC, which was, in turn, resorted to for its apparent financial and technical advantages, and could be well removed provided more exclusively attuned tools are made available or designed. The conceptual solution to these limitations will be elaborated in the closing section of this chapter.

Figure 5-13

TightVNC user properties (from www.roborealm.com)



Conclusions:

Various tools were deployed for the prototype to become functional. RoboRealm is strong open-source image processing software that was coupled with TightVNC, as a remote desktop application, through Visual Basic in order to dynamically capture the changes in working environment and react upon it accordingly. However, there are some limitations leading to withdrawal from ultimate conceivable loose-coupling in the prototype.

5-6 Programming

To integrate above-mentioned tools and couple their functionalities, Visual Basic 6 is used as the programming platform. The basic structure of the prototype could be represented by the model shown in figure 5.14.

Visual Basic is used as the central command base which binds together the functionalities of TightVNC and RoboRealm. The program will automatically run the RoboRealm and provided the webcam is appropriately plugged and adjusted, it collect receives the information about which words are identified. Once words are discovered, the program will run TightVNC to take over the target computer and direct the mouse to proper points and proceed with insertion of the related picture.

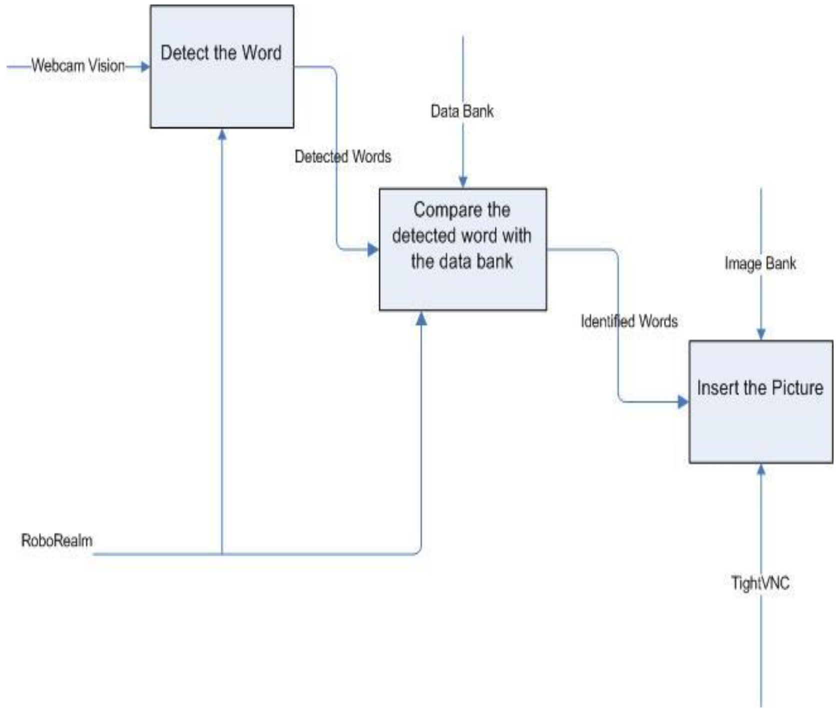


Figure 5-14

Basic process modelling of the prototype

Generally, there are two data-banks from which required information for processing will be retrieved. The first associates with the graphically manipulated snapshots of words that are required to be used by RoboRealm for shape matching.

To cushion the prototype against errors caused by possible deviations from carefully calibrated settings and, therefore, enhance the chance of accurate shape matching, several snapshots of the same words are stored. Below, there are examples of inventorized snapshots.

Figure 5-15

Examples of snapshots of words used for shape

The other data bank is the directory in which relevant would-be inserted pictures are stored. These pictures were casually selected from widely available sources on the net and each visualizes its interlinked word. These pictures are stored in the target computer so that picture insertion can proceed smoothly.

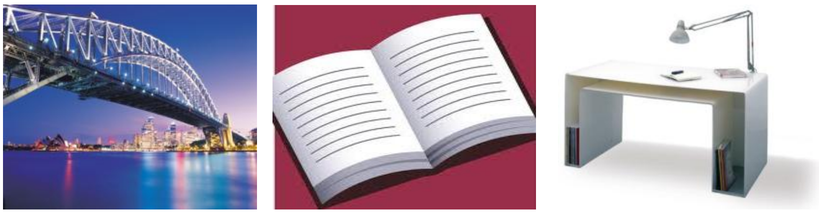


Figure 5-16

Examples of Picture used in Data bank

The main deviation from loose-coupling at the level of programming took place with regard to picture data bank. In the program, I was obliged to embed the address of the directory in which pictures were stored.

5-7 Implementations

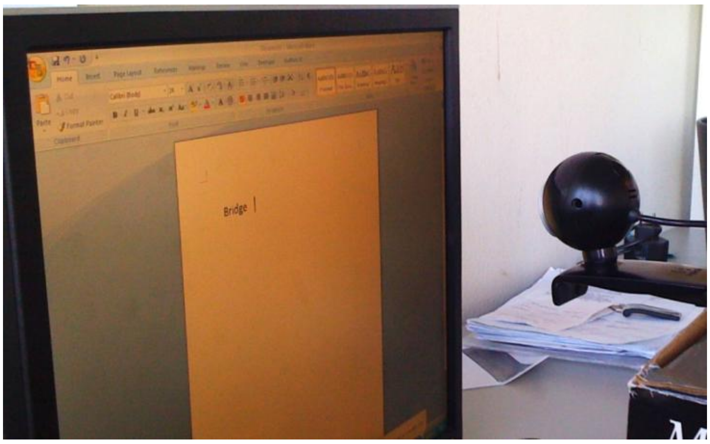
Despite its relatively simple look, the prototype took a good three month to be developed. For it to come to a consummation, several rounds of troubleshooting became necessary. Additionally, first-hand experience of the working with aforementioned tools and their respective potentials and drawbacks has led to alternation of the scope of the design for a few times.

In this section, we will travel along the application implementation step-by-step and will review the mechanism in a full-cycle run of the application.

As a legacy of technical shortcoming, improper webcam and image capturing software, the calibration and setting of the webcam is a time-consuming process. RoboRealm is sensitized only to a certain font and size and, therefore, requires the webcam to be set in a precise location from where the most similar view of words to initial snapshots could be obtained.

Figure 5-17

Webcam Calibration



Upon the successful installation of the webcam, the application could run. VB program will spontaneously activate RoboRealm and the software will look for targeted words on the screen. Each word will become subject to combination of the above-mentioned modules in the same order as mentioned; this process is illustrated in Picture 5.13.

As shown in picture 5.13, the word “bridge” is recognized with more than 90% confidence. The prototype is designed for the detection of only three words. Once the words are detected, it is turn for the VB script to order the detected words in the same sequence as the proceeding actions are required to take place accordingly. The most monumental programming challenge arose at this very point. While the RoboRealm take lower leftmost corner of the screen as the centre of coordinate and return the detected blobs on either X or Y value basis, the common way of reading English passages is to start from upmost left corner of the page to the right to the point that the line finishes and then the next line begins. Ordering the detected blobs, or words, in English reading style was a bit of a challenge which particularly became more difficult taking the usual inevitable tilt of the webcam into account.

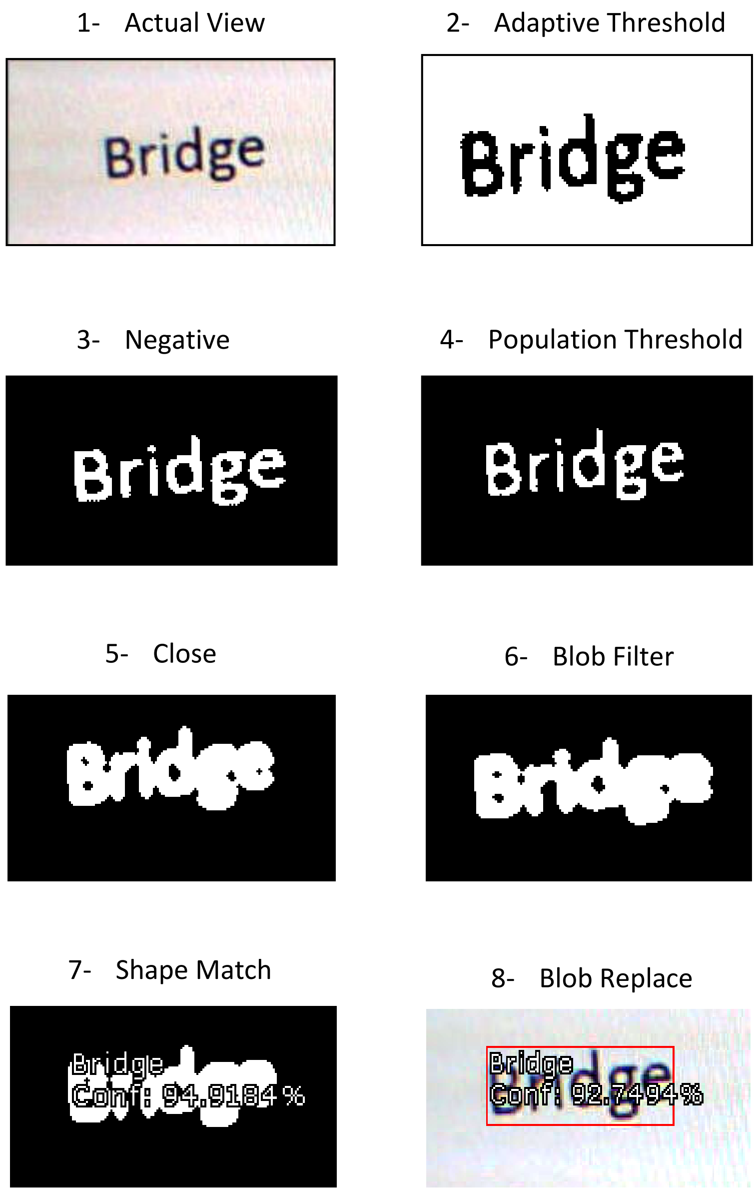


Figure 5-18

RoboRealm Word detection process

As can be seen in figure 5.6, none of possible three options would yield the result correspondent to the English reading style. For this very reason, visual basic module has to re-array the detected blobs. This is done through separate rearranging of all blobs based on their X and reverse Y values. The outcome is stored into two independent string sets.

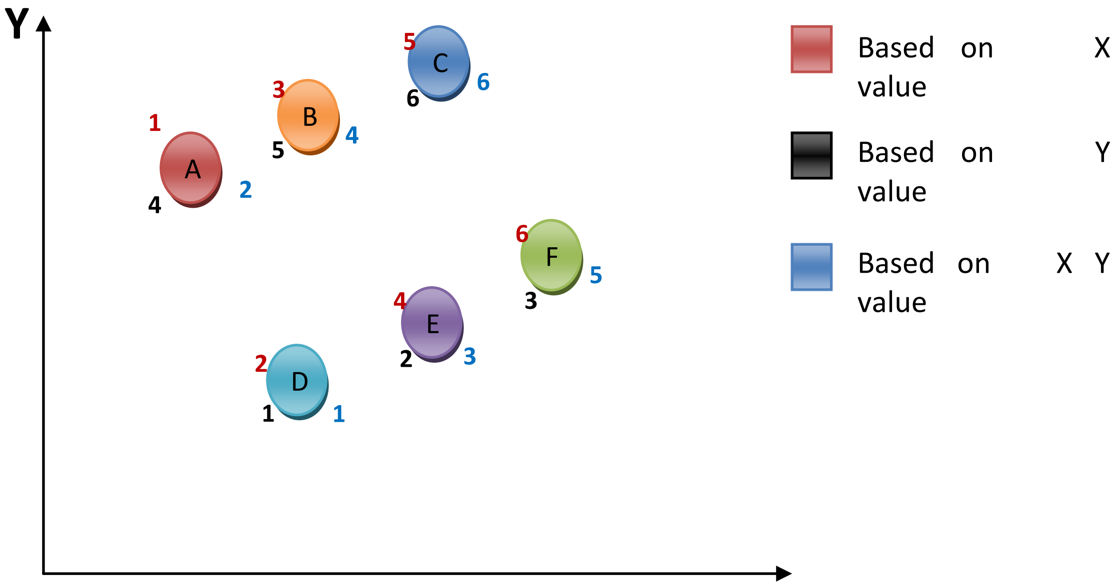


Figure 5-19

RoboRealm diverse arraying mechanism

Next, using either X-based or reverse Y-based set as the base, we can make grouping of words in certain Y-value or X-value neighbourhood. To comprehend this better, take X-value based arranging as the base. The order will be {A, D, B, E, C, F}. By defining the Y-based neighbourhood as ±50 pixels, it would be possible to group {A,B,C} and {D,E,F}. In term of language this grouping means sentence detection. Now that we have identified the sentences, the next step is straightforward, which is to order the blobs in each sentence based on their X-value from the lowest to the greatest. Noteworthy is that the neighbourhood range is solely established to buffer the adverse impact of the webcam tilt and has to be selected in such way that two different sentences are not confused.

Upon completion of correctly arranged array of words, the proceeding actions could be easily made. For this prototype, as mentioned before, the action from the beck-end system is to prompt the VNCTight to take over the target computer and insert the relevant pictures. These pictures are stored on the hard-drive of the target computer; this is another retraction made at the level of prototype that has to be re-structured if the concept of loose-coupling is to be consistently and uniformly effectuated.

