ADAPTIVE CORPORATE ENVIRONMENTS

Creating real-time interactive spatial systems for corporate offices incorporating computation techniques

- Nimish Biloria

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Proefschrift

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DEDICATED TO MY PARENTS

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SUMMARY

This research work focuses on the emerging field of interactive architecture as an inter-disciplinary systemic endeavour for addressing spatial issues linked with contemporary socio-cultural dynamism. Corporate office environments, being dynamic eco-systems prone to organizational re-structuring, mergers/mutations as well as being multi socio-cultural conglomerates are specifically chosen as an experimental field within which the precincts of Interactivity are rigorously scrutinized. The research work, operating on the above mentioned precincts, exemplifies upon an attempt to create a co-evolving (design + technological) interactive spatiality with a strong underpinning in the domains of computation, interaction design, technology and open systems. This inter-disciplinary approach is specifically deployed for the generation of a constantly informed, user centric, real-time interactive corporate office space which addresses the customized preferences of its occupants. Rather than creating conventional inert structural shells, the development of a meta-system, or in other words creating a 'soft' computationally enriched open systemic framework which interfaces with the 'hard', material component and the users of the proposed architectural construct formulates the core agenda of the research work. This inter-activating soft and hard space/meta-system serves as a platform for providing the users with a democratic framework, within which they can manifest their own programmatic (activity oriented) combinations thus creating customized spatial variants. The otherwise static/inert hard architectural counterpart, enhanced with contemporary technology thus becomes a physical interface prone to real-time spatial/structural and ambient augmentation to optimally serve its users. This research work thus specifically resulted in developing a computation aided spatial meta-system (resultant software) to be instilled within office environments which allows its users to input their ambient, spatial and social preferences through a designed interactive user interface. This meta-system further processes the inputted data per user through its internal computational routines and space allocation algorithms once the user's presence is tracked in real time (via sensor networks). This internal data-processing results in real-time simulation and physical regulation as regards automated space allocation, spatial configuration (real-time adaptability) and ambience augmentation (via actuator networks) conforming to every individual user's personal preferences.

The research work specifically operates on the outcome of a PACT analysis (people, activity, context and technology framework, conducted through interview sessions, on-site observations and literature reviews) thus developing a bottom-up componential understanding of typical office environments. This exhaustive analysis of spatial typologies, bio-rhythms of corporate offices and psychological associations/dissociations of employees working within such office environments, suggested an increasing need for customization of individual environments within otherwise static, rather insipid office shells. This need is catered to, by means of the research output: an adaptive (real-time interactive) spatial meta-system which can re-configure its physical, ambient and informational state to cater to varying activities being performed within office environments. An Inter-disciplinary approach synergistically binding the fields of computation (for data structuring and data processing), control systems (for developing sensing and actuating properties) and kinetic structures (for developing a dynamic skeletal framework), operates on the outcome (needs and desires of users) of the PACT analysis. Issues related to automation, ease of operation, a non-taxing clarity of tangible content to be represented via designed interactive interfaces, the choice of media and various spatial configurations that a singular architectural space could inherit (or physically morph into) are thus identified.

In order to materialize such an adaptive space, a componential approach, which dealt with prototyping one generic work space unit (the generic pod) fostering customization, automation, ambient lighting, sound and multiple usability of the same space via spatial augmentation/adaptation is embarked upon. This highly adaptive modular unit is designed in a way that it can be easily inserted into existing office shells, thus converting otherwise static shells into dynamic environments. After successfully evaluating the performance of this generic unit for its adaptability oriented performance, a cluster of such pod units is assembled together in-order to conceive an experimental real-time adaptive office environment. In order to interact as well as impart information pertaining to the contextual setting of such an adaptive construct, an online real-time interactive Interface is subsequently developed. The interface specifically caters to issues concerning data input pertaining to spatial (activity based), ambient and social preferences (by employees and visitors) while serving as a medium for communicating (in real time) the spatial and ambient state of the entire office. The preferences entered by each user thus serve as individual databases which are strictly adhered to while automatically allocating optimal spatial locations (the moment the users are tracked/sensed while entering the office) within the entire office environment which satisfy the ambient, configuration and social (neighbours) desires outlined by each user. The users are also provided with over-ride facilities where they can instantly change their allocated pod's spatial and ambient configuration in accordance with the kind of activity they would like to perform. Architecture, engineering as well as interior design domains are thus fused together to create the resultant real-time interactive space. This multiple usability aspect is furthered via the provisions for converting (time based) the entire office setting into an exhibition scenario (which though is pre-programmed to attain a specific spatial and ambient configuration can be further fully customized via over-ride facilities) thus creating a platform for extending otherwise non-flexible, rigid architectural constructs (physically) into highly dynamic environments.

This research initiative concludes with the development of a customized software which specifically binds two co-evolving aspects: firstly, the conception, design and prototyping of an adaptive office space and secondly the development of a real-time interactive interface as a front end to the entire system. The software is developed using Java and is left open for accepting plug-ins in order to enhance the proposed adaptive behaviour of the office space as and when required. The motivation and desire for conceptualizing architecture as a democratic construct which not only performs in order to best assist its user but also persuades one with an opportunity to be united with the designed system for manifesting space itself thus opens up an entirely new arena for creating open source architectural constructs akin to the resultant output of this research work.

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INTRODUCTION

1.1. Research abstract:

Conventional interfaces in the contemporary are almost entirely confined to the conformist graphical user interface comprising of a keyboard, monitor and a mouse. Taking into consideration that the contemporary information era promotes an increasing percentage of non verbal/digital communication, the notion of transforming the physical environment as an interface to digital information, holds an assuring promise to enrich architectural spatiality[1]. This research work is an effort to envision such an interfaced augmented spatiality in the corporate office domain, explicitly focusing upon the behavioural dynamics of occupants operating within such organizations[2]. In order to address this vision, the research agenda focuses upon developing a real-time adaptive (spatial, ambient and informational) office environment [3] acknowledging the dynamic culture of contemporary corporate organizations.

A critical look at the evolutionary transformations, which corporate offices have witnessed[4] [5], not only on the spatial front (typological, aesthetical and corporate image oriented aspects of office buildings), but also on the managerial and organizational re-structuring front, makes it evident that the so called 'orthodox' corporate body is giving way to the development of a self-organizing networked body nurturing dynamic business eco-systems[6]. Architectural substantiations for such bodies embodying dynamic business eco-systems however tend to be spatially inert in essence and deem to remain closed systemic entities owing to their adherence to rather static spatial programs in accordance with which they were initially conceptualised. This programmatic adherence driven production of architectural typologies compounded by the inherent inert materiality of building components results in the creation of a spatial system which appropriately performs for the set of programmatic demands based in which it was formulated. However, the same architectural construct tends to be inept in responding to evolving programmatic demands; a resultant of the dynamic business eco-system which it houses, owing to its static pre-programmed nature. Architectural renditions supporting such emergent forms of organizations thus need to be re-thought in order to break apart from the inherent closed system typology[7] of architectural materiality they exhibit, in favour of a dynamic typology, addressing contemporary corporate culture.

This research, embedded within such a context, thus exemplifies upon an attempt to create a co-evolving (socio-cultural and technological) spatiality with a strong underpinning in the domain of computation, interaction design and open system typologies for the generation of a constantly informed, highly adaptive (spatial, ambient, and informational) interactive corporate office space. Issues related to contemporary Information technology induced information networks, a human centric and activity oriented organizational planning as well as issues of customization[8] of work environments for enhancing productivity, forms the basis for developing the proposed interactive architectural rendition. An analytical research methodology for identifying research variables and research components is deployed for attaining this research goal. This methodology involved understanding organisational and corporate culture via a systems perspective, stratification of organizations into their operational components via the PACT framework[9] and through this understanding institutionalising the similarities between organisms and organisations. This filtered understanding is further explicitly contrasted with technological systems, primarily developing an affinity towards the field of interaction design, open systems and real time response. A parallel design based research on kinetics, control systems and computational techniques (section 4.6) constantly acknowledges the manner in which a systematised technical coherence can be developed for binding the extracted research variables and components in a spatial framework (for aiding the development of a spatial prototype).

In order to materialise the desired responsive spatiality, this research synergistically employs the expertise offered by the above mentioned fields of computation[10] for data structuring and data processing, control systems for developing sensing and actuating properties and kinetic structures for developing a dynamic skeletal framework (with variable resolution: both interior and exterior), henceforth developing a collaborative design approach towards achieving computation aided structural/spatial control of the proposed architectural body (Fig.1). The research hence functions at two levels: firstly creating a design database that is based on an intensive analysis of corporate office spaces, taking into consideration issues of flexibility and the changing nature of organisational trends (Appendix A, B) and secondly, by developing computation aided responsive structural/spatial systems, which reconfigure themselves in accordance with user requirements/preferences[11]. Intensifying and fostering flexible usability of an occupant centred work environment is thus, the proposed outcome of this research work.

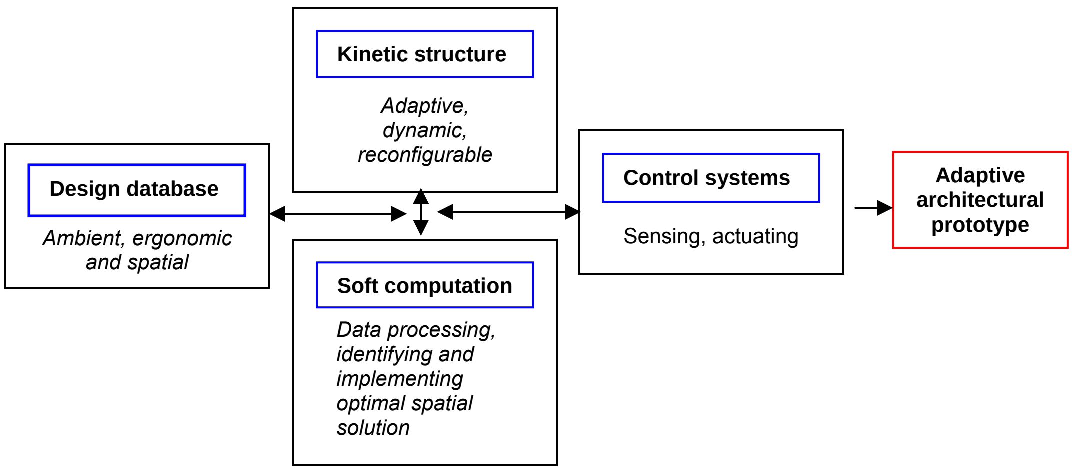

Fig. 1 Diagrammatic representation of the intended process

1.2. Research Objectives:

The research body is specifically tailored to address vital issues pertaining to the development of an interactive architectural space. The objectives hence follow a sequential progression of understanding, deciphering, conceptualizing and producing a user centric organizational vision. The research objectives can hence be exemplified as follows:

- Understanding the behavioural aspects of organizations from a systems perspective: natural, rational and open systems

- Understanding corporate culture by analysing corporate offices in terms of management related changes, work attitude, effects of information technology, and strategically abstracting the appropriate spatial structures akin to such organisational restructuring.
- Understanding flexibility from an organizational perspective
- Deciphering the evolution of corporations
- Deciphering future organizational outlooks
- Conducting case studies (stratifying organizations into their operational components)
- Understanding interaction, interactivity and interaction design
- Understanding human communication, cognition and interaction.
- Deciphering research variables
- Conducting variable based research experiments
- Deciphering system requirements
- Conceptual design of the system outlining the essential system components and their characteristics. Thinking of computing beyond the screen-space and to draft possibilities to distribute it into everyday objects such as furniture, walls, windows, floor etc. in order to create a simplified interactive interface.
- Understanding of the field of computation and its related disciplines, specifically object oriented programming and java 3d.
- Producing a system architecture
- Physical design and prototyping of the conceived system in terms of its front end and simulation aspects. The conception of such an intelligent prototype will involve both: design of spatial envelopes that could be inserted into any architectural space and virtual: design a platform (technological) enabling an ambient sense of presence, and preference oriented data augmentation fostering a human centric approach.
- Conceptualizing and testing the application of electronic and sensing mechanisms.
- Conceptualizing material innovations: embedded computing, smart materials, flexible displays.
- Understanding interaction diagrams.
- Conceptualizing and producing interface designs and human computer interaction scenarios
- Deciphering interactions within the system components to produce a real time-interactive design prototype addressing issues of customization, adaptability and multiple usability, hence visualising a responsive architectural spatiality.
- Conceptualizing information models of the research components.
- Deciphering agents (computational) at a local and a global level.
- Conceptualizing and producing interaction amongst these agents for computing and deploying an optimal organisational solution, based on user preferences.
- Producing system simulation, design and modelling.
- Application analysis and concept demonstration.
- Evaluating the proposed system

The research, hence, provides an insight into developing real time responsive architectures, tending more towards the development of a new organism appropriated to the fluctuating requirements constituting the changing definitions of reality, presence and privacy of corporate space. The research hence involves research into visualisation, simulation, sensing, processing, networking, computing and display related technologies. These technological understandings are interfaced with architectural studies of form, human behaviour and spatial organisation based in the corporate socio-cultural context eventually transcending otherwise inert architectural constructs into a real-time data processing interactive environment[12].

1.3. Research Background:

In order to situate the research work in today's information and knowledge based context, I will break down the discourse into three main parts in order to understand the proposed context. These parts would respectively be: material and the digital, architecture, and science and technology, although these will overlap.

1.3.1. Material and the digital

The spectrum of technological considerations to equip and to materialize conceptual data is enthralling and perplexing at the same time. The notion of perception, structure, material and production dialogues are some of the few issues that become critical for the realization of such conceptualizations. The contemporary scenario, heavily loaded with information and the constantly recurring relation between perceived phenomenon and spatial organisation is nowadays heavily under speculation[13]. The reality in which we situate ourselves reveals that the contemporary environment is increasingly being engulfed in the domain of information and image. They occupy our space at all the times in all places, hence rendering a means of escape from their encounter practically impossible. This notion if perceived from a broader perspective associates immediately with contemporary socio cultural scenario's increasing desire/need to absorb information from the context in which one exists. This gave rise to the possibility of researching upon the notion of Information itself becoming a possible structuring system as an area of research. The notion of how the hard edged world of architectural reality could be possibly combined with the softness and fluidity of media content is hence specifically experimented with (Fig. 2) during the course of this research. How structure could be separated from content, and content itself could become a binary problem of creative and technical vision involving increased usage of digital/analogue apparatus which in turn would require controlled, highly performative frameworks is therefore an issue where the research starts articulating itself.

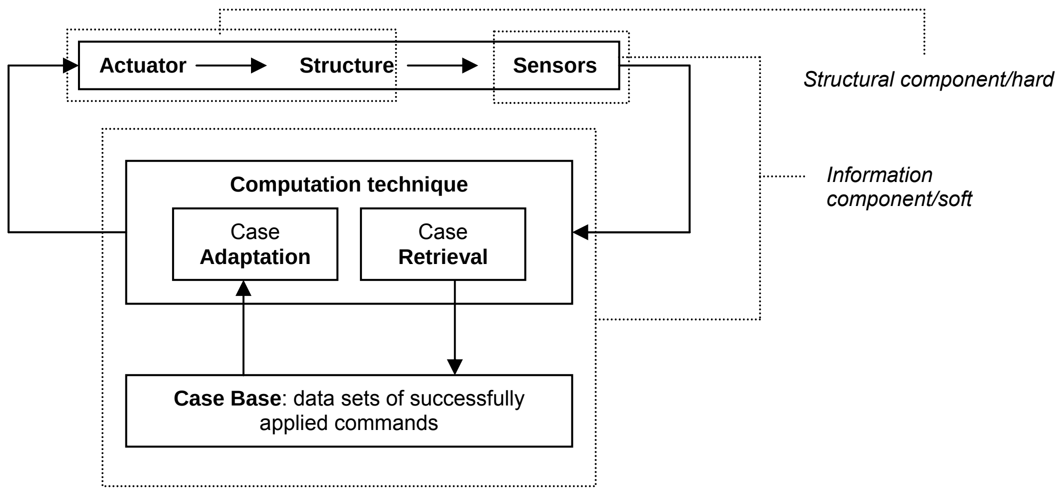

Fig. 2 Diagram representing the process of information affecting the structural adaptiveness

The manner in which we situate and affiliate our being is a highly simulated condition; the architectural realm is in a way the manifestation of these simulations into the material as well as the virtual domain. Images and information, which multiply at an enormous rate in today's reality, also build up an intricately abstract system of order of their own. They carry within the power to distort and re-configure the physicality of space. Considering the fast pace of today's life and the transitory nature of space in the contemporary, one tends to absorb information constantly through a highly strategic display of information and imagery prevalent in our immediate sorroundings. However this act of assimilating information is a highly subjective notion and hence leads to dissolution of the notion of one single interpretation of space. The digital world through the usage of complex software and 3d visualisation tools already possess the capability of creating virtual systems that simulate visually plastic and fluid environments[14] (Fig 3). However to realise these systems in the physical world, constantly entrapped in limitations of gravity, heat transfer, wind pressure, ambient light conditions and orientation, it becomes highly essential to carefully sample as well as develop new materials[15], and intelligent systems which are equipped better to satisfy various performance criterions (like developing dynamic data bases, developing self learning mechanisms, self organising principles, feed back mechanisms, real-time responsive systems etc), hence influencing operational characteristics such as fluidity, flexibility, information display, adaptability etc set forth to realise a concept.

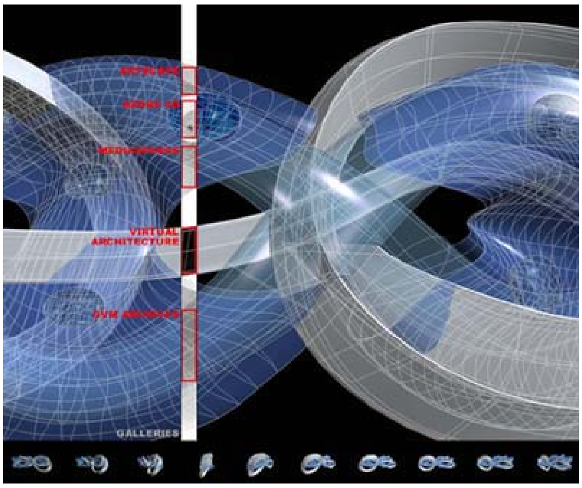

Fig. 3 This rendering of the virtual Guggenheim Museum shows the wire-framing detail of the galleries' structures. The vertical bar bisecting it is a navigational tool that passes back and forth through the structure allowing the viewer to access various zones of operation. The smaller images, below right, show the different states of the structure as the viewer moves through it: an excellent exemplification of virtual environments based on movement and visual linkages of the body.

This first and foremost calls for an inter-disciplinary approach, investigating the fields of interactive architecture, new-media, computation and control systems for eventually refining, reconstructing and enhancing interactive system performances. Investigating integrated computing processes for developing smart kinetic systems for manifesting meaningful spatial adaptability will further the role of such interactive systems beyond the computer, thus engulfing the physical (architectural) domain.

The research work thus focuses on developing a computation aided architectural meta-system which will assist in tracking users, identifying their preferences as well as help in visualising/simulating and physically regulating spatial and ambient augmentation through real time rule-based processing of the acquired data.

1.3.2. Architecture: The new paradigm

"We live today in a globally interconnected world, in which biological, psychological, social and environmental phenomena are all interdependent. To describe this world appropriately we need an ecological perspective which the Cartesian world view does not offer…" – Fritjof Capra, The turning point: a science of living systems, 1982.

Until recent times, architecture had never been imagined to contain space beyond the cartesian dimension. However this horizon has shifted from the edge of what is visible to our naked eyes to that which is visible electronically, that is to say, at the scales of non-euclidean geometries. What we have overcome is atmospheric and perspectival noise, the constraints of seeing in a straight line, and constraint of seeing from just one point or in just one direction. Perceptual limits of the body have now started to drift, with electronic body extensions (Fig 4). Architecture that had its primary function in holding an event has now been faced with new condition[16] as now exactly those grounds, that it had laid its foundations on, are shifting i.e. Visual limits of the eye and anthropomorphic attributes of the body. With modern virtual modelling and simulation technology[17] this quest for the ability to dwell beyond mundane realities is brought closer to both realisation and realistic experience. This ambition has now grown into a wide industry with developments in hardware, software and networking technologies. Clip-on-Monitors, data glove/suits, and various wearable devices are becoming increasingly common practice. Virtuality as some might say is an inevitable extension, of our age-old capacity and need to dwell in fiction, to dwell empowered or enlightened on other, mythic planes, if only periodically, as well as this earthly one.

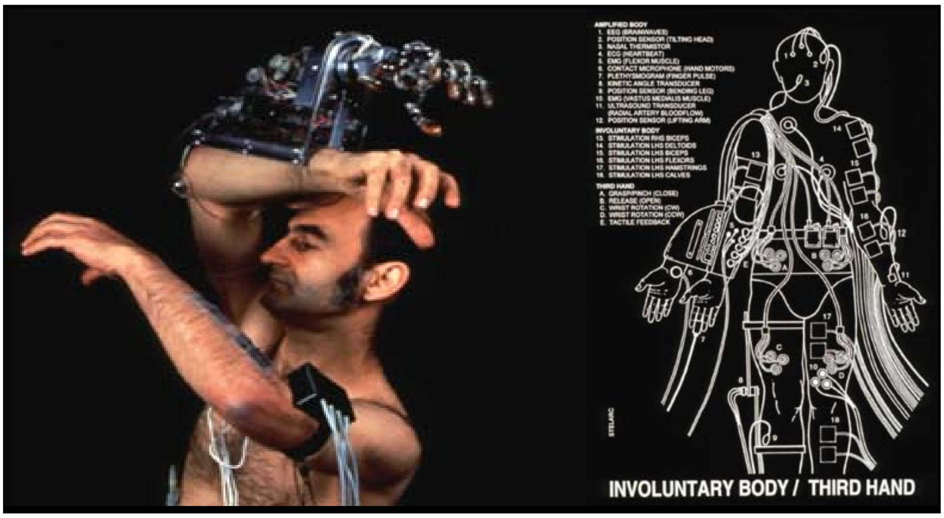

Fig. 4 Stelark with the Third hand: extension of the Body and its behaviours using electronic and robotic media.

However during this slow transition from euclidian to the non-euclidian, contemporary holistic[18] thinking also gave rise to the systems theory[19] which distinguished itself from traditional analytical approaches by laying emphasis on issues of interactivity and the idea of interconnections between various components of a system. Systems theory is thus of specific interest in the research investigations pertaining to the characteristic features of open systems as opposed to closed systems and the manner in which contemporary system dynamics can be understood with the study of non-linear sciences.

1.3.2. a. Open system typology

The above discussion's in the material and the digital and the research abstract sections, point towards a specific argument that is entrapped between them: the notion of interactively closed and open systems (an integral part of the systems theory). A transition of the nature of architectural constructs from the closed systemic character they tend to exhibit, to homeostasis, an open systems character which fosters the concepts of self regulation of internal states by means of multiple dynamic equilibrium adjustments, controlled by interrelated regulation mechanisms (thus exhibiting real-time adaptability) needs to be envisioned. A change of the operative scenario as regards both; conceiving a non-inert, dynamic physicality and self regulatory organisational structuring thus need to be investigated. Such conceptions thus inextricably point towards linking the informational (organisational structuring which become the context) with the material (physicality of architecture) eventually calling upon the development of an intelligent dynamic spatial system, which has the ability to register contemporary needs and the ability to trigger spatial adaptability as an optimal response to these needs. The issue of form becomes redundant in such environments, since the main mode of discourse shifts from the mundane-ness of such artificiality towards a more plastic conception of internal flexibility and adaptation (Fig. 5).

In order to manage contemporary data fluctuations/uncertainties of economic environments, a broad range of transformations (Appendix A, B) are being applied to existing organisational structures (management and policy re-structuring) eventually resulting in the emergence of many new and radically different kinds of hybrid organisational systems. These new hybrid organisational systems are able to deal with variable input and output, variable processes and at the same time tend to operate as self-regulating mechanisms at the informational front. Contemporary physical/hard architectural environment as seen in such a dynamic context however is still highly passive in response to accommodating/responding to such self regulatory dynamic systems, since at its core it tends to be a closed rather inert system (materially) which is constructed, eventually modified, filled in with support systems like furniture, infrastructure and finally demolished, thus serving as a system that is both physically and interactively closed. However the field of interactive systems (proposed research direction) opens up a variety of possibilities of interlinking dynamic organisational systems to employee/user preferences, their activity patterns, and subsequently to the architectural (hard) space they inhabit, thus laying the foundations for developing an interrelated interactive architectural meta-system which has the ability to respond in real-time to dynamic data fluctuations (user centric, in the case of this research).

In the physical realm a plausible breakthrough that the architectural environment can produce, is (in terms of conceiving an open system typology) to provide a semi closed flexible framework for the open system, henceforth generating a system that, like a living cell, is physically closed but is interactively and organisationally an open system. In such open systems as seen in nature, process itself becomes vital, leading an activity to a state depending upon the forces acting upon that system. However in order to physically manifest/mimic such character at the architectural front, various issues like minimizing the material aspects of a building, integration of information into used material, hence changing the material configuration at a generic level, emphasising the properties of an open system by means of creating a continuous information exchange with the context, to become self regulatory, autonomous and democratic in essence, and to develop feedback mechanisms of auto regulation will be of utmost vitality and hence formulate a major agenda for this research. Furthermore what has to be comprehended at this point is the necessity to develop collaborative means of realising such architectonics[20].

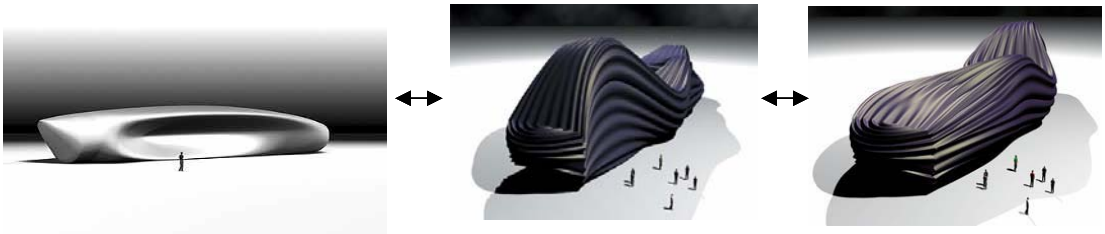

Fig. 5. ONL's Trans-ports project 1999. A Hyperbody (programmable building that changes its shape and content in real time)

In order to absorb fields such as systems theory, information technology, artificial intelligence, control systems and specialised building technology, architecture needs to blur its boundaries in order to build variable adaptive mechanisms akin to an integral living organism. In order to attain this, this research work, , adopts a bottom-up strategy for analysing socio-cultural aspects of corporate organisations with a specific focus upon the basic unit - users/employees, thus understanding the corporate environment via user interaction, preferences, comfort and productivity perspectives. Aspects of achieving flexible, adaptive as well as multitasking environments are looked at, by utilising theoretical as well as technological mediations in order to arrive at specific user centric data communication and processing protocols that are further used for spatial articulation.

1.3.2. b. Architectural effects

Looking into the aspect of architectural effects from the perspective of the Image and its associated character of information propulsion one can delve into the theoretical discourses propelled by Barthes about the sign. The field of semiology provides an interesting platform to this; the proposition made by Barthes, interestingly segregates the idea of the signifier and the signified stating how the former is associated with expression and the later with content. The sum of the expression and the content create the sign. Everyday utilitarian objects tend to fall into this category of signs due to the social and cultural interpretations that they carry, which, in turn help in framing a mental representation (the signified) of an object. One can associate the importance of the image as a mental representation of signs[21]. However, while semiology was dealing with signification and production of meaning by means of establishing the relation between the sign and the signifier, an entirely new branch called communication theory[22] which dealt with the use and effect of the aforementioned signs involving the transmission of messages/information subsequently emerged.

The research work, operating within the above mentioned dimension of information communication via image and data communication, will focus on exploring architectural repercussions as regards spatial and ambient effects generated by incorporating data driven material components (Fig 6) for conceiving the spatial envelope. The notion of identity will thus be situated between media and virtual infrastructure, providing one with the opportunity of creating highly stimulating material effects. Programming languages such as Java (3d) in conjunction with control systems will be specifically used in this regard in order to simulate skin/surface articulation aspects.

Fig. 6 Foldable LCD screens, possess the possibility of institutionalising information, and image display onto surfaces of complex curvatures, they can also be used in a variety of hand held devices enabling the material to become much more information based and effective in producing architectural affects.

1.3.3. Science and Technology

In building up concept prototypes, this research involves studies of technological tools for digital inscription, modelling, visualisation, representation and the technologies for real-time data communication, processing and storage. Scientific theory especially new sciences formulate a constant underpinning of the research for developing computation aided behavioural aspects for the interactive corporate office prototype under speculation.

1.3.3. a. Science

One of the most influential phenomenon in the field of sciences that particularly relates to the agenda of the research is the implication of the paradigm shift from a reductionist[23] perspective of the world to a holistic[24] and ecological worldview. Mechanistic conception (An outcome of Classical physics[25]) that dwelled inherently in the notion of fragmentation and analytical method of reasoning was deciphered to constitute a reductionist approach (an approach which believed that a complex entity can easily be understood by logically breaking it up into its constituent parts) from the holistic perspective. Holism on the other hand professed that all the properties of a given system (biological, chemical, social, economic, mental, linguistic, etc.) cannot be determined or explained by the sum of its component parts alone. Instead, the system as a whole determines in an important way how the parts behave.

A new conception of physics (modern physics) during the late ninetieth and the twentieth century further built upon this line of holistic thinking in science to formulate the fields of systems thinking and its derivatives like chaos and complexity theory. It is at this juncture that the idea of relations started gaining more importance; networks and their behaviour became immensely vital in understanding the whole. Modern physics as a result has its base in the idea of subatomic particles as being bundles of energy/patterns of activity and the only way to understand these particles that make up the whole is by studying their patterns of interaction and connections in a networked manner. This surge to understand the articulations of matter per se called for a new systemic approach hence giving rise to the conception of systems theory[26] which in the fields of Interaction design as well as computational media forms the heart of scientific discourse.

The systems view[27] required that importance be given to the interaction and interdependence between the parts that create the whole rather than the parts themselves. The stress hence is more on the constant flux of energy exchange and the patterns that these exchanges created. A further development was the conception of multileveled systems and the manner in which complex interactions start articulating between such structures. This also lead to a much more concentrated analysis of patterns that are created as a result of the interactions, consequently focussing on the processes which give rise to dynamic organisational structures, leading to issues of self organisation: one of the vital phenomenon that this research deals with. Approaching the phenomenon of self-organisation as an active, live processing behaviour becomes important when we start conceiving the architectural body as an information exchange and data processing being (Fig. 7). Various new sciences such as emergence[28], chaos etc have also, at the architectural front given rise to diverse theoretical discourses[29] of responsiveness[30], emotiveness, and hyper-bodies[31] that dwell in the information era and have strong roots in scientific as well as behavioural phenomena. Contemporary developments[32] at the material front too are now based on issues of self-healing[33], self-renewal and self-organisation, hence constantly trying to develop intelligent and smart behaviour as a built in property of the material constituent[34].

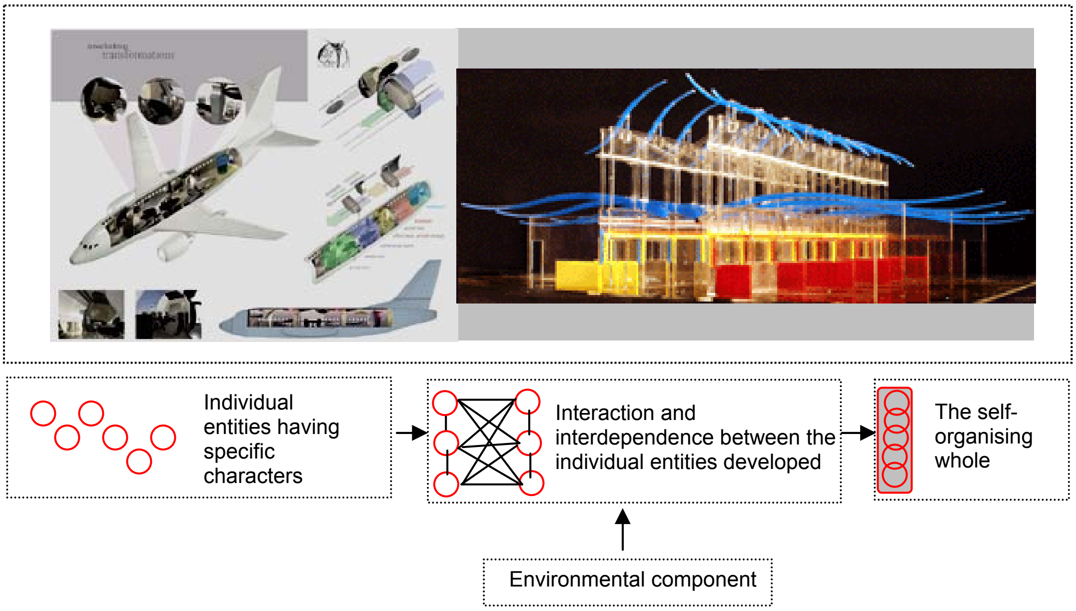

Fig. 7 Two projects by the KDG at the MIT: Business jet interior and the spine house, both working on similar principles of interaction and interdependence between parts to create a co-coordinative adaptive response: Allowing expansion, contraction and deployment of interior furniture types in accordance with the user interaction.

This research is set up within such a scientific framework and will propagate with the fundamental understanding of the organisational whole from a systems perspective as a bottom-up interrelated behavioural process of its constituents; human, spatial, ambient and informational domains.

1.3.3. b. Information technology (IT) and hardware

The ever-increasing pace of the information technology sector and related hardware component development has been astounding. Developments such as elaborate sensing technology[35], mapping and recording bodily movements[36] and gestural data, pressure, temperature sensors, eye & motion-trackers etc which are readily available and constantly being developed to map body information, Web cams and other optical input devices additional to conventional sound/text input are now established practices. Flexible or foldable LCD screens[37] are next generation output platforms that could help transcending desktop computing. Sensitive fabrics and wearable computers will not be new in the near future[38], with considerable work under way, the first models are already showing up at various research labs such as the MIT Media lab, Bristol, UK, University of Oregon etc. Digital projection technology is reaching its peak with developments in CAVE[39] and other interactive visual environments for instance in developing holographic[40] projections. Strategic use of technology and the application of relevant metaphors in structuring online environments could enable exactly those intrinsic elements that seem missing in conventional textual landscapes.

Fig. 8 Some recent developments utilising IT as an intrinsic design element: the Data glove, Image/map generating textile (could be connected via GIS) and an embedded fabric circuit.

Unfortunately until recent times the adaptation and experimentation of such information based technological development apart from being used for automatic opening and closing mechanisms for doors, windows etc hasn't been efficiently utilised for architectural conception. Miniaturisation of hardware, development of numerous input devices and sensing technologies (Fig. 8), advancements in data processing power and the rapid developments in software industry however, raises potentials for thinking design at a level where innovation could be substituted with an appropriate assembling of speculated developments with a logical vision. Such technological advancements and their resultant social implications (for instance catering to stress levels and well being related issues of users) are analysed and appropriately deployed in the course of this research by the author. This research work is thus an effort to simulate an emergent behaviour, which will effectively merge the boundaries of various IT, computation and hardware developments to envision an adaptive real time data processing architectural body (Fig. 9). This research work, thus aims at drafting possibilities for an architecture with electronic and information media as its intrinsic 'building' components.

Fig. 9 The Muscle project: Kas Oosterhuis, an experimental prototype embedded with sensing and actuating devices, which responds to its surroundings by augmenting its form. The sensor disks, which create the nodes, are embedded with proximity and motion sensors, which sense user location and proximity and in turn via a programmed behaviour engine instruct the actuators (Festo pneumatic muscles) to contract/expand, hence causing the form to expand/contract.

1.3.3. c. The-augmented environment

With improvements in sensing, processing, transmitting and display technologies, working environments are facing an enormous transformation[41] in every function and program involved with every expected activity. In today's economy, the cheap access to information processing promote rapid innovations in the production process. IT continues to be increasingly deployed in the evolution of intelligent products in order to enhance their operative performance. The entire legacy of 'better living' now revolves around sophisticated in-house informatics. Wrist watches with calculators, organisers, digital camera and GPS, palm pilots with web connectivity, MP3 players and CD/VCD/DVD are all part of this growing genre. Washing machines with fuzzy logic, microwaves with digital sensing technology, HDTV with full programmable viewing options, interactive television, and home PC are established practices. Widening the scope of information gadgets within any spatial landscape includes instruments of recording, transmitting, monitoring/controlling, and storing knowledge. Information processing and transmission are now taking advantage of the superior features of digitisation. Earlier Voice and now real time video-images can be streamed live with developments in Fibre-Optic technology. Implementation of 3G networks across Europe and America will further mark a completely new era in mobile communication with its capacities for transmitting live interactive multimedia.

A whole new genre of information gadgets evolving today serve a new spectrum of spatial functions based on our increasing socio-cultural needs and desires. However, if one breaks down these developments into three major phases, the above discussed could be considered the first phase. The second would be the emergence of new telecommunication services and improved telecommunications devices (Fig.10), and the third, development of in-house communications systems. The proposed real-time interactive spatial prototype possibly belongs to this third generation of systems.

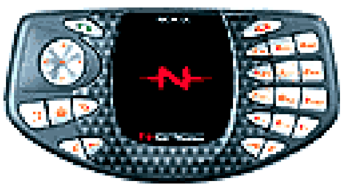

Fig. 10 Nokia N Gage: an example of the developing speed of communication gadgetry, the gadget embodies features of audio, video, gaming, as well as internet based browsing and has a complete online gaming archive devoted to it.

1.4. Research hypothesis:

The research specifically operates on the premise of creating a co-evolving (socio-cultural and technological) spatiality, which can be programmed, and has its base in the ideas of computation, interaction design[42] and open system typologies for the generation of a constantly informed and highly adaptive corporate office space. This adaptive space will specifically address the behavioural patterns and preferences (spatial, ambient and informational) of its occupants and will thus deem to be a user centric real-time interactive environment.

1.5. Research Scope and Limitations:

This research endeavour is in essence an architectural research undertaking, although it operates on the boundaries of information technology (IT), human computer interaction (HCI), and control systems. It rather plays on the boundaries of augmented[43] and virtual reality[44] and is a fusion between the objects of the real and the virtual domain. The resultant product apart from being an exploration, into the aspects of corporate behaviours, life-styles and their communication/spatial needs, embarks upon the idea of conceiving new supplementary architectural extensions appropriated to their time.

Rather than creating conventional inert structural shells (hard components), the development of a meta-system, or in other words creating a 'soft' computationally enriched open systemic framework (informational) which interfaces with the 'hard', material component and the users of the architectural construct thus formulates the core scope of the research. This soft space/meta system will serve as a platform providing the users with a framework, within which they can manifest their own programmatic (activity oriented) combinations in order to create self designed spatial alternatives. The otherwise static/inert hard architectural counterpart, enhanced with contemporary technology becomes a physical interface prone to spatial/structural augmentation to optimally serve the user's programmatic initiations.

The development of information models, data flows, system architectures[45] and the extraction of research components based on the understanding of human behaviour and activity patterns is thus an inherent part of the agenda (via the PACT: people, activity, context and technology framework). Parallel investigations into the latest technological fields of generating programmable interactive systems especially in the sector of pneumatic technologies, interaction devices, real time simulations and haptic feedback systems are also conducted for deriving technological resolutions. Both, corporate culture and technology thus become intrinsic components of the research focus for evaluating user behaviour, studying patterns of cultural processes in corporate communities, registering prevalent communication habits, future needs and Institutional space/character/vocabulary. Future technologies and devices to be incorporated in the project are based on related research in respective areas under development. The project deliberately would not confine to the technical specificities of various items it may incorporate, but would rather explore these items by taking an imaginative design approach. Considerations are given to the socio-functional aspects of contemporary culture, its future trends and how real-time interactive technologies can be deployed for such projected trends.

In the process of developing interactive spatial prototypes, the research work outlines possible functionalities, parametric product dimensions, form-studies, service architectures, simulations and interface designs, additional to its major textual research component. The research output in the form of a real-time interactive software will hence specifically involve the production of an interactive user interface, a dynamic database, an intensively programmed control system and responsive simulations of the designed spatial solution. Apart from this, the research work also actively proposes (at a conceptual level) the manner in which hardware components such as sensing and actuation systems along with their respective controllers can be linked with the informational domain (control system and sensing/actuating agents) to weave together the proposed performative system architecture and thus extend the currently simulated interactivity to the physical domain.

In order to empirically support the above stated real-time interaction oriented discourse for binding soft and hard architectural counterparts into a comprehensive whole, research experiments conducted under the guidance of the author are elaborated upon in this research work. However, the physical prototype for the proposed office environment will be built according to the amount of funding made available for this research. In the case of an absence of the physical prototype, the developed software (hosting the real-time interactive interface and simulations) combined with the aforementioned working physical prototypes should be considered for defending the proposed adaptive construct.

The notion of attaining multiple usability of the same space via technologically enhancing its performative aspects appropriately to cater to different sets of user activities is a vital aim to be attained by this research. This aim is specifically formulated in order to maintain the feasibility aspect of investing in the proposed real-time interactive spatial constructs. The amount of financial investment as regards employee satisfaction, interior design, infrastructure etc which any corporation is subjected to is deemed to be balanced via the proposed interactive construct owing to its ability to be highly participative, customizable as well as its ability to cater to different activity oriented spatial reconfigurations (in terms of furniture as well as ambience appropriation). This research work is thus an active attempt to present one of the numerous possibilities of developing real-time adaptive spaces which not only tend to be highly performative in addressing the needs of their users but also tend to be economically viable in the long run owing to their multiple usability, user centric and flexibility oriented characteristics.

1.6. Insight into the chapters:

In line with the ideas expressed in the introduction, the research thesis has been structured into five chapters, each culminating with comprehensive conclusions and end notes. This structure specifically deals with the following issues: investigations into theoretical underpinnings of organizations and corporations, conducting a case study of a contemporary corporation, identifying research variables using the PACT framework, designing the proposed interactive system in terms of its conceptual, physical and operational criteria and subsequently deriving critical conclusions from the research body. A detailed structure of the dissertation is as follows:

After elaborating upon the research inclinations, contextual settings and research constraints in this (first) chapter, chapter two exemplifies upon deriving the behavioural aspects of organizations, by means of categorically analysing them (via literature and prior corporate research based reviews) as natural, rational and open systems. This chapter further investigates the nature of corporations and the evolutionary, cultural as well as organizational structures they embody. The chapter successively explores the importance of flexibility in the organisational domain and subsequently speculates upon the nature of future organisations. The chapter concludes with an inclusive report on the projected cultural and organizational characteristics which are re-investigated in the third chapter.

Chapter three comprises of a case study: the Interpolis office, Tilburg, Netherlands, and its stratification into spatial components. Vital physiological and psychological aspects such as ambience, temperature, furniture and comfort are exemplified upon as a part of the investigation. The increasingly important role of information technology and the manner in which it helps cater to issues of flexibility are subsequently traced from the case study. The case study is also instrumental in terms of deriving variable activities and corresponding spatial constructs housing them, hence setting forth a confluence of spatial typologies formulating the entirety of a productive office environment. The chapter concludes with a critical assessment of Interpolis (also based on Interviews conducted on site) in terms of its positive and negative aspects as regards space usability, productivity and flexibility issues.

After extracting essential organisation-design related strategies, and activity oriented spatial components, chapter four exemplifies upon the manner in which the field of interaction design, its methodologies (including an occupant centred design approach) can be deployed for the identification of research variables. The chapter explicitly investigates the interrelation between the terminologies of interaction, interactivity and interaction design in order to extract the essence of designing interactions and deploys the PACT (people, activity, context and technology) framework to extract research variables. A subsequent report on research experiments conducted based on a confluence of the PACT framework is presented in the form of two experiments conducted at the Hyperbody research group, TU Delft: The Muscle Re-configured and the Bamboostic. The chapter concludes with a comprehensive outlook concerning the research experiments and hence the deplorability of a system based on a synergistic merger of computational techniques, sensing and actuation components and their immediate context.

Chapter five explicitly embarks upon the development of the proposed interactive prototype, in all its stages: from conceptual design to physical design, prototyping and evaluation. The chapter elaborates upon a set of requirements, both functional and non-functional and derives conceptual technological parallels (in terms of components) addressing these requirements. Issues of effective data transmission and speed of operation are further considered for developing a spatial dissection and in-turn the notion of developing a generic space which possesses the ability to adapt its physical structure in order to embody a variety of activity oriented typological configurations. Considerations as regards the functioning of the proposed vision further leads to developing a conceptual agent based model, interdependent upon each other for data communication and processing. This set of conceptual information is further subject to issues of customization, involving the merger of four faces of customization (collaborative, adaptive, cosmetic and transparent) to attain a comprehensive design prototype. The essential characters of the derived prototype are further exemplified upon and an appropriate system architecture for materializing the proposed vision is formulated. The chapter further explains the role of identified agents in synergistically choreographing the desired interaction routines and illustrates the evaluation and implementation phases of the system.

An elaborate conclusion of the entire research work, expanding upon a progressive view on architectural design and the changing role of designer in today’s information enriched context is put forth in the chapter six. The conclusion also serves as a critical reflection upon the research agenda while outlining the salient applicability features of the developed software. Critical recommendations from an inter-disciplinary design and research perspective for furthering this research initiative as well as envisioning performative, real-time interactive architectural constructs formulate the concluding comments for the research.

Endnotes

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[16] Disappearing architecture: From real to virtual to quantum, Georg Flachbart, Birkhauser, 2005

[17] Human computer interaction issues and challenges, Qiyang Chen, Hershey: Idea group, 2001.