The Visual Basic Module will run the TightVNC on the base computer and will take over the keyboard and mouse of the target computer.

Target Computer

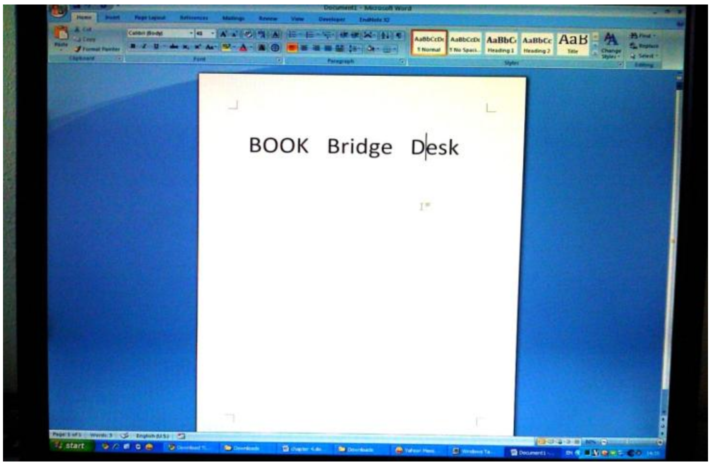
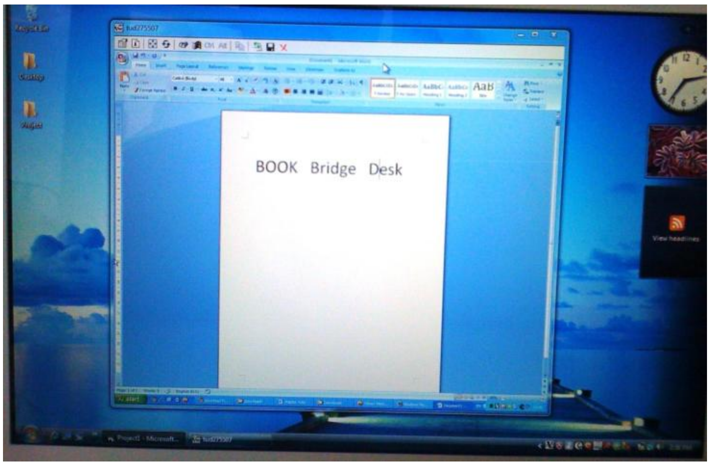


Figure 5-20

TightVNC taking over the target computer

Base Computer



Now that Visual Basic module can control the target computer, and given that the directory of pictures is pre-set in the module, it directs the mouse to Insert and then click on Picture.

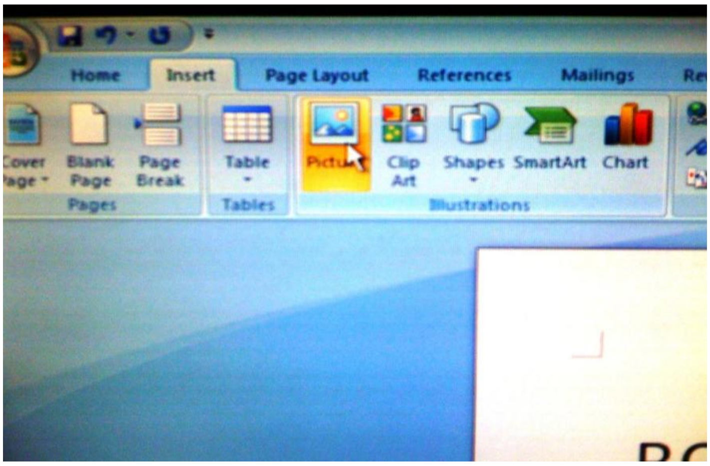


Figure 5-21

Clicking on the insert and Picture buttons

On the insert picture window, it clicks once on the address bar so that it can give the address of the picture directory to Microsoft Word.

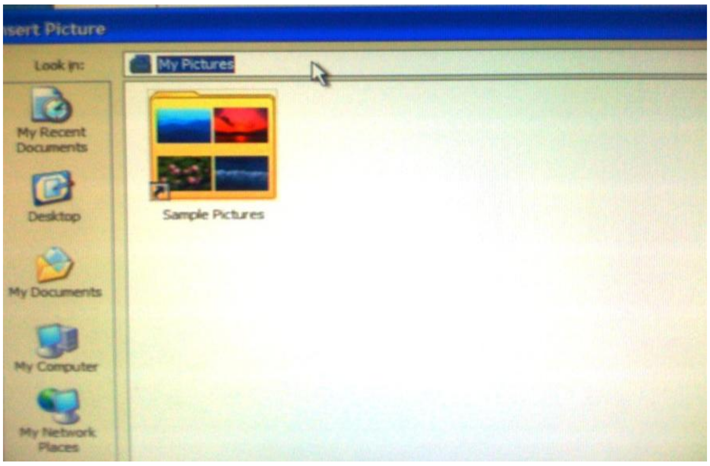


Figure 5-22

Writing the address of the image directory

Once the address is correctly set, it press the enter button starts selecting the pictures in the same order as the words are written.

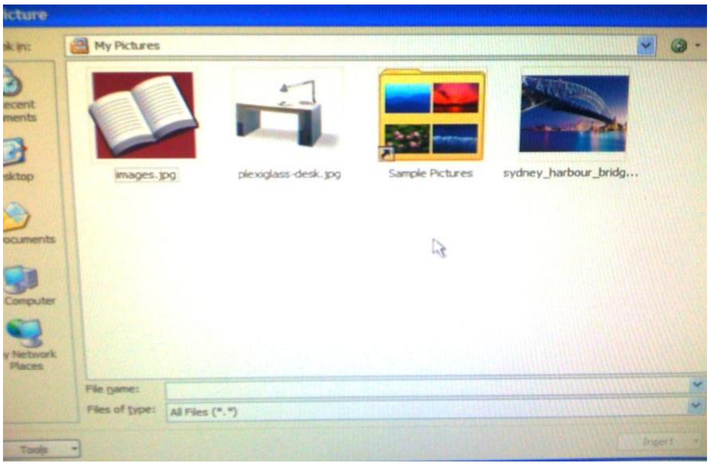


Figure 5-23

Selecting the pictures

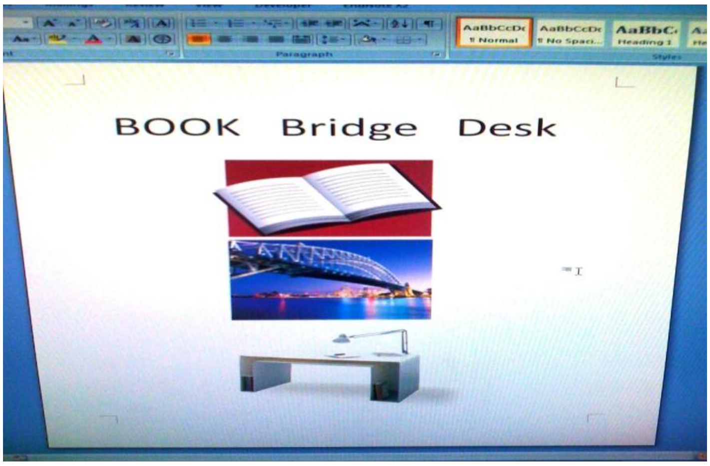


Figure 5-24

Inserting pictures in the right sequence

With the Picture 5-18 realized, the implementation of the prototype is complete and the targeted outcome is achieved.

The prototype is also made applicable in a dynamic environment, in the sense that pictures could be inserted into the word document while they are being written. The application could be run and the webcam could be set on the blank page and while the user initiates the writing, the application keeps operating. As soon as any of the targeted words is detected, the application proceeds with the picture insertion and upon completion remain operational for upcoming words.

Although the application works under the dynamic environment, there remain some bugs and errors coming up majority of which are due to memory capacity issue. Effort has not been made to improve the application's functionality in this environment as it is found to be slightly beyond the scope of prototype development and because the central concept is found to be neatly represented.

In the next section, an evaluation of prototype will be made and its drawbacks will be investigated.

5-8 Evaluation

In this section, a laconic evaluation of the prototype on the basis of the introduced usability metrics will be carried out. As stated before, the below methodology will be deployed to evaluate the interface:

Among the discussed criteria, those pertaining to situation will be dismissed as there is no particular context of use defined for the proposed interface and it has been tried to keep the discussion as much context-free as possible.

Ease of Learning: falling under the category of cognitive features, ease of learning or learnability discusses to which extent the interface needs prior training. The proposed interface requires virtually no training, and provided the philosophy is fully operationalized, the burden of learning is shifted to machine and this is the system that needs to be trained and contextualized as the surrounding context changes or the expected outcomes vary.

Ease of use: as the need for training is omitted, the interface will, in fact, need no particular understanding of its underlying mechanisms and is utterly automated. It is expected that ultimate interface design on the basis of the proposed philosophy is highly acknowledged for its ease of use.

Ease of Relearning: As a rephrasing of ease of remembering, ease of relearning is also a criterion in which the proposed interface is expected to score very high. Again as the intervention of the user in the processing of collected data by the system is minimized, there is actually very little to memorize when deploying this interface.

The above three criteria serve as ample evidences of the interface scoring high on the cognitive dimension. The interface presents a very promising picture of working with a cognitively un-intensive system. Hence, having discussed the physiological impact of cognitive features of an interface on the users' evaluation of the systems' functionality, I believe this interface will have an upper hand compared to its counterparts.

Satisfaction: high subjectivity of this yardstick leaves very little to say without sufficient amount of feedback gained from potential users to whom the prototype is presented. Only a decently organized poll-taking will represent the prototype's success in this criterion. The rigid timeframe of this research left very limited latitude for such an evaluation. Nevertheless, my conjecture is that high adaptability of the interface and the fact that ergonomically it imposes almost no cumber upon the users leaves very little to object.

Flexibility: adaptability and flexibility is the most conspicuous gain of this interface. In the developed concept, it is tried to make a setting-independent interface through deployment of loose-coupling. It is believed the concept will score the highest in this criterion.

Task Match: ostensibly, task match is the criterion at which the concept is the frailest. Task match, as stated before, does not fall immediately among the promises of loose-coupling. It is actually a sacrifice made to gain a higher extent of flexibility. Yet, this most deeply pertains to the coupling at the back-end system. The more robust the connection between the interface and the back-end system is, the more relevant the answer would be. Since the prototype did not include the back-end system loose-coupling within its scope, the judgment on its performance with regard to task match cannot be made.

To condense, as user-friendliness is one of the main goals of this concept and bearing in mind the crowning position of subjective satisfaction in appraisal of the usability, the most reliable justification of the above concept will be obtain only through presentation and experimental implementation of the prototype. Such could not be done with the developed prototype on the ground that it still needs more development before it reachs the implementable level.

- **Conclusions:**

As expected, the prototype features a very promising performance with regard to usability, ease of learning and relearning and flexibility. Subjective satisfaction of users is a criterion which could not be measured without actual implementation and feedback collection from potential users. Finally, task match is the evaluation criterion in which the prototype is expected to score relatively low, for the lack of accuracy as mentioned earlier in previous chapters.

5-8 Chapter Overviews

In this chapter, an extensive conceptual description of the user-friendly loosely-coupled interface was made. Later, the principles of the developed prototype in the light of explained objectives and expectations were clarified. Furthermore, the structure of the developed prototype and tools that made the application possible were introduced.

The scope definition of the prototype is one of the major constituents of this chapter, for it illuminates the limitations and boundaries of the design. It has been highlighted that the prototype is only to demonstrate the performance of the concept in a microcosm and while it actually represents loose-coupling at the front-end, it will remain as a mere maquette for loose-coupling at the back-end system. Once the prototype became operational, the performance became subject to evaluation on the basis of previously discussed criteria.

5-9 Conclusions

There are a handful of concessions that were made with regard to loose-coupling at the front end system. To remove the prototype’s dependence upon particular environment, namely Microsoft Word, a more robust image capture tool will suffice. In fact the structure of the prototype remains very independent of the front-end environment and the only reason for the long calibration process and font sensitivity is the suboptimal device choice. Better technical assets would also make possible to proceed with the picture insertion through the same word detection pattern rather than the existing embedding of coordination and sequence of points to be clicked on.

Finally, the above interface could be perceived as a part of a bigger humanoid project. If this prototype is seen as a humanoid's eye, the concept of loose coupling will be much more readily realized. For instance, the inter-computer connection problem will be completely swept aside as there is no need for any computer to take over another. Instead, the task will be completed through given commands to the robot's hand and the robot will move the mouse to the desired point and also handle the keyboard for any likely scripting requirements.

Overall, the concept is proved to be worthy of more meticulous attentions and serious investment. As far as usability and user-friendliness is concerned, loose-coupling excels far over tight-coupling in majority of evaluation factors. If the expectations from KMS are to provide the user with a direction to coordinate his attentions and effort, then loose-coupling will live up to the expectations as aptly as the tight-coupling is capable of.

As a conclusion to the overall discussion to this very part of the research, loose coupling seems to be of a great value and possesses very promising features for it to be deployed in KMS. It tackles interoperability problem very effectively not mainly through unification of data format but via making the data transfer independent of the format as much as possible. It creates room for in-time knowledge capture through provision of mobility. Loose-coupling serves to enhance KMS mobility and since it ideally deploys human senses, it is capable of capturing knowledge in far deeper layers than a tightly-coupled system can offer. As for crating incentive for implementation and investment, since loose-coupling contributes to maintaining the system applicability for a longer period of time due to its inherent easy modifiability, it is expected to be more alluring for the managers. Additionally, it may appeal to users to a much greater extent as its requirement for pre-introduction training is minimal, and ideally even non-existent. Finally, it is well substantiated by the prototype that loosely-coupled system is capable of offering friendliness beyond the stretch of imagination attributable to the fact that it, again, is using human senses for communication and removes the burden of ergonomic or cognitive acclimatization with the machine-imposed behaviour pattern.

With the concept of the project aptly explained, in the next chapter the author will draw tangible scenarios by which the application of the above interface will be better understood in AEC.

Application in AEC 6

"The concept is expected to carry remarkable implications upon AEC industry provided it is utilized. The KMSs that are being in use in AEC industry will hopefully evolve into more prevalent tools that appeals to a wider range of professionals and is economically justified"

6-1 Introduction

The previous chapters were mainly revolving around explanation of the needs for a new approach to be taken with regard to KMS and subsequently assessment of the loose-coupling concept's fitness for the identified area of frailty in KMS. A Prototype was developed to illustrate the possibility of the concept implementation and also give the impression of how an interface grounded on this concept might differ from tightly-coupled one.

With the above completed, time is to elaborate the possible uses of loosely-coupled interface in AEC industry. This chapter will address this need through exemplification of some of the particularly attuned uses in the industry. One example would be the way a parametric design platform could be affected and boosted by a loosely-coupled interface. This will be supplemented by another example about on-site access to relevant information. The main goal of this chapter is to bring the significant changes that loose-coupling can make in AEC industry into light.

6-2 Research Question Reformulation

The central research question addressed in this chapter would concern the applicability of the proposed interface concept in AEC industry and formulated as following:

How would Loosely-coupled interface contribute to AEC industry?

This question will be addressed through development of simple examples in typical AEC contexts.

6-3 Description of the Examples

The first example would centre on parametric design software. The application is designed to provide the project manager with a rough estimation of the project schedule and cost for a typical faculty building. In this application, while the number of parameters is enough to represent a one-of-a-kind project, they are chosen so that the burden of long form filling is taken away from the users. In the first example, it will be shown how a loosely-coupled interface could alter the application of this software.

The second example is particularly opted to exhibit the mobility that could be achieved in the virtue of the proposed interface concept. Engineers' need of technical information is not spatially bound and they could be in urgent need for help almost anywhere. Negligence or improper response to this need will cause loses of information, delays and even, extremely speaking, project failure. For this reason, the second example will be dedicated to illustrating the changes that could be brought about by the interface concept to the existing trend of information accessing.

The third and the last example would concern designing. Translation of mental picture of a design in form of drawn sketches to CAD systems could be an arduous task. However, the proposed concept is believed to be capable of radically changing the existing pattern. This will be presented in the course of the third example.

6-3-1 Parametric Design software

As stated before, the first example is about utilizing a parametric design application developed to generate rough schedule and cost estimations for a typical university faculty construction. The first step is to get acquainted with how this application works under original design principle and then to show how this could be improved if the proposed interface agent is implemented.
The application will run through a quadruple round of information feeding, each of which requires values relevant to particular determinative parameters. Parameters that are deemed to have

implications on the planning of a project at the targeted level of roughness and their quantifiable indicators are tabulated in table 6.1.

Table 6-1

Determinative Planning Parameters

Category	Parameters	Possible value
General	Capacity	Number
	Area	Number
Structure	External Wall Type	Concrete Brick Glass
	Frame Type	Concrete Steal
Floors	Height	Number
	Number of rooms	Number
	Number of classrooms	Number
Design	Design Constraints	Man power (number) Deadline (number)

As mentioned earlier, the above values are requested from the designer in four steps. the designer is required to fill out the forms step by step.

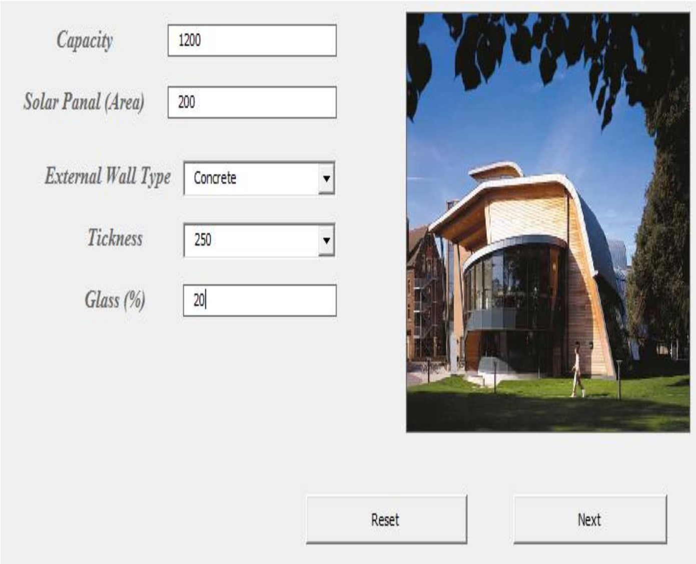


Figure 6-1

Form one in the planning parametric design application

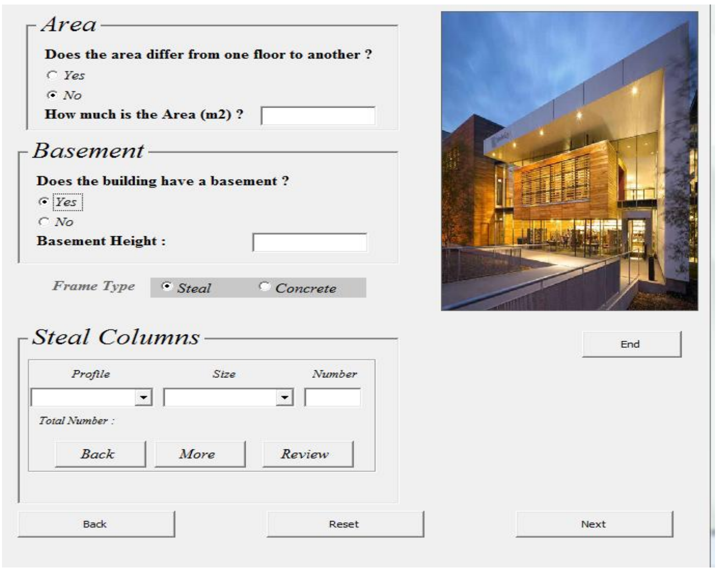


Figure 6-2

Form two in the planning parametric design application

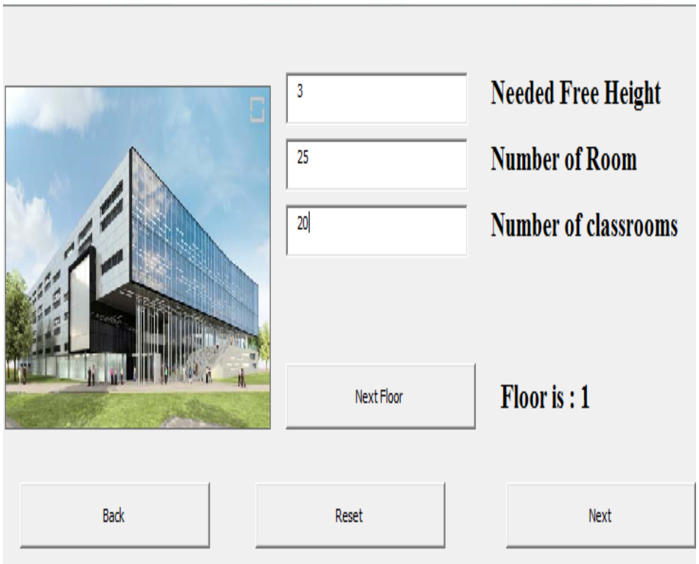


Figure 6-3

Form three in the planning parametric design application

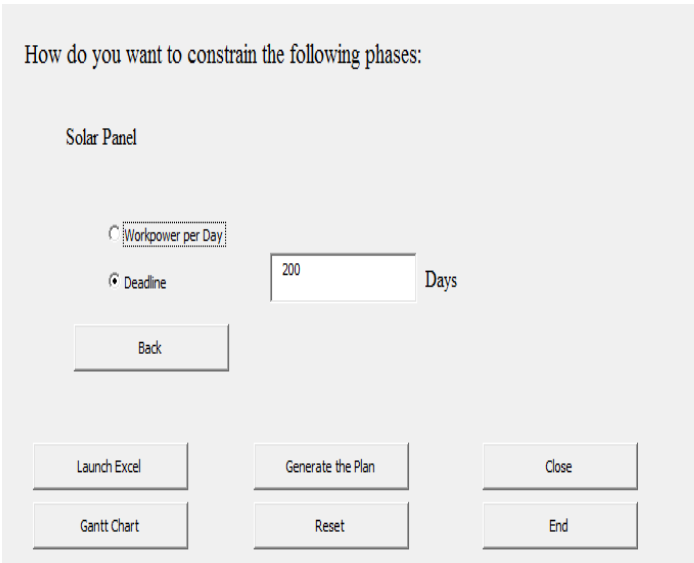


Figure 6-4

Form four in the planning parametric design application

Once the relevant data is filled out in the above forms, the application prompts with analysis and generates the below outcome.

Category	Phases	Duration	Manpower	Cost	Start	Finish
Site preparation						
	Layout	*0days*	**100person**	**0.22 M $**	*1/10/2010*	*1/10/2010*
	Grading	*11days*	**100person**	**1.14 M $**	*1/11/2010*	*1/22/2010*
	Excavation	*58days*	**100person**	**2.7 M $**	*1/23/2010*	*3/22/2010*
Foundation						
	Erect Forms	*16days*	**58person**	**3.36 M $**	*3/23/2010*	*4/8/2010*
	Pour Concrete	*2days*	**9person**	**4.44 M $**	*4/9/2010*	*4/11/2010*
	Remove Forms	*2days*	**14person**	**0.22 M $**	*4/12/2010*	*4/14/2010*
Framing						
	Floor Joists	*247days*	**100person**	**5.18 M $**	*4/15/2010*	*12/18/2010*
	Sub-flooring	*82days*	**100person**	**4.69 M.$**	*12/19/2010*	*3/11/2011*
	Stud Walls	*123days*	**100person**	**1.48 M.$**	*3/12/2011*	*7/13/2011*
	Frame Roof	*12days*	**100person**	**0.48 M.$**	*7/14/2011*	*7/26/2011*
Utilities						
	Electrical	*2days*	**101person**	**0.23 M.$**	*7/27/2011*	*7/29/2011*
	Plumbing	*11days*	**222person**	**0.74 M.$**	*7/30/2011*	*8/10/2011*
	Gas	*5days*	**138person**	**0.24 M.$**	*8/11/2011*	*8/16/2011*
Walls						
	Hang sheetrock	*8days*	**100person**	**0.43 M.$**	*8/17/2011*	*8/25/2011*
	Tape and bed	*20days*	**100person**	**0.1 M.$**	*8/26/2011*	*9/15/2011*
Roofing						
	Install sheathing	*10days*	**111person**	**0.48 M.$**	*9/16/2011*	*9/26/2011*
	Lay shingles	*10days*	**185person**	**0.5 M.$**	*9/27/2011*	*10/7/2011*
Finish Work						
	Interior	*37days*	**100person**	**4.55 M.$**	*10/8/2011*	*11/14/2011*
Solar Panel		*20days*	**0person**	**0.4 M.$**	*11/15/2011*	*12/5/2011*

Table 6-2

The application's outcome

However, running this application and similar applications would require extraction of information from various documents, paper forms, tables etc.

This application is supposed to run based on a simple project description handed out amid potential contractors to structure their bidding documents accordingly. Users are expected to extract the relevant values from the document and transfer it to the application. With the loosely-coupled interface agent proposed in this research the scenario will change as following. While the target user is browsing the document in consideration a vision source, a webcam for instance, will scan the document. If the document resembles the archetype given in picture 6.5, in content and layout, then the image processing will help detect key words and their respective values. The interface agent will be able to suggest the relevant parametric design application as the back-end system and prompt the values into the software. Subsequently, the project's schedule, table6.2, will be presented to the user. As explained, the outcome will be generated with no or minimum intervention of the user.

The loosely-coupled interface will be able to pinpoint the essential words through text parsing method and proceed with automatic filling of the form.

As stated before, this is much more user-friendly as the intervention of the users is minimized if not eliminated. Additionally, application of computer-vision as a loosening means will render the application format-independent, meaning that for the parametric design application to run the document needs not to be of a particular format or type. This will contributes to enhanced interoperability. In terms of usability or cognitive features, also, a quick look upon measuring indexes, fewer errors and easy recovery, ease of using and remembering and learnability, reveals that loosely-coupled interface would have a superior position as it requires minimal memorization and user intervention. Despite its highly subjective nature, affective features of this method are also expected to outscore that of a tightly-coupled system.