[18] Holism (from λος holos, a Greek word meaning all, entire, total) is the idea that all the properties of a given system (biological, chemical, social, economic, mental, linguistic, etc.) cannot be determined or explained by the sum of its component parts alone. Instead, the system as a whole determines in an important way how the parts behave. The general principle of holism was concisely summarized by Aristotle in the Metaphysics: "The whole is more than the sum of its parts" - "holism." Wikipedia. Wikipedia, 2007. *Answers.com* 07 Mar. 2007. http://www.answers.com/topic/holism

[19] Systems theory is a transdisciplinary/multiperspectual scientific domain that studies structure and properties of systems in terms of relationships from which new properties of wholes emerge. The domains of system philosophy, methodology and application are complementaries to this science - "systems theory." Wikipedia. Wikipedia, 2007. *Answers.com* 07 Mar. 2007. http://www.answers.com/topic/systems-theory

[20]In architecture architectonics is often defined as "of or relating to the science of architecture and design In this sense, "Architectonic" means the art and science of building and construction The word began to acquire its modern meaning in the late nineteenth century in Germany as *architektonisch* to define a type of perceived sensibility to form and design, a sensibility that preferred the simple over the complex, and the well-built over the mass-produced. Today, the word architectonics is used more narrowly in a semiotic sense to refer to the use of parts as expressive signs that comprise the language system of the building - "architectonics." Wikipedia. Wikipedia, 2007. *Answers.com* 07 Mar. 2007. http://www.answers.com/topic/architectonics

[21] In semiotics, a sign is generally defined as, "...something that stands for something else, to someone in some capacity." (Marcel Danesi and Paul Perron, "Analyzing Cultures"). It may be understood as a discrete unit of meaning, whether denotative or connotative. Signs are not just words, but also include images, gestures, scents, tastes, textures, sounds — essentially all of the ways in which information can be processed into a codified form and communicated as a message by any sentient, reasoning mind to another - "sign." Wikipedia. Wikipedia, 2007. *Answers.com* 07 Mar. 2007. http://www.answers.com/topic/sign-semiotics

[22] To explain the relationship between semiotics and communication studies, communication is defined as the process of transferring data from a source to a receiver as efficiently and effectively as possible. Hence, communication theorists construct models based on codes, media, and contexts to explain the biology, psychology, and mechanics involved. Both disciplines also recognise that the technical process cannot be separated from the fact that the receiver must decode the data, i.e., be able to distinguish the data as salient and make meaning out of it. This implies that there is a necessary overlap between semiotics and communication. Indeed, many of the concepts are shared, although in each field the emphasis is different. In *Messages and Meanings: An Introduction to Semiotics*, Marcel Danesi (1994), suggested that semioticians' priorities were to study signification first and communication second. A more extreme view is offered by Jean-Jacques Nattiez (1987; trans. 1990: 16) who, as a musicologist, considered the theoretical study of communication irrelevant to his application of semiotics.

[23] In philosophy, reductionism is a theory that asserts that the nature of complex things is reduced to the nature of sums of simpler or more fundamental things. This can be said of objects, phenomena, explanations, theories, and meanings - "reductionism." Wikipedia. Wikipedia, 2007. *Answers.com* 07 Mar. 2007. http://www.answers.com/topic/reductionism

[24] Holism (from *ὅλος holos*, a Greek word meaning *all*, *entire*, *total*) is the idea that all the properties of a given system (biological, chemical, social, economic, mental, linguistic, etc.) cannot be determined or explained by the sum of its component parts alone. Instead, the system as a whole determines in an important way how the parts behave. The general principle of holism was concisely summarized by Aristotle in the *Metaphysics*: "The whole is more than the sum of its parts". Reductionism is sometimes seen as the opposite of holism. Reductionism in science says that a complex system can be explained by *reduction* to its fundamental parts. Essentially, chemistry is reducible to physics, biology is reducible to chemistry and physics, psychology and sociology are reducible to biology, etc - "holism." Wikipedia. Wikipedia, 2007. *Answers.com* 07 Mar. 2007. http://www.answers.com/topic/holism

[25] Classical physics is physics based on principles developed before the rise of quantum theory, usually including the special theory of relativity and general theory of relativity. In contrast to classical physics, *modern physics* is a slightly looser term which may refer to just quantum physics or to 20th and 21st century physics in general and so *always* includes quantum theory and *may* include relativity - "classical physics." Wikipedia. Wikipedia, 2007. *Answers.com* 07 Mar. 2007. http://www.answers.com/topic/classical-physics

[26] Systems theory is a transdisciplinary/multiperspectual scientific domain that studies structure and properties of systems in terms of relationships from which new properties of wholes emerge. The domains of system philosophy, methodology and application are complementaries to this science - "systems theory." Wikipedia. Wikipedia, 2007. *Answers.com* 07 Mar. 2007. http://www.answers.com/topic/systems-theory

[27] The systems view is a world-view that is based on the discipline of SYSTEM INQUIRY, Central to systems inquiry is the concept of SYSTEM. In the most general sense, system means a configuration of parts connected and joined together by a web of relationships. The Primer group defines system as a family of relationships among the members acting as a whole. Bertalanffy defined system as "elements in standing relationship…. online article compiled by the Primer Group at ISSS, Bela H. Banathy writes in the article titled "Systems Inquiry".

[28] Perhaps the most elaborate recent definition of emergence was provided by Jeffrey Goldstein in the inaugural issue of Emergence.(Goldstein 1999) To Goldstein, emergence refers to "the arising of novel and coherent structures, patterns and properties during the process of self-organization in complex systems." The common characteristics are: (1) radical novelty (features not previously observed in systems); (2) coherence or correlation (meaning integrated wholes that maintain themselves over some period of time); (3) A global or macro "level" (i.e. there is some property of "wholeness"); (4) it is the product of a dynamical process (it evolves); and (5) it is "ostensive" - it can be perceived. For good measure, Goldstein throws in [supervenience] -- downward causation." (Corning 2002)

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[35] Bert Bongers: http://www.xs4all.nl/~bertbon/

[36] Human movement tracking technology: http://xspasm.com/x/sfu/vmi/HMTT.pub.html

[37] Toshiba's flexible LCD screens: http://www.pcworld.com/article/id,100643-page,1/article.html

[38] Wearable computing: http://whisper.iat.sfu.ca/

[39] A Cave Automatic Virtual Environment (better known by the recursive acronym CAVE) is an immersive virtual reality environment where projectors are directed to four, five or six of the walls of a room-sized cube - "Cave Automatic Virtual Environment." Wikipedia. Wikipedia, 2007. *Answers.com* 07 Mar. 2007. http://www.answers.com/topic/cave-automatic-virtual-environment

[40] Holography (from the Greek, *Όλος-holos* whole + *γραφή-graphe* writing) is the science of producing holograms; it is an advanced form of photography that allows an image to be recorded in three dimensions. The technique of holography can also be used to optically store, retrieve, and process information. It is common to confuse volumetric displays with holograms, particularly in science fiction works such as *Star Trek*, *Star Wars*, *Red Dwarf*, and *Quantum Leap* - "holography." Wikipedia. Wikipedia, 2007. *Answers.com* 07 Mar. 2007. http://www.answers.com/topic/holography

[41] New workspace, new culture office design as a catalyst for change by Gavin Turner and Jeremy Myerson, Gower, Aldershot, 1998.

[42] Interaction design is the discipline of defining and creating the behaviour of technical, biological, environmental and organizational systems. Examples of these systems are software, products, mobile devices, environments, services, wearables, and even organizations themselves. Interaction design defines the behaviour (the "interaction") of an artifact or system in response to its users over time - "interaction design." Wikipedia. Wikipedia, 2007. *Answers.com* 07 Mar. 2007. http://www.answers.com/topic/interaction-design

[43] Augmented reality (AR) is a field of computer research which deals with the combination of real world and computer generated data. At present, most AR research is concerned with the use of live video imagery which is digitally processed and "augmented" by the addition of computer generated graphics. Advanced research includes the use of motion tracking data, fiducial marker recognition using machine vision, and the construction of controlled environments containing any number of sensors and actuators - "augmented reality." Wikipedia. Wikipedia, 2007. *Answers.com* 07 Mar. 2007. http://www.answers.com/topic/augmented-reality

[44] Virtual reality (VR) is a technology which allows a user to interact with a computer-simulated environment, be it a real or imagined one. Most current virtual reality environments are primarily visual experiences, displayed either on a computer screen or through special stereoscopic displays, but some simulations include additional sensory information, such as sound through speakers or headphones. Some advanced, haptic systems now include tactile information, generally known as force feedback, in medical and gaming applications. Users can interact with a virtual environment or a virtual artifact (VA) either through the use of standard input devices such as a keyboard and mouse, or through multimodal devices such as a wired glove, the Polhemus boom arm, and/or omnidirectional treadmill. The simulated environment can be similar to the real world, for example, simulations for pilot or combat training, or it can differ significantly from reality, as in VR games. In practice, it is currently very difficult to create a high-fidelity virtual reality experience, due largely to technical limitations on processing power, image resolution and communication bandwidth. However, those limitations are expected to eventually be overcome as processor, imaging and data communication technologies become more powerful and cost-effective over time - "virtual reality." Wikipedia. Wikipedia, 2007. *Answers.com* 07 Mar. 2007. http://www.answers.com/topic/virtual-reality

[45] A system architecture or systems architecture is the design or set of relations between the parts of a system - "system architecture." Wikipedia. Wikipedia, 2007. *Answers.com* 07 Mar. 2007. http://www.answers.com/topic/system-architecture

02

ANALYZING ORGANIZATIONS

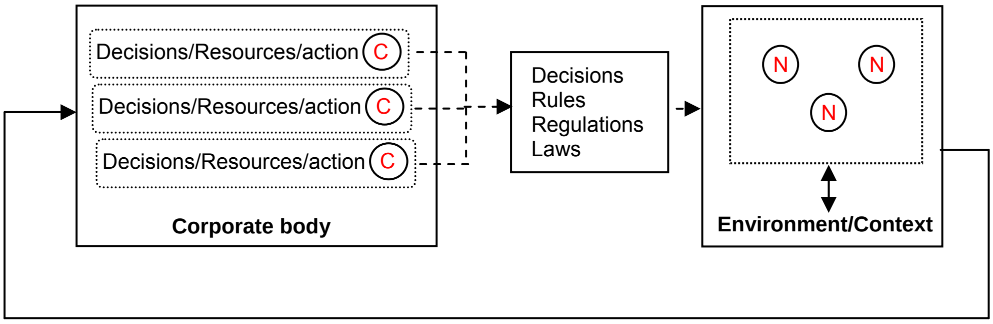
02
Analyzing Organizations

2.1 Defining organizations

or·gan·i·za·tion[1] *n.: The act or process of organizing, The state or manner of being organized, Something that has been organized or made into an ordered whole, Something made up of elements with varied functions that contribute to the whole and to collective functions; an organism, A group of persons organized for a particular purpose; an association:* a benevolent organization, *A structure through which individuals cooperate systematically to conduct business.*

Contemporary society is highly immersed in organizational behaviour[2]; it can be defined as an organizational society due to the array of organizations and corporations that guide a variety of diverse tasks in our societal framework. Organizations are essentially extensions of our own selves, deliberate mechanisms developed to fulfil tasks that are beyond an individual's comprehension. Their prevalence can be felt in every arena of our lives to such an extent that the new paradigm brings along with its self a modified societal view. The new paradigm[3], proposes to see organizations in the light of actors, may it be in the form of corporate personnel or jurisdictic people, with the enhanced extensions of taking action, resource utilization and allied processes as a collective whole. This is also a parallel development to what may be termed as 'natural humans', who constitute the general mass engulfed by such 'organizational actors'[4]. This societal scenario, of relations, and interactions between the two distinct genres of the natural and the corporeal is of extreme significance. It can be visualized as a network of relations springing from the very bottom up constituents of the societal systems that we are engrained in. A cyclic behaviour (Fig. 11) is set forth by the materialization of such organizational entities: the systems that govern the production as well as the maintenance of their behaviour also set forth a variety of social processes, governing rules, formation of norms etc. These can be seen as complex forms of organizational structure/boundaries, creating an environmental whole with which the same organization interacts in a continual manner. Such a process is essentially generated as a continual interaction between the behaviours of constituting parts of an organizational system and the environment as an immediate contextual setting (organism: Something made up of elements with varied functions that contribute to the whole and to collective functions).

Organizations, from the above stated discourse can be understood as conglomerates of parts that are in continual interaction with each other and the environment, in which they operate. This is precisely where architecture can bear resemblance in its performance as organized spatial structures. Architectural grammar and the elements comprising this grammar need to act as coherent, interdependent entities in order to create an integral dynamic composition[5]. This aspect of interdependence and continual interaction amongst constituting components and the external environment quintessential for creating a dynamic, real-time adaptive architectural construct conforms to the perspective of open systems (systems theory), which has a striking similarity in its processes of exchange, interaction, interdependence and self-organization. Such architectural constructs, embedded within today's information rich context, will hence attain the dimension of complex information processing and information exchanging intelligent environments[6].



Cyclic nature: Corporations affecting the context and the Natural humans with which it actively interacts and this augmented context affecting the corporate body inversely.

(N) Natural humans

(C) Corporate personnel

Fig. 11 Diagram representing the organisational cycle

The organizational structure can thus be viewed as an active structure coherent with the manner in which a responsive architectural entity needs to function, specifically by means of acting as a distributed network system which develops its own dynamic web of relations (Fig. 12). The manner in which various multi nationals are focusing on developing a continual 24 hours economy by means of networking various parts of the firm spread out throughout the globe sets an interesting analogy for developing programmable architectural entities. Entities that can constantly exchange data and develop a coherent intelligence: by means of which they can update in terms of formal as well as behavioural states, in a communal fashion, thus developing societies of there own.

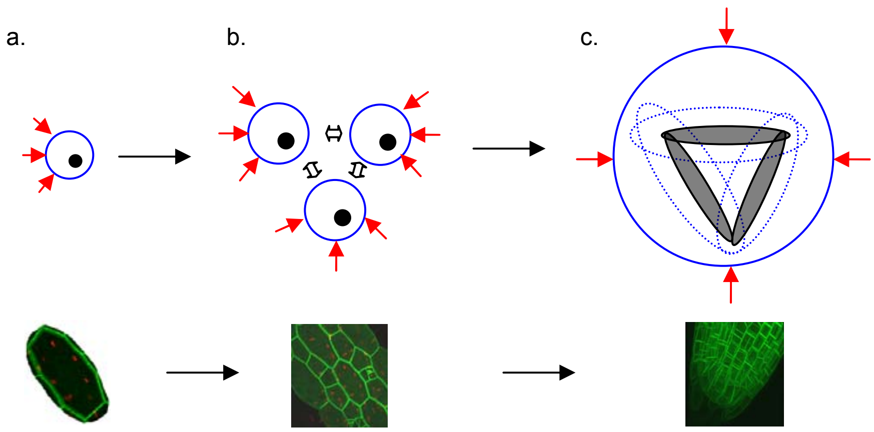


Fig. 12 a. Single responsive organisation/cellular unit interacting with their respective contexts
b. Several organisations/cellular units outsourcing and collaborating: developing the network/cellular structure
c. Organisations/cells mutating to develop ecologies and hence creating a dense swarm network, completely interdependent and interacting with each other to create a unified whole.

In order to understand the dynamic nature of organizations, the following section dwells into a critical analysis of organizations from a systems perspective. These system oriented reflections of organizations are contrasted with corresponding architectural concepts, thus hinting upon the possibility of visualizing/locating architecture within similar dynamic interactive domains. The analysis is largely based upon the work of Scott, W Richard, Englewood Cliffs, 1992.

2.2 A systems perspective on organizations

A system[7], in accordance with the Wikepedia encyclopaedia, is considered as an assemblage of inter-related elements comprising a unified whole,which facilitates the flow of information, matter or energy. The term is often used to describe a set of entities which interact, and for which a mathematical model can often be constructed. The term 'organization' is analyzed from a systems point of view in this research in order to understand its operational logistics. This approach will help in registering the nature of inter-relatedness that an organizational whole inhibits and furthermore will develop an understanding of the character of the system: closed or open, that organizations adhere to. Organization typologies can be broadly claasified from a systems perspective into the following[8]: Rational, natural and open, these three system typologies are elaborated upon with corresponding architectural design related parallels in the following sections.

2.2.1 Organizations as rational systems

ra·tion·al[9] *adj: Having or exercising the ability to reason, Of sound mind; sane, Consistent with or based on reason; logical:* rational behaviour

Rational organizations have specific characters of accomplishing set goals by means of following written rules and formal roles that help in discovering their optimal goal. The above dictionary exemplification as well as the above mentioned character of such organizations is suggestive of a high level of formalization and discipline, rather self-imposed discipline at the core of their structuring. Aspects of formalization and goal specificity are often seen as variables with higher or lower levels of applicability. The variable nature of applicability, in the case of rational organizations relates to strategic decisions taken by the board of directors in order to optimally formulate the structure of resources and agents in order to attain the set goal in the most profitable manner. However this is indicative of a closed system in terms of the evolution of its constituting systemic entities, which are restricted, and pre programmed to deal with specific outputs in accordance with pre-formulated rules. Such a strict rule-based operation (Fig. 13) hinders an evolutionary approach, which also encounters chance, unpredictable growth and related algorithmic probabilities that can be applied to enrich the organizational systems operation. Such organizations can thus be seen as anticipatory and predictive wholes where data is specifically channelised and processed towards achieving a foreseen goal. Such an approach however, helps in objectifying the structure of the organization, since both roles and the relationship of the actors, which are responsible for the production, are objectified and are external to their own interests.

Such a systematic and rule based approach can be compared to classical notions of architecture and for that matter the modernistic conception of architectural objects, which also finds its base in formalized preconceived articulation. The classical knowledge based system (sets of ergonomic data, standardized furniture, modular construction guided by standards books) is reminiscent of such an organized and machinic bureaucracy where all the actors, in this case the designers, drafters, and conceptualizers are driven to attain a specific goal: the final product. This rule driven approach had specific implementations on the definition of design and the designed product, which in my point of view accounts to predetermined objectification of conceptions. Hence in accordance with the rational organizational characteristic of objectifying the structure, architecture too employed a rationalistic problem-solving attitude towards aspects of qualitative design. Such organized behaviour stresses more on systematizing the actions of individual actors towards goal specificity rather than the interactivity and interdependence of these actors to conceptualise a complex system capable of multilevel and parallel data handling. Thus architecture, quite like rational organizations becomes an instrument designed to attain a specific goal.

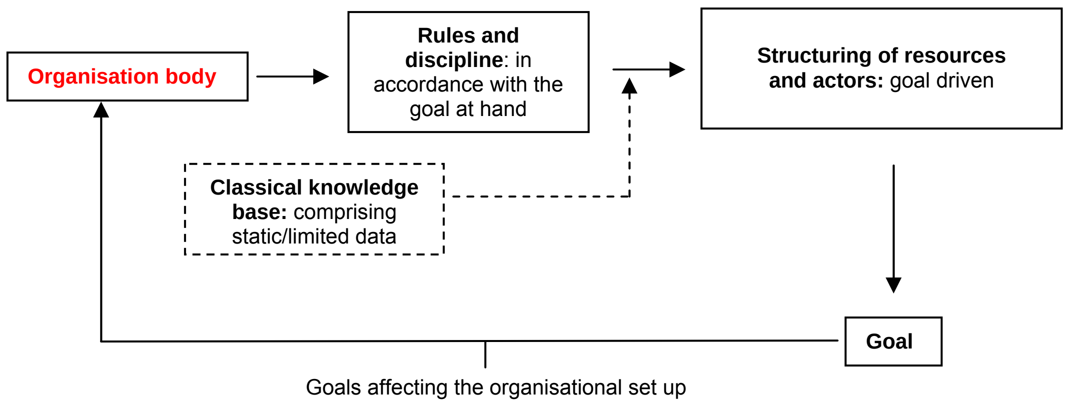


Fig. 13 Diagrammatic representation of a rational organisation

Though the perspective of natural organizations as compared to rational ones works towards achieving a goal, it has a completely different behavioural approach, specifically owing to the relations between its constituent actors. The next section exemplifies upon such organizations and compares it with an architectural parallel possessing similar behaviour.

2.2.2 Organizations as Natural systems

nat·u·ral[10] *adj: Not acquired; inherent, Having a particular character by nature, Biology. Not produced or changed artificially; not conditioned:* natural immunity; a natural reflex, *Characterized by spontaneity and freedom from artificiality, affectation, or inhibitions, Being in a state regarded as primitive, uncivilized, or unregenerate.*

Natural organizations also possess a set of rules and roles to achieve a goal; however where they differ is that the behaviour of the participants is not completely guided by them. The participants are rather guided by their own interest to develop their own behaviour but in the context of the organization as a whole through which they can fulfil their needs and interests. Though the participants are a part of the whole, they are characterized by spontaneity and freedom from artificial control. The stress in case of natural organizations is more on behavioural structure rather than on normative structure as is the case in rational organizations. Natural organizations possess a much more open systems approach in terms of the relation between the environment and the actors, however in this case the environment is perceived as a stabilizing element rather than a continual fluctuating dynamic entity. It is also assumed that natural organizations, due to their stress on behaviour tend to aim more on the activity and attitude of individual actor's for understanding the human whole (through which the behaviour of the bigger organizational whole could be better distilled). Hence a differentiation from a mechanistic approach to a more organic approach comes to the fore. Natural organizations brought with them the idea of evolution and growth as opposed to the aforementioned specifically designed approach of the rationalists. The idea of developing an informal structure that is vested in the personal characters and interests of participants (rather than the participants having to adhere to and modify there own interest in accordance with a formalized structure), of the organization, hence formulates the corporate culture in natural organizations. There is an inherent order to be discovered in an informal structure, which the natural organizations approve of, hence instead of being channelised as machinic parts, which are programmed to achieve a goal, natural organizations rather believe in evolving their own structure (Fig. 14) according to the interaction between their own sub parts and a limited interaction with the environment that engulfs it.

Though natural organizations support the notion of interactivity and interdependence at a sub-systems level, they do not tend to develop a similar intimacy with the super-system: the environment within which they operate. Subsequent to this character, the level of interaction within the organization itself is a bit constrained. This is relative to the nature of the individual actors, and the state they are in. What comes to the fore in terms of process is that the natural perspective is highly concentrated on its internal operations rather than also concentrating upon the organization itself as a complex entity. Developing a self-contained and self-sustaining structure with a highly indigenous level of interaction is thus what outlines natural systems.

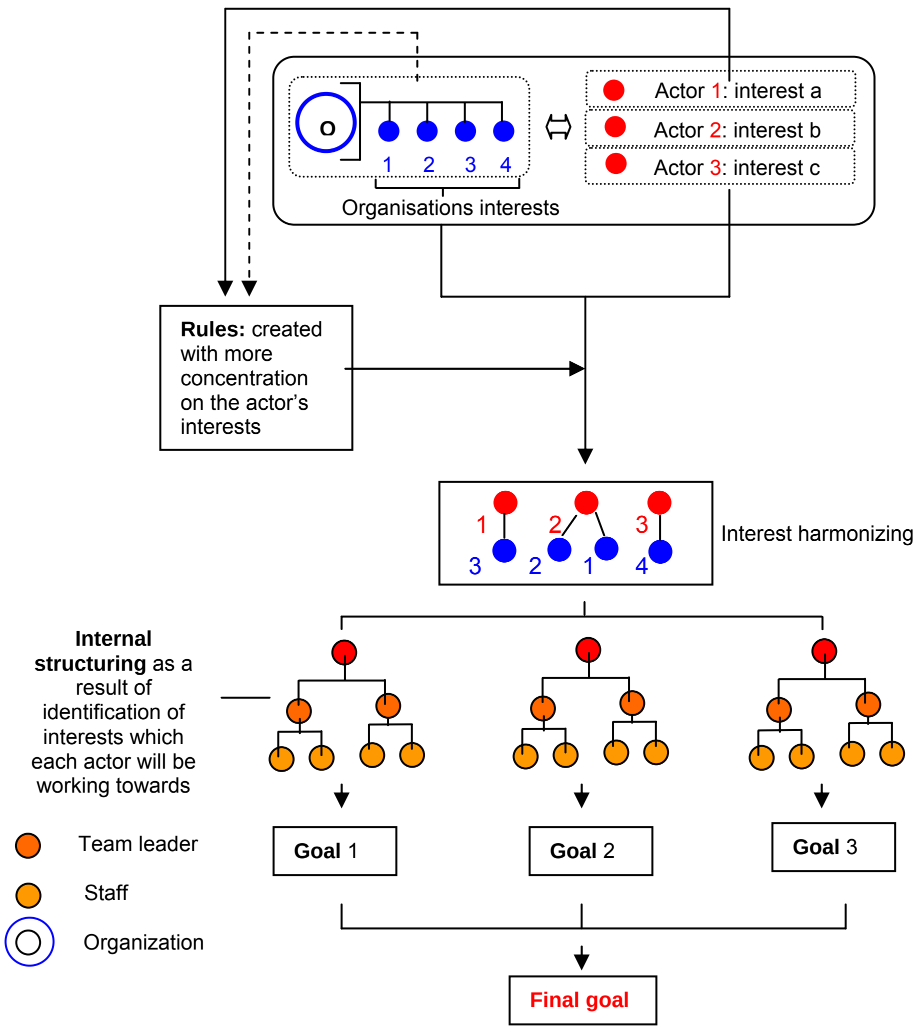


Fig. 14 Diagrammatic representation of a natural organisation

This nature of extreme concentration on internal sub-systems as opposed to relatively lesser concentration on the super-system as an analogy from an architectural point of view indicates the creation of semi-closed networks; with an utmost attention to detail out each and every individual building element (sub-system), with the intention of creating an individualistically precise construct. However it is at this junction that the built form becomes isolated and acts as a screen against the very context (super system) that it should be engaging with in order to develop and evolve with space and time. Contemporary office environments, completely wired and interconnected, are a perfect example of such organic mimicry. The conception, though rationally suggest interactivity and inter-connectedness, it lies embedded within a dormant and superfluous physical infrastructure that supports it. The inherent flexibility in terms of communication and information exchange that is desirable in such a networked environment thus tends to be encapsulated within a much more closed and non-flexible, rigid infrastructure facilitating body. In such cases, it becomes evident that the built form, in terms of its image value and the internal/actors oriented interaction that it supports, fails to operate/interact as a physical organizational body which can persist over time. The research work concentrates on similar corporate organizations, which specifically deal with Information as their core propulsion criterion but are still trapped within the static-ness of their spatial containers.

The open system perspective, to study organizations, both in terms of the processes and structure, however, creates a logical underpinning to understand complex systems and organizational dynamics. The following section, exemplifies upon salient features and parallels that an open system perspective incorporates with an evolutionary architectural viewpoint.

2.2.3 Organizations as Open systems

o·pen[11] *(adj): Affording unobstructed entrance and exit; not shut or closed, Affording unobstructed passage or view, Spread out; unfolded, Accessible to all; unrestricted as to participants, Free from limitations, boundaries, or restrictions, Being in operation; live.*

The meanings associated with the word 'open' in various perspectives, is suggestive of the nature of organizations that employ such meanings in the structuring and processing of their own selves. Open organizations, in contrast with the rational; mechanistic[12] and natural perspectives, differ in the notion of interdependence and interactivity that they inherit. Open organizations tend to be much more loosely coupled[13] systems, in context of the nature of interactions, both internal, of its participatory agents and external, environmental (Fig. 15) as compared to rational and natural organizations, with the former exhibiting a limited behaviour owing to a highly rigid structure and the later despite of being relatively less constrained behaviourally, possessing a defensive approach towards environmental interaction. Open organizations can in a way be seen as incorporating a system that not only realizes the importance of its body as a collective, but also realizes the vitality of the body's interaction with the supra-body, or the so-called environment. It is rightly termed as a system of interdependent activities, linking shifting coalitions of participants (W, Richard Scott, 1992). Though the open system perspective developed after the second world war, it is interesting to note that numerous areas of its implications, such as systems theory, operations research etc create a basis of some of the most successful organizations today. From the corporate point of view, such open system typologies can be viewed as a physical/conceptual entity, with inter-related and inter-active parts (the staff, the machinery and the departments), existing in an environment with which it interacts.

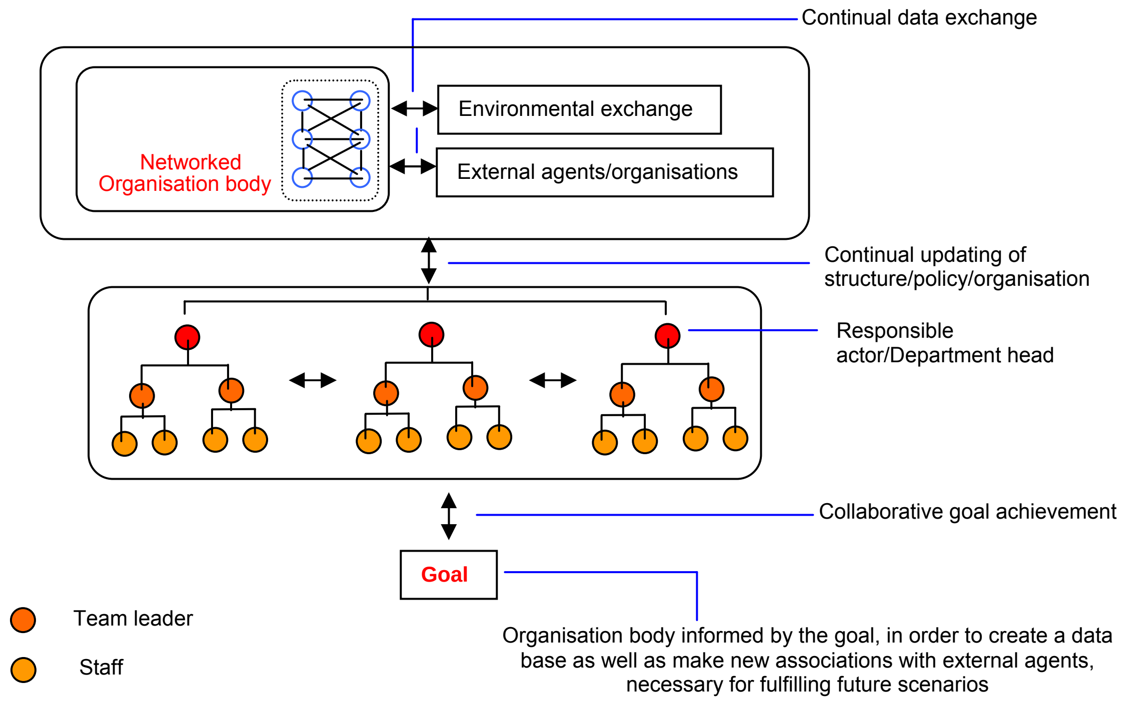


Fig. 15 Diagrammatic representation of an open organisation

It has a preferred state of profitability at its core and can be visualized as a system in interaction with its environment, hence being open, adaptive and productive at the same time. What is emergent about the nature of transitions that such organizations go through, is the continual updating and interactive appropriations that their structural and process oriented frameworks go through. This is made possible due to the nature of blurred boundary conditions that such organizations possess. These boundaries can be seen as permeable filters or rather more like an interface for throughput from the environment. It is precisely this throughput, embodying an active exchange of information that helps open organizations to escape entropy (measure of the amount of energy in a system that is available for doing work; entropy increases as matter and energy in the universe degrade to an ultimate state of inert uniformity). For such open entities, it becomes vital to address issues of adaptation, change and co-ordination. These factors usually in the case of such open entities are a result of the random, rather unbalanced and irregular information inputs that the system receives, making it develop a character of concurrency, asynchrony, decentralized control and a state of continuous activity.

Architectural space, as compared to the open system perspective, has been a perfect exemplification of a closed system; where the grammar formulating the built space is fixed and static in space and time. The notions of interaction between the actors/sub-components (in this case, building components) don't exist at all. From a scientific perspective of visualizing the active contribution of space in enhancing the performance of the nature of activity that takes place within it, space is reduced to a shelter and a comfort shell, which goes through its stages of conception, renovation and dematerialization. Architecture inherits a vital physical character which prevents it from transgressing the limits of the static and the stagnant self: the material. Though organizations, as open systems can perform successfully via interaction of their sub-parts and the environment, architecture in the material realm still remains a closed[14] entity owing to its inert material constituents. However, recent researches[15], specifically in the material sciences and the biotechnology sectors have already started concentrating on issues of imbedding information and responsive reflexes in everyday materials, which is now slowly blurring the boundaries of materiality and information based materiality. In such a context it is likely that if designers strategically merge such innovations with an equally adaptive (structurally) architectural prototype, they can provide for a semi closed/flexible network as a meta-system, which can authentically simulate the dynamics of the complex organizational system, which it sustains.

A fundamental character of open organizations, which can be used as a tool for developing such architectural possibilities, lies in its transition from the hierarchical structure (in terms of the clustering of various subsystems) to the notion of loose coupling that it professes. The loose coupling nature of open organisations, produce a much tighter and well-knit interdependency between system components. The notion of developing such tightly knit relations helps in simplifying the complexity of the overall system visualization, and helps in terms of grouping and regrouping system components, in accordance with the intensity of inter-linkage that is desired of them. This is an intriguing behaviour that can be incorporated while visualizing a variety of architectural subsystems. What can materialize is a set of 'stable subassemblies' (W. Richard Scott, 1992), operating within the super system of the architectural whole. This also helps the designer in identifying and extracting the nature of coupling and interrelations that the individual actors (sub-systems, department heads etc) prefer, in order to perform a specific task, help in optimised usage of the energies involved in the system articulation and cater to increasing the over all survival rate of the system. It is specifically such factors that are of importance when one visualizes an architectural construct that is a representative organism of the system interactions. Such an architectural body has to develop as an advanced prototype having the ability to optimise the inconsistent information flow in a dynamic and self-regulatory manner. This will imply developing state changes, formal augmentations as well as emergent behavioural profiles. The swarm perspective, also works towards eliminating the notion of centralized control and hence a hierarchical set up (in terms of governance) and rather acts as an open organization: a collective rich in its interactive and self-regulatory nature. The dynamic character which the operation of open organizations and the architectural translation of such open system characteristics as exemplified above, are suggestive of the fact that neither can be defined for a certain moment of time and can be considered finished. Rather they work as complex adaptive systems[16] with a continual input, processing and output mechanism.

After establishing a base into organizational variants and identifying open organization as a prospective field of study, the nature of corporate organisations is now elaborated upon in the subsequent section. The section, while tracing the evolution of corporate offices, (which can be related directly with the organisation typologies described in this section) will also exemplify upon the current changes in organisational trends.

2.3 Corporations

Cor·po·ra·tion[17] *n: A body that is granted a charter recognizing it as a separate legal entity having its own rights, privileges, and liabilities distinct from those of its members, Such a body created for purposes of government. Also called body corporate, a group of people combined into or acting as one body.*

The operational usage of a corporate mechanism is evident throughout the nineteenth century[18]. The accomplishment of mega-scale industrial as well as commercial projects in the nineteenth century and the amount of capital and infrastructure requirement for materializing such projects could only have been possible by a collective contribution by various organizations and investors under a centralized management system. Hence, the notion of the corporate can be summarized as an association of individuals under an assumed name and with distinct legal entity. However as discussed earlier while exemplifying the perspective of actors as organizations in section 2.0, the notion of the corporate personality/corporate/jurisdictic persons slightly moulds the above definition, specifically in terms of legalities. A corporation can hence be defined as a legal unit, a concern separated off with a legal existence, status or capacity of its own, a legal device or a medium for carrying on some business enterprise, or some social, charitable, religious or governmental activities. Sometimes called a *fictional person, legal person* or a *moral person* (as opposed to a natural person); obviously a legal fiction, a corporation enjoys many (or all) of the rights and obligations of individual citizens such as the ability to own property, sign binding contracts , pay taxes, have constitutional rights and hence participate in societal issues . Typically a corporation is governed by a board of directors, which has a fiduciary duty to look after the interests of the corporation. The corporate officers such as the CEO, president, treasurer and other titled officers manage the affairs of the corporation.

The research agenda, as was discussed in chapter 01, focuses upon the work environments of such corporations. The growing importance of occupant centred design issues and the importance of utilising measuring techniques (for both qualitative and quantitative data) as a tool to optimise office space will be exemplified upon in the following sections. The following sections hence create a vital link between the past and the future of office environment modifications based on critical changes in the working patterns witnessed over the past few years.

2.3.1. Mapping the evolution of corporations

According to Pevsner (A History of Building Types, 1996) office buildings were built either to provide premises for one firm of organization or for a number of firms not known beforehand. The consecutive story starts in London in the early nineteenth century with the County Fire Office (1819), followed up by some insurance offices. They were buildings with a monumental façade, and they evolved gradually into a type (a primitive form, the integral characteristics and qualities that a group, series, class of buildings has in common). From the mid nineteenth century buildings were also erected to be let as office suites to whoever came along and was ready and willing to pay the rent. The same development took place in Chicago and New York. Spatially, office buildings were converted dwellings. The building programme demands rentable floor space amenable to a variable lay-out where non-allotted workplaces could be utilized in all kinds of ways by users yet unknown. The demand for a maximum glazing was best satisfied by using iron, although this material at the time was not always accepted as a proper material for city facades. So buildings were covered with masonry verticals. Solids and voids however were still in balance in the façade. Thanks to the invention of the elevator, there was no limit to the number of stories a person can climb. Sullivan's Guaranty Building (Buffalo, 1890) - a high-rise structure in a U-shape, with rooms around an open court to provide natural light - presented a far more sensitive version of an office exterior and enriched it by feathery ornaments in the broad cornice and the panels above the windows according to the style of the day. The style (a collection of expressions that characterizes a certain movement or era) of office buildings varies from the Beaux Arts Classical Revival via Neo-Gothic to the International Modern Style. Wright's Larkin Building (Buffalo, 1904) a blocky block with in the four corners windowless staircase enclosures, and inside a large sky lit centre like that of a continental department store, and in keeping with such stores surrounded by galleries. The building was the first to be air-conditioned.

However, such office environments, completely immersed in hierarchichal ideologies, not only psychologically but also physically bestowed compartmentalisation, fragmentation and a stratification of space as an effective tool to enhance the importance/position of the occupants of the environment. Such a percept invariably led to what can be termed as the conventional process of designing office environments which were completely dependent upon standards emphasising area allocation/distribution in accordance with the number and the category of workers. Such a design process often involved referencing a standard database, based on a stagnant, rule system, which imposed non-flexibility and an avoidance of addressing the changing nature of work due to being embedded in a goal/production based profit driven[19] set up. The architectural constructs of such an approach can easily be seen as highly constrained machinic spaces constituting rows of free standing desks with some few private offices for officers of higher orders. Architecture, hence served as an appropriate tool for creating status-based distinctions concerning privacy and space. Such office environments, in order to induce a comfortable setting, further experimented with ongoing movements such as the green movement in design, which emphasised the inclusion of landscape and related environmental parameters while deisigning work environments. The action office, which enhanced the importance of modularity as an essential design component, to name a few, was another attempt promoting a systematised production and technology oriented vision. However most of these additional inputs ended up adhering to the increasing influence of technology that started infiltrating into work environments. Designing Offices came to be looked at as an act which involved supporting technology to save space. The results of such architectural constructs: the white collar factory, can still be seen in the 21st century.

The shift from the above mentioned early office environments to today's open office environments can be seen as a rather slow progression. What is more significant pertaining to this typological shift is the fact that the conceptual gaps and the discontinuities that existed while conceiving the earlier office environments still remain predominant. The trend, following from the rather uncomfortable and non-stimulating cubicle[20] systems to the mostly overclutered, over-stimulated collaborative environments can be witnessed as products of frantic attempts by the field of architecture and its components to interpret the complex social dynamics that operate behind the ever-fluctuating corporate environments. It is precisely at this point that it becomes evident that the lack of a consistent knowledge base and the rather strict approach of emphasizing order, efficiency, density and cost[21] incorporated by planning authorities seem to neglect human and sustainability issues as active parametric design tools.

This lack of human centred performance and productivity which in essence could lay the foundation for developing an innovative spatial construct has come under extensive scrutiny in the contemporary corporate research field. This researchwork, with its inter-disciplinary framework, hence explicitly focuses upon deriving a human centred approach for evolving a bio-system rather than another work environment typology for the corporate environment. The implementation of computation, automation, control systems and kinetic structures in order to sculpt subjective and objective data is experimented upon in this research to help create an interactive and human centric environment, capable of responding, communicating and externalizing generic linkages between occupants of space and their relation to the hard and soft components constituting corporate environments.

In order to understand the transition as regards work environments, the subsequent section briefly exemplifies on the history of office concepts, providing salient features of each, in order to trace the evolution from the pre-war period to the contemporary trends in office design. This exemplification is based on the research work conducted by the Centre for People and Buildings, The Netherlands and by the Haworth Inc. ideation group, LA, USA.

a. The Industrial office (begginning of nineteenth century):

- Proponent: Frederick Winslow Taylor (Taylorism[22])
- Developded owing to the Inclusion of the typewriter, photocopier etc. which made work a bit more faster than the traditional paper work based offices
- Workplace hence became smaller and task oriented as they were now designed for each unit seperately
- Work process devided into small units and small teams set up to specialise in these units
- Furnishing and design rationalised in accordance with work process
- Walls between the units were avoided so that work could be passed from one desk to the other like a factory
- Non-flexible organizational structure
- Eg. Larkin building, Buffalo, USA, designed by Frank Lloyd Wright (Fig 16).

Repercussion:

- Heavy criticism on the boring and monotonous experience of working in accordance with Taylor's ideas (Taylorism).

Fig. 16 Larkin building exterior, interior and plan views

b. The cellular office: 1950s:

- Proponent: architect Luis Sullivan (Fig 17)
- Series of rooms situated at the façade connected by long straight corridors in the middle
- Fixed workplace for each employee
- Management people were usually housed on the top floors owing to the wonderful views they could be provided with

- Middle management staff allocated a room for two people
- Filing department etc allocated a group area
- A variation: double corridor system with a central zone with no day light for sanitary facilities, lift, stairwell, pantry, copier etc with rooms on either side of the corridor
- Room sizes and furnishing based on authority level: higher the level, the larger the room size and the more luxurious the furniture
- Basic workspace furniture: desk, cabinet and a conference table
- Walled enclosures formulate the rooms at all levels of hierarchy
- Non-flexible organizational and spatial structure
- E.g. Winwright office, Guaranty office by Luis Sullivan

Repercussion:

- Optimal usage of space (in terms of square metres) is not attained due to the stress on status rather than functionality
- Floors with good view often assigned to people with higher authority
- Representativeness is considered more important than functionality

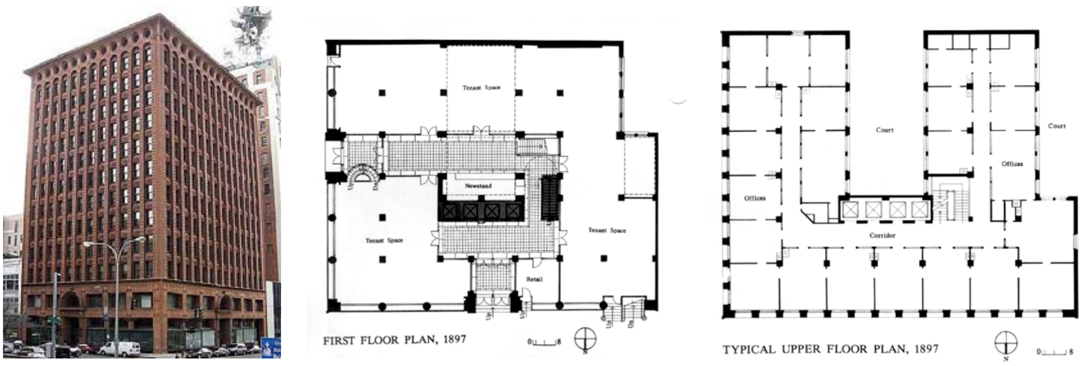


Fig. 17 The Guaranty office building exterior view and floor plans by Louis Sullivan

c. Open plan office: 1960s:

- Pioneers: Quickborner team, Germany
- Materialized due to a need for open-ness, flexibility and the need for a democratic decision making structure
- Large rooms which could be partitioned as desired
- Human relationship (department) becomes the centre of organisations
- Information flow, via functional lines which ran through hierarchical structures
- No class/status distinction, everyone sits in the open
- Air-conditioning and artificial lighting, usage of huge main-frame computers
- Furniture: plants, cabinets and medium height partition walls used as tools for segmenting the office space
- Absence of closed walls and doors favourable for communication
- Flexibility concieved as a reaction to changing organisational strategies and the IT developments
- E.g. Volvo office building, Torslanda and DHV, Amersfoort, the Netherlands (Fig 18)

Repercussion:

- Democratic decision making structure
- Opposition to hierarchy and status based space distinction
- Problems related with organisations not having adequately informed occupants of their goals in terms of design intents resulting in unwanted ownership/territorialisation of space
- Miss the opportunity to communicate and engage the worker by wedging a dumbled down product between the worker and the company spirit
- Disjuncts between the structure and the goals of the organisation and the interior frequently exist
- Uniform furniture and inability to control climate and light at a personal level
- Impersonal experience, lack of privacy
- Physical problems: dry throats, head aches, the sick building syndrome.