Description of the project:

A new faculty in the University of Xxx is planned to be constructed. The building is expected to host over 2000 student and staff at its full capacity. The building is designed to have concrete frame with pre-fabricated columns and slabs. The size of columns are roughly estimated and appended below. For sustainability reasons, a total of 200 m^2 solar has to be installed in the building. The estimated figures of the building are enumerated below:

Total Area: 20000 m^2

External wall type: 200mm bricks of which 20% should be assigned to window installation

Parking: a parking with 4 m height is desired to be allocated in the basement area

Column Specification:

Shape	Size	Quantity
Rectangular	20×20	10
Rectangular	25×25	35
Rectangular	40×40	12
Circular	R= 20	18
Circular	R= 25	17
Circular	R= 40	22

Floors Specification:

Floor	Height	Rooms	Classrooms
1st	6	10	5
2nd to 4th	3	25	4
5nd to 10th	3	20	5

Figure 6-5

Project information excerpt (page 1)

Design Constraints:

Phase	Restriction
Site preparation	120 manpower
Foundation	20 Days
Framing	200 manpower
Utilities	30 Days
Walls	20 days
Afterwards	100 manpower

Figure 6-6

Project information excerpt (page 2)

6-3-2 on-site Information Access

As stated before, the need for information is independent of time and space. A professional may be in urgent need of relevant information for making decisions. The conventional tight-coupling would require access to the full system within which information is embedded at any moment. Therefore, access to information is dependent on the mobility offered by the system itself. However, loosely-coupled interface would provide the opportunity not only to acquire data in manifold forms but also to access to the relevant information without physical access to the database. To elaborate this, an example would be of a great help.

A site inspection engineer is assigned to regularly monitor the progress of a building project. Conventionally, the engineer was expected to keep all relevant plans, detail and specification tables at his reach to master the work.

Figure 6-7

Conventional site inspection (from accessconstruction .co.uk)

Inarguably, this is a time-consuming and very error-prone way to inspect. With the advent of portable computers and laptops, the complexion has slightly changed in the recent years. The engineer can avail himself of much wider range of information stored on the computer and can even access information stored in a remote knowledge-base via network connection. This is an instance of loosened coupling at the back-end system on a miniature scale. Portable computers have been a breakthrough in removing the constraint of physical access to the data-center.

Figure 6-8

Conventional site inspection (from fgscmt.com)

The second fashion is looser in the sense that inhibition to carry information source is removed and remain relatively tight as the interaction has to remain in computer-imposed culture and also since the network connection is usually capable to connect to one source of pre-defined or user-defined knowledge-base.

Now let's see how the proposed interface may function in the above circumstance. The interface could be installed on a camera-equipped cell phone whose camera serves as the vision source for the interface agent. If the cell phone is pointed to a particular object about which information is required, the above illustrated mechanism would be able to interpret the context and proceed with some suggestions on possible information you can be provided with. For further clarity, imagine that a professional structural engineering is inspecting the site under construction. It is very likely that he needs information on stress distribution in a certain column to make sure that the properties of the bar selected for the place is precise. Instead of digging up piles of planes to pinpoint where the information lies or otherwise delving into computer files and folder, he would be able to point his webcam at the destined piece and review the technical specifications in real-time in an augmented-reality environment.

This is an instance of loose-coupling deployed at the front-end and it is not a far-fetched technology as the similar applications following the same principle in other areas are surfacing recently; to mention some, augmented reality Spanish-English translator app in iphone and, on a larger scale, Six-sense technology developed by Pattie Maes from Media lab at MIT university could be mentioned.

Figure 6-9

Augmented-reality application based on loose coupling concept

The proposed interface agent is ideally capable of maintaining loose-coupling at the back-end system alike. To put this into perspective, in the above example, the interface agent is not directly connected to any particular data-base for information mining but could give an array of options to the user ranging from structural to thermal properties of the bar in consideration. It could also advise at a much greater level and look into region-sensitive data available on the net in quest for information on whether or not the installed piece has any reported cause of trouble in similar projects.

6-3-3 Sketch recognition and Designing

Another possible area of loosely-coupled interface use in AEC industry is designing. As mentioned above, transformation of a hand drawn sketch of a building into CAD design is a time consuming process. The loosely-coupled interface provides a way to alleviate the process. It is imaginable that the same vision-based interface is capable of tracking the drawing on a piece of paper and dynamically translate it into CAD-based designed in real-time. This embodiment of the notion is probably the most attended and exemplified in literature (Masry and Lipson, 2005; Decortis et al., 2006 ; Kara et.al, 2006) .

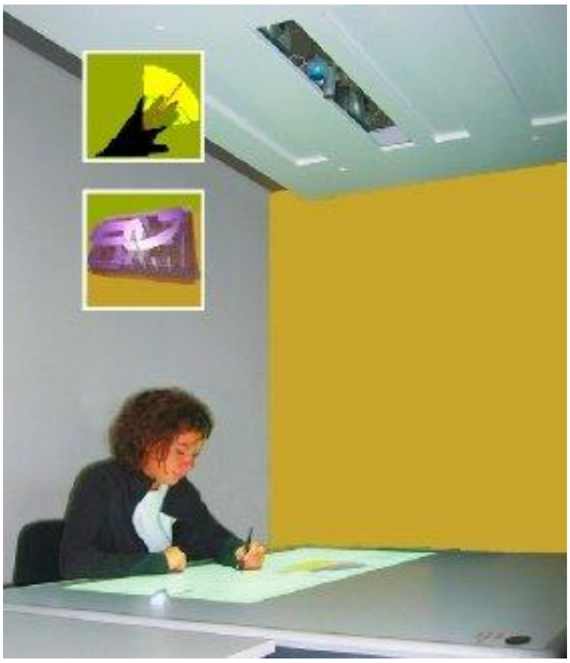


Figure 6-10

Virtual Desk designed by LUCID lab (from www.arch.ulg.ac.be)

This is also presumed to outscore in terms of user-friendliness judged based on previously discussed indicators. As can be discerned in picture 6.10, in the loosely-coupled environment, mental pictures just required to be sketched on a surface for it to become automatically transferred into computerized design.

6-4 Chapter Overview

In this chapter, the possible use of the interface concept and the way it might change the current information and knowledge management practices in the AEC industry.

There examples where drawn in the course of which as-is and to-be information management processes in different contexts were illustrated and conjectured.

6-5 Conclusions

It is well expected that, if the users' expectations are adjusted to the limitations and possibilities of loose-coupling, the concept could open up a new era of KMS design in AEC industry.

It is strongly hoped that loosely-coupled interface is capable of circulating information very smoothly and remove spatio-temporal access limitation so that everyone can avail him/herself of relevant information anywhere and at anytime.

Similarly, loose-coupling is predicted to be a breakthrough in making KMS appealing to wider demographics and economically justified.

In the next chapter, in addition to general summery and possible area of further research, the overall conclusion of the report will be presented.

Conclusions

7

"Loosely-coupled design methodology is a novel approach towards KMS design . it is expected that the proposed concept could provide a large solution area for common KMS barriers, particularly in AEC industry. However, it is well established at the benefits of loosely-coupled interface will come at the price of accuracy reduction. Therefore, for this problem to be tackled more exhaustive research is required"

7-1 Introduction

In this chapter, the entire research will be encapsulated in a general summery section. This will be accompanied by conclusions drawn in the light of the outcome of this research. Finally, the area for future research possibilities and needs will be discussed and identified.

7-2 General Summery

The central research objective is to propose loose-coupling design paradigm and concept as a solution to existing problems and barriers which deters frequent application of knowledge management systems particularly in AEC industry.

To fulfil the research objectives, the report begins with elaboration of the meanings and interpretation of knowledge. Knowledge definition later leads to better understanding of the scope and goals of knowledge management in organizations. Later, through delineating IT and KM, the knowledge management systems were introduced and this was further used to identify the many barriers which would let managers, employees, engineers and designers to make effective use of these systems.

Following the identification of documented problem pertaining to KMS, it was tried to propose loose-coupling concept as a solution. However, prior to do so, the need for determining the requirements and features of a good application was felt. This exigency led to composition of the third chapter on the usability engineering and evaluation criteria for applicable and decent information and knowledge systems.

Subsequently, the concept of loose-coupling was introduced and it discrepancies with conventional tight-coupling methodology was scrutinized. In the fourth chapter, the reasons why a loose-coupling could serve as a solution was enumerated and discussed. Once loose-coupling potentials as a solution was implicated, the research continued to conceptually design a loosely-coupled interface.

To furnish the readers with a more tangible example of loose-coupling, and similarly to bring into light the limitation of the concept, a prototype was particularly designed for this research. The fifth chapter was exclusively assigned to the description of the prototype's goals and scope. Several concessions that were made as a result of lack of necessary resources and expertise with regards to implementation of loose-coupling in the prototype were elaborately discussed in the same chapter. Finally, along with the readers, the research journeyed through the full run of the prototype.

Having felt that the implications of the proposed solution on AEC industry is not properly explained, the author illustrated the possible changes an interface designed based on loose-coupling concept can make in the industry. This was covered in the sixth chapter through making three examples of as-is and to-be scenarios in various AEC contexts.

As a consummation to the main argument of this research, the next section will elaborate on the conclusion of the research.

7-3 Conclusions

The research was a scientific endeavour to identify and seek solutions for problem areas in knowledge management systems (KMS) in Architecture, Engineering and construction industry (AEC). The main hypothesis was that an enhanced human-computer interface could offer a great possibility for strengthened application of KMS in AEC.

The indubitable need for further investigation and more in-depth research notwithstanding, loose-coupling concept is concluded to be able to revolutionize KMS design and push back the frontier of its role in AEC industry. It is strongly expected that loose-coupling will be a huge leap forward in provision of incentive for managers through prolonging the lifespan of KMS applicability and proliferating its adaptability. Since loose-coupling minimizes the need for training, it is predicted to have the same positive effect on employees through making them more willing to accept new technologies.

The concept contributes to making information more accessible than ever before and heralds an epoch when time and space are no constraints to acquisition of right and relevant information. This could be of particular interest in AEC industry where information abounds and it is frequently needed for inspection and design readjustment.

The prototype illustrated that loose-coupling at the front-end system is plausible and readily achievable if the design mindset is properly attuned to the concept of loosened coupling between the environment and system. With regard to the back system, also, although the prototype dispensed with embedding loose-coupling at the back-end, it is strongly believed that the same principle could be used to make possible the use of more variegated and eclectic knowledge-bases at any time.

It became clear that the transition towards loose-coupling is commensurate with moving from a precise ad-hoc problem-solving system towards a versatile suggestion-giving agent; for the depletion of accuracy. However, the problem of accuracy is also expected to be resolved once the interface is perceived more like an intermediating intelligent agent in which heuristics and learning mechanisms are embedded. As stated before, although notion of loose-coupling is originally linked only very remotely to humanized interface design principles, it is ostensibly best achieved if human-human interaction is used as a model. With this in mind, it seems to be fairly sensible to say that the system needs to acquire accuracy instead of having it embedded, exactly the same way as human does.

Additionally, Loose-coupling will address the issue of interoperability very effectively. Through decreasing dependencies upon particular format, and as mentioned before at the cost of less ad-hocness, the system design on this concept is capable of readily adapt to different contexts and function in a wider area. This is one of the main advantages of the loosely-coupled system in AEC industry; for the industry encompasses a wide range of disciplines and highly segmented data formats.

Also, it shall be mentioned, that loose coupling should not be confused with total independence of the module but it is a relevant concept, meaning that if we decrease the degree of dependence we will gain more adaptability and interoperability at the cost of lessened accuracy. Therefore, the confusion shall be seriously avoided that loose-coupling is an new method for the conventional gaol of creating an omniscient knowledge management systems, but rather it has to perceived as a way to gain more flexibility at a lower cost.

Nevertheless, it is worth reiteration that this interface could be seen as a part of a bigger humanoid project. As stated before, in this case the prototype could be considered as a fraction of total functionality of the eye of this humanoid. This will help to eradicate many of previously mentioned concessions made in the prototype design; since the prototype is expected to be well equipped with other human senses such as hearing and touching and capabilities such as motion.

7-4 Recommendations

In the light of the finding of this research, some recommendations could be posited. Most significantly, as mentioned before, systems designers and engineers are highly advised to give loose-coupling the weight it deserves in their design mentality. Designers are well recommended to escalate the latitude for extensibility through minimizing the inter-module dependencies and loosening the coupling between systems’ components.

Humanization of human-computer strikes as having huge potentials not only for increasing the lure of applications for target users, but also for loosening the coupling with the front-end, as a result of which a wider range of possible interaction patterns could be covered.

Moreover, further research in the area of loose-coupling at the back-end is recommended. Loose-coupling at the back-end will eventuate in a wider range of information sources becoming available at any moment.

Finally, novice readers are advised to refrain from the misconception that loose-coupling is a design philosophy leading to an omniscient system but instead they have to view this notion as an endeavour to make the most efficient use of available information in a due fashion in various contexts.

7-5 Further Research Areas

Further research could be carried out in the area of loose-coupling at the back-end system. As overtly repeated in the report, the current prototype dispenses with implementation of loose-coupling at the back-end system due to lack of resources and limited timeframe.

Although, some conceptual design was made for back-end system, it barely suffices to fulfil the expectation for a decent design. More in depth studies could be conducted on identification of interface-knowledge-based systems communication and possible ways to decrease the dependencies at that frontier.

Another possible area of research could be methods to provide the system with other human senses, particularly hearing and touch. The combination of research in these areas and the current study will help gain a solid ground for more serious efforts for the actual implementation of the interface in the business.

Finally, since the current prototype is lacking context-recognition mechanisms, mainly to lack of background knowledge of the author and tight timeframe, ways to make the current prototype context-aware and intelligent could be conducted. This will complete the learning capability and will make possible to increase the accuracy of the concept.

7-6 Reflection:

In course of developing the above research, several challenges were faced. Most strikingly, lack of sufficient literature on the intended degree of abstraction has forestalled the progress of the research. The notion of loose-coupling is very much at its infancy still and therefore rich referable resources were in scarcity.

Another inhibition was time and financial resources required for the prototype development. Had better computer vision tool been available, the prototype would have been much looser in essence and mire robust in performance.

Interdisciplinarity of the topic had a mixed effect on the research and the researcher alike. The author felt incompetent at times, for he found some areas novel and new. Yet, the research carried on with a good spirit and the author managed to lift the barriers with iron conviction to learn and proceed. The same fact helped the author not to be victimized and hampered by monotony of the research area. The research was a journey across a wide spectrum of disciplines and premises and allowed the author to decipher his real interests and capabilities for future studies.

Similarly, venturing into an area so fresh and unexplored has fuelled the author with a relentless zeal and motivation. Consummation of the report aroused noting but deep gratification and satisfaction in the author.

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Appendixes

The Prototype’s script will be presented in the appendixes. It is an application written in Microsoft Visual Basic 6 environment.

```
Option Explicit
Private Declare Sub mouse_event Lib "user32" (ByVal dwFlags As Long, ByVal dx As Long, ByVal dy As Long, ByVal cButtons As Long, ByVal dwExtraInfo As Long)
Private Declare Function SetCursorPos Lib "user32" (ByVal x As Long, ByVal y As Long) As LongPrivate Declare Function FindWindow Lib "user32" Alias "FindWindowA" (ByVal lpClassName As String, ByVal lpWindowName As String) As Long
Private Declare Function PostMessage Lib "user32" Alias "PostMessageA" (ByVal hwnd As Long, ByVal wMsg As Long, ByVal wParam As Long, lParam As Any) As Long
Private Declare Sub Sleep Lib "kernel32" (ByVal dwMilliseconds As Long)
Dim char(1 To 1000) As String
Private Const MOUSEEVENTF_LEFTUP = &H4
Private Const MOUSEEVENTF_LEFTDOWN = &H2
Private Const MOUSEEVENTF_MIDDLEDOWN = &H20
Private Const MOUSEEVENTF_MIDDLEUP = &H40
Private Const MOUSEEVENTF_RIGHTDOWN = &H8
Private Const MOUSEEVENTF_RIGHTUP = &H10
Private Const MOUSEEVENTF_MOVE = &H1
Const VK_LBUTTON = &H1
Const VK_RBUTTON = &H2
Const VK_CANCEL = &H3
Const VK_MBUTTON = &H4
Const VK_BACK = &H8
Const VK_TAB = &H9
Const VK_CLEAR = &HC
Const VK_RETURN = &HD
Const VK_SHIFT = &H10
Const VK_CONTROL = &H11
Const VK_MENU = &H12
Const VK_PAUSE = &H13
Const VK_CAPITAL = &H14
Const VK_ESCAPE = &H1B
Const VK_SPACE = &H20
Const VK_PRIOR = &H21
Const VK_NEXT = &H22
Const VK_END = &H23
Const VK_HOME = &H24
Const VK_LEFT = &H25
Const VK_UP = &H26
Const VK_RIGHT = &H27
Const VK_DOWN = &H28
Const VK_SELECT = &H29
Const VK_PRINT = &H2A
Const VK_EXECUTE = &H2B
Const VK_SNAPSHOT = &H2C
```

```
Const VK_INSERT = &H2D
Const VK_DELETE = &H2E
Const VK_HELP = &H2F
Const VK_0 = &H30
Const VK_1 = &H31
Const VK_2 = &H32
Const VK_3 = &H33
Const VK_4 = &H34
Const VK_5 = &H35
Const VK_6 = &H36
Const VK_7 = &H37
Const VK_8 = &H38
Const VK_9 = &H39
Const VK_A = &H41
Const VK_B = &H42
Const VK_C = &H43
Const VK_D = &H44
Const VK_E = &H45
Const VK_F = &H46
Const VK_G = &H47
Const VK_H = &H48
Const VK_I = &H49
Const VK_J = &H4A
Const VK_K = &H4B
Const VK_L = &H4C
Const VK_M = &H4D
Const VK_N = &H4E
Const VK_O = &H4F
Const VK_P = &H50
Const VK_Q = &H51
Const VK_R = &H52
Const VK_S = &H53
Const VK_T = &H54
Const VK_U = &H55
Const VK_V = &H56
Const VK_W = &H57
Const VK_X = &H58
Const VK_Y = &H59
Const VK_Z = &H5A
Const VK_STARTKEY = &H5B
Const VK_CONTEXTKEY = &H5D
Const VK_NUMPAD0 = &H60
Const VK_NUMPAD1 = &H61
Const VK_NUMPAD2 = &H62
Const VK_NUMPAD3 = &H63
Const VK_NUMPAD4 = &H64
Const VK_NUMPAD5 = &H65
Const VK_NUMPAD6 = &H66
Const VK_NUMPAD7 = &H67
Const VK_NUMPAD8 = &H68
```

```
Const VK_NUMPAD9 = &H69
Const VK_MULTIPLY = &H6A
Const VK_ADD = &H6B
Const VK_SEPARATOR = &H6C
Const VK_SUBTRACT = &H6D
Const VK_DECIMAL = &H6E
Const VK_DIVIDE = &H6F
Const VK_F1 = &H70
Const VK_F2 = &H71
Const VK_F3 = &H72
Const VK_F4 = &H73
Const VK_F5 = &H74
Const VK_F6 = &H75
Const VK_F7 = &H76
Const VK_F8 = &H77
Const VK_F9 = &H78
Const VK_F10 = &H79
Const VK_F11 = &H7A
Const VK_F12 = &H7B
Const VK_F13 = &H7C
Const VK_F14 = &H7D
Const VK_F15 = &H7E
Const VK_F16 = &H7F
Const VK_F17 = &H80
Const VK_F18 = &H81
Const VK_F19 = &H82
Const VK_F20 = &H83
Const VK_F21 = &H84
Const VK_F22 = &H85
Const VK_F23 = &H86
Const VK_F24 = &H87
Const VK_NUMLOCK = &H90
Const VK_OEM_SCROLL = &H91
Const VK_OEM_1 = &HBA
Const VK_OEM_PLUS = &HBB
Const VK_OEM_COMMA = &HBC
Const VK_OEM_MINUS = &HBD
Const VK_OEM_PERIOD = &HBE
Const VK_OEM_2 = &HBF
Const VK_OEM_3 = &HC0
Const VK_OEM_4 = &HDB
Const VK_OEM_5 = &HDC
Const VK_OEM_6 = &HDD
Const VK_OEM_7 = &HDE
Const VK_OEM_8 = &HDF
Const VK_ICO_F17 = &HE0
Const VK_ICO_F18 = &HE1
Const VK_OEM102 = &HE2
Const VK_ICO_HELP = &HE3
Const VK_ICO_00 = &HE4
```

```
Const VK_ICO_CLEAR = &HE6
Const VK_OEM_RESET = &HE9
Const VK_OEM_JUMP = &HEA
Const VK_OEM_PA1 = &HEB
Const VK_OEM_PA2 = &HEC
Const VK_OEM_PA3 = &HED
Const VK_OEM_WSCTRL = &HEE
Const VK_OEM_CUSEL = &HEF
Const VK_OEM_ATTN = &HF0
Const VK_OEM_FINNISH = &HF1
Const VK_OEM_COPY = &HF2
Const VK_OEM_AUTO = &HF3
Const VK_OEM_ENLW = &HF4
Const VK_OEM_BACKTAB = &HF5
Const VK_ATTN = &HF6
Const VK_CRSEL = &HF7
Const VK_EXSEL = &HF8
Const VK_EREOF = &HF9
Const VK_PLAY = &HFA
Const VK_ZOOM = &HFB
Const VK_NONAME = &HFC
Const VK_PA1 = &HFD
Const VK_OEM_CLEAR = &HFE
Const KEYEVENTF_EXTENDEDKEY = &H1
Const KEYEVENTF_KEYDOWN = &H0
Const KEYEVENTF_KEYUP = &H2
Private Declare Sub keybd_event Lib "user32.dll" (ByVal bVk As Byte, ByVal bScan As Byte, ByVal
dwFlags As Integer, ByVal dwExtraInfo As Integer)

Private Declare Function GetCursorPos Lib "user32" (lpPoint As pointapi) As Long
Private Type pointapi
x As Long
y As Long
End Type
Dim rowa As Integer
Dim columna As Integer
Dim r As Integer
Dim rr
Dim v As String
Dim p As Integer
Dim validwords1(1 To 100) As String
Dim validwords2(1 To 100) As String
Dim validwordsnumber As Integer
Dim lastrow As Integer
Dim lastitem As Integer
-----------------------------------------------------------------------------------------------------------------------
Private Sub Command1_Click()
Dim c(1 To 10) As Integer
Dim n As Integer
Dim h As pointapi
```

```
GetCursorPos h
c(1) = 135 - h.x
c(2) = 27 - h.y
For n = 1 To 100
SetCursorPos (h.x + n * (c(1) / 100)), (h.y + n * (c(2) / 100))
Sleep (15)
Next n
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
Sleep (300)
GetCursorPos h
c(3) = 217 - h.x
c(4) = 80 - h.y
For n = 1 To 100
SetCursorPos (h.x + n * (c(3) / 100)), (h.y + n * (c(4) / 100))
Sleep (15)
Next n
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
Sleep (300)
GetCursorPos h
c(5) = 344 - h.x
c(6) = 45 - h.y
For n = 1 To 100
SetCursorPos (h.x + n * (c(5) / 100)), (h.y + n * (c(6) / 100))
Sleep (15)
Next n
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
Sleep (300)
GetCursorPos h
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
c(7) = 100 - h.x
c(8) = 45 - h.y
For n = 1 To 100
SetCursorPos (h.x + n * (c(7) / 100)), (h.y + n * (c(8) / 100))
Sleep (15)
Next n
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
Sleep (300)
keybd_event VK_H, 0, 0, 0 ' press H
keybd_event VK_H, 0, KEYEVENTF_KEYUP, 0 ' release H
keybd_event VK_E, 0, 0, 0 ' press E
keybd_event VK_E, 0, KEYEVENTF_KEYUP, 0 ' release E
keybd_event VK_L, 0, 0, 0 ' press L
keybd_event VK_L, 0, KEYEVENTF_KEYUP, 0 ' release L
```

```
keybd_event VK_L, 0, 0, 0 ' press L
keybd_event VK_L, 0, KEYEVENTF_KEYUP, 0 ' release L
keybd_event VK_O, 0, 0, 0 ' press O
keybd_event VK_O, 0, KEYEVENTF_KEYUP, 0 ' release O

End Sub
Private Sub end_Click()
End
End Sub
Private Sub FindWord()
On Error Resume Next
Dim Word As Object
Set Word = GetObject(, "Word.Application")
If Word Is Nothing Then
'not running
r = 0
Else
'running
r = 1
End If
End Sub
Private Sub Form_Load()
Dim h As pointapi
Dim i As Integer
Dim riv As Long
Dim ret As Variant
Dim rt As Integer
Dim cy(1 To 30) As Long
Dim nn As Integer
Dim fword As Object
Dim worddoc As Word.Document
FindWord
If r = 0 Then
Set fword = CreateObject("word.application")
fword.Visible = True
fword.Documents.Add
Set worddoc = fword.ActiveDocument
'worddoc.InlineShapes.AddPicture FileName:="c:\Users\Public\Pictures\Sample Pictures\Dock.jpg"
Else
Set fword = GetObject(, "word.application")
Set worddoc = fword.ActiveDocument
'fword.ActiveDocument.InlineShapes.AddPicture FileName:="c:\Users\Public\Pictures\Sample
Pictures\Dock.jpg"
End If
  Set rr = CreateObject("RoboRealm.API.1")
  ' open RoboRealm if not already running
  rr.Open "c:\Program Files\RoboRealm\RoboRealm.exe", 6060
  If Not rr.Connect("localhost") Then
    MsgBox "OK", vbOKOnly, "Could not connect to RoboRealm Server"
```

```
        Exit Sub
    Else
    rr.LoadProgram "C:\Users\farid\Desktop\project\robo\goood.robo"
Sleep (5000)
Dim e As String
Dim shape(1 To 50, 1 To 9) As Double
'MsgBox "" & rr.GetVariable("IMAGE_COUNT")
'MsgBox "" & rr.GetVariable("SHAPE_FILENAME") & "" & rr.GetVariable("SHAPE_CONFIDENCE")
'MsgBox "" & rr.GetVariable("SHAPES_PATH")
e = rr.GetVariable("shapes")
'MsgBox "" & e
rr.LoadProgram "C:\Users\farid\Desktop\project\robo\goood.robo"
v = rr.GetVariable("number")
If v = "" Then
rowa = 0

     lastrow = 1
     lastitem = 0
Else
'MsgBox " number =    " & v
'If rr.GetVariable("SHAPE_CONFIDENCE") > 90 Then
'fword.ActiveDocument.InlineShapes.AddPicture           FileName:="c:\Users\Public\Pictures\Sample
Pictures\3029129-Zubizuri_Bridge_at_night-Bilbao.jpg"
'End If
Dim cc As Integer
Dim ii As Integer
Dim c As Integer
sep_string (e)
For i = 1 To v
For c = 1 To 9
shape(i, c) = Val(char((i - 1) * 9 + c))
'MsgBox "shape (" & I & "," & c & ") =" & shape(I, c)
Next c
Next i
Dim y As Integer
Dim x As Integer
For x = 1 To 9
'MsgBox "" & shape(x, 9)
Next x
' reOrdering y max to min
Dim y_order(1 To 50, 1 To 9) As Long
Dim yy_order(1 To 50, 1 To 9) As Long
For i = 1 To v
For c = 1 To 9
y_order(i, c) = shape(i, c)
yy_order(i, c) = shape(i, c)
Next c
Next i
For c = 2 To v
i = 1
```

```
Do While i < c
If y_order(c, 6) > y_order(i, 6) Then
For y = i + 1 To c
For x = 1 To 9
yy_order(y, x) = y_order(y - 1, x)
Next x
Next y
For x = 1 To 9
yy_order(i, x) = y_order(c, x)
Next x
For ii = 1 To v
For cc = 1 To 9
y_order(ii, cc) = yy_order(ii, cc)
Next cc
Next ii
i = c + 1
Else
i = i + 1
End If
Loop
Next c
  ' reOrdering x min to max
Dim x_order(1 To 50, 1 To 9) As Long
Dim xx_order(1 To 50, 1 To 9) As Long
For i = 1 To v
For c = 1 To 9
x_order(i, c) = shape(i, c)
xx_order(i, c) = shape(i, c)
Next c
Next i
For c = 2 To v
i = 1
Do While i < c
If x_order(c, 4) < x_order(i, 4) Then