Fig. 18 DHV office interiors

d. Intermediate forms, 1970s:

- Proponent: Herman Hertzberger
- Developed in order to address the psychological and physiological complaints persistent in the open office environment and as a repercussion to changing views related to work methods
- Reduction in the open areas by means of connecting smaller floor units for various groups
- Further division of the open area by providing more movable partitions
- Seperating conflicting facilities such as reception, cafetaria etc outside the work environment hence developing the idea of zoning
- Emerging team work nature fostered the need for developing the group office where project related groups could discuss, have meetings etc
- Development of communal spaces such as cafes, squares etc encouraged the idea of developing informal meeting spaces
- Occupants considered as the priority and hence stress was laid on creating humane environments
- Inclusion of ergonomic furniture and individually controlable temperature and light settings in group offices
- A delicate mix between partitioned, walled and open space
- Organizational flexibility coupled with semi flexible spatial structure
- E.g. Centraal Beheer in Apeldoorn, designed by Herman Hertzberger, 1972 (Fig 19)

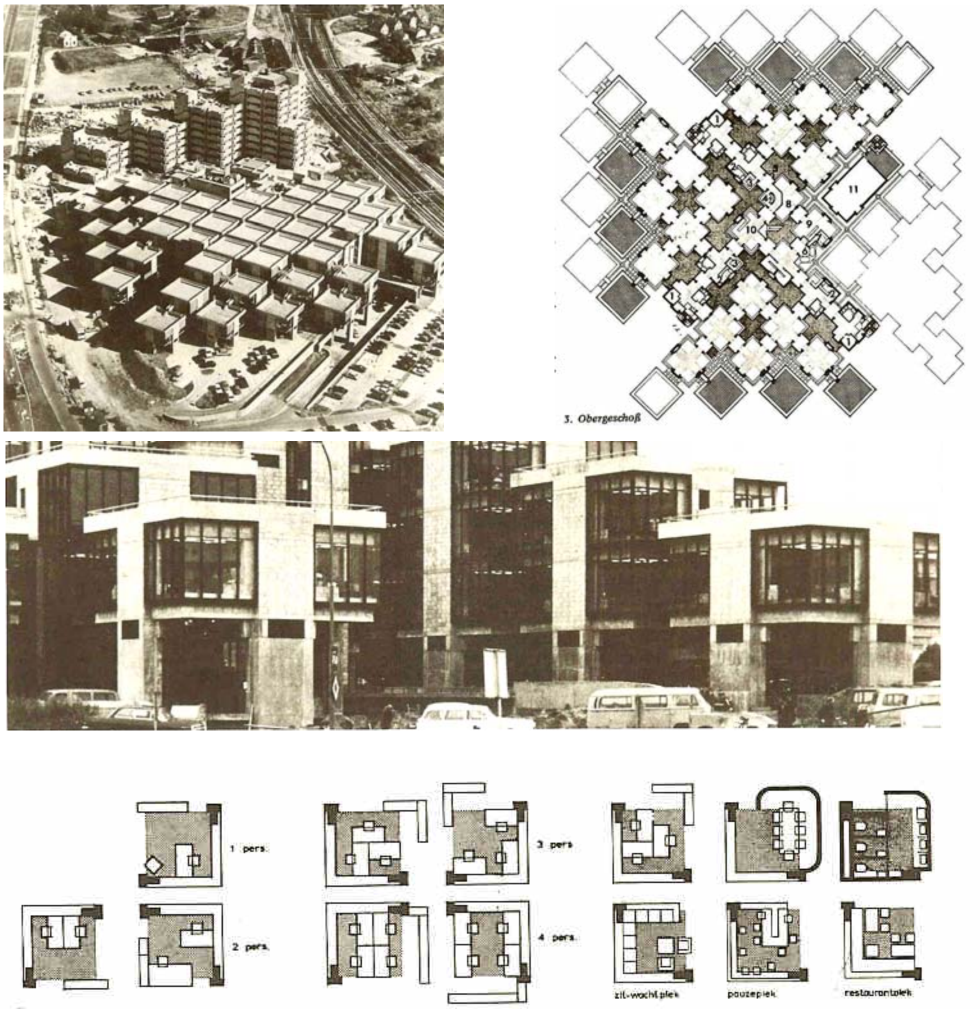


Fig. 19 Central Beheer office by Herman Hertzberge, Eternal views, Typical floor plan and a detailed workplace plan.

e. The Combi Office, 1980s:

- Proponent: originally a Scandinavian concept (during the 1970's)
- Influenced heavily due to the development in IT and personal computers and occupants of the space and the need to provide the occupant with the freedom to work wherever and whenever
- Rooms and group offices at the façade and a central area for formal and informal consultation
- Provisions for providing concentration cells and quiet workplaces besides the open and group office environments also co-exist.
- Environment fostering comfort and communication possibilities and an Informal, personal contact in the work space is aimed for.
- Communal use of printer, fax, filing cabinets etc.
- Influence on architectural form and furnishing due to the increased information technology usage was very limited
- Soothing, ergonomical furniture with variations in colour as well as variations in artificial lighting
- Balanced mixture between walled (private) and open discussion, team work and community spaces

- Organizationally flexible but spatially zoned (in terms of the nature of each space and the activity to be performed within them)
- E.g. Interpolis office, Tilburg, the Netherlands (Fig 20)

Fig. 20 Interpolis office, Exterior and Interior views, Tilburg, Nethrlands

f. Flexible working, 1990s:

- Evolved as a result of low occupancy rate of office workspaces and an increasing development in information technology (IT)
- Provision of a varied range of activity related workplaces allowing one to choose the best suited workplace in relation to the activity being performed
- Desk sharing becomes a strategic move
- IT makes it possible, with the development of internet, intranet to work from anywhere and anytime
- Working from home becomes an accepted practise
- Change in work patterns and the idea of buying and selling work days comes into play
- Facilities such as laptops, mobile phones, and network connections at the home of employees makes the work environment much more flexible and relaxed
- Various furnishing alternatives based upon the kind of activities being catered to were introduced
- A mixture of walled (for privacy) and open/semi-open spaces are clustered together
- Flexible usage of space, however an optimal usage would require a well distributed set of activities corresponding to the spaces provided within the office.
- E.g. ABN Amro effecten services, Breda, Netherlands, Hotelkantoor Bleijenburg, The Hague, Netherlands (Fig 21)

Fig. 21 ABN Amro (Left), Breda, Netherlands and plans showing interior arrangements of Hotelkantoor Belijenburg, The Hague, Netherlands.

After tracking down the evolutionary path of office design trends, the next section briefly explains current organisational trends, changing organisational structures and the changing nature of work which are based on researches conducted by the Haworth, Inc. ideation group in the year 2002. This primarily helps in developing a framework for current corporate trends and creates a basis for analysing the Interpolis office, Tilburg, The Netherlands. For the purpose of this research work, these organisational trends are looked at as a means of extracting research parameters which will be further used for computation purposes.

2.4. Understanding the corporate species

The analysis of corporate trends is based on the output of interviews conducted by the Hayworth Inc with 10 high tech executives and about a hundred facility executives and suggests the prevelance of a broad qualitative generalisation in contemporary organisations. The outlined changes which are recurrent and will mostly be prevalant in the near future too, will help in understanding the dynamics behind corporate culture fluctuations.

2.4.1. Organizational/corporate culture an underpinning

In order to understand the underlying reasons behind the exemplified corporate strategies and ensuing changes that the corporate world witnesses, the research work, in this section exemplifies upon the meaning of culture in the corporate/organisational domain. Organisational culture essentially portrays the values, attitudes, beliefs and experiences of people/human components which it harnesses. Organizational culture is the specific collection of values and norms that are shared by people and groups in an organization. These also control the way they interact with each other and with stakeholders outside the organization. Organizational values are beliefs and ideas about what kinds of goals members of an organization should pursue and ideas about the appropriate kinds or standards of behavior organizational members should use to achieve these goals. From organizational values develop organizational norms, guidelines or expectations that prescribe appropriate kinds of behavior by employees in particular situations and control the behavior of organizational members towards one another. (Strategic Management, Charles W. L. Hill, Gareth R. Jones, Fifth Edition, 2001 Houghton Mifflin, MeansBusiness, Inc.).

Another interesting relation, which brings space under speculation as regards the manner in which people feel and hence are motivated/de-motivated is associated with the kind of environment within which they operate. This feeling in-turn is responsible for shaping the personalities of individuals within the organisation which bears a direct impact on the productivity of an organisation. Productivity, as suggested by Wilf H. Ratzburg, is firstly a function of each of the employees unique personalities. Second, employees behaviors are influenced by the environments in which they find themselves. For example, an employee's behavior (and productivity) will be influenced by a dirty, hot, noisy, or dangerous worksite. Finally, an employee's behavior will be a function of that employee's innate drives or felt needs and the opportunities he or she has to satisfy those drives or needs in the workplace.

Organisational behavior can be hence understood better as a function of people and the environment within which they are situated. Design processes embedded in developing spatial aspects on the basis of an understanding of the psychological and social aspects of people working within the office is thus rather critical to attain a highly productive organisation. The critical value embedded in such process oriented designed settings is further strengthened by Frank Duffy (principle DEGW): "The big discovery we've made in the past two or three years is that the design process itself is an amazing opportunity for a company to reinvent its culture. The expressive component of architecture can be used as a medium of communication--one that makes the intentions of the business powerful and ever-present… Change management doesn't mean anything without physical redesign. That's a big lever that could be seized by management consultants."

Studying such organisational characters involves an inter-disciplinary perspective, involving the understanding of organisational components through mediums of psychology, to understand the individual (a human centric perspective), sociology, to understand the nature of group behviour, anthropology, for understanding corporate culture, economics, to decipher ways of rational decision making and political sciences for identifying the role of power and image. The spatial perspective, which draws heavily on the grounds of the above mentioned fields is hence seen as a highly calculated mobilizing medium for corporations to perform in a profitable fashion. An attempt to decipher relational logic between the above mentioned components from a human centric perspective and an activity oriented scenraio is elaborated upon in subsequent chapters.

In order to further the understanding of changing/evolving nature of todays corporations from the perspective of an evolutionary cultural phenomena, the research body now delves into mapping some vital corporate re-structuring phenomena in the following sections. This mapping is specifically based upon the research conducted by James D Cox and Thomas Lee Hazen, 2003 in their book Corporations.

2.4.2. Changing corporate strategies

- **Internal to external focus**
  - **Current factors** focused upon for improving business: internal considerations such as core competencies, personnel, suppliers, products & services, distribution, process engineering, and other “outside-in” factors.
  - **Changing strategy** as regards external considerations such as market share: customer interests, needs, wants & behaviour and Societal & cultural trends; generational trends and other “inside-out” factors are being concentrated upon for the future success of organizations.
  - Almost any technique that can reduce cycle time to understand customer issues and meet their needs with timely new products and services will be a great investment to make.
  - Corporations of the future will keep their businesses current by maintaining an external, “inside-out” focus.

- **Process to trends**
  - **Current tasks handled by a typical corporation:** design, implement, and monitor efficient internal processes and their interactions.
  - **Changing strategy:** anticipate, understand, and address the broader societal trends that influence their customers and their customers’ desires, positioning their product & service offerings to take advantage of this advance knowledge.

- **Fixed to flexible strategic planning**
    - **Past trend:** setting out a permanent strategy, which guides the organisation throughout their evolution. The propulsion of a product and task based approach.
    - **Changing strategy:** concentrating on relatively permanent strategic plans, which reach only a few years ahead, hence remaining flexible by generating responses to a number of different alternative scenarios and formulating new strategies for the next few coming years.

- **Corporate culture to society**
    - **Current situation:** We still don't know nearly enough about corporate culture—how it arises, how to influence it, or how it relates to corporate success.
    - **Changing strategy:** interchanging considerations of the corporate culture with investigations of the cultural trends within the broader society. Various global multinationals, which must respond to a number of different cultural imperatives to ensure a continued growth and success, are adhering to this change.

- **Physical to mental environment**
    - **Past trend:** evaluation of the organisations design was done without considering the occupants psychological afiliation but rather is based upon issues of area distribution, function, and infrastructure fulfillment.
    - **Changing strategy:** recognition of the impact of the physical environment on the mental functioning and capabilities of employees. Design and building performance evaluation have to be coupled with the preferences, responses, and needs of occupants. Organizations of the future will manage design projects in terms of occupant-centred definitions for both problems and their solutions. While customers will drive the "front-end" of these businesses, employees will drive the "back-end" and both constituencies will be accepted as critical for long-term survival.

2.4.3. Changing organisational structures

- **Status to performance based**
    - **Current trend:** past organisational trends and their impact on stratification of the architectural space, as was discussed earlier in the chapter were heavily based on the "How long have you been here?" question. Seniority was always judged on the basis of ones association with the organisation and this aspect led to the creation of status based issues.
    - **Changing trend:** "What have you done for me lately?" will determine space and resource allocation standards for companies of the future.

- **Hierarchical to strategic (flat)**
    - **Past trend:** a highly disciplined, hierarchichal structure, with the notion of status playing a rather significant role in every aspect of the organisational structuring. This approach indirectly led to categorisation and conscious awareness of the position that each employee held and hence created psychological gaps which led to non-eficient performance.
    - **Changing trend:** shift from the military-inspired "command-and-control" organizational structures to the flexible, "flat" corporate structures of today and tomorrow. Power is given to

individual teams to make effective decisions, which also helps in decreasing the cycle time for reaching conclusions sooner and hence enhancing the performance of the organisation.

- **Top down to local control**
  - **A repurcussion:** Although somewhat redundant with the last continuum, this trend (to move decision-making and resource-allocation down to lower levels in the hierarchy) has been important even within organizations who have retained an otherwise rigid, hierarchical structure. Again, increased speed of response represents a primary advantage of this change, along with ensuring that empowerment for making critical decisions remains closer to customers—allowing them to have a timely impact on most if not all internal processes and initiatives.

- **Organizational Chart to Functional Alignments**
  - **Implications of the change:** from rigid, fixed strategies to fluid, dynamic arrangements, now allows companies to change focus and direction much more quickly than the hierarchies of the past would allow. This change continuum has a number of salient office design implications, since the important behaviours and interactions that must be supported and leveraged within corporate office environments cannot be understood simply by studying the official organizational chart. Ideally, programming approaches include observational and other indirect methods to understand exactly where to draw the line between relatively unchanging business sectors and the dynamic re-combinations of other teams and processes.

- **Departmental "Silos" to Integrated Solutions**
  - **Past trend:** at the architectural front, the past office environments, at numerous occasions even the open plan office environments are comparable with silos, one can see a similar approach in terms of distribution of resources from an IT centred and a production oriented view point. This approach rather created ever-extending floor plates with facilities scattered on them, rather than understanding the changing nature of work and the importance of the inhabitant which could have resulted in the generation of a bio-environment rather than a machinic spatial setting.
  - **Changing trend:** with the changing nature of work, an integrated approach towards designing work environments needs to be stressed upon. The notion of a networked spatial setting comes to the fore where rather than the machinic whole; the inter-activating nature of the subcomponents, which create the machine, needs to be stressed upon. Envisioning a biotic system, which is the focus of the research, is an active step towards materialising such an approach.

2.4.4. Changing nature of work

- **Independent to collaborative**
  - **Past trend:** at least in the United States, about 60% of office workers still spend approximately 60% of their time working alone. Task based concentrated work leads to separation and specialised distinctions at an individual level and hence reduces social coherence within the organisation.

- **Changing trend:** a gradual, steady shift away from independent, "heads-down" work to more collaborative, team-based activities—even in conservative sectors such as banking & finance. Both generational differences and changes in the delivery of educational services that supply the workforce have contributed to this trend.

- **Management-directed to Self-directed**
  - **A repercussion:** As corporate strategies embrace flexibility and hierarchies crumble, individual workers become more responsible for their own contributions—from start to finish. Leveraging this "knowledge work" represents the most important challenge facing organizations of the future (according to management guru Peter Drucker). Meeting this challenge requires an integrated approach that includes adjustable, movable, re-configurable, yet dedicated environments; performance-based incentive structures; shared (group-level) performance evaluations & rewards; and adaptable perks like flex-time and ubiquitous access to technology.

- **People as Interchangeable parts to Critically Unique**
  - **Past trend:** the task of the majority of employees was reduced to implementing processes which were planned by higher level authority officials; hence the nature of work responsibility shared by these employees involved only their brawn.
  - **Changing trend:** As job descriptions widen and the variety of responsibilities that each job entails increases, worker's brains increasingly determine their effectiveness. The unique social network and other tacit knowledge acquired by each employee during their tenure represent advantages that sagacious corporations crave and exploit. The most conservative estimates of the costs to replace one employee start at 1.5 times his or her salary.

- **Repetitive (Efficiency = Speed & Accuracy) to Creative**
  - **Past trend:** Repetitive work ruled in the past, speed and accuracy for the most part equalled productivity.
  - **Current trend:** the quality of ideas rather than the quantity of activity has become the new path to success.

- **Observable/Measurable to Serendipitous/Abstract**
  - Repetitive work can be easily observed and measured, while creative innovation rarely corresponds in any meaningful way to a unit of time; additionally, the source of important creativity less and less frequently reflects the isolated contributions of single employees. The best ideas integrate several levels of abstraction within the corporation and cut across various sectors and processes, and are thus almost impossible to attribute to a single individual.

- **Process Support to Knowledge Work**
  - To reiterate and summarize many of the points made above, office environments to support future organizations must nurture knowledge work rather than large groups of workers simply implementing the processes thought of and designed by the management. Factors external to the organization now provide the most meaningful insights to determine its future course rather than internal factors, hence anticipating and designing the ideal environment to support these workers will become increasingly difficult. Flexible, adaptable office designs featuring seamless technology integration can however help in minimizing the costs & disruptions of change &

transition. Investments such as raised flooring, easily moved wall dividers & partitions, and adaptable, re-configurable technology access & support will become commonplace.

The above exemplification makes it rather clear that contemporary organisations are witnessing an overall transition concerning almost every aspect of their structuring. The conceptual shift towards a flat structure, collaborative work, external considerations, societal bend, focus on cultural trends, on mental and psychological enrichment of the occupants, local control allocation and self directed team work encouragement etc all focus towards occupant and client centred aspects or rather human centred aspects as the driving force behind tomorrows corporations.

The research work, as mentioned earlier, will thus specifically focus upon this human centred approach to conceive a real-time interactive spatial prototype whose adaptive nature will be intricately derived from a detailed analysis of user needs and demands. Such an approach will entail both; objective assessment of the psychologically meaningful dimensions of the environment (e. g., acoustics, lighting, day-lighting, thermal conditions, aesthetics, human factors & ergonomics, group identity) and subjective assessment of the occupant's preferences & responses to various alternatives differing along these dimensions. These aspects would need to be considered simultaneously for developing an appropriate spatial response (design solution). A detailed elaboration of such human centred aspects will be provided in Chapter 04 via the PACT: people, activity, context and technology framework[23]. This framework apart from analysing the corporate scenario from the psychological and physiological perspectives will also be highly instrumental in identifying interlinked research variables amongst the four components (people, activity, context and technology) hence providing a logical underpinning for the proposed prototype's behavioural response. Computation tools and techniques from the fields of ubiquitous computing[24], control systems and sensing environments will subsequently prove to be highly instrumental in addressing and mapping resultant functionalities as regards needs and demands of typical users, filtered through the PACT framework and hence will form an active part of this research.

2.4.5. Organisms and Organisations

Developing a confluence of socio-cultural and technological counterparts particularly aims at interpreting and representing contemporary corporate culture as active bio-systems[25] which can cater to dynamic influx of information (user oriented) and interact with it in a constructive (spatial, ambient and informational) manner. The foundation of such a bio-system for envisioning the proposed office prototype can be metaphorically inferred via the development of a generic diagram, which tries to establish similes between an organism and an organisation (Fig. 22). This diagrammatic expression is one of the first steps for understanding the conceptual biotic linkages, which a spatial prototype for a dynamic corporation could embody. A user centred approach is evident in the following diagram; Issues related to individuals and teams and the relational dynamics, which their interaction with the environmental context yields, is seen akin to biological processes of evolution and adaptation.

For the purpose of this research, an intrinsic linkage between biotic operations of mutation[26], evolution and self organisation[27] with respect to contextual dynamics, and the domain of real-time interaction is elaborated upon towards the end of this section. This operational linkage as regards componential interaction and constant exchange of data at a local as well as a global level is of specific interest for conceptualising interactive system frameworks for the proposed prototype.

Exemplifying upon the metabolism of corporate structures, one can see the following trait:

From the inception of the firm:

Biological system ⟷ Corporate based system:

Head/managing director – body/firm – differentiation of organs/team formation – decentralized control/team leaders of each team – differentiation of tissues/skills and operations subdivisions in the team – further differentiation/specialized design differentiation – specialization of control/head of skills and vision, operations director

↓

***Basic Body** (governed by the dynamics of differentiation and control): **Main controllers** defined at this level*

↓

*The **Body adapts** to the **context** within which it is embedded and **evolves** due to this **inter-activity***

↓

Adaptation to the environment/re-adjusting subsystems according to fitness and usability criteria (recombining and restructuring of sub departments/teams) – developing feedback and reflexes (as a direct consequence of the environmental adaptation and the variety of actors present in the environment)/Client interaction (leads to further subdivision and distribution of skills and functions to individual team members, developing an interactive interface etc)

↓

Effects: developing of integrated fully differentiated organs/creation of autonomous teams with specialized knowledge base to deal with clients and corresponding environmental data pool.

↓

Developing a connector thread/spinal chord/ finance and IT division (connecting various specialized teams/actors of the swarm)

↓

Development of an **autonomous body**/the **swarm**/collective. The **swarm further interacts** with the environments and with other swarms to **develop collaborative tasks**.

↓

Growth and transformation/input of new people – bonding of tissues/exchange with other branches – differentiation of main controls/branching into other cities – symbiosis/mergers and acquisitions – food chain/acquisitions

↓

Colonies/population/corporate/inter-activating swarms

Fig. 22 The above diagram sets up a comprehensive analogy between a corporate environment and an organismic whole, setting the idea of the relation between an organism and an organization (source: AA DRL).

Visualising the bio-system, it becomes evident that it falls under the earlier explanation of the open system perspective, with a significant stress upon the componential interactions of its sub-systems and the external context. What's interesting though is that unlike physics, biology does not usually describe systems in terms of objects which obey immutable physical laws described by mathematics. Biological systems are not completely random, as they may have predictable statistical tendencies to behave in certain ways, but these tendencies are usually not as concrete as those described in subjects such as physics. In the study of biology and its associated systemic behaviour, certain principles and concepts come to the fore: universality (bio-chemistry, cells, and genetic code), evolution, diversity (variety of living organisms), continuity (common descent of life), genetics, homeostasis (adapting to change) and Interactions (groups and environments). For the purpose of this research, we will specifically look into two crucial aspects: homeostasis and interactions in order to develop an understanding of the manner in which bio-systems/open systems maintain their internal auto-regulative state and possess an optimal level of interaction for their sustenance. Wikipedia encyclopaedia refers to homeostasis in the following manner: Homeostasis is the ability of an open system to regulate its internal environment to maintain a stable condition by means of multiple dynamic equilibrium adjustments controlled by interrelated regulation mechanisms. All living organisms, whether unicellular or multi-cellular exhibit homeostasis. Homeostasis manifests itself at the cellular level through the maintenance of a stable internal acidity (pH); at the organismic level, warm-blooded animals maintain a constant internal body temperature; and at the level of the ecosystem, as when atmospheric carbon dioxide levels rise and plants are theoretically able to grow healthier and remove more of the gas from the atmosphere.

This definition of homeostasis specifically points towards the vitality of developing and maintaining a constant real-time communication protocol amongst a larger system's components. A constant translation and exchange of data coupled with a control system which houses certain rule oriented/systematic way of addressing data and hence producing an appropriate output/internal regulation is highly desirable for maintaining a sustainable system. At the core of this controlled process lies the idea of behaviour or the nature of interaction desired from the system. In order to extract a parallel between computational interaction and biological/natural interactions let us now look into the Wikipedia encyclopaedias definition of interactions in the biological world. The encyclopaedia suggests that every living thing interacts with other organisms and its environment. One reason that biological systems can be difficult to study is that so many different interactions with other organisms and the environment are possible, even on the smallest of scales. For any given species, behaviours can be co-operative, aggressive, parasitic or symbiotic. Matters become more complex when two or more different species interact in an ecosystem. Studies of this type are the province of ecology. In the field of information sciences, communication as well as industrial design this notion of interactivity, from a systems perspective is translated in the following manner[28]: Interactivity is similar to the degree of responsiveness, and is examined as a communication process in which each message is related to the previous messages exchanged, and to the relation of those messages to the messages preceding them. Though biological systems operate by means of complex chemical balances, in the electronic media domain a rather systemized manner of writing instructions (programs, algorithms etc) are developed to attain a mimicking status. In addition to this, a variety of issues such as physiological, psychological, social as well as ethical are attached with the domain of interaction design. These will be addressed in subsequent sections (4.2.1 – 4.2.3) in order to develop an open system typology akin to biological systems for developing a corporate ecology.

Based upon the above exemplifications of the changing corporate scenario and the bio-system visualisation, the research work now illustrates upon a foreseeable organisational future.

2.5 Future organizations

The new work place will essentially be an advanced prototype of the open organizational structure, rich in its interactivity towards internal auto regulations and the external environmental settings as discussed in the previous sections. The increasing use of information technology in the everyday governance and behavioural regulation of the organization will incline it more towards creating a web of enterprise whose boundaries are blurred. The notion of having flexitime[29] as well as desegregation and downsizing of firms into smaller components such as franchises, sub contractors and small firms will all become registered trends of the future organizational behaviour. Organizations recurrently fall in the category of 'entropy'[30], which is suggestive of transient and flexible young organizational set ups. The traditional hierarchical governance phenomenon no longer holds good for the manner in which relations and interdependencies develop in the internal structure of the organization. The hierarchy is giving way to networks[31], giving rise to horizontal co-ordination rather than a much more rigid vertical division of labour.

The future of organizations will thus be completely governed by factors like: knowledge based task groups, workflow systems, electronic commerce, and virtual organizations. Such phenomena embed within them the logics that instrumentalize an organizations performance. The subtle transformation of the information driven era to a knowledge driven era is inevitable. The need to strengthen knowledge bases in any organizational set up is hence seen as the only way to step into the future of a highly informed and fluctuating context. The idea of developing knowledge based task groups, explicitly elaborates upon this notion and provides for the development of task groups that specialize in certain area of work which are highly informed/supported by the knowledge base of the organization. The idea hence is to create a specialized subsystem that is a collective of intelligent and highly active agents, working efficiently towards achieving ends in an optimised fashion.

Workflows, or the processes that aid in making a business transaction, are now aimed directly towards the core business processes, becoming much more flexible to adapt to the changes in the organizational structure and developing an inherent knowledge sharing approach which will benefit and inform various subsystems or substructures operating to produce the flow. Electronic commerce[32] is also seen as an essential role player in the creation of future organizations[33], as a vast amount of work will inevitably be processed via networks and information gateways. A variety of online marketing and buying and selling activities can already be registered on the Internet nowadays. However apart from the usage of e-commerce in such small scale transactions, it will also find its extensions in the area of creating virtual organizations, by developing contacts via the network, with specialized actors, who can further combine virtually to start off a business alliance. A variety of knowledge sharing communities, advertising sites and a different set of communication facilities via the Internet also suggest an increasing network based approach of spreading an organizations business prospects. The concept of virtual organizations will increasingly materialize due to this networked approach towards business propagation. The loose coupling of the workforce itself and flexibility in working hours, with a knowledge sharing support will be hence emphasized upon through this virtual mode of operation. A much more distributed and networked organization (Fig. 23) will inevitably materialize in the near future, with an emphasis on developing a well-structured knowledge base and vital technological advancement in the information sector.

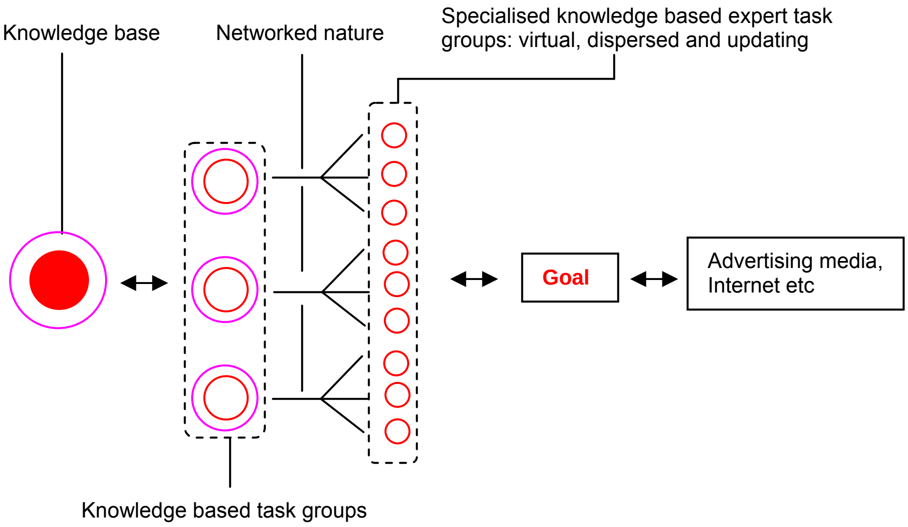


Fig. 23 Diagrammatic description of a future corporation, showing a constant updating and addition of knowledge to the organisation body

2.5.1. A spatial perspective:

With the emphasis on developing such complex infrastructures and fluid information laden work environments, it becomes but natural that architectural entities that house such knowledge economies also need to serve as a new form of intelligent interface between the human actors that work within the organization and the online digital information they produce. The notion of flexibility, growth, mutation and co existence that become inherent in the everyday functioning of such organizations, needs a specialized architectural construct that not only helps in terms of brand identity related issues but also aids dynamic functioning, provides user comfort and fosters user oriented customization opportunities.

At the architectural front, a variety of experiments[34] are being conducted, which aim at developing a seamless interface between the participants in the organization and the digital information that they acknowledge. Stress is laid upon ambient conditions and associated effects that could aid in providing a thrust to the knowledge economy that is embedded in ideas of mass innovation and the conversion of information into knowledge. The research agenda is set in such a framework where the role of organizations, in particular open organizations is being transcended through technological propulsion in a variety of sectors such as information, hardware, software, materials, engineering etc. However looking at the current trend of being governed or administered by a personal computer (PC) in more or less every sector of the organizational workflow, summons an immediate association with the industrial era. The tools (the PC, or earlier in the industrial era the typewriter or similar data processing machines) regulating work processes have changed from the past, but the manner in which organizations have utilized the tools simply suggest a substitutive approach rather than a much more serious optimisation of the information technology for enhancing user productivity as well as physiological comfort. Harnessing newer modes of information processing is not the only source through which one can visualize a holistic change in an organizations outlook, rather a synergistic merger of work environments, technology, environment (contextual and data based), architecture and structure needs to be materialized. The inherent idea of co-operation and interconnectivity, much like a swarm hence surfaces. The notion of inter-activating and co-evolving hence becomes of vital importance for the knowledge economy to prosper in an open environment.

A variety of researches[35] that have been conducted till today, often glorify the technological arena, where various intelligent IT tools are networked in an inter-activating fashion. Though experimental in their outlook, such tools, acquire a rather superficial dimension in terms of the manner in which they are often pasted onto architectural grammar: walls, windows, floors etc. In turn the interactivity that is programmed into the tools of new media is portrayed as developing intelligence into the architecture itself. Architecture on the other hand remains the same closed container bearing such pastiche. One can visualize such installations as technological interconnectedness and hence intelligence generators, but the physicality of the architectons, which are directly associated with psychological comfort and user satisfaction still remain unchanged. Speech recognition, visualizations and interfaces that are difficult to comprehend tend to be some of the basic augmentation tools in the contemporary. However visualizing the architectural physicality for breeding such intelligence is what needs to be focused upon with equal importance. The research agenda is thus directed towards materializing such an architectural construct, which will formulate a meta-system on an ad hoc basis to cope with dynamic and fluctuating organisational as well as user centric situations.

The definitions that aid in describing the characters of open organizations will be applied coherently to envision the desired physicalities of the proposed architectural space within which such organizational behaviour will germinate. Predominantly the proposed organization, much like the characters of open organizations, will deal with communication between different operational divisions (sub systems/actors) and the external environment as well, hence informing the organization in real time as regards ambient as well as physical alterations to its environment (Fig 24). A synergistic level of interaction between the internal systems, which determine the behaviour and growth of the system itself and the interaction of this systemic whole with the supra-system: the environment will be materialised for conceiving a work environment rich in its behavioural instincts. In brief, the approach features an occupant-centred design, which results in the generation of a fully customisable space envelope, capable of reconfiguring its spatial and ambient structure in real time to adapt to its user.

An attempt to measure stress levels of occupants of such responsive spaces is proposed by means of real-time monitoring (by means of physiological sensors) of stress levels in association with the Industrial design department at the TU Delft. Success can thus be defined quantitatively both in terms of objective engineering criteria and the subjective experience of occupants. Defining design problems and goals in terms of occupants allows clear comparisons among alternatives to be made in both objective and subjective terms. Organizations of the future are thus envisioned to provide an optimal environmental support for knowledge workers, and an occupant-centred design in-turn ensures they fulfil their goals in a highly productive and satisfied manner.

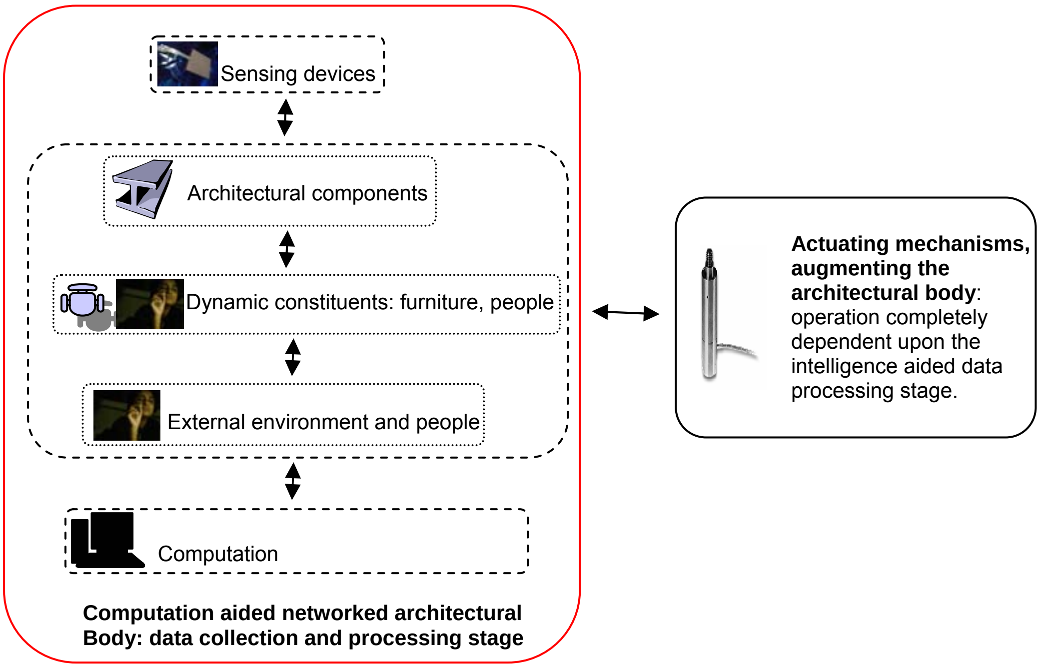


Fig. 24. Diagrammatic representation of a networked architectural whole.

After exemplifying this comprehensive view on the future of organisations, I will now focus on another important aspect: the notion of flexibility, which has been a pre-dominant concern for contemporary organizational design.

2.6. Flexibility and its interpretation in the organisational domain.

From the above descriptions of the nature of the future organisations, and the diagrammatic illustration of the similes between organism and organisations, it becomes clear that in order to envision a bio-system, the need to understand the psychological associations of occupants and the interdependence of this association upon physical as well as organisational flexibility of the space itself is of paramount importance. One of the prime implications of deploying flexibility in the organisational domain is the spatial organisation of the office itself. A spatial layout fostering the diminishing role of a hierarchical pyramid and the increasing stress upon a flat, participatory, rather interactive pattern comes to the fore. The preconceived notions of open plan offices as well as closed cubicle systems have undergone a vital transformation, when looked at from the perspective of flexibility. A trend fostering exclusive research into user oriented activity patterns and the variety of configurations required to support such activities is replacing the pre-ordained office set ups. This change in the organisational culture, which is highly characteristic of the post-fordist[36] era, tends to give much importance to the basic unit, the user and in essence tries to develop a scenario where technology and user comfort formulates the basis for generating a productive organisation.

The productivity aspects of a successful organisation in the post-fordist era, apart from the spatial counterpart also heavily rely upon the manner in which organisations emphasise upon service orientation, on working with people as opposed to working on objects, on the customisation of goods and services and on the definition of economies of scope rather than scale (Andrew Laing, DEGW

London Limited). An evolving trend, essentially a by-product of organisational culture; flex working as well as the typologies of working people (permanent staff, part time workers, consultants, trainees etc), is also suggestive of the variations in space occupancy, the nature of environments as well as the optimal usage of given space to be considered by contemporary organisations. The aspects of flexibility, in terms of organisational strategies as well as physical adaptability hence loom to be of vital importance in such fluctuating contexts. A new hybrid environment, which focuses upon an optimal mix of open, semi-open as well as cellular work environments, is bound to evolve in the near future. The ability to cater to a variety of employee types as well as possibilities of catering to time oriented occupancy and multiple usability aspect of current office environments will hence become the focus of contemporary office design. The multitude of activities (elaborated in chapter 04) and the nature of work performed in office environments re-assures the above stated supposition and have lead to the promotion of designed approaches where a variety of work environments focusing predominantly upon the quality/nature of conditions fostering creative/productive work can be developed. An increasingly popular solution (as will also be elaborated in the case study: Interpolis office, Tilburg, The Netherlands) catering to the above mentioned variety of usability and occupancy materialises is the provision of generic typologies of working spaces that can be used by different employees in varying numbers to perform a range of tasks. However, as will be elaborated in section 3.4 of this research, an underutilization and ultimately waste of space/infrastructure is often linked up with such provisionary measures.

The increasing influence of IT as a strong backbone, binding such a variety of generic spaces has proven to be an efficient connection, enhancing the development of such hybrid office typologies. The importance of information technology, in terms of data transmission, storage, evaluation and the endless possibilities of networking work environments with non-work environments (home-working) has been an essential development at the virtual front for lending apt flexibility to the increasingly evolving modes of operation in the organisational domain. The increasing array of devices such as portable computers, multi-functional communication devices, as well as an inherent connectivity via internet services throughout the globe ensures a fluid progression of work at any place at any point in time, hence proving to be a boon for contemporary organisations. However, despite the flurry of IT enhanced work support and increasingly complex software generations for supporting data communication, in terms of physical adaptability of architectural space and related ambient conditions of sound and lighting the utilisation of the field of IT has remained relatively dormant. The ample provision for facilitating soft, information oriented aspects of organisations slowly seems to be entrapped within a technological outburst with an overall emphasis on production. Process, user satisfaction, comfort as well as flexibility in the physical domain hence need to be developed at a parallel pace, in order to balance the virtual and the physical domains to cater to a sustainable design generation.

The computation aided spatial prototype which is being envisioned through this research focuses on designing a generic future prototype by looking at occupant centred office design through the prism of physical and psychological aspects (user oriented) which determine the performance of such environments. The stress upon the human centred approach also arose due to a significant statistic; over any significant period of time people cost organizations 10 to 15 times as much as their facilities[37]. It is astonishing to notice that despite of such an alarming importance associated with the occupant /user component, current-design methods still emphasise order, efficiency and density; thus, human preferences, performance, and productivity seldom inform office design and facility management. The focus on occupant centred design development, if looked at from a broader perspective, would indirectly rather improve functionality, process times, productivity and in the long run, turn out to be much more cost efficient for a corporation.

A critical utilisation of the fields of science and technology alongside crucial ergonomic and anthropometric approach hence formulates the core of this research work. Flexibility, in terms of the research framework becomes a matter of understanding the needs of individuals operating within an environment and addressing these needs/demands via a technological initiative to develop a sociable architectural space. The increasingly common practise of providing a mix of generic work spaces is also looked at from the perspective of morphing; a possibility where one generic space could inherit the blueprint of all possible space configurations and can flexibly adapt/augment into any, as and when required by its occupants. Stress upon the multiple usability aspect of office environments is also addressed via technologically enhanced means, which would make it possible for the entire office environment to be converted to an exhibition space at any point in time (as an example specifically in this research work). Such conceptions thus not only enhance the flexible usability of the same space but also cater to a variable time oriented occupancy of otherwise unused office space. The development of a responsive, interdependent flexibility amongst the spatial, ambient and informational domains is thus aimed for.

2.7. Literature review conclusion

This section outlines important conclusions that are derived from the detailed literature study presented throughout this chapter. Organisational changes and changes in working methods reflecting the common developments in new offices are summarised via the following tables: These conclusions are compared and are also supported in their outcome with the research carried out by Liang, 1998 and Bauer, 2002.

Organisational changes	**From**	**To**
Strategy	Growth planning	Flexibility, scenario planning
Structure	Hierarchical Fixed teams	Flat (network) Changing teams
Staff	Career oriented Life long work	Searching for a balance Flexible working
Management style	Top down: Checking attendance Checking amount of time spent	Participatory: Based on trust Based on results

Corporate culture	Content-related	Process-based
Systems	Hesitant Rigid Bureaucratic and formal Low employee responsibility Uniform Supportive Labour and capital management	Enterprising, pro-active Flexible Open and informal Personal responsibility Multiform Active Knowledge management

Changes in working methods: from	**To**
Individual	Teamwork
Routine	Complex knowledge work
Single tasks	Multiple tasks
Minimal autonomy	Much autonomy
Formal consultation	Informal consultation
Decentralised/personal filing systems	Centralised: team and department based filing system
09:00 – 17:00 hrs	24 hour economy, flexible working hours
In a fixed location in the office	Location independent

In the wake of such developments, this research work also primarily concentrates on the notion of employee satisfaction, as the research is inclined towards an occupant centred approach for designing the new spatial prototype. Prior research work conducted by Sundstrom[38] (1986) and Clements-Croome[39] (2000), depicting the most vital factors affecting occupant satisfaction in contemporary work environments is used here as a basic model for dissecting issues related with employee satisfaction (Fig 25). The spatial component is stressed upon in the model and a stratification of employee satisfaction through: work, work environment and indoor climate is exemplified upon.

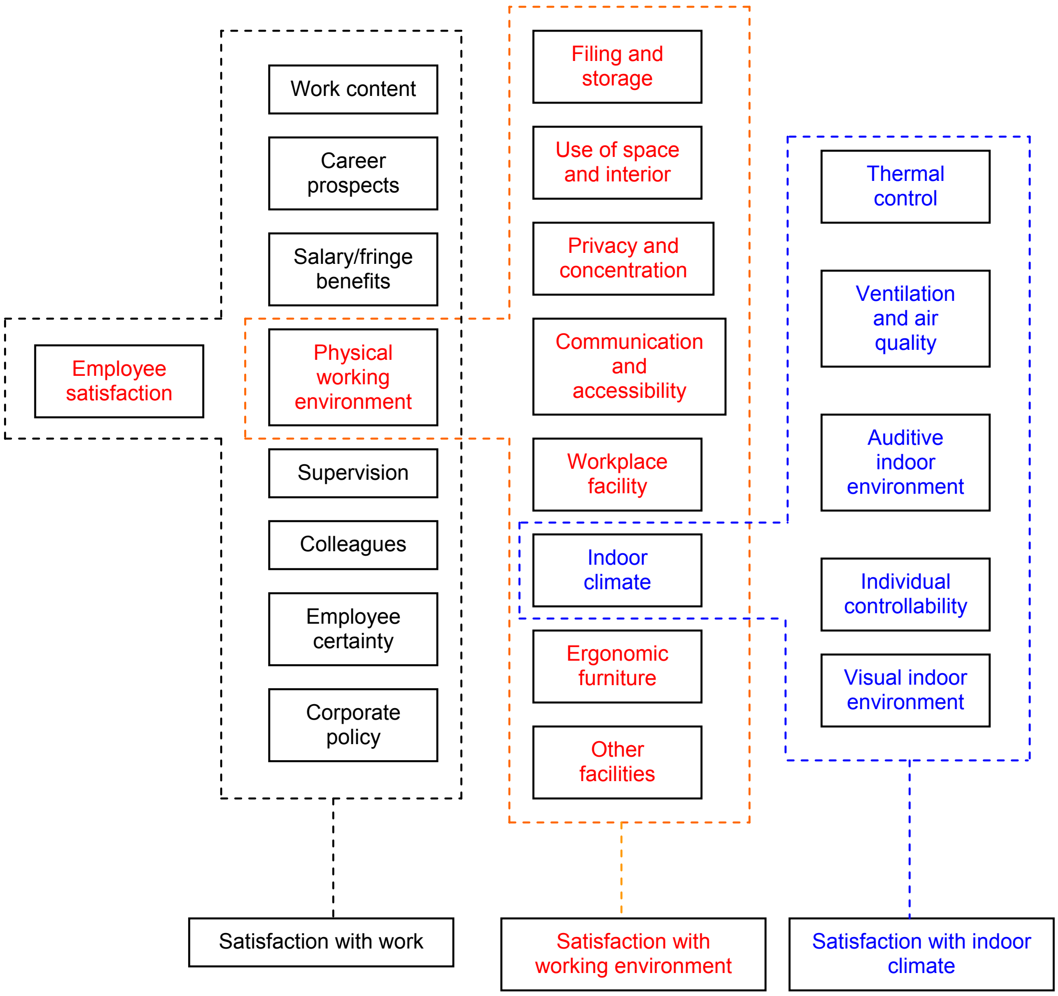


Fig 25 Diagram representing the determinants of occupant satisfaction

The research work will concentrate upon the physical factors illustrated in the above diagram, in conjunction with the nature of activity, which each individual, working in such corporate environments is associated with. Each team/group of people associated with a project, will hence be looked at as a potential activity node to which varying fields of spatial, psychological and physiological infrastructures will be attached in order of their importance to the team. The dominance of physical/spatial factors throughout the research persists, not only since the research is primarily an architectural work but also due to several research results carried out by a variety of researchers in the field which validate the significance of physical characteristics as a direct influencing factor affecting productivity (Haynes[40], 2000 and Barber[41], 2001). Some of the most important physical characteristics which have the maximum influence on user productivity (discovered as a result of studies carried out on more than 1000 respondents in 27 different office environments by the Hayworth Corporation Inc.) have been listed down in the following order:

1. Advanced technology
2. Advanced filing space
3. Ability to exercise personal control over the indoor climate
4. A quiet working place
5. Ability to personalise the workplace
6. Ergonomic chairs
7. A visually attractive working environment
8. Ability to influence lighting conditions
9. Privacy
10. Windows that open to the outside

Many of the above characteristics fall under the category of what can be termed as 'dependent variables': variables which are essentially focusing upon behavioural aspects and which depend upon what can be termed as 'independent variables' such as the physicality of space and the context. These distinctions will become clearer in chapter 04 where research variables will be extracted and exemplified upon.

The above derived conclusions focus towards the physical and psychological changes that can be brought about due to envisioning changes in the work environment. However another interesting perspective comes from the economic model (Cost and benefits of innovative workplace design, Dr. ir.D.J.M.van der Voordt, Centre for people and building, 2003), which efficiently categorises the office concept and office innovation in three ideal types: closed, open and flexible (Fig 26).