For y = i + 1 To c
For x = 1 To 9
xx_order(y, x) = x_order(y - 1, x)
Next x
Next y
For x = 1 To 9
xx_order(i, x) = x_order(c, x)
Next x
For ii = 1 To v
For cc = 1 To 9
x_order(ii, cc) = xx_order(ii, cc)
Next cc
Next ii
i = c + 1
Else
i = i + 1
```

```
End If
Loop
Next c
Dim n(1 To 20)
' forming rows
Dim row(1 To 20, 1 To 50, 1 To 9) As Long
For c = 1 To 9
row(1, 1, c) = yy_order(1, c)
Next c
Dim f As Integer
f = 1
p = 1
For i = 2 To v
If yy_order(i - 1, 6) - yy_order(i, 6) < 30 Then
f = f + 1
For c = 1 To 9
row(p, f, c) = yy_order(i, c)
Next c
Else:
p = p + 1
f = 1
For c = 1 To 9
row(p, f, c) = yy_order(i, c)
Next c
End If
Next i
'MsgBox "" & p
'n(f) represents number of words in each row, p is number of rows and v is number of words
If p = 1 Then
n(1) = v
End If
For f = 1 To p
For i = 1 To v
If row(f, i, 6) > 0 Then
'MsgBox " Row" & f & ";" & row(f, I, 6) & " and Number   :" & I & "and" & row(f, I, 4)
Else
n(f) = i - 1
i = v + 1
End If
Next i
Next f
'Ultimate ordering
Dim Ordered(1 To 20, 1 To 50, 1 To 9) As Long
Dim UO(1 To 20, 1 To 50, 1 To 9) As Long
For f = 1 To p
i = 1
For i = 1 To n(f)
For c = 1 To 9
Ordered(f, i, c) = row(f, i, c)
UO(f, i, c) = row(f, i, c)
```

```
If row(f, i, c) = 0 Then
'MsgBox " row  : " & f & " number: " & I & " code :  " & c
End If
Next c
Next i
For c = 2 To n(f)
i = 1
Do While i < c
If Ordered(f, c, 4) < Ordered(f, i, 4) Then
For y = i + 1 To c
For x = 1 To 9
UO(f, y, x) = Ordered(f, y - 1, x)
Next x
Next y
For x = 1 To 9
UO(f, i, x) = Ordered(f, c, x)
Next x
For ii = 1 To n(f)
For cc = 1 To 9
Ordered(f, ii, cc) = UO(f, ii, cc)
Next cc
Next ii
i = c + 1
Else
i = i + 1
End If
Loop
Next c
For i = 1 To n(f)
'MsgBox "" & UO(f, I, 4)
Next i
Next f
For f = 1 To p
For i = 1 To n(f)
' MsgBox " Row" & f & " X:  " & UO(f, I, 4) & " and y:  " & UO(f, I, 6) & "   and number :   " & I
'MsgBox "" & UO(f, I, 8)
Next i
Next f
Dim t
Dim k As Integer
k = 1
t = rr.GetVariable("pathh")
Do While k = 1
t = rr.GetVariable("pathh")
If t = "" Then
k = 1
Else
k = 2
End If
Loop
```

```
'MsgBox "" & t
Dim start As Integer
Dim a As Integer
Dim ending As Integer
Dim g As Integer
Dim z As String
Dim nam(1 To 20, 1 To 50) As String
For f = 1 To p
For i = 1 To n(f)
start = UO(f, i, 8)
ending = UO(f, i, 9)
x = start + ending
g = 1
z = Mid(t, x - g, 1)
Do Until z = "\"
g = g + 1
z = Mid(t, x - g, 1)
Loop
'MsgBox " g =" & g
a = 1
z = Mid(t, x - a, 1)
Do Until z = "."
a = a + 1
z = Mid(t, x - a, 1)
Loop
'MsgBox " g =" & g
nam(f, i) = Mid(t, x - g + 1, g - a - 1)
'MsgBox " the word on the row  " & f & " and the column  " & I & " is  :  " & nam(f, I)
Next i
Next f
' inserting pictures
validwordsnumber = 0
Const WM_CLOSE = &H10
Dim WinWnd As Long
For f = 1 To p
For i = 1 To n(f)
'-------------------------------------------------
' opening VNC thight if it is not already open
   WinWnd = FindWindow(vbNullString, "New TightVNC Connection")
   If WinWnd <> 0 Then
   Else
ret = Shell("C:\Program Files\TightVNC\vncviewer.exe", vbNormalFocus)
keybd_event VK_EXECUTE, 0, 0, 0 ' press enter
keybd_event VK_EXECUTE, 0, KEYEVENTF_KEYUP, 0 ' release enter
For rt = 1 To 4
keybd_event VK_NUMPAD3, 0, 0, 0 ' press 3
keybd_event VK_NUMPAD3, 0, KEYEVENTF_KEYUP, 0 ' release 3
Next rt
keybd_event VK_EXECUTE, 0, 0, 0 ' press enter
keybd_event VK_EXECUTE, 0, KEYEVENTF_KEYUP, 0 ' release enter
```

```
keybd_event VK_MENU, 0, 0, 0 ' press alt
keybd_event VK_CONTROL, 0, 0, 0 ' press ctrl
keybd_event VK_SHIFT, 0, 0, 0 ' press shift
keybd_event VK_F, 0, 0, 0 ' press f
keybd_event VK_F, 0, KEYEVENTF_KEYUP, 0 ' release f
keybd_event VK_SHIFT, 0, KEYEVENTF_KEYUP, 0 ' release shift
keybd_event VK_CONTROL, 0, KEYEVENTF_KEYUP, 0 ' release ctrl
keybd_event VK_EXECUTE, 0, KEYEVENTF_KEYUP, 0 ' release alt
GetCursorPos h
cy(13) = 786 - h.x
cy(14) = 469 - h.y
For nn = 1 To 100
SetCursorPos (h.x + nn * (cy(13) / 100)), (h.y + nn * (cy(14) / 100))
Sleep (15)
Next nn
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
Sleep (300)
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
End If
'--------------------------------------------------
'MsgBox "conf is  :   " & (UO(f, I, 1) / 1000)
Next i
Next f
For f = 1 To p
For i = 1 To n(f)
'MsgBox "conf is  :   " & (UO(f, I, 1) / 1000)
If (UO(f, i, 1) / 1000) > 85 Then
If nam(f, i) = "bridge" Then
fword.ActiveDocument.InlineShapes.AddPicture          FileName:="c:\Users\Public\Pictures\Sample
Pictures\bridge.jpg"
'------------------------------------------------------------------------
GetCursorPos h
cy(1) = 242 - h.x
cy(2) = 32 - h.y
For nn = 1 To 100
SetCursorPos (h.x + nn * (cy(1) / 100)), (h.y + nn * (cy(2) / 100))
Sleep (15)
Next nn
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
Sleep (300)
GetCursorPos h
cy(3) = 315 - h.x
cy(4) = 55 - h.y
For nn = 1 To 100
SetCursorPos (h.x + nn * (cy(3) / 100)), (h.y + nn * (cy(4) / 100))
Sleep (15)
Next nn
```

```
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
Sleep (300)
GetCursorPos h
cy(3) = 608 - h.x
cy(4) = 175 - h.y
For nn = 1 To 100
SetCursorPos (h.x + nn * (cy(3) / 100)), (h.y + nn * (cy(4) / 100))
Sleep (15)
Next nn
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
Sleep (300)
keybd_event VK_L, 0, 0, 0
keybd_event VK_L, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_I, 0, 0, 0
keybd_event VK_I, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_B, 0, 0, 0
keybd_event VK_B, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_R, 0, 0, 0
keybd_event VK_R, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_A, 0, 0, 0
keybd_event VK_A, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_R, 0, 0, 0
keybd_event VK_R, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_I, 0, 0, 0
keybd_event VK_I, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_E, 0, 0, 0
keybd_event VK_E, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_S, 0, 0, 0
keybd_event VK_S, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_DIVIDE, 0, 0, 0
keybd_event VK_DIVIDE, 0, KEYEVENTF_KEYUP,0
keybd_event VK_P, 0, 0, 0
keybd_event VK_P, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_I, 0, 0, 0
keybd_event VK_I, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_C, 0, 0, 0
keybd_event VK_C, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_T, 0, 0, 0
keybd_event VK_T, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_U, 0, 0, 0
keybd_event VK_U, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_R, 0, 0, 0
keybd_event VK_R, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_E, 0, 0, 0
keybd_event VK_E, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_S, 0, 0, 0
keybd_event VK_S, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_DIVIDE, 0, 0, 0
```

```
keybd_event VK_DIVIDE, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_P, 0, 0, 0
keybd_event VK_P, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_R, 0, 0, 0
keybd_event VK_R, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_O, 0, 0, 0
keybd_event VK_O, 0, KEYEVENTF_KEYUP, 0

keybd_event VK_J, 0, 0, 0
keybd_event VK_J, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_E, 0, 0, 0
keybd_event VK_E, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_C, 0, 0, 0
keybd_event VK_C, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_T, 0, 0, 0
keybd_event VK_T, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_RETURN, 0, 0, 0 ' press enter
keybd_event VK_RETURN, 0, KEYEVENTF_KEYUP, 0 ' release enter
GetCursorPos h
cy(11) = 600 - h.x
cy(12) = 300 - h.y
For nn = 1 To 100
SetCursorPos (h.x + nn * (cy(11) / 100)), (h.y + nn * (cy(12) / 100))
Sleep (15)
Next nn
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
Sleep (300)
SetCursorPos (1065), (420)
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
'---------------------------------------------------------------------------
validwordsnumber = validwordsnumber + 1
validwords1(validwordsnumber) = nam(f, i)
Else
If nam(f, i) = "book" Then
fword.ActiveDocument.InlineShapes.AddPicture FileName:="c:\Users\Public\Pictures\Sample Pictures\book.png"
'-------------------------------------------------------------------------------
GetCursorPos h
cy(1) = 242 - h.x
cy(2) = 32 - h.y
For nn = 1 To 100
SetCursorPos (h.x + nn * (cy(1) / 100)), (h.y + nn * (cy(2) / 100))
Sleep (15)
Next nn
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
```

```
Sleep (300)
GetCursorPos h
cy(3) = 315 - h.x
cy(4) = 55 - h.y
For nn = 1 To 100
SetCursorPos (h.x + nn * (cy(3) / 100)), (h.y + nn * (cy(4) / 100))
Sleep (15)
Next nn
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
Sleep (300)
GetCursorPos h
cy(3) = 608 - h.x
cy(4) = 175 - h.y
For nn = 1 To 100
SetCursorPos (h.x + nn * (cy(3) / 100)), (h.y + nn * (cy(4) / 100))
Sleep (15)
Next nn
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
Sleep (300)
keybd_event VK_L, 0, 0, 0
keybd_event VK_L, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_I, 0, 0, 0
keybd_event VK_I, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_B, 0, 0, 0
keybd_event VK_B, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_R, 0, 0, 0
keybd_event VK_R, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_A, 0, 0, 0
keybd_event VK_A, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_R, 0, 0, 0
keybd_event VK_R, 0, KEYEVENTF_KEYUP, 0

keybd_event VK_I, 0, 0, 0
keybd_event VK_I, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_E, 0, 0, 0
keybd_event VK_E, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_S, 0, 0, 0
keybd_event VK_S, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_DIVIDE, 0, 0, 0
keybd_event VK_DIVIDE, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_P, 0, 0, 0
keybd_event VK_P, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_I, 0, 0, 0
keybd_event VK_I, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_C, 0, 0, 0
keybd_event VK_C, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_T, 0, 0, 0
keybd_event VK_T, 0, KEYEVENTF_KEYUP, 0
```

```
keybd_event VK_U, 0, 0, 0
keybd_event VK_U, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_R, 0, 0, 0
keybd_event VK_R, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_E, 0, 0, 0
keybd_event VK_E, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_S, 0, 0, 0
keybd_event VK_S, 0, KEYEVENTF_KEYUP, 0

keybd_event VK_DIVIDE, 0, 0, 0
keybd_event VK_DIVIDE, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_P, 0, 0, 0
keybd_event VK_P, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_R, 0, 0, 0
keybd_event VK_R, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_O, 0, 0, 0
keybd_event VK_O, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_J, 0, 0, 0
keybd_event VK_J, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_E, 0, 0, 0
keybd_event VK_E, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_C, 0, 0, 0
keybd_event VK_C, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_T, 0, 0, 0
keybd_event VK_T, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_RETURN, 0, 0, 0 ' press enter
keybd_event VK_RETURN, 0, KEYEVENTF_KEYUP, 0 ' release enter
GetCursorPos h
cy(11) = 513 - h.x
cy(12) = 300 - h.y
For nn = 1 To 100
SetCursorPos (h.x + nn * (cy(11) / 100)), (h.y + nn * (cy(12) / 100))
Sleep (15)
Next nn
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
Sleep (300)
SetCursorPos (1065), (420)
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