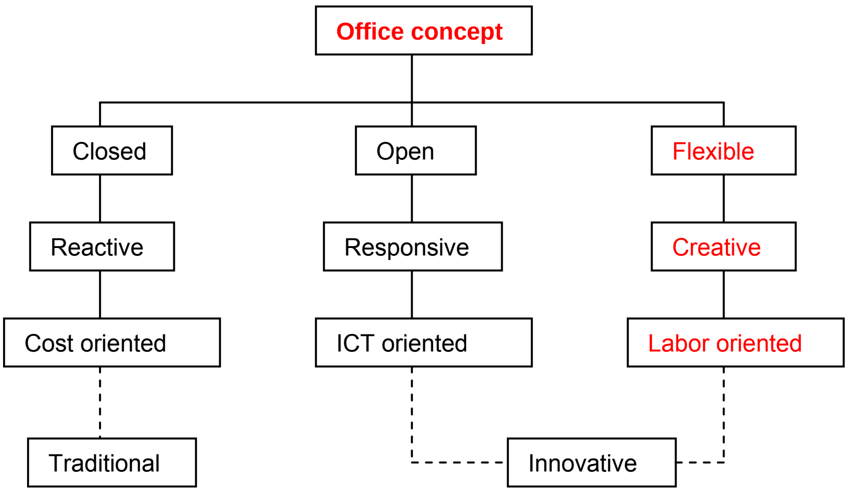


Fig 26 Diagram representing office innovation categories

According to the economic analysis done by the Centre for people and building, Delft, Netherlands, the idea of offsetting the costs associated with a specific choice of office concept against all other expenditure possibilities, including direct investments in information and communication technology (ICT) and labour should be stressed upon. Under such circumstances, it can be seen that labour costs are relatively higher when compared with ICT and cost oriented investments. However it is also seen that a relatively large number of cost savings resulting from cost-oriented office innovation is quickly counterbalanced if it leads to even a small decrease in productivity amongst personnel. Hence it seems rather logical to invest in labour oriented office innovation, rather than technological or cost oriented office innovation. The salient features of such an organisational concept can be categorised into the following sub points:

Work place	o Combi-office (mix of open office, concentration cells and enclosed spaces) o Open and flexible layout, without sections, containing varied activity related workspaces. o Fully flexible work spaces in public areas o Integration between back and front office
Organisational features	o Network organisation o No hierarchy-equal relationship o No division between management and personnel
Features of work	o Project oriented work o Communication based o Creative and specialist o Working in different teams o Innovative product development o Central digital filing system o Wireless, mobile ICT.

An interesting spatial product of such a flexible office concept can be found in the design of Interpolis, head Office at Tilburg, the Netherlands (chapter 03: case study conducted by the author). The next chapter will evaluate the design of the Interpolis office, from a spatial and organisational point of view in order to derive positive and negative aspects of one of the many flexible office concepts in the contemporary.

Endnotes

[1] "Organization." The American Heritage® Dictionary of the English Language, Fourth Edition. Houghton Mifflin Company, 2004. *Answers.com* 26 Feb. 2007. http://www.answers.com/topic/organization

[2] Corporations by James D. Cox and Thomas Lee Hazen, Aspen, New York, 2003.

[3] Paradigm shift is the term first used by Thomas Kuhn in his 1962 book *The Structure of Scientific Revolutions* to describe a change in basic assumptions within the ruling theory of science. It has since become widely applied to many other realms of human experience as well – Wikipedia Encyclopaedia

[4] Corporations by James D. Cox and Thomas Lee Hazen, Aspen, New York, 2003.

[5] Architecture goes wild, Kas Oosterhuis, 010 Publishers, Netherlands, 2002.

[6] Soft architecture machines, Negroponte N, Mass: MIT Press, Cambridge, 1975.

[7] System (from Latin *systēma*, in turn from Greek *σύστημα* sustēma) is a set of entities, real or abstract, comprising a whole where each component interacts with or is related to at least one other component. Any object which has no relation with any other element of the system is not part of that system but rather of the system environment. A subsystem then is a set of elements, which is a system itself, and a part of the whole *system*. The scientific research field which is engaged in the transdisciplinary study of universal system-based properties of the world is general system theory, systems science and recently systemics. They investigate the abstract properties of the matter and mind, their organization, searching concepts and principles which are independent on the specific domain, independent of their substance, type, or spatial or temporal scales of existence.

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[9] "Rational." The American Heritage® Dictionary of the English Language, Fourth Edition. Houghton Mifflin Company, 2004. *Answers.com* 26 Feb. 2007. http://www.answers.com/topic/rational

[10] "Natural." The American Heritage® Dictionary of the English Language, Fourth Edition. Houghton Mifflin Company, 2004. *Answers.com* 26 Feb. 2007. http://www.answers.com/topic/natural

[11] "Open." The American Heritage® Dictionary of the English Language, Fourth Edition. Houghton Mifflin Company, 2004. *Answers.com* 26 Feb. 2007. http://www.answers.com/topic/open

[12] Mechanistic organization is a term defined by T. Burns and G. M. Stalker to refer to bureaucratic organizations with stringent rules and rigid hierarchies. The differentiation of tasks, specialisation, departmentalisation, centralisation, standardisation, and formulation are their highest values and so is integration. Though a practically impossible form of organisation, much of early organisations of the early 19th and late 20th centuries are more mechanistic.
C. Handy refers to such an organisation as the Apollo Organisation, with its Greek temple figure, whilst the context of his analysis and of that of Burns and Stalker suggest that Mechanistic and Apollo

Organisations are highly similar, but not necessarily the same. This definition coincides with Max Weber's definition of Bureaucracy as the rational-legal form of effcient organisation, but organisations nowadays are being moved from this unitary form (U-Form) to a smaller decentralised unitaries, to form a multi-divisional structure (M-Form) either through mergers or division. This is the product of studies of O. E. Williamson. A Mechanistic Organisation is the opposite of an Organic organisation or Organismic organisation.

[13] Loose coupling describes a resilient relationship between two or more systems or organizations with some kind of exchange relationship. Each end of the transaction make their requirements explicit and make few assumptions about the other end. The notion of loose coupling is found in computer systems, and was introduced into organizational studies by Karl Weick.

[14] Closed system (¦klōzd ′sis·təm): (*engineering*) A system for water handling that does not permit air to enter. (*thermodynamics*) A system which is isolated so that it cannot exchange matter or energy with its surroundings and can therefore attain a state of thermodynamic equilibrium. Also known as isolated system - "closed system." McGraw-Hill Dictionary of Scientific and Technical Terms. McGraw-Hill Companies, Inc., 2003. *Answers.com* 26 Feb. 2007. http://www.answers.com/topic/closed-system

[15] Biologically-inspired intelligent robots by Yoseph Bar-Cohen and Cynthia Breazeal, SPIE press, Bellingham, 2003.

Biomimetics: Biologically inspired technologies, Bar-Cohen, Yoseph, Taylor and Francis, Boca Raton, 2006.

Everyware: The dawning age of ubiquitous computing, Adam Greenfield, Peachpit Press, 2006

Praxis: Journal of writing and building, issue 6, New technologies://New architecture, Praxis Inc, 2004

Skin, Surface Substance + Design, Ellen Lupton, Laurence King Publishing Ltd., London, UK, 2002.

Techno Textiles, Revolutionary Fabrics for Fashion and Design, Sarah E. Braddock and Marie O'Mahony, Thames and Hudson Publication, London, UK, 1998.

[16] A Complex Adaptive System (CAS) is a complex, self-similar collection of interacting adaptive agents. The study of CAS focuses on complex, emergent and macroscopic properties of the system. Various definitions have been offered by different researchers:

- John H. Holland

A Complex Adaptive System (CAS) is a dynamic network of many agents (which may represent cells, species, individuals, firms, nations) acting in parallel, constantly acting and reacting to what the other agents are doing. The control of a CAS tends to be highly dispersed and decentralized. If there is to be any coherent behavior in the system, it has to arise from competition and cooperation among the agents themselves. The overall behavior of the system is the result of a huge number of decisions made every moment by many individual agents. (source: *Complexity: The Emerging Science at the Edge of Order and Chaos* by M. Mitchell Waldrop)

- Kevin Dooley

A CAS behaves/evolves according to three key principles: order is emergent as opposed to predetermined (c.f. Neural Networks), the system's history is irreversible, and the system's future is often unpredictable. The basic building blocks of the CAS are agents. Agents scan their environment and develop schema representing interpretive and action rules. These schema are subject to change and evolution. (source: K. Dooley, AZ State University)

- Other definitions

Macroscopic collections of simple (and typically nonlinearly) interacting units that are endowed with the ability to evolve and adapt to a changing environment. (source: Complexity in Social Science glossary a research training project of the European Commission)

[17] "Corporation." The American Heritage® Dictionary of the English Language, Fourth Edition. Houghton Mifflin Company, 2004. Answers.com 26 Feb. 2007. http://www.answers.com/topic/corporation

[18] Corporations by James D. Cox and Thomas Lee Hazen, Aspen, New York, 2003.

[19] Corporate fields: new office environments by the AA DRL, Brette Steele, AA Publications, London, 2005.

[20] Schlosser, Julie. Cubicles: The great mistake CNNMoney.com, 2006

[21] Schlosser, Julie. Cubicles: The great mistake CNNMoney.com, 2006

[22] Scientific management, Taylorism or the Classical Perspective is a method in management theory which determines changes to improve labour productivity. The idea first coined by Frederick Winslow Taylor in his *The Principles of Scientific Management* who believed that decisions based upon tradition and rules of thumb should be replaced by precise procedures developed after careful study of an individual at work.

[23] Designing interactive systems people, activities, contexts, technologies, David Benyon, Philip Turner, Susan Turner, Pearson Education, Harlow, 2005.

[24] Ubiquitous computing (ubicomp) integrates computation into the environment, rather than having computers which are distinct objects. Other terms for ubiquitous computing include pervasive computing, calm technology, things that think and everyware. Promoters of this idea hope that embedding computation into the environment and everyday objects would enable people to interact with information-processing devices more naturally and casually than they currently do, and in whatever location or circumstance they find themselves - "ubiquitous computing." Wikipedia. Wikipedia, 2007. *Answers.com* 26 Feb. 2007. http://www.answers.com/topic/ubiquitous-computing

[25] A living organism or a system of living organisms that can directly or indirectly interact with others - "biosystem." The American Heritage Stedman's Medical Dictionary. Houghton Mifflin Company, 2002. *Answers.com* 26 Feb. 2007. http://www.answers.com/topic/biosystem

[26] Mutation: A word familiar to all fans of science fiction, *mutation* refers to any sudden change in DNA—deoxyribonucleic acid, the genetic blueprint for an organism—that creates a change in an organism's appearance, behaviour, or health. Unlike in the sci-fi movies, however, scientists typically use the word mutant as an adjective rather than as a noun, as, for example, in the phrase "a mutant strain." Mutation is a phenomenon significant to many aspects of life on Earth and is one of the principal means by which evolutionary change takes place. It is also the cause of numerous conditions, ranging from albinism to cystic fibrosis to dwarfism. Mutation indicates a response to an outside factor, and the nature of that factor can vary greatly, from environmental influences to drugs to high-energy radiation – Science of everyday things, Gale Group, Inc.

[27] Self-organization is a process in which the internal organization of a system, normally an open system, increases in complexity without being guided or managed by an outside source. Self-organizing systems typically (though not always) display emergent properties - "self-organization." Wikipedia. Wikipedia, 2007. *Answers.com* 26 Feb. 2007. http://www.answers.com/topic/self-organization-1

[28] "Interactivity." Wikipedia, Wikipedia, 2007. Answers.com 27 Feb. 2007.
http://www.answers.com/topic/interactivity

[29] Flextime (or flexitime) is a variable work schedule, in contrast to traditional work arrangements requiring employees to work a standard 9am to 5pm day. Under flexitime, there is typically a "core time" period of the day when employees are expected to be at work (for example, between 10 am and 4pm), whilst the rest of the working day is "flexitime", in which employees can choose when they work, subject to achieving total daily, weekly or monthly hours in the region of what the employer expects, and subject to the necessary work being done - "Flextime plan." Wikipedia. Wikipedia, 2007. *Answers.com* 27 Feb. 2007. http://www.answers.com/topic/flextime-plan

[30] Entropy (ĕn'trəpē), quantity specifying the amount of disorder or randomness in a system bearing energy or information. Originally defined in thermodynamics in terms of heat and temperature, entropy indicates the degree to which a given quantity of thermal energy is available for doing useful work—the greater the entropy, the less available the energy. For example, consider a system composed of a hot body and a cold body; this system is ordered because the faster, more energetic molecules of the hot body are separated from the less energetic molecules of the cold body. If the bodies are placed in contact, heat will flow from the hot body to the cold one. This heat flow can be utilized by a heat engine (device which turns thermal energy into mechanical energy, or work), but once the two bodies have reached the same temperature, no more work can be done. Furthermore, the combined lukewarm bodies cannot unmix themselves into hot and cold parts in order to repeat the process. Although no energy has been lost by the heat transfer, the energy can no longer be used to do work. Thus the entropy of the system has increased. According to the second law of thermodynamics, during any process the change in entropy of a system and its surroundings is either zero or positive. In other words the entropy of the universe as a whole tends toward a maximum. This means that although energy

cannot vanish because of the law of conservation of energy, it tends to be degraded from useful forms to useless ones. It should be noted that the second law of thermodynamics is statistical rather than exact; thus there is nothing to prevent the faster molecules from separating from the slow ones. However, such an occurrence is so improbable as to be impossible from a practical point of view. In information theory the term entropy is used to represent the sum of the predicted values of the data in a message - "entropy." The Columbia Electronic Encyclopedia, Sixth Edition. Columbia University Press, 2003. *Answers.com* 27 Feb. 2007. http://www.answers.com/topic/entropy

[31] Networks: Once a company has assessed their core capabilities, they can find themselves in a situation where they can't compete on attributes as they don't have the necessary resources. Because of this, networks are formed to utilize the advantageous attributes, and the importance here is dependant upon a mutually beneficial relationship, that significantly adds to the value of a firm's market offering. With this, there comes a critical responsibility to thoroughly analyse the respective competitors, as there are both significant opportunities and risks associated with network partnerships. - Dr.Chavez, "business network." Wikipedia. Wikipedia, 2007. *Answers.com* 27 Feb. 2007. http://www.answers.com/topic/business-network

[32] Business transactions conducted via electronic means; most often referring to Internet-based relationships between customers and vendors, but also including CD-ROM catalogs; also called internet marketing. The Internet, direct marketing's newest channel, has provided an unprecedented opportunity on a global basis for businesses to interact with, reach out to, and be accessible by their customers without limitations with respect to physical location or time zone. E-commerce practitioners utilize the Internet to disseminate company or product information, generate leads, take orders, and build customer databases. CD-ROM catalogs permit the distribution of vast amounts of personalized product information via a cost efficient medium. Business-to-business sales are expected to dominate e-commerce by 2003 reaching $1.3 trillion, whereas consumer sales are projected to be $108 billion. Electronic commerce may be adopted more readily by buyers of services and products such as software, information, and photos, because these items can be both sold and distributed over the Internet - "e-commerce." Dictionary of Finance and Investment Terms. Barron's Educational Series, Inc, 2006. *Answers.com* 27 Feb. 2007. http://www.answers.com/topic/electronic-commerce

[33] Information systems and technology in the international office of the future, Glasson, Bernard C, Vogel, Douglas R, Bots, Peter W G, Chapman and Hall, London, UK, 1996.

[34] Corporate fields: new office environments by the AA DRL, Brette Steele, AA Publications, London, 2005.

[35] IBM Blue space: http://www.research.ibm.com/bluespace/

[36] Post-Fordism is the mode of production and associated socioeconomic system theorized to be found in most industrialized countries today. It can be contrasted with fordism, the productive method and socioeconomic system typified by Henry Ford's car plants, in which workers work on a production line, performing specialized tasks repetitively.
Post-Fordism is characterized by the following attributes:
- New information technologies.

- Emphasis on types of consumers in contrast to previous emphasis on social class.
- The rise of the service and the white-collar worker.
- The feminization of the work force.
- The globalization of financial markets.
- "post-Fordism." Wikipedia. Wikipedia, 2007. *Answers.com* 27 Feb. 2007. http://www.answers.com/topic/post-fordism

[37] Costs and benefits of innovative workplace design, Dr. ir. D.J.M. van der Voordt, Centre for people and buildings, Delft, Netherlands, 2003.

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[39] Creating the productive workplace, Clements-Croome, D. (ed), E&FN Spon, New York, 2000.

[40] Does property benefit occupiers ?: An evaluation of the literature, Haynes, B. et al, Occupier.org Report No. 1, Facilities Management Graduate Centre, Sheffield Hallam University, 2000.

[41] The 21st century workplace, Barber, C, In: Kaczmarzczyk et al, People and the Workplace, GSA Office of Governmentwide Policy, Washington DC, 2001

03

THE CASE OF INTERPOLIS

03
The case of Interpolis

After expanding upon essential characteristics and systemic typologies of organizations, the following sections will analytically stratify a generic contemporary corporate organization: Interpolis, Tilburg, Netherlands. The case study is specifically undertaken to reassure the predictions and conclusions drawn in chapter 02 as regards the highly innovative contemporary spatial and informational solutions being developed for corporate office environments. The analysis specifically de-constructs the corporate setting into its physiological as well as informational components, hence providing a distilled vision as concerns spatial organization, interior aspects (ambience, furniture, temperature) and informational networks prevalent in contemporary organizations.

3.1. Interpolis profile

Interpolis is one of the largest and most innovative providers of insurance, old-age provisions and staff availability services (reintegration, absenteeism, occupational health and safety, etc.) in the Netherlands. It provides customized solutions for private persons and businesses for a wide variety of risks. This not only involves solid products, but also good, personalized advice and real support in the event of damage or loss. Interpolis is a modern company that is aware of its social responsibilities. The work climate for employees at Interpolis, is certainly modern (Fig 27), including flexible places of work and sophisticated information technology. Interpolis is also a trend-setter in the field of tele-working. As one of the pioneers for inducing flexible working into its organisational structure, Interpolis is specifically selected for analysis representative of a generic breed of contemporary offices. The case study incorporates salient features of Interpolis in terms of its organizational set up, flexibility aspects (spatial and informational), a systematic break-up of its work environments and the growing incorporation of IT induced technological support incorporated within the organization. Interpolis, as a successful contemporary organization can be profiled through the following points:

- Largest and the most progressive Dutch insurance company offering Insurance, company care and pensions
- Offers solutions for the most divergent questions and financial dangers
- Fast and smooth service with minimum formalities
- Modern company aware of its social responsibility, making a constructive contribution to the local community
- Work climate for the occupants is a central concern: If the employees are satisfied, then their work performance increases resulting in satisfied clients
- Turnover in 2002: 4.7 billion euros
- Interpolis clients: More than 1 million individuals and around 1000 companies:

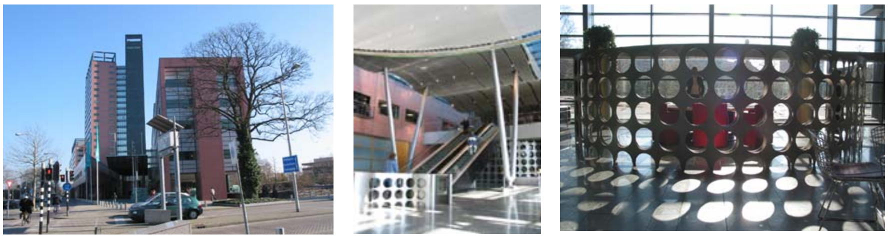


*Fig 27.*Interpolis head office, Tilburg, The Netherlands: external view and interior foyer views

3.1.1 The Interpolis body (organization structure)

Interpolis is divided into seven market organizations. These market organizations are managed by the General Management which consists of Mr. Kick van der Pol (chairman), Mr. Huub Hannen and Mr. Roel Wijmenga. Corporate staff departments (elaborated below) are responsible for support in the fields of finance & control, human resource management, ICT and communication (Fig 28).

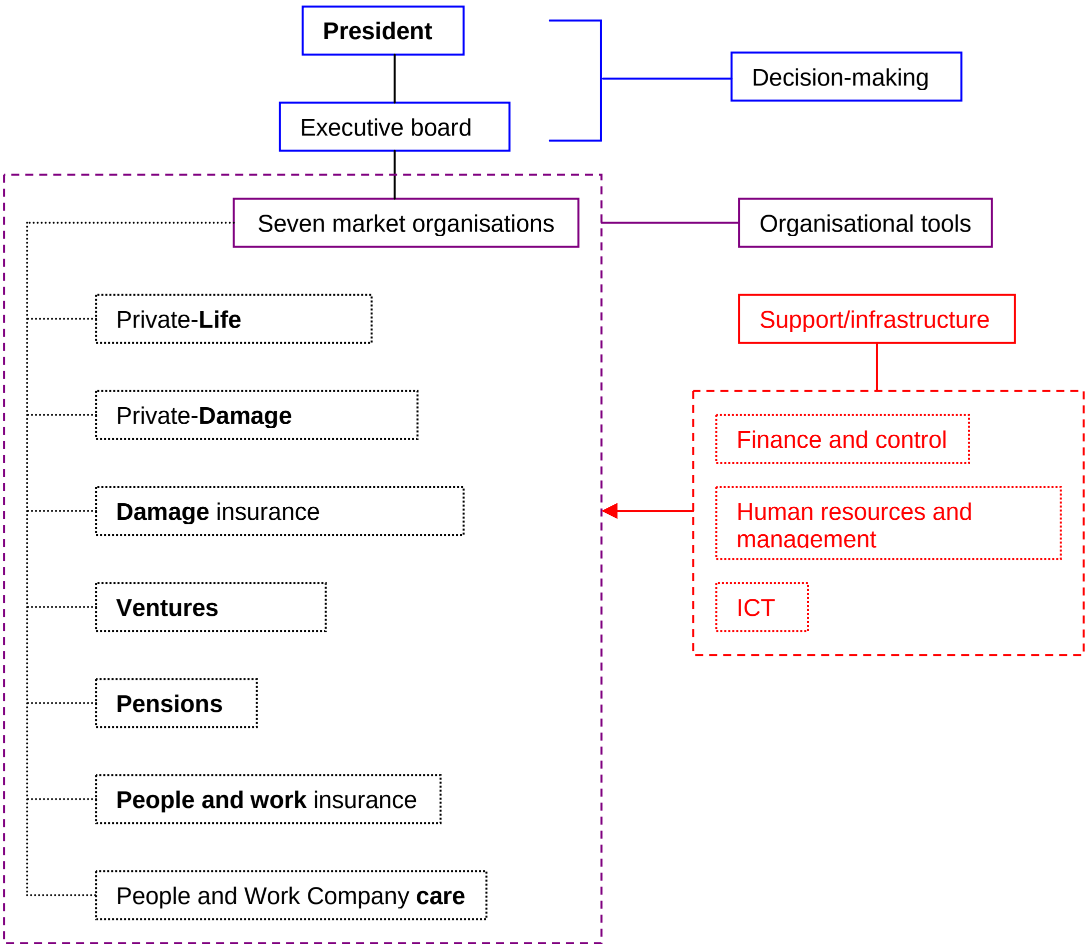


Fig28 Organizational structure showing decision making, organisational tools and support components working in coherence with each other

- **Life personal lines:** concentrates on life insurance, old-age provisions, savings products and mortgages.
- **Non-life personal lines (Damage):** concentrates on non-life insurance for private clients, such as liability insurance, motor insurance, household contents and buildings insurance, and travel insurance.
- **Non-life commercial lines (ventures):** focuses on non-life insurance for businesses, both small and medium-sized, and agricultural businesses. Global Neth (claims in foreign countries) and Interpolis credit insurance are part of this market organization.
- **Pensions:** takes care of the management and administration of pensions on behalf of pension funds.

- **Mens & werk verzekeringen (People & work insurance):** offers solutions for employers for the absenteeism risk in their company. Besides insurance for continued wage payment in case of absenteeism due to illness, the income of the employer him or herself can be insured.
- **Mens & werk bedrijfszorg (People & work company care services):** offers advice and support in the area of staff availability. The market organization includes Commit, the 'arbo' service company Prevend (specializing in large enterprises) and Salto Reïntegratie (reintegration specialist).

3.2. Work environment at Interpolis (salient features)

1. **Occupant centred design**: confidence, autonomy and responsibility granted to the employees, resulting in utmost freedom in terms of selecting their own times to work, option to work from home, choose the environmental settings they want to work in etc hence fostering a healthy social environment within the built environment.
2. **ICT, human resources and management and finance departments** create the core of the flexible work environment, insuring that technical support, financial security and a well-organised organisational distribution of resources are always maintained.
3. **Result oriented teamwork** develops an objective setting attitude in the teams, provoking working in a focused manner. A logical step is considered as a reward towards finishing the task at hand.
4. **Flat organisational structure:** highly flexible management fosters creative growth through an informal environmental management attitude. Management bodies have frequent meetings with the employees to seek their advice on work environments, hence developing a non-hierarchical, rather collegial relation with the seven company components.
5. **ICT makes work more independent of time and space:** opportunities of working from home, flexible printing and fax receiving facilities, privacy options to maintain confidential printing facilities, wireless networking makes sure that every employee is always connected through basic facilities such as phones and e-mails.
6. More or less **paper free office**: information exchange is mostly digital, saves processing and proposal developing time proving to be much more efficient.
7. Office becomes an important **meeting spot**. It is seen as a spatial entity derived as a merger of comfort and work: work, discuss, meet, relax and eat, hence developing into a place to live in rather than a routine office task performing area (Fig. 29).

Fig 29 A combination of work, relaxing, eating and meeting environments clustered together to create a club environment for the employees. Self service and payment of food bills is seen as a way of showering responsibility and trust in the employees.

3.3. Interpolis design strategy

The Interpolis office design benefits from the ingenious collaborative design strategy it employed. The design was specifically carried out as a confluence of one architect working together with seven artists in order to create interior variations within one singular office environment. This strategy specifically aimed at combining work and pleasure into one singular spatial product, shaped by the individual visions of the seven artists in seven different forms. The exclusive environments hence produced, transform the office from a place of routine work into an informal as well as formal meeting place for socialising as well as concentrated working. What's also interesting to note, is the manner in which a fixed set of programmatic components (as illustrated in 3.3.1.) are arranged in different combinations to create visually (ambience and interior variations) diverse settings. These environments perform as space envelopes specifically catering to employee oriented psychological inclinations such as addressing varying ambient preferences of the employees working within the organization. The following sections (3.3.1 – 3.3.3) attempt to stratify the Interpolis body into its spatial, ambient and informational components to eventually create an understanding of the organisational whole by studying the relations between its parts.

3.3.1. Spatial components:

The dissection of spatial aspects of Interpolis specifically aims at deriving the physical components that constitute its varying operational environments. The analysis delves into abstract representations of networks that prevail within the physical domain through images as well as diagrams of inter-connections existent within Interpolis. A subsequent data collection, as regards the spatial parts and their sub-components which constitute activity oriented environments is administered through this analysis. The floor plate distinction sections explicitly categorise the space forming components into nodes and diagrammatically specify the interconnections and combinations of these to create specialized space clusters furthering the notion of hybrid (formal and informal) environments.

Connectors (paths): Bridges connect the vertical tower workspaces at various heights (Fig 30), These are transparent in nature and allow for constant movement of employees to be seen from the external context. The connectors are conceived as strategic design interventions emphasizing flexibility through visually emphasising connective architectural elements. The transparent nature also helps psychologically in terms of providing the employees with a sense of being connected with the external context hence discarding the feeling of being entrapped within work settings.

Fig 30 The connecting bridge elements: exterior and interior views

Floor plate distinction:

Ground (Fig 31): The ground floor level is a confluence of the following nodes: waiting and informal interactions (**repose** nodes), central reception (**distribution control** node), centralised security entry and exit to the floors above (**primary distribution** node), service points, for tea, coffee and storage (**auxiliary** nodes)

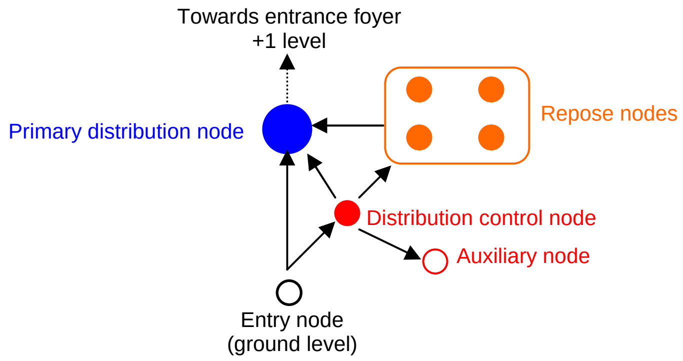


Fig 31 Connectivity diagram: Ground floor

+ 1 level (Fig 32): is devoted for client and employee interaction, meetings – formal and informal, entertainment, food, theme based environmental variations (a series of high activity nodes connected to each other to create a transitional path), primary conference areas (**formal conference** node), and a future expansion being developed for constructing more meeting areas (**future expansion** node). This level also houses the (**support** nodes): ICT, Personal relations (PR), and Management as pivot points for the surrounding flexible infrastructure.

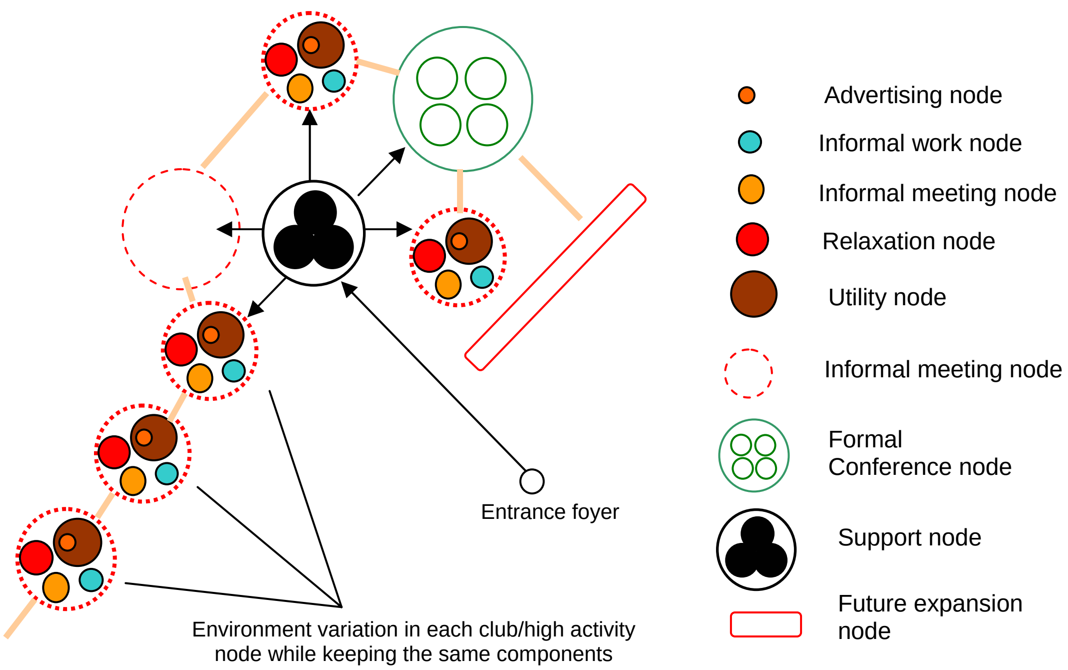


Fig 32 Connectivity diagram: +1 level, showing the centrality of the support node and the transitional path created as a node transition scenario.

- **High activity nodes** (Fig 33) – are constants throughout the +1 level and categorically embody a combination of the following dedicated nodes:
  - **Utility** nodes: eating, drinking-group based
  - **Advertising** nodes: advertising screens/visual media
  - **Informal work** nodes: individual, group
  - **Informal meeting** nodes: closed environment-group based
  - **Relaxation** nodes: silent rooms-group based

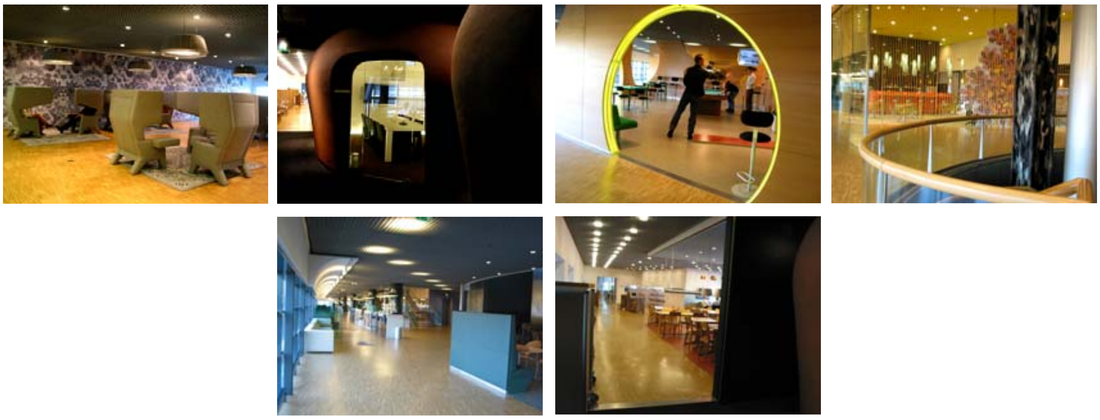


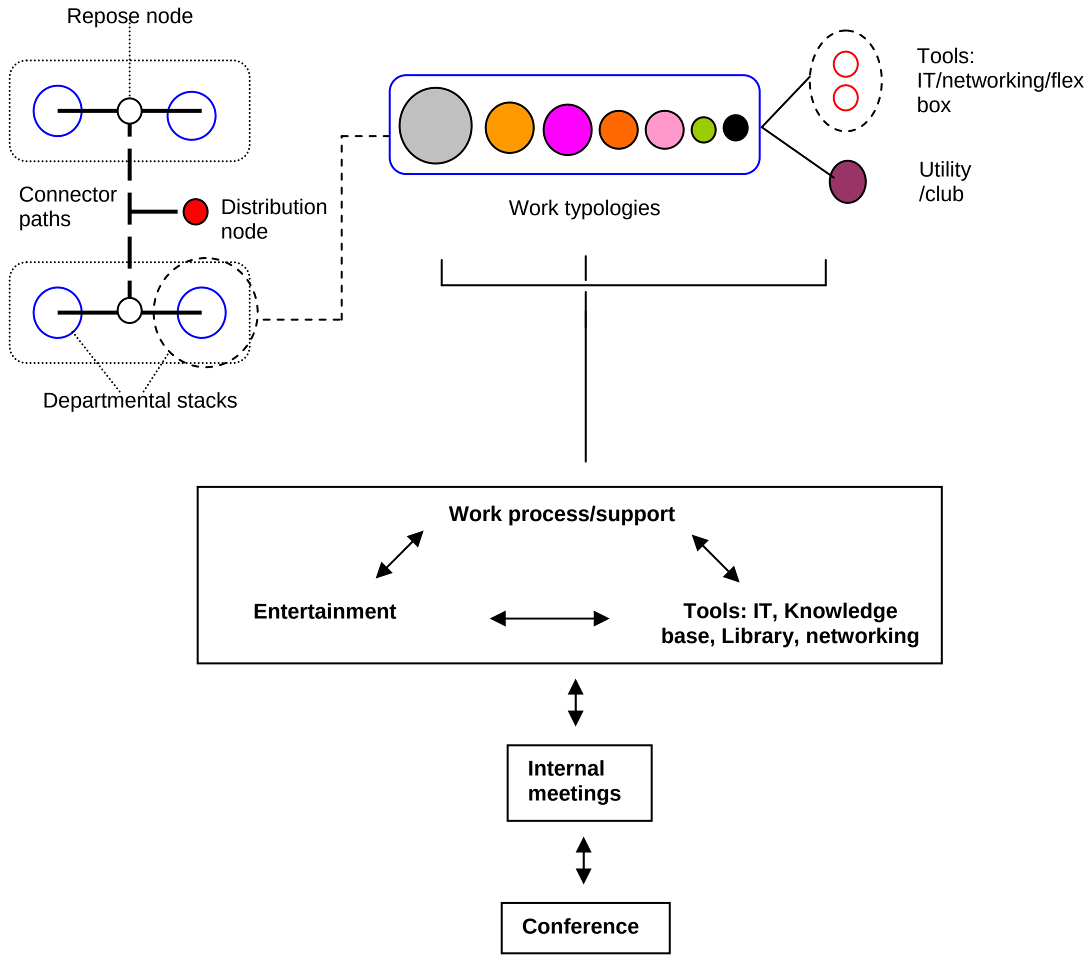
Fig 33 Images of various thematic high activity nodes: from left: Huyskamer, Steenhuis, Vergadergebied/Ontspanningsruimte, Weefhuis, Spoorhuis.

- **Formal conference nodes** (Fig 34) – are also a constant feature throughout the +1 level and are specifically utilised for vital meetings/presentations. Each conference node is highly equipped with IT enhanced features like central control units (for light, sound and presentation co-ordination), adjustable screens etc and vary extensively in terms of their interior décor.

Fig 34 Images of one of the many formal conference nodes with adjustable presentation screens and an IT enhanced conference table.

+2 - +10 levels: Flexibility prevails: vertical movement through the Interpolis links the work spaces on the floors above. The lift landing units serve as distribution nodes, which lead to bridges connecting the two towers, on either sides of which work spaces are stacked on top of each other (Fig. 35 a). The work space levels (+2 - +10) are distributed amongst the seven departments (departmental stacks). The analysis further elaborates upon a generic department node dissecting it into its sub-components. Flexibility is attained in a favorable manner by means of endowing each departmental node with a variety of work typologies/nodes (Fig 35 b) hence, catering to the innate psychological needs/desire of occupants as well as providing varied nature of space for specific activities at the organizational front. Each departmental stack is supported with IT oriented tools such as individual phone units, a flex box: which holds personal lap-top and related devices, which essentially provide each employee with a local sense of customization. Each departmental stack in-turn is also provided with a utility/club node for informal activities like having refreshments, surfing the web, having informal talks etc and formal meeting nodes for hosting internal conferences.

a.



b.

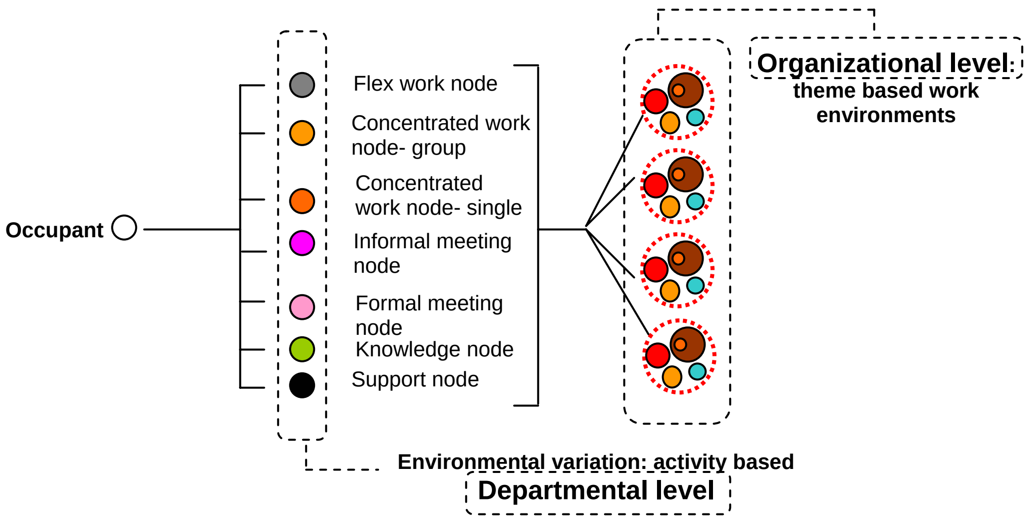


Fig 35 a. Diagram showing the relations between the department nodes
b. Flexibility in terms of connecting department based Primary work nodes to organisational level high activity nodes (at the +1 level): work at any place. Occupant is provided with a variety of choice suiting his psychological state.

Each employee further has the possibility of working at the +1 level in any of the elaborate theme based organizational level clubs, hence catering to flexibility aspects of the entire office environment. A generic department node can be exemplified upon as being a confluence of a variety of activity specific nodes in the following manner:

- **Department node**(Fig 36) **–** a typical department node comprises the following:
    - **Repose** node: informal sitting, quick check corner before attending conferences
    - **Information tool distribution** node: personal mailboxes, cell phones (mobile intercom, which is also programmed as a fax-receiving tool)
    - **Mobile office** node: flex office box (containing a laptop, personal files, stationary etc, which can be carried around everywhere in the Interpolis office building for work purposes)
    - **Club** node:
        - **Utility** node: eating, drinking-group based
        - **Informal work** node: individual/group emailing facilities and informal discussions
    - **Primary work** node:
        - **Concentrated work** nodes- individual
        - **Concentrated work** nodes- group
        - **Formal meeting** node- group
        - **Informal meeting** node- group
    - **Service** node- printing, fax, copying, individual/group
    - **Knowledge** nodes- library, magazine referencing, individual/group
    - **Flex work** nodes- anyone can choose his or her own tables, group

Fig 36 Department node images: from left to right- repose, information tool distribution, mobile office - flex case, club, concentrated work (individual and group), service, knowledge and flex nodes.

3.3.2. Ambiance

After analyzing the physical components constituting Interpolis, the following sections exemplify upon ambient environmental aspects such as the usage of color, lighting, furniture as well as temperature control. Ambiance related components are highly instrumental in shaping atmospheres and moods of the spaces under speculation and hence prove to be vital in terms of engaging its users in a desirable manner.

- **Colour variation**

A variety of interior colours set the tone for distinguishing the diverse environments at Interpolis. Colour is used in an efficient manner to cater to varying psychological states that an employee could possess and hence acts as an efficient tool for addressing human oriented mood requirements. The ensuing nature of spaces makes them susceptible for being patronized by certain groups of individuals hence developing a micro-ecology within the entire office building. The following sections will provide salient features as regards the usage of color at the + 1 and +2 - +10 levels.

- **+1 level** (Fig 37 a, b)

    - **Conference rooms:** A sense of identity for each conference environment is materialised by means of colour coding them and naming them as the red, green, blue and white rooms. These are specifically conceived in this manner to cater to varying psychological moods of the occupants and the nature of the meetings which would be conducted within these settings.
    - **High activity nodes/clubs:** colour variation is theme dependent in accordance with each artist's perception. However it was noticed that the colours used for the interior surfaces which house informal work activities are always painted in bright reflective colours to allow for maximum light reflectivity, hence providing impression of an active visual setting.

- **+2 - +10 level** (Fig 37 c, d)

    - **Club/utility node**: vibrant colour, which is encountered at the entrance of the office space (psychologically uplifting).
    - **Work areas:** Subtle pastel shades (minimal distraction facilitates concentrated work)

a b c d

Fig 37 Images showing colour variations in high intensity nodes (a, b), +2 level utility node (c), and the primary work node (d).

- **Lighting variation**

A variety of lighting fixtures emitting lights of different intensity (controllable) are utilised throughout the Interpolis office. Apart from adding to the ambiance (in terms washing light over the variety of colours), these lighting levels also emphasize upon work and leisure as being distinct and hence provide an automated stimulus for being productive or being relaxed, as and when required by the employee. Two basic variations, at the +1 level and +2 - +10 levels are described in terms of their salient features in the following sections.

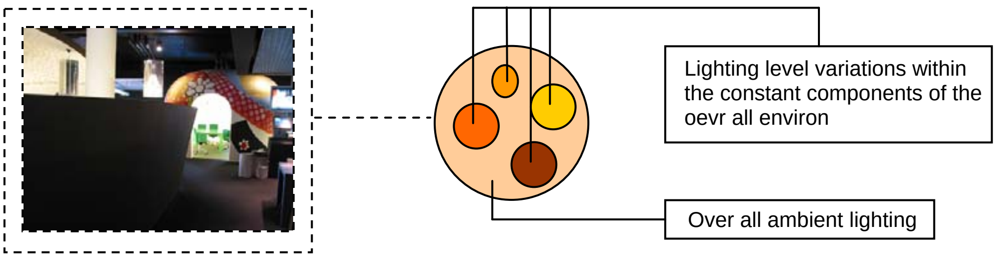
- o **+1 level** (Fig 38 a)

    - ▪ **High activity nodes/club areas**: witness a predominant variation as regards environments being lit up. However there is always a provision to appropriately light up areas specifically designed for informal work with the help of spot lights, work lights within the club areas. Lighting varies in accordance with the nature of activity attached with each sub component of the node: utility, advertising, work, meeting, and relaxation – these can be altered independent of each other.

- o **+2 - +10 level** (Fig 38 b)

    - ▪ **Primary work node: uniform lighting (both direct and indirect),** proximity of work areas to windows is always maintained. Provision of spotlights, tubes and adjustable lights in work areas is customary.

a.



b.

Fig 38 Images showing light variations in high intensity nodes (a), +2 level primary work nodes (b), showing a proper mix of natural ambient lighting and the provision for artificial lighting for work related zones.

➢ Furniture

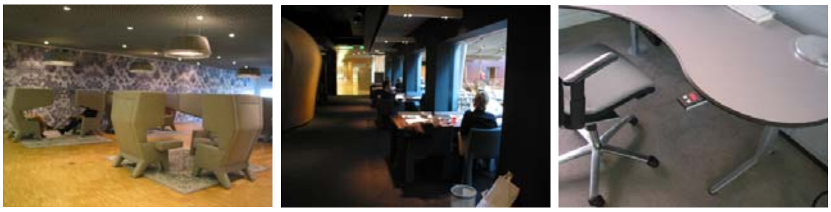
Interpolis deploys a wide range of furniture in accordance with the changing ambiance and related activity patterns. Furniture systems range from comfortable couches for relaxing and informal working to ergonomically designed electronically adjustable work tables and chairs. Every theme based environment further incorporates a lively choice of upholstery in tune with the theme envisioned by the artists. The following sections describe the salient features of furniture typologies within Interpolis.

- **+1 level**

  - **High intensity nodes/clubs:** variation in furniture (theme dependent) maintains the interest of the occupants. A balanced mixed of relaxing, eating and working based furniture typologies provides the occupant with appropriately matching the activity nature to the furniture types (Fig 39 a, b).

- **+2 level**

  - **Primary work node:** ergonomically designed furniture (adjustable height) to suit a varying range of occupants. Ergonomically designed furniture helps in increasing the comfort level of the occupants and helps them perform better. Variation is sought by means of differentiating furniture types in three nodes: utility node, concentrated work-group node and the other work spaces (Fig 39 c).



a. b. c.

Fig 39 Furniture variations in differing environmental settings

- **Temperature control**

  - Air conditioning is not considered as a suitable means of controlling temperature for the interior spaces due to a variety of study results concerning the sick building syndrome (a result of stale air circulation throughout the work environment). Instead, heating the space by means of ducts carrying hot water in the ceilings was decided upon. Uniform heating at the +1 level and the +2 - +10 levels and the provision of individually controlling the heating in concentrated work nodes-single, is provided throughout Interpolis. All the floors have the provision of openable windows, providing ample fresh air in every workspace (occupant centred decision, keeping in mind the physiological means necessary for fostering productivity).

3.3.3. Information Technology

- Information technology plays a vital role in the flexibility provision at Interpolis. The IT based resources can be categorised in three distinct sections: **static (*)**, **dynamic (*)** and **discrete** (plug in *).

Facilities	Shared	Organisation based	Department based	Personal
Laptop				*
Desktop				*
Printer			*	
Network		*		
Phone				*
Fax			*	
Video screens & projector			*	
Video screens	*			
Electricity grid	*			
Communication network	*			
Wireless network		* (+1 level)		
Optic fibre network		*		

Apart from the above mentioned categorisation, it is interesting to note the manner in which Interpolis, integrates a seamless wireless network protocol, enabling receiving of print-outs, faxes as well as personalization of hardware (Fig 40) based upon one's location within the entire office building. An un-interrupted fluid flow of information via internal network connections as well as external information input is made possible through the integration of information technology (IT). Apart from the office oriented functionalities that IT induction provides, it also acts as a major support for the increasing home working, out of office working staff, hence making it much more acceptable as a productive tool for enhancing the functioning of today's offices.

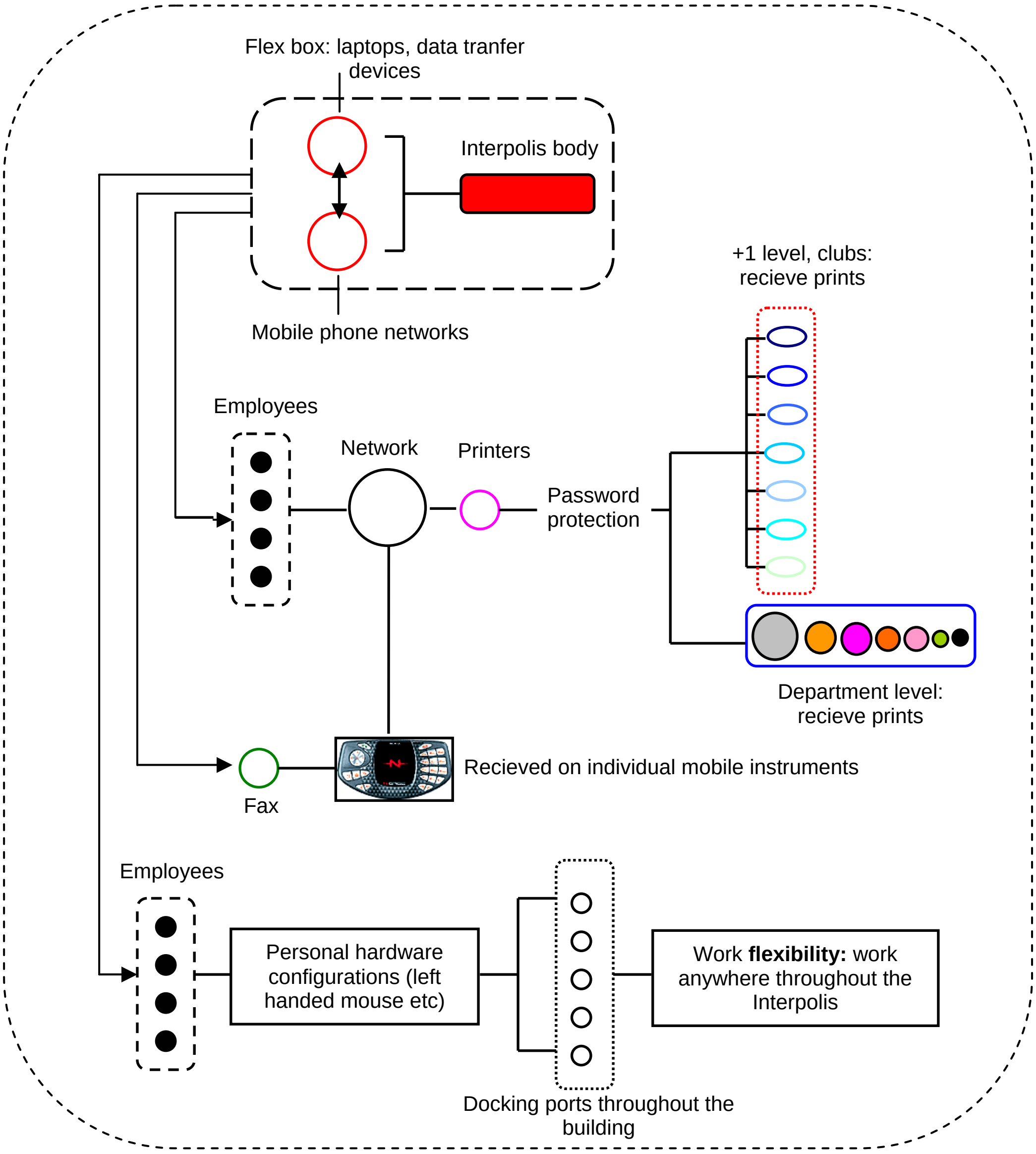


Fig 40 A few examples of network operations within Interpolis fostering flexibility

This feature is self explanatory of the manner in which an Information technology aided office environment can boost productivity while adding convenience and customisation oriented characteristics to a modern work place. According to Cisco Systems wireless LAN benefits studies, in today's information processing world, the implementation of a Wireless LAN can enhance the productivity of an office by 22 % while at the same time increasing the saving margin per user in terms of his/her enhanced productivity by about $ 7000. According to Frank Duffy (Principal DEGW), the beauty of wireless environments is that, if properly designed, they allow everyone a much wider range of choices about how and where and with whom to work. Outside the office wireless environments open up all the resources of the city for richer encounters. Every café, street, airport lounge becomes part of the networked landscape of work. The Interpolis case study is an active proponent of utilising IT for providing user satisfaction as a prime goal and as a result witnesses satisfied users inputting high performance, production and service into the organisation. The next section will conclude the case study based observations and will elaborate upon some interesting derivations made from the same.

3.4. Case study conclusion

A critical analysis into the manner in which the Interpolis office operates, makes it rather clear that an occupant centred approach strategically aimed at providing flexibility and enhancing performance of its employees from an IT/technology oriented perspective is stressed upon during its formulation. The built form, in terms of its materiality and physical structure however, still portrays a closed container within which IT and facility management try to foster a fluid systemic network. Technological pastiche persists throughout the built environment, and architecture, as mentioned in chapter 01, is utilised as a static envelope that is stitched together with IT based networking, rather than integrating the two to spatially perform in coherence. Despite segregating the linear form of Interpolis into various sub-nodes, the form remains inherently non-flexible in its physicality. Introducing fixed furniture, which pins down the programmatic usage of the space itself, further enhances this non-flexibility, at the architectural/interior front.

This aspect is in-turn compensated by the provision of a variety of spaces (high activity nodes), especially on the +1 level, which intentionally target the psychological nature of occupants rather than providing an architectural solution to the notion of flexibility. This psychological displacement, however is also confined to specific floor levels (mainly the +1 level), as a result, the time spent in commuting and readjusting to different spatial contexts (environment, ambience, facilities) is also an issue of concern. What is of vitality is the fact that these spatial allocations for varying theme-based constructs are materialised as artistic expressions irrespective of the consideration as regards the number of people who would be utilising them. This result in a large number of club areas remaining vacant for a long period of time while some are overwhelming with activity (based on the author's observations). This can be considered as a waste of resources at the physical front (physical built-up space irrespective of its optimal usage). The fixed furniture feature further enhances the fact that the programmatic attributes assigned to each space cannot be changed owing to the ambient quality and the feel criteria in accordance with which each of these spaces are very specifically designed. Hence multiple usability of space is a question that remains un-answered. Individual resource allocation remains of vitality in such a scenario (however this aspect could also be a result of the manner in which the management structure operates). The strategic move employed in the Interpolis office of providing heating solutions by means of circulating warm water throughout the ceiling in addition to providing personalized zones (individual work units) where temperature can be individually controlled holds promising implementations for integrating utilitarian services into the architectural envelope in future office spaces.

Flexibility resulting from effective usage of Information Technology (as shown in Fig 40) is seen as a positive aspect that comes through the Interpolis case study and will be specifically considered for seamless data connectivity while developing the spatial prototype. The usage of artistic motifs and advertising media used as image building tools and information imparting mediums will also be considered as vital design issues for the prototype (specifically the skin/surface). The notion of approaching architectural design from multiple disciplines such as psychology, art, information technology, collaborative design and the idea of considering the occupant's requirements as the basis of design generation can be seen as vital inputs for obtaining user satisfaction (statement made by the author after various interviews with the occupants of Interpolis). The approach of envisioning an open office scenario keeping in mind constant plug-ins such as utility, advertising, relaxation etc (as shown in Fig 32) while at the same time providing privacy and concentrated work spaces within the same open framework is also considered a positive observation (in terms of satisfying people with different psychological states) in the Interpolis. However, the issue of infrastructure and space allocation, which at times deem to be unused, is still of central concern for such hybrid office layouts. This issue will be specifically experimented with in conceptualising the proposed prototype by creating adaptable spaces, which can be configured in real time to serve the needs/demands (activity based and psychological) of employees as and when needed. Multiple usability of space and a designed/programmed manner of approaching ambience and time-based utility of space will also be considered as key design issues for the proposed prototype. The usage of colour for responding to psychological states and the probability of developing an integrated IT-structure-skin envelope will become vital as opposed to developing a redundant architectural construct, which is superficially grasping to technological innovations. A similar approach (integrated IT-structure-skin envelope) will be deployed for conceiving natural lighting and ventilation solutions by developing an automated external skin opening mechanism for the building (external intelligent cladding system) within which the proposed prototype will be inserted (Appendix C).

Being a confluence of artists and architects, the Interpolis building, caters to the issue of occupant centred or rather an occupant catering design via a deliberate focus on the nature/ambience of a variety of spaces to be offered to the end user. This jump, to conceptualise space and its associated psychological impacts as opposed to critically mapping typical user activity in relation with his/her productivity via interviews, observations etc resulted in the production of highly diverse interior spaces. However, the provision of such diversity does not necessarily ensure a high occupancy/usability level. Nonetheless, the Interpolis office is still one of the foremost trendsetters in contemporary office designs and does portray a healthy organisational culture, via a spatial non-hierarchy of work environments.

This case study results in the extraction of vital design issues (spatial, ambient and informational) to be considered while conceiving the proposed interactive prototype. These can be summarised in the following manner:

- Consider the skin and the structure as an integrated element catering to ambient aspects (light, sound, image, temperature, airflow)
- Information Technology based networking solutions to foster informational and data accessibility oriented flexibility (printing, faxing, spatial interconnectivity etc)
- Use of colour, art and images (to be conceived as integral to the surface/skin via electronic means)
- Providing multiple space usability solutions through augmenting architectural space (physical space morphing and automated ambience regulation)
- Time based spatial occupancy to be conceptualised in an efficient manner (coupled with multiple usability of the same space at different time frames for different activities)
- Team based interactions as an occupant centred behaviour (to be considered for developing social networks via computational means)
- Volumetric variation of spatial nodes in accordance with the occupation criteria e.g. number of people present (for maintaining optimal space utilization)

- Co-relating flat organisational structures with an equally flat, networked architectural whole (every space configuration to be given equal importance akin to a network which gives equal position to all its elements and is hence considered to be democratic)
- Re-think the usage of fixed furniture (dead load, fixing the programmatic usage of space) with re-configurable surface articulations
- Utilise visual media tools such as presentation screens, advertising plasma screens, flexible displays etc as image building tools
- Develop coherence between external architectural form and the internal sub component behaviour, hence visualising a bio-system model for the organisation (internal auto-regulation affecting the external appearance of an organism)
- Develop a networked whole via communication possibilities offered by discrete devices like the cell phone, PDA's etc (as local networking devices/local agents).
- Program formulation to be considered in order to address user behaviour related variables (such as proximity, resource sharing possibilities) and for supporting both formal and informal activities.

After analyzing the Interpolis office and extracting the above exemplified design issues, the next chapter exemplifies upon the manner in which the real-time adaptive spatial nature of the proposed prototype (meta-system for conceiving an interactive office space) interfaces with the field of interaction design and its methodologies. The chapter demonstrates the manner in which a specific design framework: PACT (people, activity, context and technology) used in the interaction design domain can be deployed for the identification of user centric research variables for the case of this research. These identified variables will subsequently be utilised to extract the proposed meta-system's requirements and lead to the creation of a case specific system architecture.

04

IDENTIFYING RESEARCH COMPONENTS

04
Identifying research components

4.1 Architectural affects (a case for interaction design)

'Being inherently closed systemic networks', an issue, which current corporate architectural typologies (in terms of their physicality) inherit, deems to be a proponent of the industrial and modernistic design conceptions[1] which formulate their base. Such design ideologies, often characteristic of explorations in the fields of form and material configurations at an objective level resulted in the increased focus on production, infrastructure and facility management as vital design constraints during conceptual design stages of office environments[2]. The resultant, technologically improved spatial domains which would effectively operate as efficient production machines often tend to give little significance to a user oriented design initiative. In today's world of parallel processing and knowledge oriented work force (knowledge workers[3]), a vital shift from the above mentioned (modernistic) objective design ideologies towards ideologies fostering the importance of an interdisciplinary[4] approach, which involves the consideration of technological prowess, architectural design, science, economy and socio-cultural aspects as equivalent counterparts has been evident (please refer endnote 4).

Embedded in such a context, a scientific perspective concerning the nature and growth of organizations and the analogies that they share with biological systems, understanding the manner in which behaviours such as growth, mutation, entropy, metabolism and the resulting inter-actions materialize, is vital to this research. A componential stratification of biological systems into their sub-components to understand how sensing and actuating capabilities within each component operate in accordance with a series of rules, subsequently affecting the overall behaviour (dynamic adaptation[5]) of the system gives vital clues as regards finding technological parallels to such complex systems[6]. This broader notion of dynamic adaptability as well as the nature of interaction, which living systems exhibit towards their environment, is where the explorations towards developing a principally similar architectonic[7] at the spatial front germinate. However, what is of central concern for the conception of such a prototype is the understanding of the very issue of interaction (from a human as well as a technological perspective) and the manner in which a sophisticated level of interactivity, between the components of the prototype and with its context can be developed. In order to envision the nature of interaction required off the prototype, a scenario specifically concentrating upon building computationally enhanced kinetic adaptability into static, closed system container like setting has been specified. The proposition is hence to develop a novel architectural prototype, which considers the responsive structural behaviour of the speculated space as an architectural affect. This hypothesis concerning the nature of the construct thus sets the stage for conceptualising an inter-activating mechanism that functions in real time, responding to the work dynamics of its inhabitants. The notion of providing an interaction based architectural affect hence becomes a prospective case for understanding the term 'Interaction' and to subsequently understand the design and analysis methodologies employed in the field of Interaction design.

Keeping in mind the above hypothesis as a potential scenario, the next section of the research work, specifically focuses upon the issue of Interaction and consequently elaborates upon the field of interaction design and its research methodologies in order to initiate an inter-disciplinary approach for conceptualizing the basic research parameters.

4.2 Understanding interaction

In order to understand the essence of interaction, it is important to focus on three terminologies: interaction, interactivity and finally the term interaction design. The inherent characteristics of each term, and their usage in a multitude of fields will be elaborated upon in the following sections.

4.2.1 Interaction

Interaction is a terminology used to elaborate the action which occurs as two or more objects have an effect upon one another. The generation of a two-way effect/dialogue instead of a one-way causal effect/monologue is the basic underlying principle for interaction. The combinations of many such, simple interactions can lead to surprising emergent phenomena (as was mentioned earlier in terms of biological systems possessing varying levels of componential interactions). Interaction has been interpreted in a variety of manners in differing fields of sciences such as medicine, communication, media art, physics, sociology and statistics. However, for the purpose of this research, the usage of the term with respect to the fields of communication, media art and sociology, (based on the Wikipedia encyclopaedia definitions) have been elaborated upon.

Communications

In the field of communications, an interactive communication is said to occur when sources take turns transmitting messages between one another. This should be distinguished from trans-active communication, in which sources transmit messages simultaneously. The notion of dialogue, conventionally speaking, is hence forth instigated.

Media art

In media art, interaction is essentially considered as a feature of the media in question. Interaction, in the field of Media art as such can exist in virtual spaces or in the real space (physical interactive installations). In virtual interaction, interaction usually takes place in the space of a computer with the monitor providing visual cues, while the keyboard, mouse or joysticks are used as tools allowing interaction. A variety of video games as well as software applications are based in this realm. In physical space however, the creation of interaction usually involves sensors, actuators and computer systems with code that allow interactive systems to respond to human position, touch and sound. The physical domain thus requires to be enriched technologically by means of control systems as well as computational logic to propagate interaction. Two projects done at the TU Delft, under the author's guidance will be presented towards the end of this chapter (section 4.6) specifically focusing upon two such real-time interactive physical prototypes: the Muscle Re-configured and the Bamboostic.

Sociology

In the field of sociology, the term interaction is looked at from a social interaction perspective. Social interaction is categorised as a dynamic, changing sequence of social actions between individuals (or groups) who modify their actions and reactions due to the actions by their interaction partner(s). Social interactions can be differentiated into:

- Accidental - not planned and likely not repeated. For example, asking a stranger for directions or shopkeeper for product availabity.

- Repeated - not planned, bound to happen from time to time. For example, accidentally meeting a neighbour from time to time when walking on your street.
- Regular - not planned, but very common, likely to raise questions when missed. Meeting a doorman or a security guard every workday in your workplace, dining every day in the same restaurant etc.
- Regulated - planned and regulated by customs or law, will definitely raise questions when missed. Interaction in a workplace (coming to work, staff meetings, etc.).

Apart from being the basis for social relations, the social interaction domain has also been actively modelled and simulated via a variety of computation tools in order to mimic human behaviour. The notion of boids[8], crowds and predictive modelling in the field of AI also has its roots in the social interaction field. The organizational behaviour/culture section, as described earlier also bears its roots in this field, though it also involves an added constraint of performing within set organizational rules. It is rather interesting to note that within such regulated interaction modes, a variety of dynamic interactions (accidental, repeated, regular) do operate, which further lead to emergent behaviours like group formations as well as developing affinity towards certain spaces.

The area of physical Interaction where a technologically mediated whole is conceptualised with the central issue of Interaction is of specific importance to this research. The physicality of space itself, tends to be perceived as a subject (rather than the modernistic/industrial objective notion), possessing its own behaviour, which is carefully developed with a user oriented (Human computer interaction) perspective. A response (programmed in accordance with event based scenarios), specifically acting upon the interpreted logic from a received message/action (sensed data) formulates the basis for a successful interaction. Such responsive behaviour is specifically termed as interactivity[9].

4.2.2 Interactivity

Interactivity is similar to the degree of responsiveness, and is examined as a communication process in which each message is related to the previous messages exchanged, and to the relation of those messages to the messages preceding them – Sheizaf Rafaeli[10]. The understanding of the term is further clarified when taken into consideration the degree of responsiveness substantiated in the interaction process. As Sheizaf states, there are three basic levels of interactivity: interactive, reactive and non-interactive. These respectively account for the following levels of response:

- Interactive: a state when a message is related to a number of previous messages and the relation between them
- Reactive: a state when a message is related to only one previous message
- Non interactive: when a message is not related to previous messages

What this implies is that in the case of interactive and reactive response, the roles of the sender and the receiver are interchangeable with each subsequent message. Thus, a basic condition for interactivity to prevail is a coherent response from each communicant. The content of the response however could be of two forms: regular response, a response to previous messages, or simply response, which acknowledges previous responses. Szuprowicz (1995) identified three levels of interactivity: user-to-user, user-to-documents, and user-to-computer (or user-to-system). Others have identified similar three-dimensional constructs (Barker and Tucker, 1990; Haeckel, 1998; Jensen, 1998). Kayany, Wotring, and Forrest (1996) suggested that within these three types of interactivity users exert three types of control: relational (or interpersonal), content (or document-based) and process/sequence (or interface-based) controls. Additional interactivity dimensions have been identified that are setting-specific. For example, Stromer-Galley and Foot (2000) identified 'citizen-campaign interaction' in political web sites and Chesebro and Bonsall (1989) added dimensions for program-dominated interaction and artificial intelligence. However, when it comes to designing performative new-media oriented systems exhibiting a high degree of interactivity, it is still difficult to predict whether this can be attained by mechanisation or via human participation. According to Sheizaf, the only way to attain this is by means of allowing interchangeable communication roles (role assignment and turn-taking are to be non-automatic or nearly so). What this also implies in the case of this research, is that the two meta-components; physical space and occupants should possess certain degrees of freedom in terms of communicating information. A highly interdependent relationship amongst the two is hence of vital importance. What is also of interest in the context of the proposed prototype is the effective operation of it in two domains, namely the physical (engineered prototype) and the virtual (the interface between the physical and the informational). This area of research where the physical and the digital collide specifically falls under the interaction design field, which will be elaborated upon in the next section.

However, before we jump into the intricacies of interaction design, let us dissect interactivity into its components, in order to understand the specific character which the prototype should inherit. Interactivity can be, according to Nathan Shedroff (Creative designer Vivid studios) dissected into the following components[11]:

- Feedback
- Control (Sophisticated navigation, high audience control)
- Productivity (Creation tools, Creation help)
- Creativity/Co-creativity (Productivity applications, tools, living information)
- Communication (Discussion forums, communities, knowledge systems)
- Adaptability (Customization, Personalization, Time sensitive and location sensitive interfaces)

This componential split, also reassures the above discussion about interchangeable communication roles via the control and communication characteristics, while at the same time enhancing upon the increasingly important issue of customization. Customization, its theoretical underpinnings, typologies and the manner in which it is utilised for shaping the prototype, is elaborated upon in chapter 05. An increasing precedence given to user centric design conception is also evident from the above mentioned components when dealing with issues of communication, creativity, control and personalization. The idea of providing a participatory nature to any system with the help of creation tools, discussion forums as well as real time information update itself is suggestive of the need for a well crafted interface as a front end[12] to the system. This aspect of interactivity is specifically attached to the filed of human computer Interaction[13] (HCI) and is of vital concern in the field of interaction Design. In general, the design of an interactive system (similar to the responsive prototype under speculation) concerns the following (David Benyon, Phill Turner and Susan Turner in Designing Interactive systems):

- Design: involving the creative process of specifying something new and to the representations that are produced during the process. Design in itself is an iterative process involving the exploration of requirements (what the system is meant to do and how it should do it) and design solutions.

- Technology: involving interactive systems, products, devices, components and software systems. An important goal of empowering an interactive system with technologies is to deal with transmission, display, storage or transformation of information that people can perceive. Essentially interactive systems tend to be devices and systems that respond to people's actions.
- People: who will use the system and whose lives we would like to make better through our designs.
- Activities and contexts: what people want to do and the contexts within which those activities take place.

The proposed meta-system takes into consideration the above mentioned concerns and through the mode of interaction designs attempts to decipher research components in a user centric fashion. In order to understand the above mentioned theoretical constructs, the research now focuses upon the field of interaction design.

4.2.3 Interaction Design

Interaction design is a discipline concerning the defining and creating of human interaction with digital, environmental or organizational systems. Interaction design defines the behaviours or interactions of an object or system over time with its user population. Interaction design hence deals with the notion of interaction and interactivity, with a rather interdependent user centric aspect at its core. Interaction designers create products and services that are typically informed by user research, designed with an emphasis on behaviour as well as form, and evaluated in terms that include emotional factors instead of mere usability.

''Interaction design is the art of effectively creating interesting and compelling experiences for others''. - Shedroff, 1999. The experiential aspect, in the case of interaction design is of particular importance in today's ever increasing trend of churning technologically enhanced gadgetry (with increasing complexity and features). In order to enhance the usability, understand-ability and hence interaction promoting nature of any system/product it becomes rather important to give particular attention to the manner in which its interaction can be designed. A predominant way of imparting information about the product's usability is its interface. The interface can include both hardware and software and the field of interaction design specifically concentrates upon the manner in which a favourable combination of both can lead to high levels of interactivity. Human computer interaction (often associated with Interaction design for developing usable and user friendly front ends to complex systems) as a broader field of research is specifically aimed at understanding user interfaces and their usability (clarity in terms of communicating content and ease of operation). Interaction design, as concerns the interface development however, concentrates on the aspects (of the interface) that define and present its behaviour over time, with a focus on developing the system to respond to the user's experience.

Associated fields such as interactive art[14] and social interaction design are emerging at a rapid pace and are representative of contemporary socio-cultural dynamism. The propositions put forth by the field of interaction design in terms of developing associations amongst the digital and the physical realms are absorbed and represented in favourable manners by the above mentioned fields. The fact that both the fields are concerned with a rather generic affiliation to human behaviour, the relation amongst humans, their relation with devices and the relation amongst devices themselves, brings forth the complex network of relations that can be handled via the broader field of interaction design. The research work operates on the borders of such emergent fields and hence is an active attempt to portray the manner in which designed interactions can be beneficial in the production of performative spatial structures.

4.3. Deriving a design strategy

After this brief analysis (into the terminologies related with interaction),geared towards deciphering the behavioural profile of the proposed prototype, it can be deduced that a two-way effect/dialogue instead of a one-way causal effect/monologue should in essence form the basic underlying principle for the proposed interactive space. The degree of response to be generated from and to the system will in effect be benefited by an efficient interaction design focusing upon issues of feedback, control, productivity, creativity, communication and adaptability. Such issues, in the course of this research will be specifically approached from a human centric and a spatial perspective, in an attempt to constantly maintain an architectural inclination towards the deployment of interactivity. A generic framework, supporting such a (interactive system design) perspective, widely followed in the field of interaction design world over called the PACT[15]; people, activity, context and technology is exemplified upon in the next section. This approach, is specifically utilised for identifying research variables, based upon a componential split of a typical office environment and then re-assembling these under the above four categories. A design strategy specifically aimed at understanding the role of interaction in the conceptualization of the proposed prototype from a Human centric perspective is hence stressed upon. The application of the PACT framework is intended to derive an understanding of the immediate context surrounding the proposed system in its entirety (people, kinds of activities and the context), in-turn deriving a logical build-up towards a technological confluence needed to support activity typologies.

This strategy strengthens the vision of developing a co-evolving (design + technology) spatial conception, hence avoiding the traps of being either governed by technology or on the other hand being steeped into production, facility and management perspectives. The PACT analysis for understanding the research variables eventually leads to a comprehensive output in terms of a set of requirements highly specific to the office environment under speculation. The requirements are in-turn utilised for the conceptual design of the proposed system and for conceptualising an appropriate system architecture (elaborated upon in chapter 05). These are eventually transformed into physical (real-time simulated) designs appropriated for a highly specific purpose; developing an occupant centred, technologically mediated interactive office environment. In the design process to follow, an attention to aspects of new media and the emergence of varying social clustering as a result of the ensuing interaction will become apparent and will hence point towards the increasingly vital role of human communication, for producing emergent behavioural phenomena.

The next section will outline the essential characters of the PACT framework that is deployed in the research work and will subsequently elaborate upon each component in accordance with the context (corporate offices) within which the interactive system will be deployed. Research findings from chapter 03, the Interpolis case study, will also be used as an underpinning for extracting the research variables linked with each component. The definition of the PACT framework is in accordance with David Benyon, Philip Turner and Susan Turner's views in their book Designing Interactive systems.

4.4. The PACT framework

The PACT framework, or more specifically People, Activity, Context and Technology framework is one of the most widely used frameworks in the field of interaction design. It essentially emphasizes a human centric approach by means of concentrating on the typology, physiology and psychological inclinations of people for whom an interactive system needs to be envisioned. The framework creates a synergy between the four components by establishing a singular statement; People undertake activities in contexts using technologies. It hence proves to be a logical percept setting up an interdependent relationship between the four components. This inter-relation specifically supports the essence of Interaction as was discussed in the previous sections and puts the human as a centre around which activities within a certain context influence the technological appropriations. Activities which take place within their contexts give rise to a set of technological requirements, which are highly interlinked; any technological change affects the manner in which the activity within a context is performed. A healthy exchange of roles is hence predominant within such a framework (Fig 41).

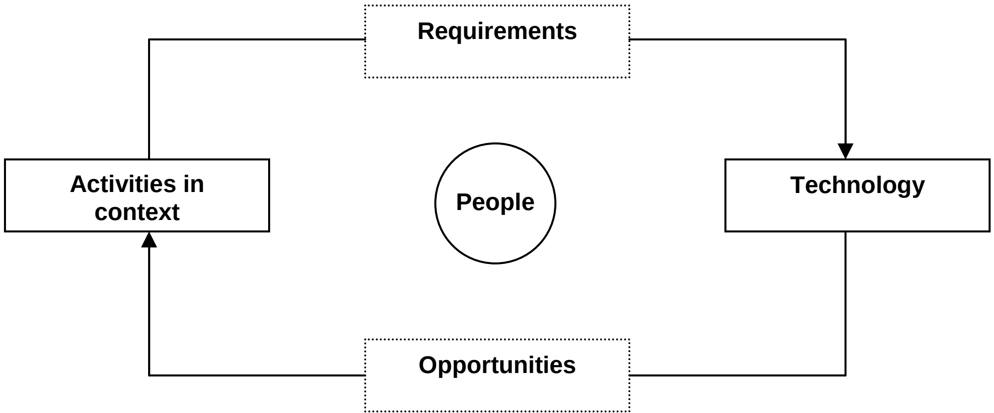


Fig 41 Interdependence amongst the PACT components

What comes to the fore while implementing such a framework is the cyclic nature of the interactivity amongst the four components (people, activity, context and technology). It becomes vital to cater to this cycle in order to ascertain a successful system intervention for any domain: in this case the corporate office. Though the study of corporate culture, office typologies, organizational changes etc (as discussed in the previous Chapters) facilitated in developing an understanding of the whole (office environment), a detailed insight into the operational components of such environments is now expanded upon in the following sections. The sections focus upon the plenitudes of variables that fall under each component of the PACT framework. A deduction of some of the most vital aspects from the PACT framework will be considered subsequently for the development of a specific conceptual model for the proposed interactive prototype.

4.4.1. People

The first component in the PACT framework; people, specifically demands a critical look while formulating the basis for the entire system. The terminology can also be used to suggest the users of the system and hence an exemplification of the typologies (in terms of their position within the office environment), their physical differences, their psychological differences and usage differences would be of vital concern. The elaborations presented in this section, also take into consideration the fact that the users under speculation are in some way or the other related to the office environment and hence would be intuitively expected to abide by certain moral rules of conduct. This central component (people) tends to be rather dynamic in terms of its behavioural profile and hence its precise stratification into its variables will be helpful for the research.

4.4.1. a. Typologies

After developing an understanding into corporate culture and based on the observations made at the Interpolis office, a broad classification of the people who would be visiting a typical office can be outlined in the following manner:

Regular employees

- A mix of **typical 09 – 05 working employees and the flexible working employees** with a generic set of requirements from the work space. Such employees will predominantly develop a set mode of operation within the office environment and will be utilising almost all resources (infrastructure, physical, ambient, IT based) available at the office. Regular employees distinctively develop affiliations and close relations with a set of like minded people or are otherwise compelled to do so by over-riding organization rules (creation of teams, clubbing people with a similar specialization etc). An emergent pattern in terms of employee clusters based on each individual's preference hence formulates. Contemporary employees tend to be computer literate, invariably possess communication devices like mobile phones, palm tops etc and are mostly connected to the world via the world wide web. In general, they are sufficiently equipped with a basic level of navigation and control related principles in the technical/informational realm. Regular employees, owing to their long hours of occupancy of office environments tend to perform a variety of activities (will be elaborated in the activity component) and hence tend to be catered to in a way which is comforting as well as encouraging for them to be more productive. Flexible work oriented employees also share the above mentioned characteristics apart from being connected via a sufficiently fast internet connection at respective homes. They also possess additional knowledge in terms of data transfer, data storage and management in order to meet the dead lines set forth by the organization. The regular users, as has been observed and interviewed tend to get jaded by the same office space which they have to occupy on a regular basis. This tends to make their work appear to be a routine which they have to legitimately follow. An informal discussion with such employees suggested that a much more flexible arrangement of space occupancy would be helpful for them to be more productive.

- **Managers/controllers** within office environments are people governing the work flow of teams. Since they are associated with such responsibilities, they often control a spatial dominance in terms of bigger spaces with a constant amount of presentations and conferences being undertaken in such spaces. They usually prefer fixed locations within an environment from where they can administer the presence as well as activities being conducted by the staff. They tend to be highly skilled in terms of computer literacy (specific for the profession they are involved with) and are mostly responsible for maintaining an active communication for encouragement as well as problem solving amongst the group he/she is heading. They are also responsible for client entertainment and for organizing a host of other socio-cultural activities in the interest of the organization.

Visitors

- **Clients** are regular/periodic visitors who command respect in the organizations operation. Clients could either be in the form of a singular entity, a group of people or other organizations. This category of people are usually entertained, are a part of meetings and presentations which are of interest to their investments and as such are attracted by an organizations image, its performance and a sense of mutual interest. Clients need not necessarily be computer literate, but do possess a variety of communication and home based devices which make them literate in terms of basic interface navigation principles. Clients usually would not mix with the regular employees, but would be directly connected with superior managers/controllers for an overview of the developments of concern to them. However, this category of people tends to conduct meetings on the basis of set appointments which allows for regular employees to structure their tasks within these time frames. Client appointments and the utilization of conference/meeting facilities are mostly inter-dependent which demand a structured presentation and efficient discussions.

- **Regular/infrastructure related visitors** are of the likes of mail delivery, courier delivery, food and beverages delivery, technicians etc. These are usually restricted to certain portions of the office unless and until their presence is demanded in other zones. Their visit during certain intervals of the day is expected and hence do not necessarily need setting up of appointments. They have very little to do with the above two categories of (regular and client) people at a personal level, but are rather facilitory in nature.

- **Spontaneous visitors** like friends/relatives etc of the employees of the office come under this category. They are, based on the discretion of the employee either entertained within specific areas of the office or are otherwise asked to meet by means of appointments. Their level of computer literacy is not of much concern for this research. However, it is assumed that they would be aware of basic codes of conducts of an office environment and would be apparently greeted at the reception by corresponding employees.

Cleaning/Maintenance

- People associated with **cleaning and maintenance**, waste disposition, over-all cleaning of the office spaces etc fall under this category. These people are not necessarily computer literate or good at controlling communication devices. They have strict routines in terms of when and where, would cleaning activities be conducted. This group of people usually do most of the cleaning and maintenance work either before office starting hours or else after office hours and are hence the first ones to enter the office. After interviewing some people from this category, it became evident that they could do their work more efficiently if there was not too much clutter in the office, and if a maximum number of surfaces were flat and ergonomically positioned. They also refrain from being involved in the handling of complex control systems and would prefer not to handle any gadgetry which they fear they could damage due to a lack of knowledge about such technologies. In essence, they would prefer clear, unobtrusive environments to perform their jobs in the most efficient manner.

Security staff

- **Security related personnel** are quintessential to any organization. They usually are trained and hence are attuned to complex control systems related with various aspects of the office's security. They operate in shifts, and hence tend to be rather alert. Apart from taking care of the security of the office, many a times the security officials, due to their position (usually near the entrance) tend to confront many a visitor queries, and at times express the need for being well informed about the occupancy status of people present in the office.

4.4.1. b. Physical aspects

Another important aspect to consider while designing interactive systems (especially when it comes to designing spatial/physical installations) is the physical differences which people possess. These are often associated with weight, height, reach etc. in general the entire spectrum of senses: vision, sound, touch and smell are to be considered when designing a suitable interactive system. A system addressing these senses in an appropriate manner can in-turn become more usable and performative. The faculty of vision can be useful while considering issues of clarity of conveying a message (signage), colour blindness, peripheral vision and movement. Sound is an equally important tool for attracting attention and can be much more effective than light for communicating alerts, appointments and emergency situations. Touch, another vital sense can be used in a variety of ways, specially in cases of physical/spatial outputs in combination with varied technologies such as haptics[16], pneumatics etc and can be employed for the development of tactile interfaces as well as physical augmentation of interactive entities. The sense of smell[17] is already being deployed in a variety of office environments to enhance psychological inclinations towards being more productive, more relaxed etc. Issues related to memory, both short term and long term, the ability to retain information and the assistance that technology can provide for sharing the memory load in the physical world can also be used effectively to enhance the usability of interactive systems.

4.4.1. c. Psychological aspects

Differences in psychological capabilities such as spatial abilities, remembering abilities need to be taken into consideration while conceptualizing interactive systems. According to David Banyon, Phil Turner and Susan Turner it's always better to design interactive systems considering people with the least psychological abilities. Considering the design of interactive systems from this perspective makes one consider the design of perceived affordances (the properties of an object which suggest how one could use it) in the most simplistic and easily understandable manner. The issue of mapping, or relationships between controls and their effects on a system also becomes central while catering to psychological differences amongst humans. A simplistic and intuitive relationship between controls (switches, interface buttons etc) and the corresponding system under consideration assist the user in a seamless manner, hence building up a symbiotic relation between the two. The more graspable and easier to understand the relation between controls and their impacts on a system, the better it is absorbed in the human domain. Less stress in terms of memorizing the functionalities of a system due to the simplistic nature of its controls is what strengthens its acceptability and productive use by people. Another aspect closely linked with human psychology is constraints. Constraints are usually referred as the physical, cultural or logical limitations of possible use which a designed object/system possesses.

An interlinked relation between affordances which suggest the range of possibilities and constraints which suggest the limitations of use alternatives hence operates as an internal subsystem. This simple relation coupled with the idea of affordances proves to be rather helpful, especially in an environment like corporate offices, where stress and tiredness, which reduce the capacity to memorize instructions are prevalent. Cultural conventions on the other hand are also equally important in shaping the system controls at a local level. Conventions are predominant in different parts of the world and systems are hence developed to adhere to them in order to avoid unnecessary effort on the people's part to attune them to a foreign convention. This further helps in decreasing the time spent to learn and operate a system in its entirety and hence speeds up the productivity of an office environment with very less effort spent in educating people as concerns the operability of a new system.

4.4.1. d. Usage issues

The degree of affinity that people possess towards efficiently using a technology is also of vital concern in the shaping of a system. For people who are exposed to a system for a long time, it is much easier and quicker to intuitively remember the details involved in its operation. However for a novice user, the time spent for one to get accustomed to the variety of issues involved in a technological system could be a major cause of non-productivity. Even though people are not necessarily meant to possess complete knowledge about the technicalities involved in a system's operation, attempts should be made to clearly represent the front end/interface of any system in the most comprehensive manner so that the usability not the technicality of the system is easily deciphered. It is the role of a designer to design and represent the interactivity involved in a system in a manner which is not too much over bearing for people. This helps in sustaining the interest level of people and hence eventually leads to a desirable level of communication between the two. The notion of designing for a homogenous group of people within an office environment as opposed to designing for a heterogeneous audience is also of crucial importance in terms of making the system and its controls much more specific to its context. A clear set of instructions (in case of a procedural task) is often helpful in accelerating the pace at which one can navigate/operate a system. Such systems should be eventually tested via user experimentation to derive the best possible manner of representing its features.

4.4.2. Activities

The second component within the PACT framework; activities, is specifically looked at in the context of this research from the corporate office perspective. Activities performed within an office environment by the different typologies of people, mentioned in the earlier section, vary in terms of their characteristics, duration and their outcomes. In order to distil this variety, the following sections will concentrate upon identifying purpose oriented activity typologies and will subsequently focus upon the features of these activities (temporal, co-operation, complexity, safety critical and the nature of content).

4.4.2. a. Typologies

A typical office environment can be analysed in terms of the kinds of activities it sustains in close relation with the typology of people using the office space in the manner exemplified in this section. These typologies are also distilled from the case study conducted in chapter 03; the Interpolis office, Tilburg, Netherlands. Activities can be broken down into four distinct types: solo, group, congenial and social. An office environment becomes much more efficient if these activity types work in coherence with each other.

Solo

- Solo activities, as the name suggests, are usually associated with a singular person. However since an office environment also accounts for constant interactions with colleagues involved with the same projects etc, solo activities can be extended to cover actions such as sharing a conversation, exchanging notes etc. writing, drawing, telephoning, selling, word processing, computing, thinking, reflecting, researching, reading, filing etc can be seen as examples of such activities.

Group

- Group activities can be termed as those, which involve working with a number of people sharing the same goal, project etc. The group could either be temporary or a permanent one, depending upon the organisational policy to group them in accordance with certain projects. Such activities can be associated with a team, which works constantly towards attaining a set target, and at the same time can be associated with an activity like presenting, meeting etc which involves the coming together of a certain number of individuals. Santa Ramond and Roger Cunliffe in their book Tomorrows office, have carefully derived a manner of classifying group activities into distinct roles:

2-3 people	12 people	24 people	24+ people
Mentoring, counselling	Interviewing Monitoring Team working	Team working Meetings Brainstorming Informing Briefing	Informing Briefing Conference

Congenial

- Activities having a distinct social element attached to them. Irrespective of the kind of activity: social, solo or group, any activity which involves such social behaviour, involving informal conversations, imparting information, etc not necessarily work related can be clubbed in this category. Some examples can be: making a cup of coffee while chatting with a friend, talking to colleagues in the toilets, circulation; using the lifts, corridors etc, paper processing, mailing, filing, coffee breaks, eating lunch while working etc.

Social

- Social activities are activities involved with an intensive exchange of ideas, and knowledge development by means of interactions in the office. These could be within a group, a client to group/individual, or even at a very informal level such as chatting for a few minutes in corridors etc. Activities like eating, entertainment, chatting, smoking, exercising etc are some examples of social activities.

Activities, apart from being typified, can also be visualised with respect to their characteristics. These characteristics can be broadly classified in the following manner:

Creative

- Brain storming, designing, strategic planning, report writing

Persuasive

- Negotiating, presenting, training, selling

Absorbing

- Reading, researching, computing

Reflective

- Thinking, philosophising

Humdrum

- Word processing, photocopying, filing, storage

Refreshing

- Greeting, eating, socialising, exercising

Informative

- Actively telling, passively overhearing

Compassionate

- Counselling, helping

4.4.2. b. Communication

Communication, as another important activity performed in office environments will be dissected into its typologies in the following sections. Communication as a variable can be split into three components namely movement of people, movement of Objects and movement of information. Issues related to choice of flexible working can also e clubbed under this section. This section, as the previous one bases its dissections on the typology of people and the observations made at the Interpolis office.

Movement of people

- Movement of people involves the activity associated to groups and individuals either visiting the office or of the employees of the office themselves. This variable is also associated with issues of safety, clarity of direction, sound generation, privacy and image building of an office environment.

Movement of objects

- Movement of objects involves any activity related with the movement of paper: printing, faxing, filing etc, office equipment: furniture and machines, office supplies: paper work, photocopiers, cartridges, printers etc. Objects related to the clubrooms, restaurants: food supplies, beverages etc, and waste: garbage, paper etc also fall under this category.

Movement of information

- Movement of information involves exchange of either digital, verbal or text based information. A variety of devices can be attached with these: phone, fax, printers, copiers, emailing, networking etc. filing and archives can also form a part of this category.

Choice (Flex working)

- Choice, deals with the idea of providing an aspect of mobility to the employees. It involves the implementation of flexible working possibilities; so that the employees can be free to choose their office hours and can additionally also work from home at their convenience. Wireless networking, hot-desking, as well as developments in IT based communication networks also lead to possibilities where the employee becomes free to work anywhere in the office. Such flexibility proves to be vital when issues of productivity and psychological comfort of employees is reviewed.

4.4.2. c. Nature of activities

The above mentioned activity typologies can be further categorised in accordance with the nature of these activities. Nature of activities can be broadly categorized under the following sections:

Temporal

- The temporal nature of activities lays emphasis upon time based aspects of activities. This would mean, understanding how regular, irregular, spontaneous or periodic activities are. It is also directly related with the typology of people undertaking certain activities and can hence be of varied intensities. Specifically considering office environments, it is also important to note the state of the people under consideration; are they under time pressures and hence tensed thus requiring minimal distractions and ease of operability of a system etc. An important implication of this concern is the considerable time required for a system component's actuation. System response times hence need to be carefully choreographed in order to provide the users with a sense of comfort and assurance in terms of their expectations from the system. Too long a waiting period could result in frustration and eventual repulsion from the technological system.

Co-operative

- Requirements for certain of the above mentioned activities would necessitate the people working together in groups rather than working alone. Issues of accessibility, communication and co-ordination hence become crucial to be considered under such circumstances.

Complexity

- Involves the nature; how simple and straight forward or how difficult an activity actually is. This has direct implications on the design of the system per say. A simple task oriented activity can be catered to by means of developing a simplified step by step approach which can be easily followed by means of simple instructions, however, a more complex task would want an information network to be set in place, which allows for people to browse through varied sets of information in order to retrieve important information. In both cases, the clarity of conveying instructions, either by means of graphics, symbols or physical augmentations should be designed adequately.

Safety critical

- Some activities to be performed will have to be more concerned in terms of safety issues attached to them. The system design should hence speculate before hand what could go wrong and the nature of damage that it could cause to people using the system. A design catering to safety issues which have been well thought of before hand deems to be much more successful in terms of saving time during evaluation stages of the system and proves to be psychologically acceptable by the people using the system.