'--------------------------------------------------------------------------------
validwordsnumber = validwordsnumber + 1
validwords1(validwordsnumber) = nam(f, i)
Else
If nam(f, i) = "desk" Then
fword.ActiveDocument.InlineShapes.AddPicture FileName:="c:\Users\Public\Pictures\Sample Pictures\desk.jpg"
'---------------------------------------------------------------------------------
```

```
GetCursorPos h
cy(1) = 242 - h.x
cy(2) = 32 - h.y
For nn = 1 To 100
SetCursorPos (h.x + nn * (cy(1) / 100)), (h.y + nn * (cy(2) / 100))
Sleep (15)
Next nn
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0

Sleep (300)
GetCursorPos h
cy(3) = 315 - h.x
cy(4) = 55 - h.y
For nn = 1 To 100
SetCursorPos (h.x + nn * (cy(3) / 100)), (h.y + nn * (cy(4) / 100))
Sleep (15)
Next nn
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
Sleep (300)
GetCursorPos h
cy(3) = 608 - h.x
cy(4) = 175 - h.y
For nn = 1 To 100
SetCursorPos (h.x + nn * (cy(3) / 100)), (h.y + nn * (cy(4) / 100))
Sleep (15)
Next nn
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
Sleep (300)
keybd_event VK_L, 0, 0, 0
keybd_event VK_L, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_I, 0, 0, 0
keybd_event VK_I, 0, KEYEVENTF_KEYUP, 0

keybd_event VK_B, 0, 0, 0
keybd_event VK_B, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_R, 0, 0, 0
keybd_event VK_R, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_A, 0, 0, 0
keybd_event VK_A, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_R, 0, 0, 0
keybd_event VK_R, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_I, 0, 0, 0
keybd_event VK_I, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_E, 0, 0, 0
keybd_event VK_E, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_S, 0, 0, 0
keybd_event VK_S, 0, KEYEVENTF_KEYUP, 0
```

```
keybd_event VK_DIVIDE, 0, 0, 0
keybd_event VK_DIVIDE, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_P, 0, 0, 0
keybd_event VK_P, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_I, 0, 0, 0
keybd_event VK_I, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_C, 0, 0, 0
keybd_event VK_C, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_T, 0, 0, 0
keybd_event VK_T, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_U, 0, 0, 0
keybd_event VK_U, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_R, 0, 0, 0
keybd_event VK_R, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_E, 0, 0, 0
keybd_event VK_E, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_S, 0, 0, 0
keybd_event VK_S, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_DIVIDE, 0, 0, 0
keybd_event VK_DIVIDE, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_P, 0, 0, 0
keybd_event VK_P, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_R, 0, 0, 0
keybd_event VK_R, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_O, 0, 0, 0
keybd_event VK_O, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_J, 0, 0, 0
keybd_event VK_J, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_E, 0, 0, 0
keybd_event VK_E, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_C, 0, 0, 0
keybd_event VK_C, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_T, 0, 0, 0
keybd_event VK_T, 0, KEYEVENTF_KEYUP, 0


keybd_event VK_RETURN, 0, 0, 0 ' press enter
keybd_event VK_RETURN, 0, KEYEVENTF_KEYUP, 0 ' release enter
GetCursorPos h
cy(11) = 682 - h.x
cy(12) = 300 - h.y
For nn = 1 To 100
SetCursorPos (h.x + nn * (cy(11) / 100)), (h.y + nn * (cy(12) / 100))
Sleep (15)
Next nn
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
Sleep (300)
```

```
SetCursorPos (1065), (420)
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
'-----------------------------------------------------------------------------------------
validwordsnumber = validwordsnumber + 1
validwords1(validwordsnumber) = nam(f, i)
End If
End If
End If
End If
Next i
Next f
'---------------------------
'closing VNCTight
   WinWnd = FindWindow(vbNullString, "faridaddinvahda")
   If WinWnd <> 0 Then
      PostMessage WinWnd, WM_CLOSE, 0&, 0&
   Else
   End If
'----------------------------
    rowa = (v)
    lastrow = p
    lastitem = n(p)
    End If
    'MsgBox "" & lastitem
   End If
End Sub
```

```
Private Sub sep_string(e)
Dim s(0 To 1000) As Integer
Dim d As String
Dim o As Integer
Dim i As Integer
Dim pp As Integer
o = 0
s(0) = 0
i = 1
Do Until Mid(e, i, 1) = ""
d = Mid(e, i, 1)
If d = "," Then
o = o + 1
s(o) = i
pp = s(o) - s(o - 1) - 1
char(o) = Mid(e, s(o - 1) + 1, pp)
End If
i = i + 1
Loop
o = o + 1
s(o) = i
pp = s(o) - s(o - 1) - 1
```

```
char(o) = Mid(e, s(o - 1) + 1, pp)
End Sub
Private Sub Label1_Click()
End Sub
Private Sub Timer1_Timer()
Dim h As pointapi
Dim i As Integer
Dim riv As Long
Dim ret As Variant
Dim rt As Integer
Dim cy(1 To 30) As Long
Dim nn As Integer
'--------------------------------------Closing the loop------------------------------------
'Dim intResponse As Integer

'intResponse = MsgBox("Are you sure you want to quit?", _
'vbYesNo + vbQuestion, _
'"Quit")
'If intResponse = vbYes Then
'End
'End If
'-----------------------------------------------------------------------------------------
Dim fword As Object
Dim worddoc As Word.Document
FindWord
If r = 0 Then
Set fword = CreateObject("word.application")
fword.Visible = True
fword.Documents.Add
Set worddoc = fword.ActiveDocument
'worddoc.InlineShapes.AddPicture FileName:="c:\Users\Public\Pictures\Sample Pictures\Dock.jpg"
Else
Set fword = GetObject(, "word.application")
Set worddoc = fword.ActiveDocument
'fword.ActiveDocument.InlineShapes.AddPicture FileName:="c:\Users\Public\Pictures\Sample
Pictures\Dock.jpg"
End If
   Set rr = CreateObject("RoboRealm.API.1")
   ' open RoboRealm if not already running
   rr.Open "c:\Program Files\RoboRealm\RoboRealm.exe", 6060
   If Not rr.Connect("localhost") Then
      MsgBox "OK", vbOKOnly, "Could not connect to RoboRealm Server"
      Exit Sub
   Else
  rr.LoadProgram "C:\Users\farid\Desktop\project\robo\goood.robo"
 Sleep (5000)
Dim e As String
Dim w As String
Dim shape(1 To 50, 1 To 9) As Double
```

```
rr.LoadProgram "C:\Users\farid\Desktop\project\robo\goood.robo"
v = rr.GetVariable("number")
If v = "" Then
Else
If v < rowa Then
Else
Sleep (3000)
e = rr.GetVariable("shapes")
Dim cc As Integer
Dim ii As Integer
Dim c As Integer
sep_string (e)

For i = 1 To v
For c = 1 To 9
shape(i, c) = Val(char((i - 1) * 9 + c))
'MsgBox "shape (" & I & "," & c & ") =" & shape(I, c)
Next c
Next i
Dim y As Integer
Dim x As Integer
For x = 1 To 9
'MsgBox "" & shape(x, 9)
Next x
' reOrdering y max to min
Dim y_order(1 To 50, 1 To 9) As Long
Dim yy_order(1 To 50, 1 To 9) As Long
For i = 1 To v
For c = 1 To 9
y_order(i, c) = shape(i, c)
yy_order(i, c) = shape(i, c)
Next c
Next i
For c = 2 To v
i = 1
Do While i < c
If y_order(c, 6) > y_order(i, 6) Then
For y = i + 1 To c
For x = 1 To 9
yy_order(y, x) = y_order(y - 1, x)
Next x
Next y
For x = 1 To 9
yy_order(i, x) = y_order(c, x)
Next x
For ii = 1 To v
For cc = 1 To 9
y_order(ii, cc) = yy_order(ii, cc)
Next cc
Next ii
```

```
i = c + 1
Else
i = i + 1
End If
Loop
Next c
' reOrdering x min to max
Dim x_order(1 To 50, 1 To 9) As Long
Dim xx_order(1 To 50, 1 To 9) As Long
For i = 1 To v
For c = 1 To 9
x_order(i, c) = shape(i, c)
xx_order(i, c) = shape(i, c)
Next c
Next i
For c = 2 To v
i = 1
Do While i < c
If x_order(c, 4) < x_order(i, 4) Then
For y = i + 1 To c
For x = 1 To 9
xx_order(y, x) = x_order(y - 1, x)
Next x
Next y
For x = 1 To 9
xx_order(i, x) = x_order(c, x)
Next x
For ii = 1 To v
For cc = 1 To 9
x_order(ii, cc) = xx_order(ii, cc)
Next cc
Next ii
i = c + 1
Else
i = i + 1
End If
Loop
Next c
Dim n(1 To 20)
' forming rows
Dim row(1 To 20, 1 To 50, 1 To 9) As Long
For c = 1 To 9
row(1, 1, c) = yy_order(1, c)
Next c
Dim f As Integer
f = 1
p = 1
For i = 2 To v
If yy_order(i - 1, 6) - yy_order(i, 6) < 30 Then
f = f + 1
```

```
For c = 1 To 9
row(p, f, c) = yy_order(i, c)
Next c
Else:
p = p + 1
f = 1
For c = 1 To 9
row(p, f, c) = yy_order(i, c)
Next c
End If
Next i
'MsgBox "" & p
If p = 1 Then
n(1) = v
End If
For f = 1 To p
For i = 1 To v
If row(f, i, 6) > 0 Then
'MsgBox " Row" & f & ";" & row(f, I, 6) & " and Number   :" & I & "and" & row(f, I, 4)
Else
n(f) = i - 1
i = v + 1
End If
Next i
Next f
'Ultimate ordering
Dim Ordered(1 To 20, 1 To 50, 1 To 9) As Long
Dim UO(1 To 20, 1 To 50, 1 To 9) As Long
For f = 1 To p
i = 1
For i = 1 To n(f)
For c = 1 To 9
Ordered(f, i, c) = row(f, i, c)
UO(f, i, c) = row(f, i, c)
If row(f, i, c) = 0 Then
'MsgBox " row  : " & f & " number: " & I & " code :  " & c
End If
Next c
Next i
For c = 2 To n(f)
i = 1
Do While i < c
If Ordered(f, c, 4) < Ordered(f, i, 4) Then
For y = i + 1 To c
For x = 1 To 9
UO(f, y, x) = Ordered(f, y - 1, x)
Next x
Next y
For x = 1 To 9
UO(f, i, x) = Ordered(f, c, x)
```

```
Next x
For ii = 1 To n(f)
For cc = 1 To 9
Ordered(f, ii, cc) = UO(f, ii, cc)
Next cc
Next ii
i = c + 1
Else
i = i + 1
End If
Loop
Next c
For i = 1 To n(f)
'MsgBox "" & UO(f, I, 4)
Next i
Next f
'MsgBox "" & n(f)
For f = 1 To p
For i = 1 To n(f)
 'MsgBox " Row" & f & " X:  " & UO(f, I, 4) & " and y:  " & UO(f, I, 6) & "   and number :   " & I
'MsgBox "" & UO(f, I, 8)
Next i
Next f
Dim t
Dim k As Integer
k = 1
t = rr.GetVariable("pathh")
Do While k = 1
t = rr.GetVariable("pathh")
If t = "" Then
k = 1
Else
k = 2
End If
Loop
'MsgBox "" & t
Dim start As Integer
Dim a As Integer
Dim ending As Integer
Dim g As Integer
Dim z As String
Dim nam(1 To 20, 1 To 50) As String
'MsgBox " t=   " & t
For f = 1 To p
For i = 1 To n(f)
start = UO(f, i, 8)
ending = UO(f, i, 9)
x = start + ending
g = 1
z = Mid(t, x - g, 1)
```

```
Do Until z = "\"
g = g + 1
z = Mid(t, x - g, 1)
Loop
'MsgBox " g =" & g
a = 1
z = Mid(t, x - a, 1)
Do Until z = "."
a = a + 1
z = Mid(t, x - a, 1)
Loop
'MsgBox " a =" & a
nam(f, i) = Mid(t, x - g + 1, g - a - 1)
'MsgBox " the word on the row  " & f & " and the column  " & I & " is  :  " & nam(f, I)
Next i
Next f
' inserting pictures
Const WM_CLOSE = &H10
Dim WinWnd As Long
For f = lastrow To p
If p > lastrow Then
lastitem = 1
Else
End If
For i = lastitem + 1 To n(f)
'-----------------------------------------------------
If (UO(f, i, 1) / 1000) > 85 Then
'MsgBox "conf is  :   " & (UO(f, I, 1) / 1000)
'-------------------------------------------------
' opening VNC thight if it is not already open
    WinWnd = FindWindow(vbNullString, "faridaddinvahda")
    If WinWnd <> 0 Then

Else
ret = Shell("C:\Program Files\TightVNC\vncviewer.exe", vbNormalFocus)
keybd_event VK_EXECUTE, 0, 0, 0 ' press enter
keybd_event VK_EXECUTE, 0, KEYEVENTF_KEYUP, 0 ' release enter
For rt = 1 To 4
keybd_event VK_NUMPAD3, 0, 0, 0 ' press 3
keybd_event VK_NUMPAD3, 0, KEYEVENTF_KEYUP, 0 ' release 3
Next rt
keybd_event VK_EXECUTE, 0, 0, 0 ' press enter
keybd_event VK_EXECUTE, 0, KEYEVENTF_KEYUP, 0 ' release enter
keybd_event VK_MENU, 0, 0, 0 ' press alt
keybd_event VK_CONTROL, 0, 0, 0 ' press ctrl
keybd_event VK_SHIFT, 0, 0, 0 ' press shift
keybd_event VK_F, 0, 0, 0 ' press f
keybd_event VK_F, 0, KEYEVENTF_KEYUP, 0 ' release f
keybd_event VK_SHIFT, 0, KEYEVENTF_KEYUP, 0 ' release shift
keybd_event VK_CONTROL, 0, KEYEVENTF_KEYUP, 0 ' release ctrl
```

```
keybd_event VK_EXECUTE, 0, KEYEVENTF_KEYUP, 0 ' release alt
GetCursorPos h
cy(13) = 786 - h.x
cy(14) = 469 - h.y
For nn = 1 To 100
SetCursorPos (h.x + nn * (cy(13) / 100)), (h.y + nn * (cy(14) / 100))
Sleep (15)
Next nn
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