Content

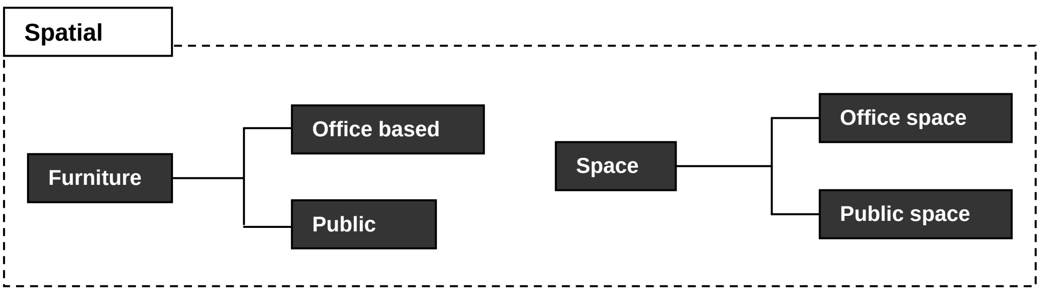
- It is always beneficial to be critical in terms of making a choice of the appropriate media to be used as a medium for supporting the nature of expected activities. An analysis of the above mentioned activity typologies conveying features most required such as display, speech recognition, data input etc will direct one towards the appropriation of media most suitable for sustaining the activities. These will be discussed in subsequent sections.

4.4.3. Context

Context, a vital component of the PACT framework is closely related with the former exemplification of the activity component. A mutual inter-relation between the two necessitates a broader exemplification of the context within which the above stated activity typologies are situated. For the specific case of office environments, the following section stratifies space, facilities as well as ambience related variables which make up a typical corporate organization. Office environments can be split into two distinct categories, apart from the human occupant: spatial/physical environment and resource/organizational based. Ambience related aspects such as light, sound, colour etc are considered as dependent variables and are subsequently exemplified upon towards the end of this section, however, a mutual relation between all the three variables is evident throughout the provided exemplification and hence a possibility of some overlap is persistent. The following categorization also takes into consideration the Interpolis case study and is a synergistic output of a variety of similar corporate settings.

4.4.3. a. Spatial

The spatial variable takes into consideration the typologies of furniture as well as space which constitute the corporate setting. A systematized split of these variables into their sub-components also reveals the nature of activities which can be sustained by the typologies and hence develops a relational logic between activities and their physical environment.



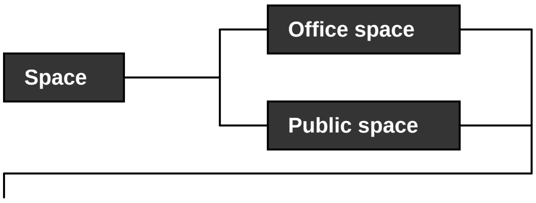
These categories can be further split into sub components in the following manner:

Furniture — **Office based**

- Laptop
- Desktop
- Printer
- Fax
- Desk and chairs
- Meeting tables
- Laptop chairs
- Phone
- Partitions
- Conference tables
- Video screens
- Projectors
- Flex box
- Group library units
- Main library units
- Archive storage units
- Storage racks
- Mailing room tables, chairs
- Informal refreshment area tables and chairs
- Small kitchenette
- Locker spaces
- Mail boxes and phone charging units

Furniture — **Public**

- Video screens
- Projectors
- Speakers
- Desktops
- Informal seating/waiting tables and chairs
- Benches
- Training area tables and chairs



Primary

- o Primary spaces are spaces used for solitary, collective and group work. As was seen earlier, in the case of Interpolis, a favourable mix of these three varieties of spaces can result in an increased productivity and occupant satisfaction. As was discussed earlier in the case of Interpolis, they can be seen as the primary work node, comprising of:
  - Concentrated work nodes- individual
  - Concentrated work nodes- group
  - Formal meeting node- group
  - Informal meeting node- group
  - Knowledge nodes- library, magazine referencing, individual/group
  - Flex work nodes- anyone can choose his or her own tables, group
  - These can be further linked with Relaxation nodes: silent rooms-group/individual based and Utility nodes: eating, drinking-group based

Ancillary

- o Ancillary spaces are spaces, which support the office environment. They are usually responsible for activities like paper processing, filing, informal refreshment points (small kitchenettes) and toilets. From the earlier study of Interpolis, the service node-printing, fax, copying- individual/group, Information tool distribution node: personal mailboxes, cell phones (mobile intercom, which is also programmed as a fax-receiving tool!) and the utility node: eating, drinking-group based can fall under this category.

Support

- o Support spaces serve the entire organisation as such and could also involve some public spaces. Spaces like the reception area, libraries, mailing rooms, small auditoriums, archives and medical facility can be termed as support spaces. Knowledge nodes: library, magazine referencing, individual/group, repose nodes: informal sitting, quick check corner before attending conferences, reception spaces, and informal work node: individual/group emailing facilities and informal discussions can be seen as some examples from the Interpolis case which fall under this category.

Social

- o Social spaces can be termed as spaces that are usually the hubs of the office. Mostly used for entertainment, leisure, exercising, music listening, television watching etc. these spaces, though usually separated from work, can be seen as a vital resource of the office which fosters activities like meeting people, knowledge exchange etc. Club rooms, restaurants, bars relaxation areas fall under this category. From the Interpolis study, the high activity nodes, comprising the following can be seen as a part of this category:
  - ➢ Utility nodes: eating, drinking-group based
  - ➢ Advertising nodes: advertising screens/visual media
  - ➢ Informal work nodes: individual, group
  - ➢ Informal meeting nodes: closed environment-group based
  - ➢ Relaxation nodes: silent rooms-group based

Service

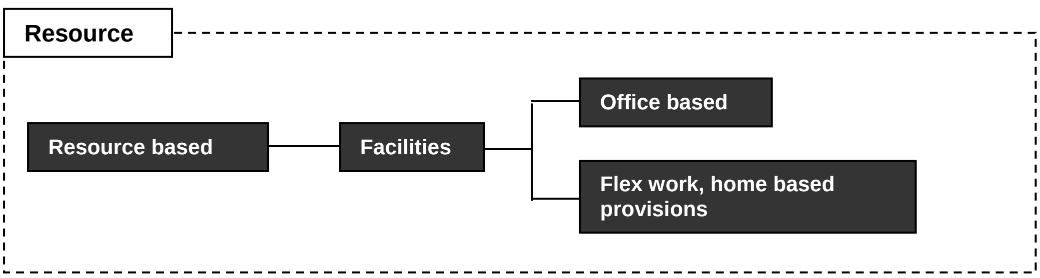
- o Service spaces can be seen as spaces, which are used for specific purposes, for work support and infrastructure provision. Spaces like workshops, plant rooms and store rooms come under this category.

Circulation

- o Circulation spaces, as the name suggests are spaces which house means of transporting people from one portion of the office to the other. However apart from that, these are the spaces where the maximal amount of chance interactions and informal exchange of data take place. Hence these places become rather crucial for reflecting the organisations image and productivity. Spaces like corridors, lifts and lift lobbies, staircases, escalators etc fall under this category.

4.4.3. b. Resource

The resource variable is usually associated with organizational infrastructure. In accordance with the activity and people typologies, they essentially fall under two broad categories: Office based and Flex work based (Generic employee typologies). The following section exemplifies upon these two sub-components in terms of facilities operational within a typical office environment.



Facilities — **Office based**

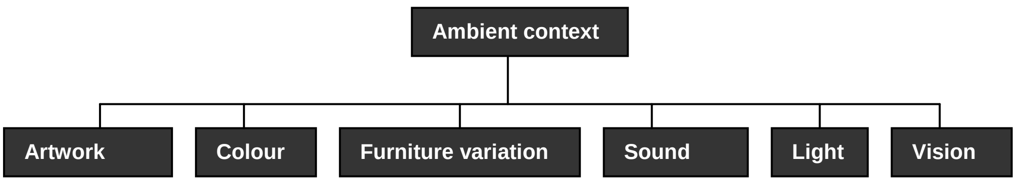
Communication network
Wireless network
Optic fibre network
Electricity
HVAC
Self service facilities
Bicycle sheds
Security

Facilities — **Flex work, home based provisions**

Communication network
Optic fibre connections at homes
Networked printing facilities
Video conferencing
Security

4.4.3. c. Ambient context

Ambient aspects, relate directly with natural as well as physical extensions of the body. These are intrinsically linked with psychological feelings and requirements of the occupants and hence are of vitality as regards the comfort and productivity oriented aspects. Ambient context, specifically for the case of office environments can be sub-divided into the following components: Artwork, colour, furniture, sound, light and vision.



Artwork

- Artworks can be seen as both an image-building plug in as well as a strategic means to provide psychological comfort. Big corporations usually own private art collections, which in turn, reflect the monetary as well as work culture related images of the company. Apart from these, art has always been associated with humanity and is a definite means of developing intimacy as well as associations within a work environment, populated by the mechanical and information driven tools.

Colour

- Colour can be seen as a positive application, which can foster productivity and comfort levels in a workspace. Colour variations, in accordance with the work activity: Light pastel shades which are not too reflective in nature, and are soothing to the eye etc, can be best suited for concentrated work spaces, reflective, highly textured colour paints etc can be applied to informal waiting areas etc according to the discretion of the designer. In the case of Interpolis, I have already exemplified upon the importance and the variation that can be generated using colour, a similar approach can be derived for the proposed prototype.

Furniture variation

- Furniture variation, as was also seen in the case of Interpolis, proves to be one of the important tools for creating variation and sustaining interest in an otherwise uniform spatiality of conventional office environments. Variation in furniture, along with colour and material variations, can also help in developing favoured seating areas, leading to associations and developing a communal setting. One can also think of extending the furniture resource, by means of adding IT based utilities to the furniture object. A variety of experiments conducted through out the world, point towards the integration of video screens, conferencing facilities, communication portals etc to be embedded within an otherwise inert chair/table. Furniture variation can also be thought of in terms of creating distinctions between various nodes in the office environment: work, relax, utility, refreshment etc.

Sound

- Sound can be both a positive and a negative factor. Informal working areas, as well as clubs, restaurants and informal meeting spots, could possibly be tolerable towards a certain range of sound, however areas like concentrated work zones, solitary working, reading, thinking, conferencing and concentrated team work, would be tolerable to very less amount of sound generation. It is in accordance with this that privacy thresholds as well as utility and service based areas should be positioned. Material selection could also play a vital role in subduing sound. Sound also falls in the Physiological sector, which suggests the human level of sound tolerance, which could describe a state as disturbed, calm and concentrated.

Light

- Light becomes an important criterion when deciding about its application to activity-based spaces. Light quality and intensity, are extremely vital for work environments, and a multitude of light varieties can be deployed for illuminating, for instance a working table or a mailing room, the refreshment and entertainment zones within the same office. It is a rather essential factor for developing a particular ambience, which corresponds with specific spatial requirements and activity patterns.

Vision

- Vision links up with a variety of aspects such as perception of space, colour, furniture, light as well as image building. However vision can also be seen as an important manner of communicating and feeling connected in a space. Visual access to team members, as well as for supervision purposes and an uncluttered environment is essential to be developed.

4.4.3. d. Psychological aspects

In conjunction with ambient aspects, one can also consider a variety of psyche related aspects (usually fuzzy), which can be associated with it. These are essentially outcomes of physical aspects and thus can be seen as designed repercussions on the office environment. Three of the most vital aspects have been considered for this research: privacy, accessibility, and personalisation.

Privacy

- Privacy can be linked with a variety of activities: especially the ones involving concentrated work. It can be seen as a manner in which productivity can be boosted up as well as a way of respecting professional boundaries of the employees. Noise generated by a group of people, machines, coffee corners etc can be seen as a source of disturbance, and facilities, possibly through material enclosures, which are sound proof to some extent should be deployed for such privacy zones. The nature of enclosure provided is of vital importance, as it also suggests the attitude of the organisation (a closed or a semi closed nature). At times privacy of a group can also be considered as a way in which the group could put in concentration into the task at hand and avoid getting disturbed by frequent passer byes. However at another level privacy can also be extended towards utility-based functionalities. Password protected printing and faxing facilities come under this section.

Personalisation

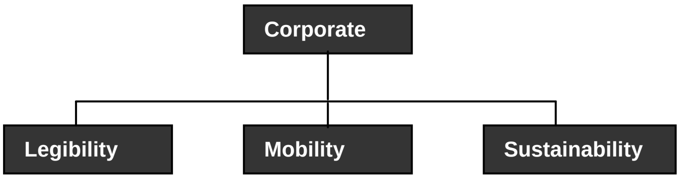
- Personalisation can be seen as a manner in which comfort and association levels can be dealt with at a much more intimate level. As opposed to territorialisation, personalisation could be achieved by rather subtle modes: a favourite furniture piece, art works, screen savers, welcome notes on the phones etc.

Accessibility

- Accessibility is related with clarity of navigating through an office space. A clear display of signage's, uncluttered pathways and a certain level of ease to the floor plan of the office can be helpful for making people save time as well as feel confident of their surroundings.

4.4.3. e. Corporate aspects

Corporate aspects are associated with the organizations image via the services and visual perception that it initiates. Corporate aspects can be broken down into three sub components: Legibility, mobility and sustainability. These three sub-components have been arrived at after discussions with the Interpolis office staff and via an explicit literature review of contemporary corporate office environments.



Legibility

- Legibility is related to the notion of clarity and readability of the office space itself. It specifically focuses upon architectural components, signage systems, visibility and issues related to psychological comfort and safety.

Mobility

- Mobility deals with the possibility of working throughout the globe, which also includes working anywhere in the office. This aspect is directly attached with developments in the IT and communication networks: flex working, wireless networks, docking ports, phones, faxes, video conferencing etc. it is an important step towards cultural integration and social interaction within and outside the office environment.

Sustainability

- Sustainability can be seen from an ecological perspective as the inclusion of green environments, relaxation spaces, spaces for reflection, thinking and communicating. It is an additional element, which fosters psychological stability and the increase in comfort and productivity.

4.4.4. Technology

Technology, the final component of the PACT framework, has extensive co-relations with the activities performed by people within a context. Technologies and activities tend to possess a synergistic relation and mutually affect the performance/development of each other. Technologies for the case of this research are specifically looked at from the perspective of deploying an interactive system within corporate offices. Interaction, in the case of this research is looked at as a manner of providing spatial and ambient adaptability corresponding to the variety of people, activities and context through computational means. Spatial adaptability in turn entails technological assistance for physical augmentation of the spatial structure, ambient (sound, light, colour) environmental variations as well as an understandable front end to the system, all working in the users consent. Apart from deploying wireless networking facilities which were exemplified upon in the Interpolis case, envisioning an interactive system which supports the activities performed by people as well as enhances the comfort level and productivity of the employees thus involves an in-depth look at the variables which formulate the technological counterpart. The following section will exemplify upon four basic technological considerations (according to David Benyon, Phil Turner and Susan Turner in their book Designing Interactive systems): input, output, communication and content. These generic considerations are eventually assigned specific technologies and are bound together in an inter-activating framework. This framework is elaborated upon in the following sections and its performance is validated by two research experiments conducted under the author's guidance at the TU Delft, Department of Architecture.

4.4.4. a. Input

Technologies for input deal with the manner in which data can be entered into a system. Input technologies, specifically for the case of this research should deal with an intuitive level of data transmission related to presence and proximity of people within the office environment without creating any obtrusions in their daily activities. Issues related to tracking (the presence of people) and the variety of adaptations (physical and psychological), which users have to encounter within an office environment also need to be considered while designing the input modes. In office environments, an observed desire of people to be in control of their environments either intuitively or in a regulated manner is in itself suggestive of the need to conceptualize a technological counterpart which allows the users to effortlessly customize spatial, neighbour oriented and ambiance related preferences. However, such a technological conception also needs to cater to where and when these preferences can be entered as data into the proposed system and depending upon this, cater to the amount of data that one needs to enter. For instance, a person can easily enter a moderate amount of data outlining his preferences when at home as opposed to a rather swift entry of the most critical data entry when he/she is already engaged in office related work.

A conscious decision, as regards preferences hence needs to be derived in accordance with the needs most often displayed by people working in corporate offices. Preferences specifically derived via extracting such generic individual needs, further the user centric concern of the research. The resolution of data to be entered (technological concern), considering flex-working and routine working patterns, would eventually lead to visualizing the data entry process at two levels: global (predominantly from anywhere outside the office) and local (from within the office). This segregation of input specifically relates with the amount of data and the type of data that one can enter while being in varying settings (inside or outside the office environment). An appropriate choice of the kinds of interface's to be provided for such varied settings hence needs to be carefully thought of. Contextual information, as relates the environment for which the data entry is supposedly meant for should also be presented either graphically or via real-time media streams in-order to enhance the psychological comfort of the user as well as for effective and transparent communication of the effects of one's data entry into the proposed system.

In addition to the above mentioned interface oriented Input design, a network of sensors fostering a ubiquitous manner of tracking the presence, proximity and position of people as input data should also be embarked upon. Such intuitive tracking systems can track hardware devices linked which every individual; hence avoiding unnecessary delays for entering data via swipe card enabled security gateways fostering a much more intuitive manner of surveillance as opposed to apparently imposed scenarios.

The input modes will thus constitute the following:

- Interactive interface (graphical in nature with elaborate but easy to select preferences)
- Sensing networks (with a variety of sensors)

4.4.4. b. Output

The kind of output to be attained from an interactive system plays a vital role as regards active communication of information to people as well as physical structures. As was exemplified in the input section, the notion of technology being supportive as well as psychologically being comforting and assuring is linked to a great extent to a system's output. Presentation of contextual information (as mentioned above) in terms of visuals, graphics, text, sound etc falls under this category. In the case of this research, where spatial adaptability is of paramount importance, issues related to mechanical actuation of hardware (leading to surface manipulations), visual communication of spatial alteration and ambiance related environmental variations become vital system outputs and hence should be catered to in a sensitive manner. Sound can be used as an important system output for drawing attention of people towards emergency situations as well as for informing people as regards appointments etc. However, care should be taken in order to maintain a controlled amplification level in-order not to disturb the surrounding office settings.

Apart from the above modes of graphical displays and sound generation, the spatial nature of the research actively demands an investigation into adaptable kinetic structure typologies and hence in terms of output would be requiring actuators for altering the physical configuration of a space. Mechanical actuators thus form an integral part of the system output. Appropriate actuation mechanisms depending upon the nature of augmentation and the requirements of safety as well as structural height variation etc should be decided upon. A variety of pneumatic[18], hydraulic[19] as well as electronic actuation mechanisms should hence be explored and a suitable mechanism should be deployed as a structural augmentation based output. The presence of a diversity of configurations supporting the vast variety of activities that a typical user performs within office settings also involves a co-ordinated setting of light levels acknowledging the activity demands. This demand adds another dimension of automated ambient lighting to be considered as a primary system output. A strategic selection of generic light levels (in terms of colour as well as white light levels) taking into consideration the amount of lumens required per activity will hence formulate the basis for a corresponding ambient output. In addition to the above stated system outputs, the notion of streaming media, for advertising as well as for exhibition purposes would prove to be beneficial for enhancing and conveying the office ideologies as well as its image (this attribute will be assigned to the skin of the proposed prototype and will be speculated upon in chapter 05).

The output of the proposed system should hence comprise the following:

- Real time updating visual/graphical displays (3d as well as 2d)
- Sound
- Mechanical actuators (for physical adaptation of physical structure in accordance with the change in activity desired by the user)
- Lighting levels (automated to compliment the nature of activities to be performed within set configurations)
- Streaming media (as a proposition for advertising media on a flexible surface)

4.4.4. c. Communication

Communication, as an important criterion deals with exchange of information between people and the devices involved in the system. For the case of this research, the speed of data transmission is rather critical. The exchange of information as regards the media displays as well as physical augmentation should preferably happen in real-time[20] in order to avoid any discomfort or wastage of time of the people working within such spaces. The real-time factor implies that the relay of information such as contextual status as well as actuations of the structure will take place in the least possible time. A constant update of information should thus be regulated throughout the system, assuring that the information displayed is extremely precise. However, in order to materialize such accuracy, it becomes vital to develop a thorough control system which houses the computational processes necessary for swift processing and output of information. This control unit should be fed in with updated sensor status (Input) via a real-time updating database and should house internal computing algorithms as well as data flow sequences. The ability of the control system to churn output at a rapid pace and inform corresponding system components (hardware and software) will hence play a crucial role for sustaining an optimal communication level. A well planned network of micro-controllers linked with the control system's output should be developed in order to insure the efficient transmission of output data. This will assist in terms of speeding up the process time required for mechanical actuations as well as ambient settings, hence aiding the comfort and performance aspects of the employees.

The communication aspects of the system can hence be summed up in the following manner:

- Real time data transmission (for visual displays as well as physical augmentations)
- Control system development (for computational processes)
- Networked controllers (for efficient output data transmission and actuation)

4.4.4. d. Content

The content of the system as regards the visual and physical outputs should be extremely accurate and updated in real time. The information presented to the people should be relevant as concerns the context within which the system is operating and hence should avoid un-necessary cluttering of information. The font end of the system as was explained in the Input section should hence prove to be extremely efficient in terms of data entry while being visually stimulating and pleasing in order to maintain the user's interest. In terms of functionality, the touch screen interface should be precise in terms of its graphical outputs, conveying the most essential sets of alterations that can be activated, hence avoiding wastage of time and effort on the employee's behalf.

4.5. Technological confluence (a scenario)

Based on the above stated technological counterpart and the initial PACT analysis, a generic technological framework is speculated. Considering the user driven physical adaptability oriented aspects of the research, a solution was sought in the synergistic merger of three fields: structural engineering (focused upon extending possibilities of kinetic design), computation (focusing on real time data communication and rule based computation techniques) and control systems (embedded computation sensing and actuation technology as a computational control medium). At the intersection of these fields one can discover attributes of database development, efficient control and the materialization of active structures (Fig 42). This technological conception will specifically work in accordance with user input in terms of their proximity, movement, spatial and social preferences etc and hence at its core entail a human centric vision fostering constructive spatial adaptability. The following sections will exemplify upon the three outlined components: structural engineering, computation and control systems, and will elaborate upon the synergistic performance aspects of the framework. This conception will be tested for its performance via two research experiments conducted under the author's guidance in subsequent sections.

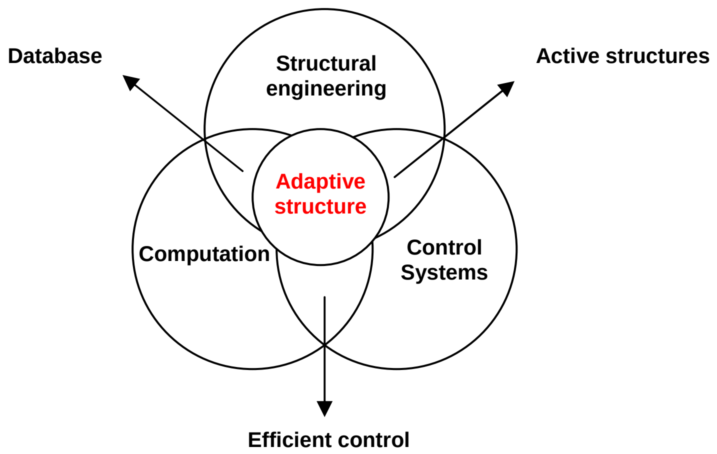


Fig 42 Diagram illustrating the synergistic conception of interactive structures

4.5.1 Structural component

The area of structural engineering, in the case of this research specifically concentrates on kinetic typology, which directly links up with the nature of adaptability required off the proposed architectural space. The issue of adaptability thus focuses upon complete structural transformability based upon the nature of activities that a space will host. The designed system should take into account the rapidly changing patterns of human interaction within the built environment and should actively reconfigure its physical configuration, in accordance with user preferences towards generating optimal spatial efficiency. This will in turn lead to the transformation of an otherwise inert mono-functional space into a multi-use platform, thus proving beneficial in the economic as well as performance aspects of space utilization.

In terms of the kinetic typology, a distributed computation oriented approach, which enhances the development of a networked community of adaptable structures, will be experimented with; dynamic kinetic structures. This typology defines a system, which can act independently, at a local level, with respect to the architectural whole. The idea of distributed control and communication between such adaptable structural grids will be actively sought through this research. Working prototypes with embedded computational tools such as micro processors, micro motors, actuators etc required for such computation aided structural systems would thus serve as testing platforms for such structures. Subsequent sections (4.6.1, 4.6.2) of this research will exemplify upon two working prototypes for testing such assemblies and for developing a logical base for analysing the envisioned spatial behaviour in detail.

Issues of optimising structural performance by reducing the number of elements actively working towards making a kinetic gesture, and developing networked ways of actuation so that a distributed and mutually activating mechanism develops are some of the vital areas of investigation for this research. However this structural integrity will not only be looked at from a network of skeletal connections point of view, but will rather be visualized as a complete architectural system comprising of a smart skin, embedded computational devices within the smart skin, connectors/tendons and finally their adherence with the kinetic structure/the skeletal structure of the system. Hence apart from deriving a novel structural system which has the capacity to warp, twist, turn, stabilize, sustain and distribute weight etc an equal stress will be laid upon devising the skin membrane which also caters to material sciences and embedded computation realms.

4.5.2 Control component

Control systems, specifically in this research, will deal with the deployment of sensor mechanisms as well as external activity capturing aids such as RFID tags and various actuating devices such as pistons, pulleys, and motors etc. The control component is vital in terms of aiding kinetic movement in a defined computationally controlled manner (Fig. 43). These defined implications of the nature of control will also help further in devising construction techniques, issues of handling, repair, operation and most importantly for developing an interactive tangible environment dealing with human-computer interaction.

The conception of such a system involves various sensor, actuator and motor mechanisms as a networked whole. This network behaviour when conceived as a computer controlled phenomenon entails the development of mathematical algorithms/sequencing which aid in deciding upon logical, well thought of commands. These algorithms/computation processes can usually be triggered by means of sensor inputs which constantly track user related data. In order for the control system to be able to read Input data at a rapid pace, the development of a real-time updating database[21] is quintessential. This database holds a variety of tables which are directly linked with the changing status of sensors laid throughout space and refreshes every time a change in the sensed data is witnessed. The trigger can then set on computational sequences within a control system, subsequently producing actuation related output commands. As was discussed earlier, these output commands can either be communicated to specialized hardware controllers or can relay the data to a centralized controller (as a software block). A real time sensing, computing and actuating sequence can hence be swiftly attained by means of methodically developing a control system.

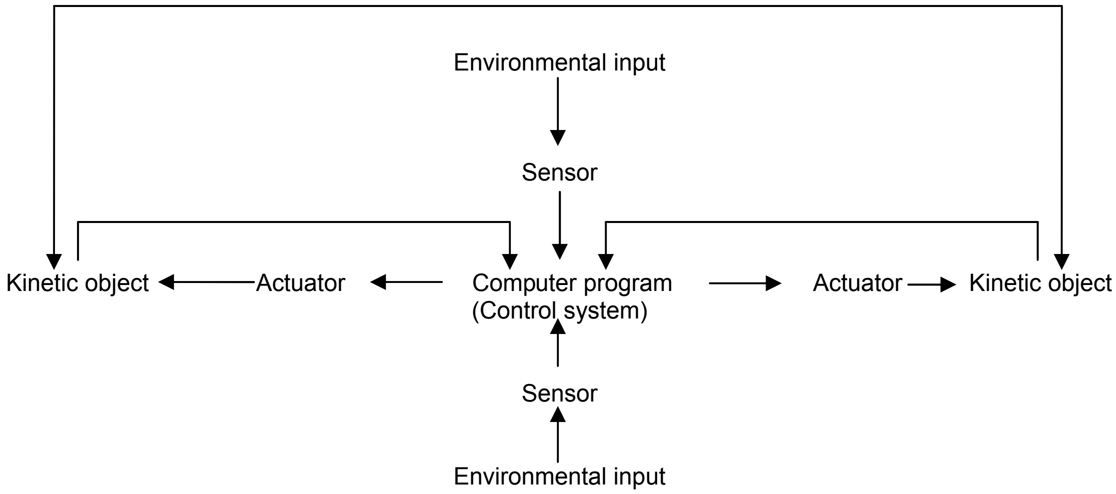


Fig 43.Diagram representing heuristic responsive indirect control

4.5.3 Computation

Computation involved in the conception of such interactive systems specifically concentrates upon real time data communication. Real time data communication, apart from being used for actuating physical components will specifically be looked at as a medium for generating simulations in the course of this research. The initial testing of an interactive system can be conducted via these simulations in order to verify the plausibility of the conceptual response to an action. A variety of software tools such as Virtools[22] and Max MSP[23], to name a few can be utilised for this purpose. Installations performing in real-time utilising these will be exemplified upon in the following section. However, object oriented programming languages such as Java as well as C can also be comprehensively used for producing real time data communication and at times prove to be rather beneficial when developing a complex simulation. These languages, owing to their generic nature help in eliminating the need for buying and installing specialized software (in servers) to be able to actuate an interactive system.

The object oriented programming approach at the core of these programming languages as well as the software tools also substantiate a componential interaction approach where each object is capable of receiving messages, processing data and sending messages to other objects, hence displaying an inherent interactive nature. The real-time aspect attached with these programming languages and software tools, is in itself suggestive of a mission critical aspect attached to them, hence provoking a rapid response via the computational processes to the actuation systems. The degree of complexity involved in such software development itself is complimented by the manner in which Object oriented programming incorporates a modular approach towards organizing the code/data communication protocols. Modularity per say is the property of computer programs that measures the extent to which they have been composed out of separate parts called modules. This organized nature comprising the internal structuring of a program assists in the rapid processing of data and hence in attaining a real time response from the system. Computation techniques hence form a vital linkage between the structural and the control components, for supporting the database module, and eventually for the creation of active structures and materializing efficient control.

4.6. Research experiments

In order to test the validity and performance of the above exemplified technological confluence, a series of research experiments have been conducted at the Hyperbody research group, TU Delft. Two prominent experiments: The Muscle Reconfigured and Bamboostic, conducted under the author's guidance are exemplified upon in the following sections. The experiments were conducted with a team of bachelors as well as masters students in order to test the performance and validity of the proposed technological confluence. The Muscle reconfigured project, has been widely presented at conferences through out the world and has been widely recognized by the international community for its real-time interactive nature as well as its organized collaborative inclinations between the Industry and the education sector. The Bamboostic, another real time interactive installation was specifically conceived for the Game Set and Match conference 06 at the TU Delft, Department of Architecture and displays the logics of swarm behaviour oriented interactivity. The two projects are inter-disciplinary constructs embodying interactivity as an inherent feature fostering networked spatial augmentation for relaxation as well as entertainment purposes.

4.6.1. The Muscle Re-configured (*An investigation into aspects of ambient intelligence, human machine symbiosis and ubiquitous computing for developing a generic real-time interactive spatial prototype)*

Abstract: The research paper exemplifies upon a design-research experiment conducted by the Hyperbody research group (HRG), TU Delft, Faculty of Architecture under the supervision of the Author and Prof. Kas Oosterhuis (Director HRG and ONL). The research work, specifically aimed at developing a real-time interactive spatial prototype, fostering multiple usability of space: 'The Muscle Re-configured'. The ensuing Muscle Re-configured project is essentially an architectural design research undertaking manoeuvring on the precincts of augmented and virtual reality, exemplifying a fusion between the material and the digital counterpart of the architectural domain. This fusion is attained through harnessing a synergistic merger between the fields of ambient intelligence, control systems, ubiquitous computing, architectural design, pneumatic systems and computation (real-time game design techniques). The prototype identifies the idea of manifesting novel supplementary architectural extensions appropriated to their time and can be visualized as a complex adaptive system, continually engaged in activities of data-exchange and optimal augmentation of its (system's) components in accordance with contextual variations.

Underpinnings

The Hyperbody research group (HRG), TU Delft, functions as a research body driven by contemporary Information communication technologies, specifically focusing upon issues of collaborative design in a media (digital and electronic) augmented spatial environment. The notion of visualizing a real-time interactive environment, at the HRG is conceived through building a generic connectivity with virtual prototypes (representative of existent spatial scenarios) articulated with parametric relations and embedded sensing technologies. Such inclinations allows one to simulate emergent spatial behaviours through real time data exchange, connectivity and a networked nature of the architectural grammar constituting corresponding physical prototypes. Simulating real-time scenarios through multi player game designs, re-formulating real life constraints in a structure of logical rule settings and an optimal usage of an elaborate sensor field to develop a complex adaptive architectural system underlie the research ideology of the Hyperbody research group.

The HRG, worked consistently with ONL, a multidisciplinary design office (directors: Kas Oosterhuis and Ilona Lénárd), where architects, visual artists, web designers and programmers work together and join forces, practicing the fusion of art, architecture and technique on a digital platform, to develop the spatial prototype: The Muscle reconfigured. The prototype is essentially a re-configured version of an interactive installation: the 'Muscle', developed by HRG and ONL for the Non-standard Architecture Exhibition 2004, Centre Pompidou Paris (Fig. 44).

The 'Muscle', a completely programmable building, was endowed with the capacity to change shape by contracting and relaxing industrial muscles. The contractions, being the resultant of rigorously programmed direct response to sensed contextual data (proximity and movement of people). A pressurized soft volume wrapped in a mesh of tensile Festo muscles, which change their own length in accordance with air pressure variations, the 'Muscle' project exhibited the manner in which sensing technologies and corresponding tactile responses could be fused together to develop an architectural body akin to an alive organic entity. Apart from the direct response scenario, the 'Muscle' was also programmed to embody its own moods (differing pre-programmed tactile variations), to which the audience would also have to respond, hence making it a pro-active building typology.

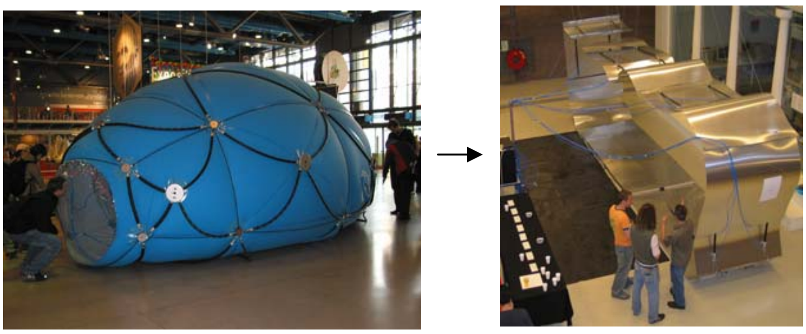


Fig.44.The Muscle project and its re-configured version

The systemic prototype: The Muscle re-configured, was subsequently developed to exemplify similar responsiveness, as an electronic and digital media augmented spatial loop. It demonstrates an automated kinetic response with respect to contextual parametric changes (proximity, pressure and movement of people) by means of tactile variations of its physical components. The research builds upon the dynamism inherent in information exchange systems, and extends the possibilities of mapping ambient data onto physical/architectural constructs. The tactile variations, generated as a resultant of contextual modulations (ambient data fluctuations) are hence attained by means of integrating the physicality of materials with the realm of digital, electronic and information media. This inter-disciplinarity aids in the creation of an interactive (real time) spatial interface which can be used for architectural applications as innovative and intelligent-active surfaces.

Conceiving a networked spatiality

The conception of an inter-activating spatiality bears it's ground in the idea of optimal information exchange between the Muscle Re-configured components. The notion of visualising the information component as the thread, linking the parts of the bigger whole together as a connected web of relations bears its footing in understanding the manner in which communication can be conceived as pure information flow. This base helps in nurturing a new sense of approaching architectural constructs; from their initial conceptualization phase. The research experiment consistently focused upon visualising the prototype from a systems perspective. This further helped in terms of dissecting the entirety or rather a conventional top-down visualization of the construct into a connective bottom up assemblage of informed elements. Each connecting junction is understood as a network of nodes (node junction), which behave in a swarm like fashion to materialize an apposite reaction of the system.

This perspective stressed upon building localised relations between consecutive nodes, and hence visualising the performance of the built entity as an emergent act of communication exchange between networks of nodes. Information flow becomes a continual process in such interactive prototypes, hence converting them into executable processing and reacting systemic entities. The Muscle Re-configured continually tries to understand its context in terms of human proximity and activity variations within its vicinity, through its sensing extensions and reconfigures its own self in real time as an act of adaptation to its contextual settings. The construct hence is akin to a living entity, sending and receiving information, processing this information locally and producing an optimal output.

Flocking behaviour

The above stated interaction is akin to the notion of Flocks: flocking behaviour and boids, as stated by Craig Reynolds. Boids, replicated in the case of the prototype by system components (specifically the sets of pneumatic muscles), are active members of a flock, calculating their position in real-time in relation to each other. What is of particular interest is the dramatic similarity, which the prototype possesses in terms of its scripting component (specifically the segregation of computational commands to be executed by components) and the principle incorporated by flocking mechanisms of computing a limited set of simple rules, locally, by each boid. This behaviour of localised and limited computational performance by parts of the entire system, bring about complex reactions at a wholistic level. These simple sets of rules, can hence be interpreted as the behaviour producing genes of the nodes (junctions in the prototype) and these behaviours in-turn, are directly related with the formal articulation of the prototype: a bottom up approach directly inducing top down performance determination.

In the specific case of the Muscle Re-configured prototype, this vision of building a generic connectivity between nodes is handled by instrumentalizing the connective elements (the fluidic pneumatic muscles) between the nodes as the medium of information (air pressure variation). Owing to the nature of compression, which the muscles embody, the medium itself becomes responsible for inducing the desired behaviour into the nodes, hence morphing the prototype into meaningful reactionary statements with respect to its context.

Real time behaviour

The demand from the prototype, to perform/react to an input-output latency of split seconds, typifies its real-time behaviour criterion. The notion of visualising the prototype as a descendent of the 'Hyper-architecture' breed brought with it the realisation of nurturing the real-time connectivity between users of space and the space itself. This conception of connectivity is further moulded as an interactive domain, taking into consideration that interaction necessitates the presence of two active entities: in this case the built prototype with its extended sensing and actuating possibilities and the users who in essence are active complex systems. Both, the 'Muscle' and the Reconfigured versions are proponents of real-time interactivity, and hence assume a reversal in the conception of architectural spatiality, liberating it from performing as a closed system, and instead situating it in the open systems domain.

Technological considerations

The notion of transforming everyday utilitarian space into a living organism, which augments itself through time to cater to its inhabitants, places the user in the foreground hence completely reversing the conventional ICT based scenario where the user has to usually adapt to the IT enhanced object. The prototype is hence conceived as an experiment in inculcating ambient intelligence (focusing upon perceived intelligence) with a human centric computing component engrained within. Its behaviour, being carefully programmed in accordance with its core conception: human centric design in order to intensify and foster multiple usability of space while reacting to and interacting with its contextual dynamics. The prototype reacts to contextual changes by means of tactile variations of physical entities/system components, hence maintaining optimal surface variations for relaxation, food consumption and related leisure purposes. Ambient intelligence[24] plays a vital role in formulating the core conception of the space, imparting physical as well as psychological notion of control over the behavioural aspects of the spatial loop. The creation of an environment which can be aware of the activities that it is induced to (by means of sensing devices) and can act appropriately to these activities actively aids in reducing the cognitive load on the users of such spaces and can hence improve the efficiency and performance of both architectural space and its users. An intuitive interaction, opinionated towards seamless information exchange between the otherwise closed systemic framework of the architectural world is hence initiated through the research experiment, transforming everyday utilitarian space into an inter-activating responsive organism.

Ubiquitous computing[25] is seen as the backbone of such a construct. The prototype is seen as a network of nodes, which are linked in space in a highly interdependent manner, constantly exchanging information and behaving as a collective whole to attain spatial re-configurations. Simple 'If-then' rule-based control algorithms are developed, to coherently knit these internal and external nodes of the system, enabling the programmed behaviour's to materialize. Ideas inherent in swarm based behaviour, information exchange, self organisation and biotic processes are used to develop a continual information flow between these components, enabling a dramatic response, which transcends the hard edged articulated nature of the strip (in its neutral mode) into soft luxuriant but meaningful progressions.
A typological hybrid, the prototype is conceived as an inter-disciplinary construct, focusing on a synergetic merger of science, technology, art and architecture.

Collaborative systems

The HRG and ONL propagate the concept of collaborative design through extending a shared sense of virtual space, within which specialists from varying fields work in coherence with each other. The Muscle reconfigured project, hence witnessed a scenic merger of knowledge from the fields of architecture, software design, control systems as well as mechanics, further demonstrating the collaborative concept. A novel mode of compilation of the collaborative knowledge base can be visualised in the graphical scripting underlying the soft component of the prototype. This scripting platform acts as the shared virtual space where specialised knowledge is rigorously compiled, tested and analysed.

The Muscle reconfigured

The Muscle reconfigured, prototype is developed as an evolved version of afore mentioned Muscle project, though the core conception, of utilizing pneumatic actuations as a medium of producing tactile variations persists (utilizing the same set of actuating components: Pneumatic fluidic Festo muscles). Conversely, instead of the soft volumetric alterations of the external form (as was materialized through the 'Muscle' project) this novel prototype embodied an approach emphasizing internal spatial response. The soft inflatable skin of the 'Muscle' project, experiences a complete reversal of material aesthetic (Fig.45) owing to the usage of 'Hylite' panels for constructing the prototype's spatial envelope. The notion of utilizing the shear compression power of the pneumatic muscles, to bend and warp the hard-edged hylite compositions into soft, luxuriant and meaningful variations are successfully accomplished by the Muscle reconfigured installation.

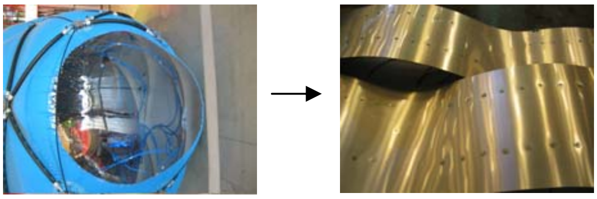


Fig.45. Material variation (an inflatable soft envelope to a flexible hard-lined typology)

Inter-disciplinarity

In order for the proposed tactile variations, to attain a meaningful substantiation, materializing an intuitive responsive reaction (the root of the research) towards the occupants of the spatial loop became quintessential. As a result, the inter-disciplinary construct: the prototype is formulated as a strategic alliance between the fields of ambient intelligence, control systems, ubiquitous computing, architectural design, pneumatic systems and computation (real-time game design techniques) and is highly instrumental in mapping the inherent linkages prevailing between these fields of concentrations. This synergistic approach (Fig.46) towards conceiving the spatial prototype substantiates a generic systems view (open-systems) for conceptualizing architectural space and hence the central issue of fostering multiple usability of space via spatial augmentation attains the dimension of constructing an adaptive system continually engaged in activities of data-exchange and optimal augmentation of its own self. A systematized exploration into the above mentioned research fields led to the careful extrapolation of specific threads of interest which were instrumental for binding the material and the digital components of the prototype: parametric design - via real time information exchange between software and hardware components, control systems - embedded sensing and actuation technologies, ambient intelligence - focusing upon human-computer symbiosis, pneumatic systems – identifying actuation possibilities, computing – utilizing graphical scripting techniques (Virtools: interactive game design software) and ubiquitous computing - interdependent nodal networks. Such techno-logical inclinations and a bottom-up systems approach allowed one to simulate emergent spatial behaviours through the resulting real time data exchange between the prototype and its contextual settings.

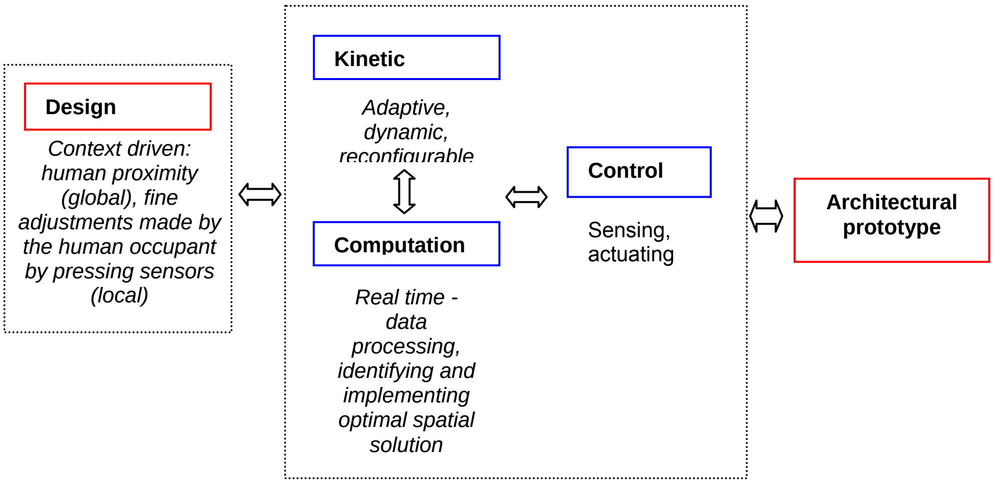


Fig.46. Conceptual diagram representing the synergistic confluence

Envisioning the prototype

The prototype is visualized as a three dimensional section in space, which is cohesively programmed to respond to human occupants through its sensing, processing and actuating enhancements (Fig.47). This three dimensional strip/loop like conception in space, akin to a genotype, embodying the behavioural logistics of a typological variant, further hint upon the possibilities of developing an ever expanding programmable spatiality by simple means of attaching similar spatial strips (each delivering specific performance criteria) in succession. The experiment was hence seen as a platform to encourage meaningful spatial mutations, which would result in the production of a networked bio-system of intelligent archetypes. The prototype, as it stands now, is a scenario driven, singular loop developed for testing purposes. The notion of conceiving the whole through successive agglomeration of individual components in a rather systematized manner (by means of developing inherent communicative connectivity), further lead to envisioning the prototype as a collective whole. This conception results in a strategic extraction of system components to be woven as a singular entity, actively communicating with each other.

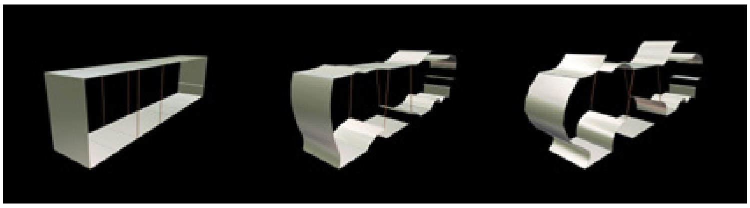


Fig.47. Spatial loop (soft) animated simulations

The bottom-up approach

An exhaustive methodological dissection, in order to materialize such a complex adaptive system has been charted out, by incorporating a bottom-up design perspective. The entirety of the system is seen as a product of a generic inter-action between the soft (virtual/digital) models, representative of constructed scenarios and the hard edged world of architectural reality, essentially the hardware/system components constituting the system architecture. A detailed list of the system components, further segregating them in accordance with their generic usage led to the identification of the following typologies:

Pneumatic Entities

Fluidic Muscle Type MAS: A flexible tube with reinforcing fibres in the form of a lattice structure for up to 10x higher initial force compared to a cylinder of identical diameter. The muscles tend to contract 20 percent of their initial length with the induction of air pressure, hence making it act as an actuating device to alter the node positions of the prototype (Fig.48).
Properties: Diameters 10, 20 and 40 mm, rating length 30 ... 9,000 mm, no stick-slip effect, low weight, hermetically sealed.
Application: Actuating devices connecting the Hylite plates into a singular networked whole.

Fig.48. Fluidic muscle

The Black Box: A hard-edged box housing the switching mechanisms: I/O boards connected to the 72 valves controlling the air pressure lock of the fluidic muscles. The box has provisions to attach the compressed air intake pipes through distribution channels; houses the CPU and power back up mechanisms (Fig.49).
Application: Used as a secure container, housing the brain of the installation through which the fluidic muscles are instructed to attain the contraction or relaxation modes.

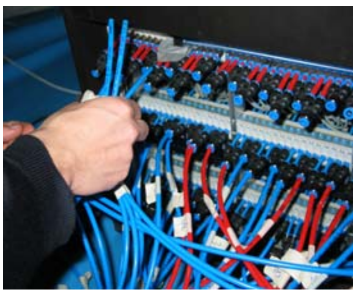


Fig.49.The black box

Flexible Skin: Hylite panels: Hylite is a sandwich sheet comprising two thin aluminium layers with a plastic core in between. It was developed for car body parts. It integrates high flexural stiffness and extreme lightness. Compared to steel sheet with the same flexural stiffness (0.74 mm) and aluminium (1.0 mm), Hylite is 65% and approximately 30% lighter respectively. These results have been obtained by combining the best properties of aluminium and plastic in a single material. The Hylite panels were specifically selected for the skin of the prototype due to its flexibility criterion and the ease involved in its handling (Fig.50).
Application: Spatial envelope, interactive furniture surface, projection surface

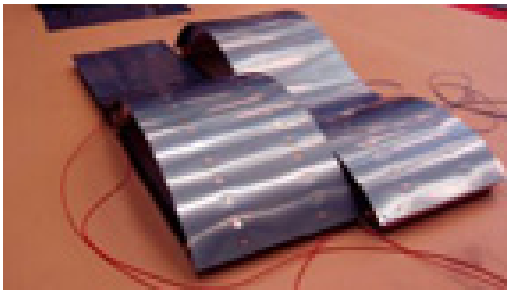


Fig.50.Hylite panels

Control System: Sensing devices (Fig 51) used to enrich the activity recognition criterion of the prototype. The selection of the sensors, involved two basic distinctions in the manner in which we wanted data to be sensed: firstly, the global level – dealing with proximity of users with respect to the prototype and secondly, the local level – dealing with finer adjustments made to the panels by means of individual inputs through touch sensors, hence providing partial control by the user.
Proximity sensors: for sensing the distance of the occupant from the installation (specifically attached to the furniture elements)
Touch sensors: for sensing the amount of pressure exerted upon a surface (specifically attached to the furniture elements: seating surfaces)

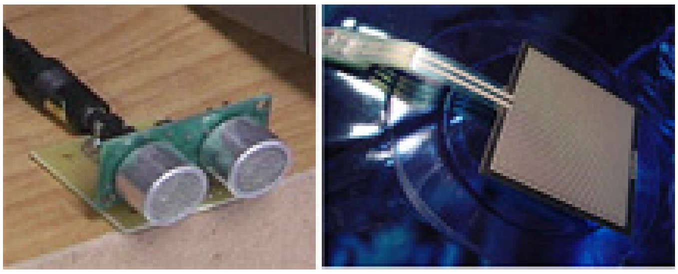


Fig.51.Proximity and Touch sensors

MIDI and PCI Cards: MIDI: Digital to Analogue and vice versa converters: connecting the sensor input channels and the actuator output channels to and from the CPU. MIDI was used as a middleware for transferring data sensed through the sensors: both proximity and touch sensors to the processing scripts made in Virtools. These sensor inputs (essentially analogue) are primarily converted into digital format through the MIDI and further update sets of arrays that are envisioned as a dynamic database for the sensors themselves (Fig.52).
Application: Used for sensed data transfer (analogue) to the CPU (digital).

Fig.52.MIDI units

PCI Cards: were specifically used to handle the output processed via the processing scripts. These are termed as ‘smartlab controllers’ developed at ONL and HRG, and are specifically programmed to receive the output signals (a long numeric string corresponding with the number of fluidic muscles, indicating the status shift of each node: on/off) and communicate them to the In/Out board mentioned earlier (black box), hence controlling the sequential opening and closing of airlock valves.
Application: the PCI cards specifically deal with the output part of the system and help in attaining appropriate spatial variation of the prototype through actuators (fluidic muscles).

Game-Design Software: Virtools Dev 3.0, software used for interactive game design, is utilized for scripting the behaviour profiles of the prototype. Virtools revolutionary technology allows one to create interactive applications by graphically assembling "behaviours" in Dev’s intuitive interface (Fig. 53).
Application: developing an inherent connectivity between the sensed data and the expected behaviour output from the prototype (by means of programming output rules for the system). The software is used as the main computation tool which receives inputs from the MIDI device (sensed data), processes data in accordance with the scripted behaviours programmed into it and sends output digital signals via PCI cards device, which are directly linked with actuating mechanisms.

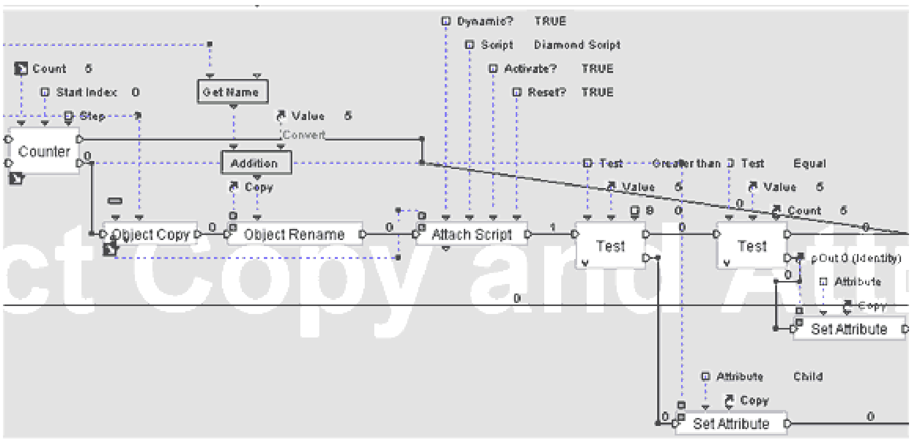


Fig.53. Graphical scripting through Virtools

Scripting: The graphical scripts are systematically composed to communicate dynamic data, related with proximity of users (through sensors) to a set of arrays built into the software file, which act as the interface between the real and the virtual worlds. These arrays are constantly updated via the ‘sensor reading script’ developed at the HRG, which primarily utilise the MIDI inputs for this purpose. Apart from this script, a parallel operation which concerns the status of each system unit: 1 Hylite panel attached with two pneumatic muscles, is tracked constantly in real time by means of updating the corresponding valve status linked with the pistons. These two operations formulate the so-called first level operations of the scripts, which are aimed at capturing the context within which the prototype is embedded.

The second level involves the ‘data processing’ script (Fig.54) to check in parallel with the previously acquired information: the status and the sensor reading scripts, hence abstracting the change in context by means of reading the updated array and the current position status of each system unit. This information is gathered by means of compiling it in the form of genotypic numeric strings, which are forwarded to the smart lab PCI cards.

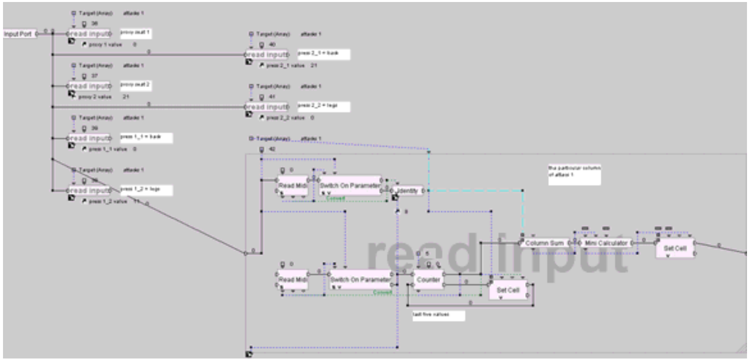


Fig.54. Processing script linking with the Smart lab controller scripts

The PCI cards, as mentioned earlier, further relate these numeric strings in correspondence with airlock valves status and runs re-checks for any updated arrays in parallel to create a phenotype string, which involves a long numeric string equivalent to the number of pneumatic muscles in the prototype and represents the new on, off status commands by means of numeric 1 and 2 codes. This processed data directly communicates with the airlock valves and results in the opening/closing of valves corresponding with the numeric data delivered to the black box, hence actuating specific sets of pneumatic muscles to produce an appropriate system response.

The graphical scripting environment of Virtools made it possible to assemble these scripts in a manner that every individual system unit would act locally while communicating the change in its state to its immediate neighbour, hence creating a flock like behaviour which gives rise to meaningful spatial variations.

System performance

The system architecture conceived to bind the above mentioned components successfully transmits contextual data by means of the systems sensing capabilities to the behaviour enriched graphical scripts developed in Virtools, where rule based computations generate optimal solutions in terms of digital parameters controlling the switching mechanisms of the pneumatic system, directly affecting the compression factor of the actuating elements (the fluidic muscles linked to the Hylite panels), to generate the real-time augmentation. The prototype, at a higher scale of subsystem is further typified into three units: relaxing furniture units (relaxation chairs and table), responsive ceiling units, and responsive wall units. Each of these typologies is held together by a network of fluidic muscles in differing configurations to create desired effects from the overall construct. A carefully scripted rule based operation scenario further responds intelligently to create coordinated augmentation between the three units, hence supporting the holistic appropriation of the spatial loop.

Relaxing furniture units

The furniture units are viewed as a hybrid entity, constituting of two sheets of Hylite fixed together (as the seating surface) which are supported underneath by rows of wedge shaped styrofoam blocks, with two wooden sections on either end of the unit. This hybridization is aimed at increasing the strength of the otherwise fragile Hylite sheets in order to allow people to sit/lie down on the furniture entities. The wedge shaped blocks, lock together as the surface curves. This variable curvature of the units is a result of the compressive force, which is generated by the fluidic muscles, fixed at either ends to the wooden sections of the unit. The muscles, in turn are actuated when they receive the appropriate signal from the data processing units (the internal nodes).

This actuation works at two stages by means of two sets of sensing devices: firstly, the data, concerning with the proximity of people near the units is captured by means of proximity sensors, embedded at the facing edges of the furniture units. This sensed data, captured as analogue signals is transmitted through the MIDI interface (where it is converted to digital signals) to the CPU, where the data is processed through Virtools (interaction design software) to return actuation commands which are re-routed through the PCI cards interface and sent back to the black box to trigger the muscle contractions. This first stage creates an initial curvature in the furniture surfaces, enough to allow people to sit on it. The second stage involves a much more direct interaction of the people sitting on the furniture surface. The surface has two touch sensors attached to it, which trigger the adjustments in height and curvature of the furniture units (Fig. 55). The data communication, this time concerning the amount of pressure exerted on the touch sensors, follows the same sequence as mentioned for the first stage and hence materializes in appropriate curvature variations in accordance with the choice of the user. The actuations are not only limited to the furniture units but also extend to the enveloping surfaces: the walls and the ceiling units in immediate vicinity of the seated occupant.

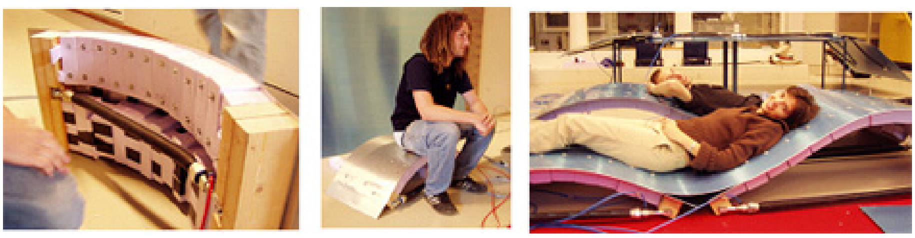


Fig.55. Responsive furniture units (testing the weight enduring capacity and tactile variations)

Responsive ceiling units: The ceiling is materialized as a network of connected Hylite panels. These panels are placed in position by creating rigid connections between them with the fluidic muscles. The positioning/orientation of the panels is directly related with the manner in which the ceiling units have to operate (Figure 56). The operation involves the creation of projection surfaces, generation of smooth curvilinear soothing forms for relaxation purposes and for materializing openings in ceiling surface for allowing light to venture through. These operations are visualized with one connecting property of the fluidic muscles: the compression forces that it can generate (which will in turn bend the Hylite panels) and the ease with which they can be linked together to create one long string of compression elements.

Fig.56. Responsive ceiling units (controlled behaviour producing soothing augmentations)

The ceiling units have been programmed to operate in two modes: the local level, and an automated behaviour setting (pre-programmed). The local level, as mentioned earlier, specifically deals with the users input: touch sensor readings obtained from the seating units. The ceiling units directly above the seating units are bound together hence acting in co-ordination with each other. Pressure exerted on the touch sensors, also creates a subsequent change in configuration of the ceiling units, creating a harmonious spatial augmentation. The automated mode is set into action if the prototype doesn't encounter any activity in its immediate context and hence uses this tactile response as a manner of attracting potential users. This automated performance is pre-programmed in Virtools, and is attained by simply instructing the air lock valves corresponding with the pneumatic muscles (connected to the ceiling Hylite panels) to induce air pressure if no sensor data is received (which results in null updating of arrays) within a set period of time.

The Responsive Wall Units: The wall elements constitute the same generic Hylite panels, which are woven together to create a continuous surface with the ceiling elements. The same principle of compression strengths goes into materializing the wall, which, when actuated bends to create projection surfaces and seating surfaces (Fig.57). The actuation of the wall and ceiling elements are also intrinsically linked up with the furniture element actuations, hence weaving the entire construct into a cumulative whole. However there are also provisions in which, for experimental reasons, one can individually trigger these entities.

Fig.57. Responsive wall units (context aware manipulation of states)

Conclusion

The installation performs in Real-time, transforming from a hard-edged rectangular sectional strip to a much softer, humane envelope (Fig.58). This shift from the traditional modes of perceiving space as a closed container object to a more subtle responsive body is intimidating and perplexing at the same time. The Hyperbody research group worked in a rather consistent manner with ONL, over a period of three weeks, to materialize this vision, which has been an exciting experiment in developing spatial alternatives and visualizing a responsive whole.

Fig.58. System components working in cohesion as an intelligent being

An intuitive interaction, opinionated towards seamless information exchange is initiated through the research experiment, hence transforming everyday utilitarian space into an inter-activating responsive organism. The prototype convincingly fuels the idea of developing pro-active spaces communicating and reconfiguring in real-time, while being sensitive towards their context. The successful accomplishment of the project is also suggestive of the benefits yielded by a collaborative manner of working with varying fields of expertise and stresses upon further envisioning emotive architectural beings which understand and respond to its occupants. Another systemic construct exemplifying a networked behaviour of system components, The Bamboostic was further developed at the TU Delft, under the authors guidance and is exemplified upon in the next section.

4.6.2. Bamboostic

The Bamboostic installation operates on similar principles as was elaborated upon in the Muscle reconfigured project. In terms of hardware though, apart from the pneumatic muscles utilized for actuation purposes, a central mast of bamboo specifically chosen for its flexibility aspects was considered (hence the name). The initial conceptualization stressed upon the idea of this mast being embedded in a heavy base, with the top being free so that the bamboo could be pulled in different directions by means of attaching pneumatic muscles (connected via steel cables) on three sides of the bamboo. In order to materialize this conception, self detailed steel clamps were specifically developed in a manner that they could be fixed at regular intervals along the length of the bamboo (a smaller clamp towards the top end and a larger clamp towards the mid height of the bamboo). Steel strings, interconnected with three pneumatic muscles placed on three sides of the central bamboo post were eventually woven through the clamps and connected to the rigid base. Actuation of each individual muscle hence produced the conceptualized movement of the bamboo in defined directions (Fig. 59).

Fig.59. Components: bamboo stick, pneumatic muscles, two clamp assemblies woven together to create the kinetic construct.

Group dynamics

After successfully building and testing one prototype, a series of the same were created and grouped together to create an organized forest of kinetic bamboo structures. However, in order to derive a meaningful sense of interaction from this mechanical forest, it was decided to develop a mutual interdependence between the environmental settings within which the installation would be positioned and the nature of actuation which each structure would be subjected to. Two sets of activities were specifically chosen for the project, the first being very natural: the movement of people in space, and the second one an artificially induced one: the movement of a goldfish in a water tank. These movement patterns were to define the manner in which the mechanised forest would respond. An approach akin to a swarm (as was discussed in the Muscle reconfigured project) was hence decided upon. This approach entailed that the kinetic behaviour would be regulated in accordance with the proximity of people near each individual bamboo structure. The so called tree nearest to an individual will bend towards him/her the most and this bending movement will be replicated in a decreasing degree of bend angle by the surrounding trees. At times when there would be an absence of people in the field, the movement of the goldfish would substitute the interaction pattern. In order to materialize this vision, issues related to tracking in real time and developing each individual tree as an agent following a simple set of rules akin to a boid (in accordance with Craig Ronald’s 1986 definition of a boid) were embarked upon. The overall complexity of the interaction will hence stem from the interaction between these agents.

Tracking and scripting behaviour

Tracking in real time is conducted at two places: the floor area on which the installation is placed and the fish tank in which the goldfish is placed. In terms of hardware, two web cameras are utilized for the tracking purpose. The camera tracking the floor area is positioned near the ceiling from where it monitors a patch of 5m X 8m within which the installation is planned. A graph sheet proportionate in ratio to the floor area mentioned above is spread out below the base of the fish tank over which the second web camera monitors the movement of the fish. Critical nodes where the mechanical trees are positioned are also plot out on the graph sheet hence developing a mirror image of the installation in graphical terms. The live stream from these two web cameras are directly fed into the real time game design software Virtools where scripted routines act upon the tracked movement in a rule based manner. This rule base is essentially responsible for communicating data as regards the proximity of an individual to any of the nodes/trees to the corresponding (nearest) bamboo stick. Each tree/bamboostic, in itself is considered as a boid, as mentioned above and hence carries its own set of generic rules corresponding to the direction in which the construct has to bend. The entire population of mechanised trees is also networked in a manner that each individual tree is aware of its set of immediate neighbours. This networking further bound by another set of generic rules, specifically helps in regulating the amount of bending (in a reducing degree) to be actualized by successive neighbours of the tree corresponding to the closest moving body. A swarm like behaviour, rich in its responsive behaviour hence germinates (Fig 60).

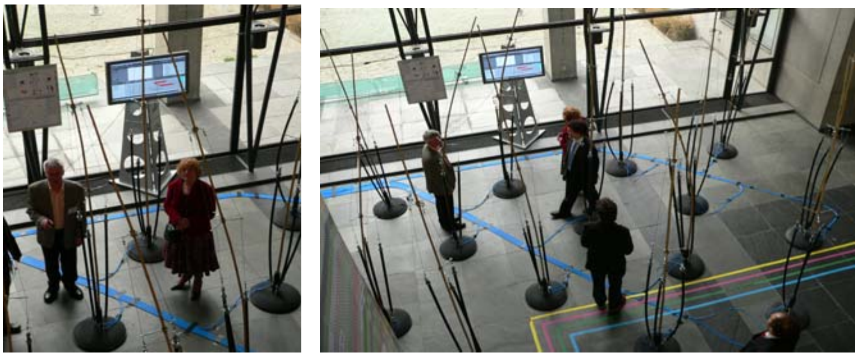


Fig.60. Interactive response from the mechanised trees; bending of trees corresponding to individuals nearest to them followed by a restrained bending of neighbouring trees.

The bending induced in the trees is a direct result of the compression of the pneumatic muscles attached to each bamboo member. Three pneumatic muscles surrounding each member in three directions further ensure that the bending of each individual member in any direction whatsoever is made possible. This directional variation is hence simply an outcome of the compression of the muscle corresponding to the required bend and at times a combination of the compression of two muscles to provide a definite directionality to the bamboo. The black box, as was mentioned earlier still remains a constant feature in this installation and continues to act as a means of automated switching (of air valves) mechanism allowing for highly controlled actuation of the muscles. The scripts encoding the behaviour, as was mentioned earlier are directly responsible for communicating their output as regards which muscles need to be activated, to the PCI cards within the black box. This instruction relayed in real-time in turn results in an automated switching of corresponding air valves, hence compressing the muscles instantaneously for a rapid response from the interactive system (Fig 61).

Fig.61. Images showing the computers hosting Vitriol's scripts connected to the black box (under the table) and the real time tracking of people and the gold fish.

Conclusion

The Bamboostic installation, successfully exhibited the proposed technological confluence, resulting in a meaningful interaction between people and their technological counterpart. The swarm like behaviour produced by the entire mechanised field effectively exemplified the componential systemic approach, which specifically dealt with the notion of developing an emergent behaviour via concentrating upon componential interaction and hence promoted a bottom-up perspective.

Fig.62. Images of the installation performing in real-time at the GSM conference, TU Delft.

The real time data communication aspect and the manner in which an apt context oriented spatial response can be generated (Fig 62) using such communication principles is made evident through the installation. The installation thus proved to be assertive in nature as regards the benefits of inter-disciplinarity and an organized systems oriented approach towards conceptualizing interactive spatial entities.

4.7. Conclusion

An exemplification of the terminologies associated with Interaction and an intensive PACT analysis concerning office spaces brings forth a variety of research variables completely perceived from a human centric outlook. This variable based output essentially stratifies a typical office environment into its components, both physical and psychological and in the process exteriorizes the interdependence shared amongst the variables. This bottom-up approach of understanding the whole thus proves to be rather illustrative of the manner in which a detailed understanding of an entity engulfed within specific contexts can be conducted effectively. The sequential exemplifications of the PACT framework is also indicative of the intricate relation shared between people, performing activities within a context and the technological counterpart which assist people to perform those activities in the most efficient manner, henceforth enforcing the proposed co-evolutionary vision (design + technology). Research experiments specifically conducted to verify a devised technological confluence re-assure this vision, hence providing a base for developing the proposed responsive office space. The PACT analysis, from a design perspective thus proves to be a beneficial tool for realizing a detailed componential relation formulating a construct. Tracing the components itself, entices an understanding of current implications of individual components and furthers one's thinking as regards possible improvements to be made to these components. An eventual synchronization between the various PACT elements in the architectural domain will result in the successful conception of the proposed interactive prototype.

The inherent characteristics of Interaction pertaining to the proliferation of a two way pro-active dialogue as opposed to a one way monologue comes through as a prominent feature vital for a system's effective performance. The degree of responsiveness, as a communication process in which each message is related to the previous messages exchanged, and to the relation of those messages to the messages preceding them is thus proclaimed as the underlying principle for attaining interactivity. The PACT analysis with a strong focus on the essence of interaction and interactivity subsequently brings forth the notion of embarking upon an interaction design oriented process for defining and creating human interaction with the digital, environmental and organizational systems. A prelude to conceptualizing the proposed interactive office system, the PACT analysis thus helps in defining and understanding the behaviours or interactions of an object or system over time with its user population.

The PACT analysis largely benefited from the interviews and the on-site observations as well as a detailed theoretical review of office environments[26]. Furthering this analysis into a conceptual realm, chapter 05 will specifically delve into deriving functional and non-functional requirements from the above deciphered list of variables. This extraction of requirements will create a fundamental base for developing a systematized framework, both technological as well as design oriented for the proposed prototype.

Endnotes

[1] Modern architecture: new architectural style that emerged in many Western countries in the decade after World War I. It was based on the “rational” use of modern materials, the principles of functionalist planning, and the rejection of historical precedent and ornament. This style has been generally designated as modern, although the labels International style, *Neue Sachlichkeit,* and functionalism have also been used.

Form and Materials: By 1920 there was an increasingly wide understanding that building forms must be determined by their functions and materials if they were to achieve intrinsic significance or beauty in contemporary terms, without resorting to traditional ornament. Instead of viewing a building as a heavy mass made of ponderous materials, the leading innovators of modern architecture considered it as a volume of space enclosed by light, thin curtain walls and resting on slender piers. The visual aesthetic of modern architecture was largely inspired by the machine and by abstract painting and sculpture.

The Style Evolves: Increasingly, during the 1950s, modern architecture was criticized for its sterility, its “institutional” anonymity, and its disregard for regional building traditions. More varied and individual, as well as regionalist, modes of expression were sought by architects of the next generation, although the basic emphasis on structure and materials continued. This tendency was evident in the works of Louis Kahn, Edward Durell Stone, and Philip Cortelyou Johnson in the United States, and the architects of the so-called New Brutalism movement in England. A dynamic sculptural unity distinguished the buildings of Eero Saarinen and the late works of Le Corbusier. Other leading architects of this generation include Alvar Aalto of Finland, the Italians Pier Luigi Nervi and Paolo Soleri, and in Central and South America, Lúcio Costa, Oscar Niemeyer, Juan O'Gorman, and Felix Candela.

- "modern architecture." The Columbia Electronic Encyclopedia, Sixth Edition. Columbia University Press. 2003. *Answers.com* 28 Feb. 2007. http://www.answers.com/topic/modern-architecture

[2] Corporate fields: new office environments by the AA DRL, Brette Steele, AA Publications, London, 2005.

[3] Knowledge worker, a term coined by Peter Drucker in 1959, is one who works primarily with information or one who develops and uses knowledge in the workplace. Due to the constant industrial growth in North America and globally, there is increasing need for an academically capable workforce. In direct response to this, Knowledge Workers are now estimated to outnumber all other workers in North America by at least a four to one margin (Haag et al, 2006, pg. 4). A Knowledge Worker's benefit to a company could be in the form of developing business intelligence, increasing the value of intellectual capital, gaining insight into customer preferences, or a variety of other important gains in knowledge that aid the business - "knowledge worker." Wikipedia. Wikipedia, 2007. *Answers.com* 28 Feb. 2007. http://www.answers.com/topic/knowledge-worker

[4] Inter-disciplinarity is the act of drawing from two or more academic disciplines and integrating their insights to work together in pursuit of a common goal. "Interdisciplinary Studies", as they are called, use inter-disciplinarity to develop a greater understanding of a problem that is too complex or wide-ranging

(i.e. AIDS pandemic, global warming) to be dealt with using the knowledge and methodology of just one discipline.

Interdisciplinary programs sometimes arise from a shared conviction that the traditional disciplines are unable or unwilling to address an important problem. For example, social science disciplines such as anthropology and sociology paid little attention to the social analysis of technology throughout most of the twentieth century. As a result, many social scientists with interests in technology have joined science and technology studies programs, which are typically staffed by scholars drawn from numerous disciplines (including anthropology, history, philosophy, sociology, and women's studies). They may also arise from new research developments, such as nanotechnology, which cannot be addressed without combining the approaches of two or more disciplines. Examples include quantum information processing, which amalgamates elements of quantum physics and computer science, and bioinformatics, which combines molecular biology with computer science. In a sense, those who pursue Interdisciplinary Studies degrees or practice inter-disciplinarity in their lives are seen as pioneers (and even risk-takers) at the cutting edge of scholarship, science, and technology. In this way, inter-disciplinarians are able to acknowledge and combat the present and future problems of humanity.

At another level, inter-disciplinarity is seen as a remedy to the intellectually deadening effects of excessive specialization. On some views, however, inter-disciplinarity is entirely indebted to those who specialize in one field of study--that without specialists, inter-disciplinarians would have no information and no leading experts to consult. Others place the focus of inter-disciplinarity on the need to transcend disciplines, viewing excessive specialization as problematic both epistemologically and politically. When interdisciplinary collaboration or research results in new solutions to problems, much information is given back to the various disciplines involved. Therefore, both disciplinarians and inter-disciplinarians must work complementary to each other in order to solve problems.

[5] Adaptation: In biology, the process by which an animal or plant becomes fitted to its environment. It is the result of natural selection acting on inherited variation. Even simple organisms must be adapted in many ways, including structure, physiology, and genetics; movement or dispersal; means of defense and attack; and reproduction and development. To be useful, adaptations must often occur simultaneously in different parts of the body - "adaptation." Britannica Concise Encyclopedia. Encyclopædia Britannica, Inc., 2006. *Answers.com* 28 Feb. 2007.
http://www.answers.com/topic/adaptation

[6] Biomimetics: Copying ideas from Nature into Engineering, article from The University of Reading-Centre for Biomimetics, UK. (http://people.bath.ac.uk/en2pdd/Pete%20Site/biomimetic-report.htm).

[7] Architectonic: In philosophy, Architectonics is the scientific systematisation of all knowledge. The term was first used by Aristotle in his *Politics* to describe politics, meaning that politics *encompasses all knowledge*. In architecture it is often defined as "of or relating to the science of architecture and design". In this sense, "Architectonic" means the art and science of building and construction. In architecture it refers to use of parts as expressive signs that used together comprise the language system of the building. Beginning in the 1970's the application of semiotics to achieve a systemization of building design - "architectonic." Wikipedia. Wikipedia, 2007. *Answers.com* 28 Feb. 2007. http://www.answers.com/topic/architectonic

[8] Boids, developed by Craig Reynolds in 1986, is an artificial life program, simulating the flocking behaviour of birds. As with most artificial life simulations, Boids is an example of emergent behaviour; that is, the complexity of Boids arises from the interaction of individual agents (the boids, in this case) adhering to a set of simple rules. The rules applied in the simplest Boids world are as follows:

- separation: steer to avoid crowding local flockmates
- alignment: steer towards the average heading of local flockmates
- cohesion: steer to move toward the average position of local flockmates

More complex rules can be added, such as obstacle avoidance and goal seeking.

The movement of Boids can either be characterized as chaotic (splitting groups and wild behaviour) or orderly. Unexpected behaviours, such as splitting flocks and reuniting after avoiding obstacles, can be considered emergent. The boids framework is often used in computer graphics, providing realistic-looking representations of flocks of birds and other creatures, such as schools of fish or herds of animals. Boids work in a manner similar to cellular automata, since each boid "acts" autonomously and references a neighbourhood, as do cellular automata.

[9] "Interactivity." Wikipedia. Wikipedia, 2007. *Answers.com* 28 Feb. 2007. http://www.answers.com/topic/interactivity

[10] Professor Sheizaf Rafaeli (ילאפר ףזיש), Israel (B.A., Haifa University, M.A. Ohio State University, M.A., Ph.D., Stanford University) is Director of the Center for the Study of the Information Society InfoSoc and a Professor at the School of Management (Graduate School of Business Administration) Haifa GSB, University of Haifa Israel. In the 1980s and 1990s he served as head of the Information Systems area at the GSB in the Hebrew University of Jerusalem. He was selected to head the School of Management at the University of Haifa, starting October, 2006.

[11] Thoughts by Nathan: http://www.nathan.com/thoughts/process/index.html

[12] Front end: The head, starting point or input side in a system. For example, it may refer to the graphical interface on a user's workstation where all data are entered or to a communications system, such as a front end processor or TP monitor that accepts incoming transactions and messages - "front-end." Computer Desktop Encyclopedia. Computer Language Company Inc., 2007. *Answers.com* 28 Feb. 2007. http://www.answers.com/topic/front-end

[13] Human-computer interaction: An interdisciplinary field focused on the interactions between human users and computer systems, including the user interface and the underlying processes which produce the interactions. The contributing disciplines include computer science, cognitive science, human factors, software engineering, management science, psychology, sociology, and anthropology. Early research and development in human-computer interaction focused on issues directly related to the user interface. Some typical issues were the properties of various input and output devices, interface learning ability for new users versus efficiency and extensibility for experienced users, and the appropriate combination of interaction components such as command languages, menus, and graphical user interfaces (GUI). Recently, the field of human-computer interaction has broadened and become more attentive to the processes and context for the user interface. The focus of research and development is now on understanding the relationships among users' goals and objectives, their personal capabilities, the social environment, and the designed artifacts with which they interact. As an applied field, human-

computer interaction is also concerned with the development process used to create the interactive system and its value for the human user - "Human–computer interaction." McGraw-Hill Dictionary of Scientific and Technical Terms. McGraw-Hill Companies, Inc., 2003. *Answers.com* 28 Feb. 2007. http://www.answers.com/topic/human-computer-interaction

[14] Interactive art is a form of art that involves the spectator in some way. Some sculptures achieve this by letting the observer walk in, on, and around the piece. Other works include computers and sensors to respond to motion, heat or other types of input. Many pieces of Internet art and electronic art are highly interactive. Sometimes visitors are able to navigate through a hypertext environment; some works accept textual or visual input from outside; sometimes an audience can influence the course of a performance or can even participate in it - "interactive art." Wikipedia. Wikipedia, 2007. *Answers.com* 28 Feb. 2007. http://www.answers.com/topic/interactive-art

[15] Designing interactive systems people, activities, contexts, technologies, David Benyon, Philip Turner, Susan Turner, Pearson Education, Harlow, 2005.

[16] Haptics (′hap·tiks): (*computer science*) the study of the use of touch in order to produce computer interfaces that will allow users to interact with digital objects by means of force feedback and tactile feedback - "haptics." McGraw-Hill Dictionary of Scientific and Technical Terms. McGraw-Hill Companies, Inc., 2003. *Answers.com* 28 Feb. 2007. http://www.answers.com/topic/haptics

[17] Aroma therapy: http://www.aromatherapy-stress-relief.com/

[18] A pneumatic actuator converts energy (in the form of compressed air, typically) into motion. The motion can be rotary or linear, depending on the type of actuator. Some types of pneumatic actuators include: Tie Rod Cylinders, Compact Air Cylinders, Rotary Actuators, Grippers, Escapement mechanisms, Rod less Actuators with Magnetic linkage, Rod less Actuators with Mechanical linkage, Specialty actuators that combine rotary and linear motion--frequently used for clamping operations Vacuum Generators - "pneumatic actuator." Wikipedia. Wikipedia, 2007. *Answers.com* 28 Feb. 2007. http://www.answers.com/topic/pneumatic-actuator

[19] Hydraulic actuator: a cylinder or fluid motor that converts hydraulic power into useful mechanical work. The mechanical motion produced may be linear, rotary, or oscillatory. Operation exhibits high force capability, high power per unit weight and volume, good mechanical stiffness, and high dynamic response. These features lead to wide use in precision control systems and in heavy-duty machine tool, mobile, marine, and aerospace applications - "Hydraulic actuator." McGraw-Hill Dictionary of Scientific and Technical Terms. McGraw-Hill Companies, Inc., 2003. *Answers.com* 28 Feb. 2007. http://www.answers.com/topic/hydraulic-actuator

[20] Real-time systems: Computer systems in which the computer is required to perform its tasks within the time restraints of some process or simultaneously with the system it is assisting. Usually the computer must operate faster than the system assisted in order to be ready to intervene appropriately.
Real-time computer systems and applications span a number of different types. In real-time control and real-time process control the computer is required to process systems data (inputs) from sensors for the purpose of monitoring and computing system control parameters (outputs) required for the correct

operation of a system or process. The type of monitoring and control functions provided by the computer for subsystem units ranges over a wide variety of tasks, such as turn-on and turn-off signals to switches; feedback signals to controllers (such as motors, servos, and potentiometers) to provide adjustments or corrections; steering signals; alarms; monitoring, evaluation, supervision, and management calculations; error detection, and out-of-tolerance and critical parameter detection operations; and processing of displays and outputs - "real-time computing." McGraw-Hill Encyclopedia of Science and Technology. The McGraw-Hill Companies, Inc., 2005. *Answers.com* 28 Feb. 2007.
http://www.answers.com/topic/realtime-system

[21] Database: Collection of data or information organized for rapid search and retrieval, especially by a computer. Databases are structured to facilitate storage, retrieval, modification, and deletion of data in conjunction with various data-processing operations. A database consists of a file or set of files that can be broken down into records, each of which consists of one or more fields. Fields are the basic units of data storage. Users retrieve database information primarily through queries. Using keywords and sorting commands, users can rapidly search, rearrange, group, and select the field in many records to retrieve or create reports on particular aggregates of data according to the rules of the database management system being used - "database." Britannica Concise Encyclopedia. Encyclopædia Britannica, Inc., 2006. *Answers.com* 28 Feb. 2007. http://www.answers.com/topic/database

[22] Virtools software description: http://www.virtools.com/

[23] Max is a graphical development environment for music and multimedia developed and maintained by San Francisco-based Software Company Cycling'74. It has been used for over fifteen years by composers, performers, software designers, researchers and artists interested in creating interactive software. The Max program itself is highly modular, with most routines existing in the form of shared libraries. An API allows third-party development of new routines (called "external objects"). As a result, Max has a large user base of programmers not affiliated with Cycling'74 who enhance the software with commercial and non-commercial extensions to the program. Because of its extensible design and graphical interface (which in a novel way represents the program structure and the GUI as presented to the user simultaneously), Max is widely regarded as the lingua franca for developing interactive music performance software - "Max." Wikipedia. Wikipedia, 2007. *Answers.com* 28 Feb. 2007. http://www.answers.com/topic/max-software

[24] The concept of ambient intelligence or AmI is a vision where humans are surrounded by computing and networking technology unobtrusively embedded in their surroundings. The concept of ambient intelligence (AmI) was developed by the ISTAG advisory group to the European Commission’s DG Information Society and the Media. AmI puts the emphasis on user-friendliness, efficient and distributed services support, user empowerment, and support for human interactions. This vision assumes a shift away from PCs to a variety of devices which are unobtrusively embedded in our environment and which are accessed via intelligent interfaces.
In order for AmI to become a reality a number of key technologies are required:
- Unobtrusive hardware (miniaturisation, nano-technology, smart devices, sensors etc.)
- A seamless mobile/fixed web-based communication infrastructure (interoperability, wired and wireless networks etc.)
- Dynamic and massively distributed device networks

- Natural feeling human interfaces (intelligent agents, multi-modal interfaces, models of context awareness etc.)
- Dependability and security (self-testing and self repairing software, privacy ensuring technology etc)
Briefly, systems and technologies need to be sensitive, responsive, interconnected, contextualised, transparent and intelligent.
- "Ambient intelligence." Wikipedia. Wikipedia, 2007. *Answers.com* 28 Feb. 2007.
http://www.answers.com/topic/ambient-intelligence

[25] Ubiquitous computing (ubicomp) integrates computation into the environment, rather than having computers which are distinct objects. Other terms for ubiquitous computing include pervasive computing, calm technology, things that think and everyware. Promoters of this idea hope that embedding computation into the environment and everyday objects would enable people to interact with information-processing devices more naturally and casually than they currently do, and in whatever location or circumstance they find themselves - "ubiquitous computing." Wikipedia. Wikipedia, 2007. *Answers.com* 28 Feb. 2007. http://www.answers.com/topic/ubiquitous-computing.

[26] Tomorrow's office; creating effective and humane interiors, Raymond Santa, Cunliffe, Roger, Spon, London, 1997.

New workspace, new culture office design as a catalyst for change by Gavin Turner and Jeremy Myerson, Gower, Aldershot, 1998.

The European office design and national context by Juriaan Jan van Meel, 010 publishers, Rotterdam, Netherlands, 2000.

Workplaces of the future ed. by Paul Thompson and Chris Warhurst, MacMillan, London, UK, 1998

New environments for working the re-design of offices and environmental systems for new ways of work, Andrew Laing, Spon, London, 1998.

05

DESIGNING THE INTERACTIVE SYSTEM

05
Designing the interactive system

05
Designing the interactive system

5.1. Intent

Harmonizing the conceived PACT[1] framework in order to derive a logistic set of operations to be performed by the proposed interactive system, involves a careful extraction of a set of generic functional and non-functional requirements. This extraction process specifically reflects upon each component of the PACT analysis and will delve into deriving explicit set of demands/requirements per component in order to develop a data pool of context specific (corporate offices) demands. This data pool will be further confronted with a set of technological and design propositions, specifically addressing each demand type in a performative manner. The exemplified set of requirements should specifically be looked at as propositions for what the output space and system must do or as qualities the proposed system and space should embody. These two perspectives of categorizing the evolved set of requirements comprise the Functional and Non-functional requirement criterion to be addressed via the system.

5.2. Functional requirements

Functional requirements as stated above are the set of requirements that the proposed system and the space ''Must Satisfy ". This conditionality makes it extremely vital for the careful extraction of people, activity, context and technology oriented requirements from the analysis performed in the previous Chapter. A set of requirements pertaining to the salient aspects per component of the PACT framework is thus exemplified upon in the following sections. The exemplification specifically stresses upon the most vital set of requirements (after iterative brain storming sessions) and hence provides with a concise summary of requirements.

5.2.1. People oriented system requirements

- Psychological affiliations amongst like minded people often lead to a dynamic internal grouping/re-grouping within office environments. In order to attend to this phenomenon in an intuitive and easily understandable manner; the system should host neighbour selection (as regards who one would like to sit with) options in order to develop personal networks (at a local level) and thus strengthen socio-cultural patterns within the office staff.
- An increasing desire to customize work environments with the aid of ambient tools in order to feel more attenuated and comfortable with one's work space brings about the need for introducing ambient preferences which can enable one to be in control of his/her environmental settings such as ambient colour and lighting levels. These should be provided for and conveyed in a clear manner via the system.
- Considering the variety of activities that are performed by regular employees, utmost consideration should be given for developing comfortable activity oriented spatial configurations categorically focused upon increasing the performance level per employee.
- Considering the observed need to alter spatial settings in accordance with activity variations (work-presentation-meeting-relaxing etc) or the need to create specialized spaces for satisfying

activity oriented spatial needs, a scenario where spatial configurations can be augmented in real-time to provide an automated adaptive space, suitable for a generic set of activities should be experimented with. The possibility of one generic space being able to transform into varying spatial configurations will hence be required as the system output.

- Following the above proposition, provisions allowing a user to select the kind of spatial configuration most suited for the nature of activity being performed by him/her in time should also be provided via the system.
- Aspects related to orientation of space in case of space augmentation need to be taken into consideration. An effortless manner of changing orientation as regards work surfaces, seating surfaces etc allowing one to interact and communicate with his/her neighbours hence needs to be attained.
- Continual/routine occupation of the same space/location within an office was also considered by a majority of people as a predominant factor of getting uninterested in formalized office set ups. Building upon this discussion, an approach by means of which a freedom of choice as regards location oriented preferences such as occupying a fixed location within the office or being able to occupy any spatial location within the entire office (in a manner which satisfies his/her preferences of neighbours) needs to be provided to the users. A need for automation as regards the development of space allocation sequences hence needs to be an intrinsic part of the system.
- Considering that the expanse/scale of offices could be varied in nature, an intuitive manner in which users can easily identify the automated space allocated to them without wasting too much time needs to be formulated.
- The need for social gathering (in small numbers) in the course of working hours for informal chats/discussions necessitates the provision of appropriate places of repose in proximity to occupied office spaces.
- Misunderstandings due to miscommunication as well as being non-informed as regards timings/schedule of appointments and meetings etc needs to be catered to. The system should thus possess output qualities which maintain transparency in terms of schedules as well as informs the users of their future engagements.
- Due to the diverse nature of activities being performed by each user of the office, appropriate lighting levels corresponding with the kind of activity and hence the kind of spatial configuration needs to be activated in an automated fashion as the system's output.
- Users in managerial positions usually require a fixed position in space, strategically selected in order to monitor the body of team members he/she is heading, however they are also responsible for conducting meetings and client entertaining activities. Considering this aspect, the users in general should have the option of inputting meeting times via the systems interface. In order to avoid psychological pressure/worry in terms of being assured as regards the availability of a meeting space, it is strongly recommended that the proposed system in accordance with the inputted time, automatically allocates an appropriate meeting space with a configuration apt for conferencing purposes.
- Visitors should be given equal importance by means of providing them with an easy to understand manner in which they can make appointments with employees of the office. This helps in avoiding unnecessary delays and wastage of time in making continual phone calls for reserving appointments.

- As regards maintenance and cleaning related employees, interviews revealed there preference for clutter free straight surfaces for efficient and fast cleaning of the office environment. The system should hence provide alternatives to attain such a surface quality via spatial augmentation principles.
- Security related employees should have an overview of the employees present in the office at all times for security reasons as well as for informing visitors as regards the presence of the employee whom they want to visit. The system should hence provide means for conveying this information in real-time to maintain an updated occupancy status of the entire office.

Physiological requirements

- Architecturally, the need for developing clarity of vision in terms of spatial layout with clear circulation arteries are pre-requisites for developing a harmonious character of the office within which the proposed system will be embedded.
- Surfaces dedicated for advertising as well as general information should be provided for. This requirement will be directly associated with the output of the system and hence should be catered to as an important system task.
- Tangible technologies which incorporate the sense of touch are required as means of entering data. The tangible nature of such technologies helps in terms of reinstalling a sense of control (over-riding options) over one's environment rather than completely depending on automation.

Psychological requirements

- Perceived affordances as regards the cause and effect relation between hardware and the system output should be clear and easy to understand. This will help in avoiding confusions and help in terms of speeding up the familiarization and usability aspects of the system.
- A clear outline of usage alternatives should be provided via the system. This will help in reducing the time spent over unnecessarily exploring the interface and will hence increase the efficiency of the employees.
- A manner of communicating spatial augmentations via physical as well as visual (via displays) means should be instrumentalized via the system in real time in order to maintain maximum transparency as regards one's context (current occupancy and spatial status of the office).