Sleep (300)
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
End If
If nam(f, i) = "bridge" Then
fword.ActiveDocument.InlineShapes.AddPicture FileName:="c:\Users\Public\Pictures\Sample
Pictures\bridge.jpg"
'-------------------------------------------------------------------------
GetCursorPos h
cy(1) = 242 - h.x
cy(2) = 32 - h.y
For nn = 1 To 100
SetCursorPos (h.x + nn * (cy(1) / 100)), (h.y + nn * (cy(2) / 100))
Sleep (15)
Next nn
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
Sleep (300)
GetCursorPos h
cy(3) = 315 - h.x
cy(4) = 55 - h.y
For nn = 1 To 100
SetCursorPos (h.x + nn * (cy(3) / 100)), (h.y + nn * (cy(4) / 100))
Sleep (15)
Next nn
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
Sleep (300)

GetCursorPos h
cy(3) = 608 - h.x
cy(4) = 175 - h.y
For nn = 1 To 100
SetCursorPos (h.x + nn * (cy(3) / 100)), (h.y + nn * (cy(4) / 100))
Sleep (15)
Next nn
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
Sleep (300)
keybd_event VK_L, 0, 0, 0
```

```
keybd_event VK_L, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_I, 0, 0, 0
keybd_event VK_I, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_B, 0, 0, 0
keybd_event VK_B, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_R, 0, 0, 0
keybd_event VK_R, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_A, 0, 0, 0
keybd_event VK_A, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_R, 0, 0, 0
keybd_event VK_R, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_I, 0, 0, 0
keybd_event VK_I, 0, KEYEVENTF_KEYUP, 0

keybd_event VK_E, 0, 0, 0
keybd_event VK_E, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_S, 0, 0, 0
keybd_event VK_S, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_DIVIDE, 0, 0, 0
keybd_event VK_DIVIDE, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_P, 0, 0, 0
keybd_event VK_P, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_I, 0, 0, 0
keybd_event VK_I, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_C, 0, 0, 0
keybd_event VK_C, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_T, 0, 0, 0
keybd_event VK_T, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_U, 0, 0, 0
keybd_event VK_U, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_R, 0, 0, 0
keybd_event VK_R, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_E, 0, 0, 0
keybd_event VK_E, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_S, 0, 0, 0
keybd_event VK_S, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_DIVIDE, 0, 0, 0
keybd_event VK_DIVIDE, 0, KEYEVENTF_KEYUP, 0


keybd_event VK_P, 0, 0, 0
keybd_event VK_P, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_R, 0, 0, 0
keybd_event VK_R, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_O, 0, 0, 0
keybd_event VK_O, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_J, 0, 0, 0
keybd_event VK_J, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_E, 0, 0, 0
keybd_event VK_E, 0, KEYEVENTF_KEYUP, 0
```

```
keybd_event VK_C, 0, 0, 0
keybd_event VK_C, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_T, 0, 0, 0
keybd_event VK_T, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_RETURN, 0, 0, 0 ' press enter
keybd_event VK_RETURN, 0, KEYEVENTF_KEYUP, 0 ' release enter
GetCursorPos h
cy(11) = 600 - h.x
cy(12) = 300 - h.y
For nn = 1 To 100
SetCursorPos (h.x + nn * (cy(11) / 100)), (h.y + nn * (cy(12) / 100))
Sleep (15)
Next nn
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
Sleep (300)
SetCursorPos (1065), (420)
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
'---------------------------------------------------------------------------
validwordsnumber = validwordsnumber + 1
validwords1(validwordsnumber) = nam(f, i)
Else
If nam(f, i) = "book" Then
fword.ActiveDocument.InlineShapes.AddPicture FileName:="c:\Users\Public\Pictures\Sample Pictures\book.png"
'-------------------------------------------------------------------------------
GetCursorPos h
cy(1) = 242 - h.x
cy(2) = 32 - h.y
For nn = 1 To 100
SetCursorPos (h.x + nn * (cy(1) / 100)), (h.y + nn * (cy(2) / 100))
Sleep (15)
Next nn
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
Sleep (300)


GetCursorPos h
cy(3) = 315 - h.x
cy(4) = 55 - h.y
For nn = 1 To 100
SetCursorPos (h.x + nn * (cy(3) / 100)), (h.y + nn * (cy(4) / 100))
Sleep (15)
Next nn
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
```

```
Sleep (300)
GetCursorPos h
cy(3) = 608 - h.x
cy(4) = 175 - h.y
For nn = 1 To 100
SetCursorPos (h.x + nn * (cy(3) / 100)), (h.y + nn * (cy(4) / 100))
Sleep (15)
Next nn
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
Sleep (300)
keybd_event VK_L, 0, 0, 0
keybd_event VK_L, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_I, 0, 0, 0
keybd_event VK_I, 0, KEYEVENTF_KEYUP, 0

keybd_event VK_B, 0, 0, 0
keybd_event VK_B, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_R, 0, 0, 0
keybd_event VK_R, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_A, 0, 0, 0
keybd_event VK_A, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_R, 0, 0, 0
keybd_event VK_R, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_I, 0, 0, 0
keybd_event VK_I, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_E, 0, 0, 0
keybd_event VK_E, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_S, 0, 0, 0
keybd_event VK_S, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_DIVIDE, 0, 0, 0
keybd_event VK_DIVIDE, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_P, 0, 0, 0
keybd_event VK_P, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_I, 0, 0, 0
keybd_event VK_I, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_C, 0, 0, 0
keybd_event VK_C, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_T, 0, 0, 0
keybd_event VK_T, 0, KEYEVENTF_KEYUP, 0

keybd_event VK_U, 0, 0, 0
keybd_event VK_U, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_R, 0, 0, 0
keybd_event VK_R, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_E, 0, 0, 0
keybd_event VK_E, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_S, 0, 0, 0
keybd_event VK_S, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_DIVIDE, 0, 0, 0
```

```
keybd_event VK_DIVIDE, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_P, 0, 0, 0
keybd_event VK_P, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_R, 0, 0, 0
keybd_event VK_R, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_O, 0, 0, 0
keybd_event VK_O, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_J, 0, 0, 0
keybd_event VK_J, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_E, 0, 0, 0
keybd_event VK_E, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_C, 0, 0, 0
keybd_event VK_C, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_T, 0, 0, 0
keybd_event VK_T, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_RETURN, 0, 0, 0 ' press enter
keybd_event VK_RETURN, 0, KEYEVENTF_KEYUP, 0 ' release enter
GetCursorPos h
cy(11) = 513 - h.x
cy(12) = 300 - h.y
For nn = 1 To 100
SetCursorPos (h.x + nn * (cy(11) / 100)), (h.y + nn * (cy(12) / 100))
Sleep (15)
Next nn
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
Sleep (300)
SetCursorPos (1065), (420)
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
'-----------------------------------------------------------------------------
validwordsnumber = validwordsnumber + 1
validwords1(validwordsnumber) = nam(f, i)
Else
If nam(f, i) = "desk" Then
fword.ActiveDocument.InlineShapes.AddPicture FileName:="c:\Users\Public\Pictures\Sample Pictures\desk.jpg"
'-----------------------------------------------------------------------------

GetCursorPos h
cy(1) = 242 - h.x
cy(2) = 32 - h.y
For nn = 1 To 100
SetCursorPos (h.x + nn * (cy(1) / 100)), (h.y + nn * (cy(2) / 100))
Sleep (15)
Next nn
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
```

```
Sleep (300)
GetCursorPos h
cy(3) = 315 - h.x
cy(4) = 55 - h.y
For nn = 1 To 100
SetCursorPos (h.x + nn * (cy(3) / 100)), (h.y + nn * (cy(4) / 100))
Sleep (15)
Next nn
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
Sleep (300)
GetCursorPos h
cy(3) = 608 - h.x
cy(4) = 175 - h.y
For nn = 1 To 100
SetCursorPos (h.x + nn * (cy(3) / 100)), (h.y + nn * (cy(4) / 100))
Sleep (15)
Next nn
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
Sleep (300)
keybd_event VK_L, 0, 0, 0
keybd_event VK_L, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_I, 0, 0, 0
keybd_event VK_I, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_B, 0, 0, 0
keybd_event VK_B, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_R, 0, 0, 0
keybd_event VK_R, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_A, 0, 0, 0
keybd_event VK_A, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_R, 0, 0, 0
keybd_event VK_R, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_I, 0, 0, 0
keybd_event VK_I, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_E, 0, 0, 0
keybd_event VK_E, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_S, 0, 0, 0
keybd_event VK_S, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_DIVIDE, 0, 0, 0
keybd_event VK_DIVIDE, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_P, 0, 0, 0
keybd_event VK_P, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_I, 0, 0, 0
keybd_event VK_I, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_C, 0, 0, 0
keybd_event VK_C, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_T, 0, 0, 0
keybd_event VK_T, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_U, 0, 0, 0
```

```
keybd_event VK_U, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_R, 0, 0, 0
keybd_event VK_R, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_E, 0, 0, 0
keybd_event VK_E, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_S, 0, 0, 0
keybd_event VK_S, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_DIVIDE, 0, 0, 0
keybd_event VK_DIVIDE, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_P, 0, 0, 0
keybd_event VK_P, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_R, 0, 0, 0
keybd_event VK_R, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_O, 0, 0, 0
keybd_event VK_O, 0, KEYEVENTF_KEYUP, 0

keybd_event VK_J, 0, 0, 0
keybd_event VK_J, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_E, 0, 0, 0
keybd_event VK_E, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_C, 0, 0, 0
keybd_event VK_C, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_T, 0, 0, 0
keybd_event VK_T, 0, KEYEVENTF_KEYUP, 0
keybd_event VK_RETURN, 0, 0, 0 ' press enter
keybd_event VK_RETURN, 0, KEYEVENTF_KEYUP, 0 ' release enter
GetCursorPos h
cy(11) = 682 - h.x
cy(12) = 300 - h.y
For nn = 1 To 100
SetCursorPos (h.x + nn * (cy(11) / 100)), (h.y + nn * (cy(12) / 100))
Sleep (15)
Next nn
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0
Sleep (300)
SetCursorPos (1065), (420)
mouse_event MOUSEEVENTF_LEFTDOWN, 0, 0, 0, 0
mouse_event MOUSEEVENTF_LEFTUP, 0, 0, 0, 0

'-----------------------------------------------------------------------------------------
validwordsnumber = validwordsnumber + 1
validwords1(validwordsnumber) = nam(f, i)
End If
End If
End If
End If
Next i
```

```
Next f
'----------------------------
'closing VNCTight
   WinWnd = FindWindow(vbNullString, "faridaddinvahda")
   If WinWnd <> 0 Then
      PostMessage WinWnd, WM_CLOSE, 0&, 0&
   Else
   End If
'----------------------------
For i = 1 To validwordsnumber
validwords1(i) = validwords2(i)
Next i
rowa = v
lastrow = p
lastitem = n(p)
End If
End If
End If
End Sub
```