5.2.2. Activity and Context oriented system requirements

- The variety of activity oriented aspects presented in the previous sections puts forth a large amount of information (as regards the kinds of activities). However in order to make it more comprehensible for the experimental purpose of this research, this data requires to be condensed to the most generic set of activities predominant in office environments.
- Spatial configurations addressing these essential sets of activities require to be developed in accordance with observed and desired user requirements.
- The proposed spatial adaptability scenario necessitates that the systems response in terms of adapting spatial attributes in accordance with the nature of activity being performed to be as rapid as possible. This requirement will lay specific focus upon the manner in which data

structuring and communication protocols operate within the system and hence should be given specific consideration while designing the system.

- An explicit selection as regards the types of spatial entities e.g. chairs, desks, computers etc that can be assigned a dynamic nature (prone to augmentation) as opposed to heavy machinery, printing equipment etc should be developed. This is required at the architectural front to propel a conscious reductive approach which enables spatial adaptability to be more manageable and realizable while controlling the scope of the research.
- Safety critical issues like the structural stability of the physical prototype in load bearing areas such as the floor requires additional attention in order to avoid accidents. A construction strategy which has direct implications on the topology of the activity oriented surface adaptations hence needs to be addressed.
- Appropriate choice of media as a system output, supporting the nature of activities being performed by each individual within the office needs to be catered to. The choice of media could range from text oriented information to sound, streaming video, images etc.
- Wireless networks instead of cable oriented fixed network plug-ins should be initiated throughout the office. This would enable access to data irrespective of spatial location of the users and avoid unnecessary wiring initiatives to be undertaken and hence save time and effort while increasing the productivity and comfort levels of the users (by making information easily accessible).
- The perception of space or rather the aesthetic qualities which the resultant office would possess shouldn't appear to be mechanical in nature but should rather portray a comforting humane environment which is pleasing and functional at the same time. This requirement will invariably bear implications on the mechanics as well as the skin used for the surface articulation. A manner in which subtle spatial adaptations can be attained hence needs to be looked into.
- Individual as well as group oriented working and seating arrangements needs to be addressed to enhance productivity of the users while providing them with control as regards the manner in which they would like to conduct the work at hand (solitary or group oriented).
- Issues related to sustainability and the appropriate usability of space via transforming it to a multiple-usability platform formulates a vital requirement to be catered via the proposed system. This would help in the optimal usage and performance of space without the usual addition of programmatic spaces for fulfilling different sets of activities individually.

5.2.3. Technological requirements

- Modes of input for the system should be represented either via easy to understand interfaces or should be made ubiquitous in nature to avoid unwanted wastage of time in understanding the manner in which data can be entered as and when required by the users.
- The systems data input possibilities should be available to the users while working within the office as well as while outside the office.
- The amount/resolution of data to be entered into the system should be decided upon in accordance with the context (inside/outside the office) within which the data entry operations will be performed.
- The system output (ambience, actuation, sensing, display etc) should perform in real-time in order to provide constantly updated occupancy information and spatial status to the users. The

real-time aspect deals with issues of minimum amount of time spent during data communication and output and hence directly affects the performance of space (in terms of physical adaptation) and its users (by being made aware of their context)

- Requirements related with setting up a performative network of controllers for controlling hardware related triggers and processes need to be addresses via the interactive system.
- Visually stimulating and context conscious interface displays should be developed in order to provide the user with a sense of association as regards the context within which the system is operating and hence providing them with a possibility of visualizing the impacts of their data input in real time via the interface.

5.3. Non-functional requirements

Non-functional requirements, as mentioned earlier are the qualities that the system must have in order to foster the operation of functionality of the system. These are usually associated with aspects such as acceptability of the system, sales as well as the usage of the system. An assortment of some essential Non-Functional requirements, as regards corporate offices is elaborated upon in this section.

- Image: the proposed system should project a professional, rather subtle and formal outlook as regards its front end (the interface) and the nature of the content that it holds within. It becomes vital that the system output illustrates formalised, clear and communicative set of information which is extensively tailored to the office typology within which it is embedded. A direct communication and representation of the context and the possible alterations that the context can be induced with should formulate the image of the proposed system. This quality of precise communication, expressed via a professional, well defined interface should be brought forth via the system.
- Usability: the usability of the system depends upon its ease of operation, understanding and the nature of conventions used in the communication of information by the system. It is thus necessary that the system's front end puts forth a clear set of perceived affordances outlining the possibilities of options and preferences that the employee can address. This un-ambiguous quality of the system will help in supporting the ease of usability as well as help in avoiding un-necessary wastage of time (in browsing for alternatives). The system should incorporate appropriate conventions (in terms of graphics/language/signage etc) prevalent within the context (country as well as the office) in order to substantiate a quicker familiarization with the proposed system. The ease of accessing the system in order to change one's preferences will also enhance the usability of the proposed system.
- Performance: as mentioned in the earlier sections, the need for the system to perform in real-time is of specific importance. The ability to communicate up to date information as regards the context as well as the presence of employees within the office is crucial for the psychological comfort and assurance (in terms of reliable information) of the employees.
- Security: the proposed system should be bound with possibilities of protecting personal information and should primarily operate on the basis of personalized passwords. This quality of the system further strengthens an assured and committed dependency (of the users) on the system, hence making it an integral mode of data communication and personalization.
- Legal restrictions: the proposed system should perform as well as set forth the nature of preferences allowing one to customize his/her office oriented adaptations in accordance with

the corporate regulations or the codes of operational behaviour set forth by each individual organization. Legal issues pertaining to the acceptability of the proposed customization (via the system) under the organizations rules and regulations is vital in terms of setting up the varied customization options for the entire office. Setting up customization strategies in accordance with the legal frameworks of the corporation is hence vital as regards maintaining the corporate culture prevalent within the office.

5.4. Conceptual design of the interactive system

After extensive deliberation and brain storming sessions aimed towards addressing the set of functional and non-functional requirements stated above an architectural design as well as a technological confluence is decided upon. A strategy which looks at the above requirements from these (design + technology) perspectives was considered essential in order to avoid a singular mechanistic viewpoint and to enforce a co-evolution of design and technology. The following sections will specifically exemplify upon the salient features, which will be considered for materializing the interactive system.

5.4.1. Architectural considerations

The set of functional and non-functional requirements and the initial hypothesis of the research necessitate the conception of a real-time adaptive space. Adaptation for the case of this research is specifically conceived as the result of physical and ambient augmentation with respect to the nature of activities being performed within the office environment. This inherent dynamism to be embedded within the proposed space is considered as a generic solution for the requirements elaborated in the previous section (5.3). The conceptual design phase thus involves the development of a strategy outlining the manner in which a series of spatial configurations could be instrumented or rather inherited by one generic set of surfaces (the ceiling and the floor planes). The proposed interactive system would hence inherit the logistics concerning the systemic operation of such an adaptable space while hosting an interactive interface as a front end/tool for user oriented control of such a space. The notion of materializing this physical equivalent of digital morphing techniques necessitates the extraction of a set of activity driven spatial states as specified spatial transition targets. Automation as regards the deployment of these distilled spatial configurations in accordance with the preferences (of the users) entered via the systems front end will hence formulate one of the tasks to be attained in real-time via the system.

The environment, in the case of this research is seen as the global setting (physical, informational, and psychological) of the entire office body. However considering such an environment as a rather large entity to deal with as a unified whole (data intensive), an alternative of visualising it in a compartmentalised manner (local level) is adopted by considering the whole as a resultant of the interaction amongst its constituting smaller parts. The office environment to be experimented with hence adopts the dimension of a cluster of generic work pods composed of a set of ceiling and floor planes onto which varying spatial configurations would be mapped. This notion of the environmental split is specifically adapted to aid rapid experimentations to be imposed upon a generic unit thus fostering faster data processing and data communication protocols upon a singular unit. A successful experimentation as concerns the surface adaptability of a singular work pod can be further replicated and mapped onto a larger space composed of similar units, hence ensuring a faster, constructive output bearing the logistics of spatial adaptation. The resultant space despite of being composed of the same generic unit, owing to the inherent property of transforming (via physical augmentation) into varying activity oriented configurations deems to be extremely dynamic and appropriate for office environments (hosting numerous activities and corresponding space typologies).

This generic unit will be directly responsible for addressing requirement oriented solutions and in doing so will specifically engulf four components: physical, psychological, informational and spatial as elaborated upon in Fig 63.

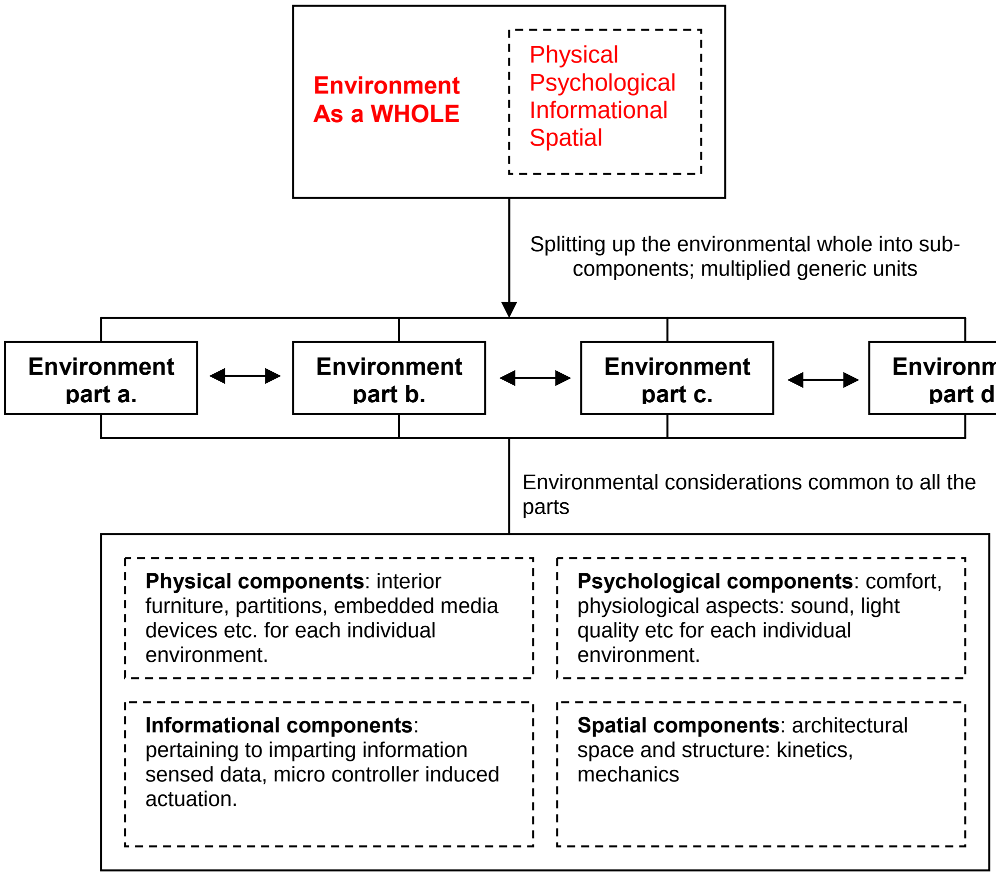


Fig.63. Environmental split implications

A subsequent inquiry into the above mentioned components and their inherent linkage with the set of requirements exemplified in section 5.3 lead to the following space oriented conceptions:

A detailed study as regards the spatial typologies related with varying activities performed within office environments brought forth a multitude of seating, working surfaces and ceiling profiles either prevalent or desired by the employees. However, as was mentioned in the requirements section (5.3), a generic break-up of these activity oriented typologies, in an attempt to focus the scope of the research, necessitated the conception of the following three generic typologies: work, discussion and relaxation. A collage constituting variations of spatial arrangements which can be clubbed under the above mentioned categories is also developed (Fig. 64) simultaneously in order to filter two essential spatial variants per typology (work: W1, W2, discussion: D1, D2, relaxation: R1, R2). A dimension of 3.6 X 3.6 m is conceptualized as a generic measure for the set of planes (floor and ceiling) onto which the above mentioned spatial variants, in accordance with anthropometric considerations per activity can be mapped. The mapping to be implemented via java coding, inculcates a scenario where spatial adaptation (physical) akin to digital morphing[2] can be performed in real time upon the generic set of planes (floor and ceiling planes). The resultant spatial model will hence embody all the configurations (Fig. 65) and will be capable of subsequently implementing/actualizing the configuration apt for the kind of activity being performed via user oriented preferences. A scenario where no activity is being performed (in case of non occupancy of the space) would hence exhibit two horizontal planes devoid of any configuration mapping. This neutral state in itself is considered as a configuration and will be denoted as Empty, the seventh configuration via the systems interface. This empty state would specifically be helpful in addressing the issues of cleaning and maintenance by providing the corresponding staff with linear surfaces which they can clean with utmost efficiency. An automated scenario, where the generic pods would acquire an Empty configuration as soon as its corresponding employee leaves the office space hence needs to be developed. This automation will ensure that all the generic pods would acquire an empty configuration by the time the cleaning staff would arrive (mornings: before the office hours begin and night: after the office hours), hence providing them with a flat easy to clean and maintain surface.

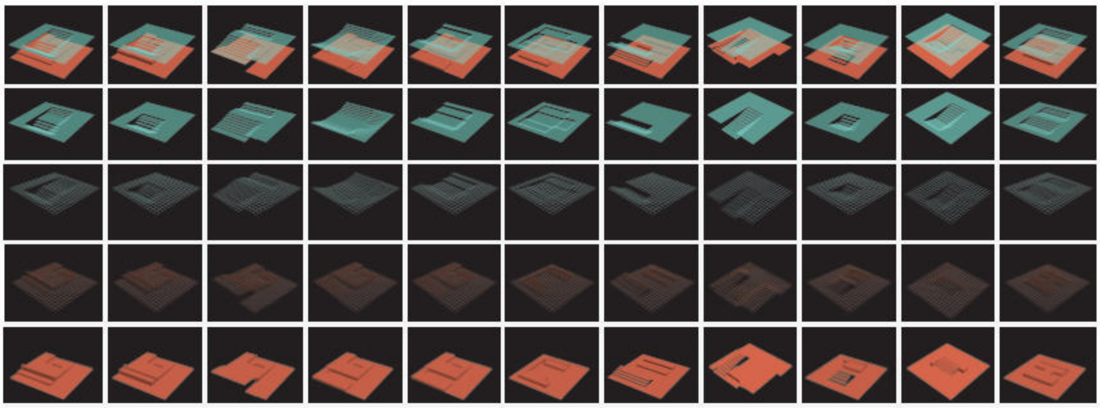


Fig.64. Work, Discussion and Relaxation oriented spatial variants

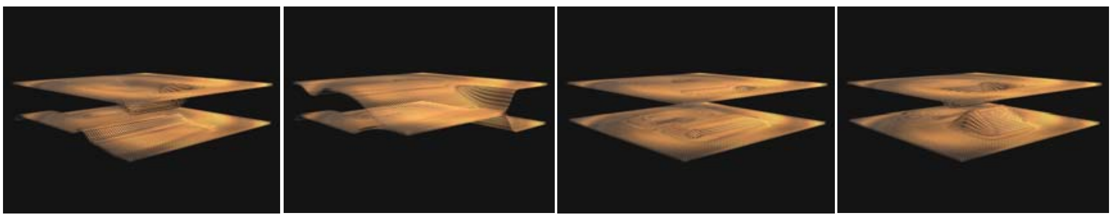


Fig.65. Set of generic planes onto which variable configurations can be mapped (conceptual soft models)

Another requirement oriented solution, which demands the presence of an informal gathering space where activities like drinking coffee, discussing etc together with other employees within the office can be conducted is conceived as the eighth generic configuration and is termed as a Temporary space. This space would constitute a mixture of seating as well as standing alternatives and would foster informal gatherings in a regulated manner (via system automation). A set of rules which governs/triggers the allocation of this temporary space on the basis of the number of people present in the office, hence deciphering the number of temporary spaces at any point in time thus needs to be decided upon and translated as coded instructions for the proposed system.

The above mentioned configurations, in order to fulfil the requirement of substantiating a communicative and social environment, need to possess the possibility of orientation changes. This possibility allows the users with the freedom to orient themselves in two directions (scope reduced for the research) in order to communicate/interact with his/her neighbours. This orientation change will essentially be the resultant of user based selection, which alters the directionality of the actuations (mechanics) operating behind the two generic planes.

Another important aspect as regards the manner in which the surface actuations create numerous configurations is the nature of the resultant topology that it creates. As was demanded in the requirements section 5.3, the need to create humane and comforting environments is addressed via conceptualizing the above mentioned surface augmentations as a combination of smooth, curvilinear geometry (ceilings) and a slightly curvilinear though predominantly orthogonal geometry (floor). This combination would help in maintaining the conventional functionality of work surfaces as regards the floor and its augmented resultants (working and seating surfaces) while providing the users with a much lighter, fluid feel to the ceilings. The curvatures embodied by the ceiling can also serve specific functions such as advertising, light emission as well as presentation screens, hence addressing the requirement of advertising/image building within the office environments.

A conference oriented configuration catering to issues of presentations and discussions in a formal set-up should be conceived as the additional ninth configuration. A typical conference scenario where a large group can sit around a central table and discuss as well as present information is hence proposed. The conference configuration, owing to its scale is conceptualized as a space combining two generic pods into a unified whole, apt for presentation and discussion purposes.

Occasions like exhibitions, open houses (events when the office is open for public viewing) etc pose an additional requirement in terms of re-organizing and re-configuring the interior set-up of offices. The concept of harnessing an adaptive spatial strategy can prove extremely beneficial in such cases and is hence utilized for conceiving the last configuration; Exhibition, in order to address the architectural set of requirements filtered from section 5.3. Unlike the other nine configurations, which either deal with the augmentation of a singular pod or a set of two, the exhibition mode engulfs the entire office space (the twelve pods) and is thus responsible for a complete transformation of work oriented space to an entertainment and exhibiting space (elaborated upon in section 5.5). Every generic pod constituting the office will hence adapt to specialized configurations for creating a sequential exhibiting space where the office can display their latest offerings/achievements. Owing to the temporal nature of such events (conferences and exhibitions), a strategy for linking the actuation of such spaces in an automated time based manner would be initiated. This would imply that the users/managers can personally enter the preferred time for starting and ending the conference and be psychologically assured that via the systems automation process a corresponding space will be assigned within the office, hence avoiding unnecessary booking/persuasion to acquire a suitable conference venue.

At a conceptual level, the following configurations are hence decided upon:

- Work: W1, W2.
- Discussion: D1, D2.
- Relaxation: R1, R2.
- Empty
- Temporary
- Conference (involving a set of two pods)
- Exhibition (involving all the pods)

In the process of augmentation and the resulting adaptive nature of the space, conventional physical entities (as were stated in the PACT framework) such as chairs, tables, display, lights etc not only acquire a dynamic nature but are conceived as embedded entities which foster conventional usability (of such entities like furniture) gestures via topological variations of one singular surface. Issues related to activity oriented augmentations, leading to a variety of configurations also necessitate the conception of a scenario where lighting levels per activity and hence per configuration can be automated. Light intensity variations can hence be associated as plug-ins (coded) and assigned to each spatial variant, thus producing an ambience best suited for the kinds of activities being performed by the user at any point in time. A manual over-ride option can also be provided to the users for such purposes, to reinforce the notion of being in control of their surroundings.

The resultant office environment per se is conceived in terms of a grid composed of twelve generic pods connected together via a flexible (prone to physical augmentation) circulation system (Fig 66). The grid framework is specifically selected to provide the users with the clearest possible view and sense of directionality as regards the manner in which they can navigate through the office space. The twelve generic pods, embedded with augmentation capabilities could hence operate within this circulation framework as independent entities prone to user based customization. A resultant field of activity oriented customized space prone to augmentation and thus topological variation in time hence materializes. This conception is akin to a bio-system[3] where interaction of components creates a meaningful and responsive whole, constantly addressing contextual fluctuations. The circulation cores themselves are conceived as adaptable entities capable of altering their floor and ceiling surfaces, hence supporting a scenario where two generic work pods could be combined to create a bigger space to be utilized for conferencing and exhibition oriented purposes.

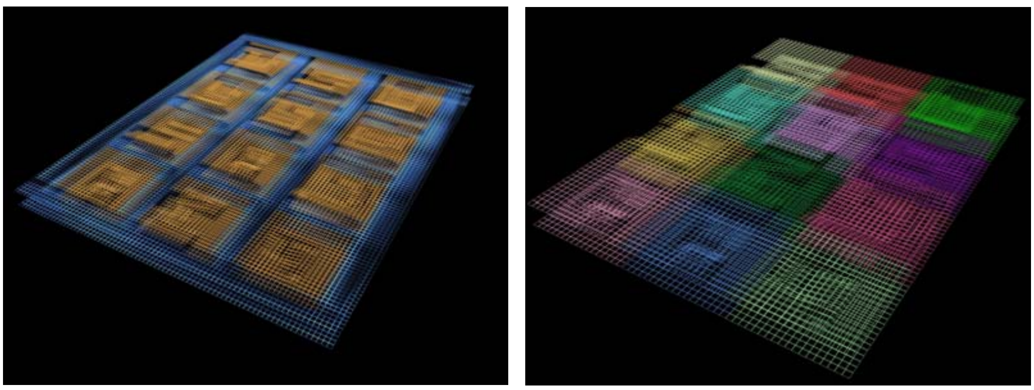


Fig.66. Soft models showing the twelve generic pods with variable configurations embedded within a flexible circulation framework.

A detailed explanation of the manner in which the above mentioned conceptual spatial configurations are prototyped (form finding and construction) and the underlying computational logic for automation sequences will be discussed in section 5.5 (5.5.2 – 5.5.5).

After conceptualizing the architectural propositions for the generic pod, and visualizing the manner in which multiples of the same generic pod comprise the proposed office environment, a technological thread binding the propositions in an operational manner is conceptualized in the next section. In order for the proposed configurations to be initiated, a vital requirement of obtaining and transmitting information as regards triggering a configuration, ambience settings, automation in terms of space allocation, information and display etc needs to be derived. The generic pod is hence analyzed subsequently from the perspective of the most vital set of information that would be required for augmenting the pod in a meaningful and user centric manner. Three essential aspects are specifically chosen: human interactions, interior re-configurations and building envelope effects. These three aspects are assigned technological counterparts in the form of autonomous agents[4] who will specifically cater to the intricacies involved in deriving and communicating specific data. These agents are termed as human agents, local agents and global agents and are elaborated upon in terms of their essential characteristics in the following section.

5.4.2. Technological Appropriations

5.4.2. a. Human agents

As the term implies, is the technological counterpart representing and assisting the employees working within the office environment. Human agents primarily deal with tracking of employees in real time as well as serve as the front end of the entire system which fosters a direct communication (input and output of data) between the employees and the proposed system. Technological counterparts per employees are conceptualized as traceable devices such as RFID[5] tags, embedded within mobile devices (Fig. 61) provided to each employee. These agents possess their own ID (identification numbers) and thus in an abstract manner symbolically denote per user via this individual ID. The ID's are specifically meant to be tracked via a RFID antenna, hence tracking the position of the employee in real time. This set of agents would hence specifically cater to aspects of detecting the presence, absence and the location of each employee entering, leaving or already present within the office. Another aspect equally crucial for the human agents is the manner in which they can foster direct communication of the employees with the proposed system. A technological appropriation for such communication is conceptualized via the Interface development or the front end of the system. This category of human agent is further split into two typologies (Fig. 67); an online interface which can be accessed by every employee from outside as well as within the office and a specially designed storage cum touchscreen[6] unit for entering data from within the office. This category of Local agents is hence specifically concerned with the ease of data input (in terms of entering user preferences), by the employees of the office. The online interface however, apart from serving as a means of data input can also adopt a vital data output role, specifically concerning the manner in which employees can be informed about their contextual settings.

The online interface category is specifically conceived to serve as a space customization tool corresponding to the set of requirements exemplified earlier. In doing so, the online interface essentially serves as a medium for specifying individual preferences concerning aspects like; where would one want to sit in the entire office, with whom would one like sit, what kind of spatial configuration would one like to be active when he/she enters the office, what ambient colour does one prefer, what orientation would one prefer etc.

Fig.67. Human agents (from left to right) RFID tags embedded mobile devices, Online interface, Pluggable touch screen cum storage units.

The set of preferences provided via the online interface also extends towards the visitor category with options for entering relevant data such as; whom would one like to meet, when would one like to meet the respective employee and what purpose does the meeting involve. The same online interface can also be used to communicate time oriented preferences such as when would conference and exhibition oriented, configurations need to activated etc to the interactive system. This category of human agent is hence of crucial value for detailed data entry related issues and is hence conceived as a medium which can be accessed via the internet from any location possible. The storage cum touchscreen interface unit however specifically addresses another requirement oriented demand catering to the ease and rapid entry of data during times when the employees are extremely busy and hence do not have time for entering detailed data as was the case with the online counterpart. This category of the human agent provides the employees with a highly simplified set of data entry options in a tangible manner corresponding specifically to the change in spatial configurations and orientation of his/her generic pod. The touch screen unit hence can be seen as a sub-system operating as a fine tuning medium for quickly altering configuration related issues by rather simple selection criteria.

The above mentioned categories of data entry related human agents would possess a clear, professional outlook and will embody appropriate media such as graphics, textual information as well as simulations to support perceived affordances in the utmost understandable manner. This aspect of communication also involves a real-time update as regards the display hosted by the interface. The simulations embedded within the interface per say are specifically conceived of as display mediums communicating a constantly updating contextual setting via showing real-time three dimensional alterations being made to any of the twelve generic pods. Two-dimensional real-time updating occupancy status in terms of the entire office grid being denoted via images of the employees occupying corresponding grids is also conceived as another manner of ensuring the communication of updated contextual information via the online interface. This category of human agents are hence crucial in addressing various people, activity as well as context oriented requirements by providing the users with an easy to use and understand data entry as well as an up dated information providing medium.

Another category of human agents operating as a sub-system is conceived as a set of IR (infra red) sensors per generic pod. The function of this sub-system would be to track the entering/leaving of the employee into/away from the generic pod. This inherent tracking (per pod) is linked with triggering certain ambience related adaptations (lighting variations) corresponding to the spatial configuration selected by the employee. This interdependence will be further elaborated upon in Section 5.5, which deals with the physical design and prototyping stage of the research.

All the above mentioned categories of human agents, though inherently linked with various aspects of the human counterpart operate as autonomous agents fostering communication as regards tracking and preference oriented data with Local agents (Fig. 68).

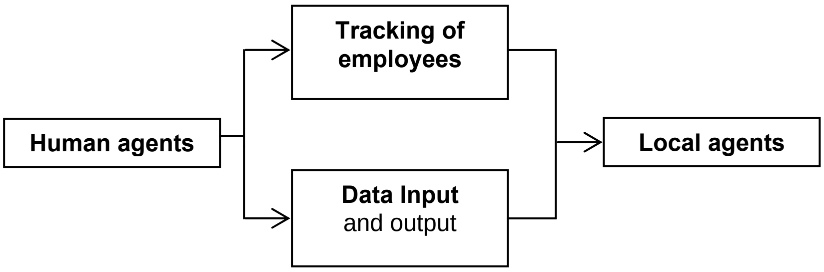


Fig.68. Interaction sequence between Human and Local agents.

5.4.2. b. Local Agents

Local agents specifically cater to issues related to storage of data and localized (per pod) control. The conception of local control illustrates the importance placed upon the implementation of a distributed computation approach. This is critical in terms of reducing the load upon a central system (global agent), which is completely concentrated towards computing the dynamics of an entire built construct. Such an approach helps in making the computation process much faster and efficient. Local agents can be specifically split into three components: a centralized data base, localised central processors and actuation related hardware (connected to the output channels of the localised central processors).

The centralized database (Fig. 69) is conceptualized as an organized store for all the preferences entered by the employees of the office. However, since Human agents, as described earlier (RFID tags, IR sensors and the Interfaces) are inherently attached with the employees, tables for storing their status; active or inactive, and the preferences opted for per employee are also stored within this local agent. The ability to store data as and when human agents are updated, either via the interface or the sensing mechanism, necessitates this local agent to attain a real-time updating character, hence proving to be an accurate source of data. The centralized data store also accommodates secondary data related with timings and information as regards meetings, conferences and exhibitions thus serving as a centralized data storing component of the entire system. This category of local agents is continually communicated with for retrieving and updating data by the Global agent and by other local agent components.

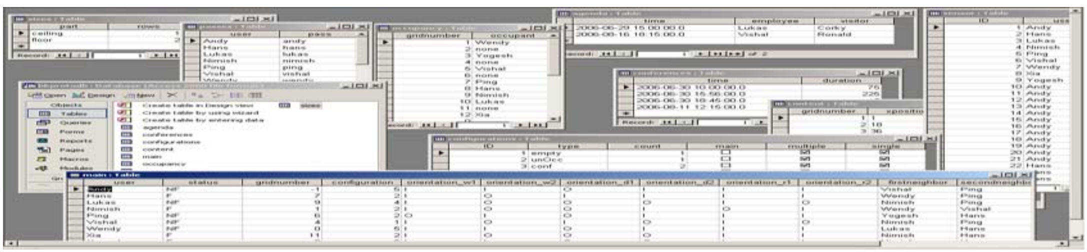


Fig.69. Centralized Database: Local agent.

The next category of Local agents specifically deals with localized control. This local control refers to individual generic pod oriented spatial as well as ambient adaptations and is hence directly associated with actuation related hardware, or more specifically the system output. Technological substantiations of this category of agents are conceived as two categories of controllers: the CPX controller (Festo's pneumatic system's controller) and the Parallax controller (Fig. 70). The two controllers are embedded within each generic pod and operate specifically for the pod to which they are dedicated. The two controllers will subsequently provide optimal control over two distinct system output categories; physical augmentation and ambience augmentation. The technicalities involved in the processes involved in such control systems will be elaborated upon in section 5.5. The local nature of control is suggestive of the dependence that these controllers have upon the global agent for approving the actuation of any of the above mentioned system output categories. These local agents thus embody the computational logistics as concerns the programmed codes for each spatial configuration (stored in the CPX controller as the amount of thrust or compression related variations each pneumatic actuator has to actuate to attain the desired configuration) and its associated ambience related data (stored in the Parallax controller as programmed codes to be actuated with each configuration alteration). The ambience related aspects would specifically cater to lighting, coloured lighting and sound. Each of these aspects is specifically formulated in accordance with the requirements elaborated upon in Section 5.3.

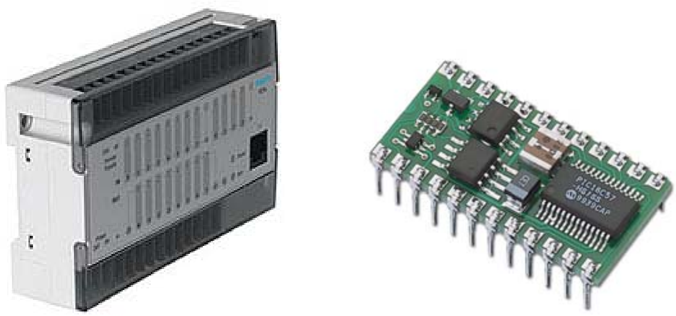


Fig.70. Local agents; CPX controller (left) and the Basic Stamp controller (right)

Lighting variations are conceived as automated sequences based upon the optimal intensity of lumens required per activity and are hence considered as embedded sub-routines to be autonomously controlled by the Parallax controllers (on being informed about the kind of configuration to be actuated via the global agent). A comfortable environment tailored to activity oriented spaces is hence aspired for. The coloured lighting scenario is conceived as a manner of informing the employees at a glance as regards the automated space allocated to them (as colour preferences per employee are already selected via the human agents counterpart per employee). This vision oriented tracking of personal spaces is particularly helpful in cases of large offices where navigating through space in order to identify a non-fixed automated space could be an issue involving wastage of time and hence lower productivity. Sound, as was discussed in the requirements section, is conceptualized as a tool for drawing attention and is hence used for communicating/reminding the employees as regards important meetings, appointments etc. thus avoiding any miscommunication.

The two categories are thus specifically conceived as technological means for addressing spatial as well as ambient requirements elaborated upon in section 5.3 in a real-time manner via utilizing a distributed computing strategy for speeding up the computational processes involved in hardware actuation. A constant communication with the global agent is considered mandatory for all the categories of local agents (Fig 71). Communication of real-time updated data from the centralized database agent (which is informed via the Human agents) and the communication of a hierarchical approval (for carrying out computational processes) to the local controlling agents is hence visualized as a vital mode of interaction between the three categories of agents (human, local and global).

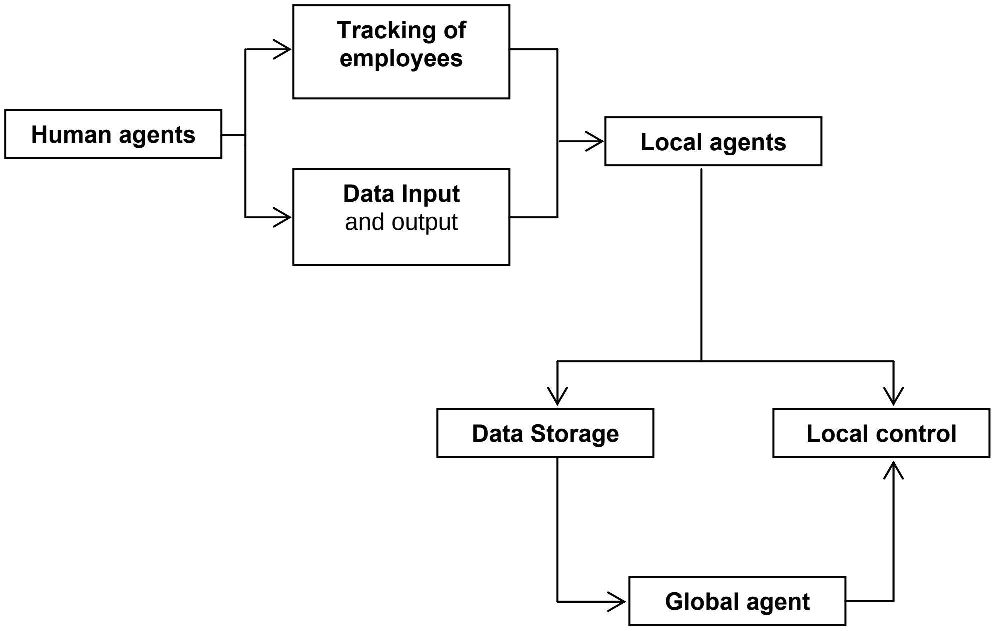


Fig.71. Interaction sequence; Human, Local and Global agent

The third category of local agents comprise of mechanical actuators. These are specifically conceived as pneumatic entities possessing the ability to elongate and compress to their original size on the basis of air input and output. Two varieties of actuation devices (pneumatic muscles and pneumatic pistons) attached to kinetic structural mechanisms are proposed in order to materialize the proposed physical configuration translations. The actuators in essence are devoid of any computational basis, they specifically operate upon the instructions provided to them via local controllers embedded within each generic pod. As mentioned above, these instructions specifically contain data pertaining to the amount of air-pressure to be induced into individual actuators, thus creating customized actuation sequences for attaining the instructed configuration. Peripheral hardware (Fig. 72) such as an air compressor and additional switching units needed for attaining the proposed actuations are hence mandatory and are also termed as Local agents. A detailed description of the kinds of actuators and the peripherals will be provided in detail in section 5.5, explaining the manner in which the entire actuation sequence would operate.

Fig.72. Local actuating agents, from left to right; Pneumatic Muscle, Piston, Switches, Air compressor

5.4.2. c. Global agent

The global agent is conceived as a singular entity housing the brain/computational codes for processing the data received from the local agent (the centralized database). The global agent thus has an autonomous role related to processing and data output in terms of instructional codes. This category of agents is hence crucial in weaving the later two; human and local agents together to create a comprehensive system. In a broader perspective, the global agents can thus be seen as inherently responsible for the overall ambient and spatial reconfiguration of the entire built construct.

The global agent can be visualised as a computational engine, possessing an input channel, for receiving sets of data from the centralized database (local agent) and output channels for sending activation commands back to an array of controlling local agents. As was mentioned earlier, these actuation commands, which are circulated to an array of local agents, are specifically aimed at altering the spatial and ambient configurations of the respective worlds/generic pods the local agents reside in. The global agent embeds scripted routines akin to rules for acting upon different kinds of data which it receives via the local agent. The data could vary in terms of communicating the entrance of an employee within the office vicinity to time oriented preferences entered for exhibitions and conferencing purposes. The role of the global agent is hence to acquire as much data as possible in relation with the employee under speculation from the Local agent and run space allocation algorithms leading to automated allocation of space for the employees as well as for finding the most optimal location for a conference to be hosted at a given time within the entire office. In doing so, the global agent also operates in accordance with the set of user preferences such as whom would one like to sit with, what configuration would one like to be actuated, what colour preferences has the employee entered etc as a set of constraints adhering to which it has to precisely generate output data. This output data is conceived to be in the form of instructional codes concerning the final data pertaining to spatial as well as ambience related augmentations to be mapped onto the generic pod being allocated (via the automation procedures) for a user, conference or exhibition. This set of data/instructional codes are directed towards corresponding Local (control) agents, which, via embedded computational sequences deploy actuation routines to attain the desired effect.

The global agent, in terms of its output, apart from conducting the above exemplified task, will directly communicate with the online interface counterpart of the human agent. As was mentioned earlier in the requirements section 5.3, the need to communicate essential data pertaining to the context within which the system operates, forms the basis for this direct communication. The global agent's output in terms of spatial and ambient augmentation is conceptualized as being translated in terms of three dimensional simulations as well as two dimensional graphical counterparts constituting the online interface (local agent). The three dimensional updating is thus specifically linked with the augmentation (spatial and ambient) of individual pods based upon the Global agent's real-time automated space allocation as well as ambient augmentation oriented instructions that it provides to the local controllers. This translation of coded instructions into the graphical realm helps in constantly informing the users as regards the overall spatial state of the office environment (three dimensional) and an updated view (two dimensional) as regards who is present in the office. The later is extremely helpful for security related personnel as well as managers etc to keep track of the occupancy and regularity of employees within the office. Psychological requirements for conveying the cause and effect relations between the proposed system and the physical world can also be successfully accomplished via this two way communication (Fig. 73) of the global agent (visual and physical), hence installing the trust of people towards the proposed system inclusion.

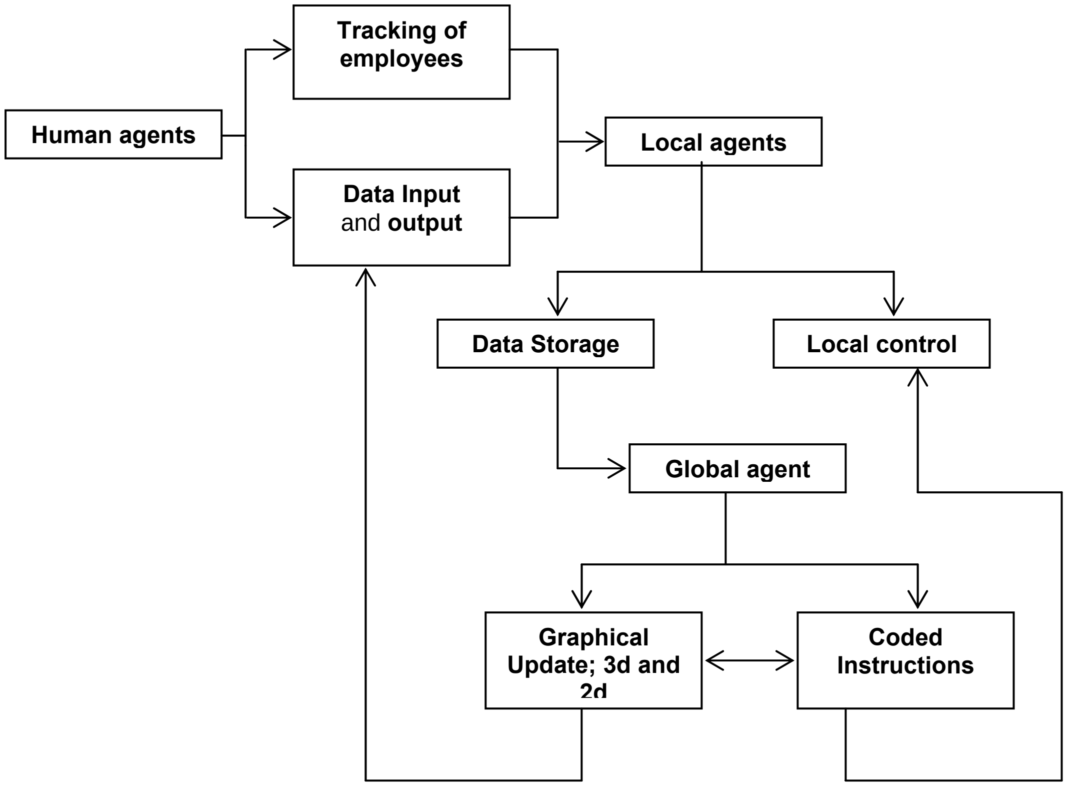


Fig.73.Looped Interaction sequence; Human, Local and Global agent

The above exemplified conceptual outlook towards an underlying interactive technological appropriation formulates the core design strategy for the proposed system. A detailed description of every component formulating the three agents and their operational logistics will be exemplified in section 5.5.6. Apart from the above described framework, a networking strategy for enabling the proposed system to be connected to several computers over the web is also conceptualized. This is of particular importance when issues related to data input via the online interface (human agent) have to be materialized. The networking scenario is described in the following section and is followed by a conceptual description of the computation methods/programming languages to be used for making the entire system operational.

5.4.2. d. Networking

The set of requirements exemplified in section 5.2 and 5.3, pose a central issue as regards the networked nature of the proposed system. It is essential for the system's users to be able to enter their preferences at any point in time from either outside or inside the office space and hence a need for inherent connectivity between numerous computers is mandatory. A solution fostering this connectivity is proposed via developing an inbuilt client and server counterparts within the software application to be developed for the entire system. A host computer is selected to house the software (with its internal server). This computer is referred to as the parent computer. The internal server of the software is subsequently assigned the IP address of the host computer (or can even be provided with a domain name attached to that address). This specific IP address provides the generic linkage to the entire system via numerous computers.

Other computers (lap tops) throughout the office host a copy of the same software with their client counterparts pointing towards the IP address of the above mentioned parent computer as the main source of data input. The client computers would hence run the interface and data entered in terms of preferences via this interface is specifically communicated to the computer towards which the client computers are directed. It is not necessary in such a set-up for the server to know the IP addresses for the clients since any connection set up by the clients acts both ways thus allowing the server/parent computer to talk back to any client computer. The computers are subsequently networked via the internet and make use of the wireless and broad band connections within and outside the office for data communication purposes. A scenario where a variety of clients are linked to a central server, for receiving and sending data is thus propagated.

A report on the evaluation of the conceived networking framework will be provided in section 5.5.6. d, which specifically deals with testing the completed software application in real time. The next section elaborates upon the underlying language, structuring as well as a projected implementation view of the computational techniques proposed for materializing the research.

5.4.2. e. Computation

Computation is the most vital underlying medium for binding the proposed system components (human, local and global) together into a coherent entity. It also formulates the underlying logic for developing the above mentioned networking framework and is hence crucial for the systems functioning. As was mentioned in the requirements section 5.3, the necessity for the proposed system to perform in real-time and the diverse media oriented outputs which it has to cater to, lead to a critical selection as regards the kind of programming language which would be supportive as well as efficient for delivering the proposed output. This section specifically elaborates upon the final selections and the underlying reasons behind the selections pertaining to the category of programming language, the conceptual manner in which the program would be structured and deployed for developing the proposed interactive system. A broader categorical exemplification relating the desired nature of the computational approach with the architectural and technological appropriations elaborated earlier is considered as a logical departure for defending the decisions and is hence elaborated upon in the following section.

a. Object Oriented Programming and structuring

Object oriented programming[7] is seen as a paradigm that uses abstraction to create models based on the real world. The following elaboration of this paradigm is based on the literature provided in the Wikipedia encyclopaedia and specifically caters to elaborating the essential characteristics of the paradigm.

Object-oriented programming may be seen as comprising a collection of individual units, or objects, that act on each other, as opposed to a traditional view in which a program may be seen as a collection of functions, or simply as a list of instructions to the computer. Each object is capable of receiving messages, processing data, and sending messages to other objects. Each object can be viewed as an independent little machine or actor with a distinct role or responsibility. Object-oriented programming is claimed to promote greater flexibility and maintainability in programming, and is widely popular in large-scale software engineering. Furthermore, proponents of OOP claim that it is easier to learn for those new to computer programming than previous approaches, and that its approach is often simpler to develop and to maintain, lending itself to more direct analysis, coding, and understanding of complex situations and procedures than other programming methods.

The above stated definition is particularly apt for the manner in which the architectural and the technological appropriation are conceived. The propositions put forth in these appropriations point towards a componential manner of approaching a design solution. Envisioning the entire architectural space as a resultant of the collective behaviour of generic spatial pods and subsequently the technological counterparts envisioned as a set of components (human, local and global) each hosting a set of sub-components with specific behaviour attached to each is thus very closely related to the underlying logic displayed by the object oriented paradigm. The ease of further categorizing such technical and architectural entities as objects capable of being communicated with for producing the desired output is seen as a positive aspect for developing a comprehensive object oriented framework with embedded rules of operation. However, a suitable object oriented programming language which could be utilized as a medium for embedding this interactive framework had to be decided upon. After various brain storming sessions and trials (using 3ds max scripting and Virtools), Java, an object oriented programming language was decided upon.

Java, as an object oriented programming language was developed in the early 1990s at Sun Microsystems and was designed to be compiled to bytecode which is interpreted during runtime. Bytecode is a binary representation of an executable program designed to be executed by a virtual machine rather than by dedicated hardware. This property of Java was considered vital for the research as it allows programs written in Java to run on any platform (platform independence). This aspect makes it much simpler to embed the software within a variety of existing office set ups without the need to install specific hardware or software entities for supporting the proposed system. Apart from the above mentioned characteristic Java as a programming language hosts four more vital characteristics which make it apt for the proposed research. These are; utilization of the object oriented programming methodology, hosting built-in support for using computer networks, ability to execute code from remote sources securely and the ease to use by selecting good parts of other object oriented languages. These characteristics help in addressing the requirement sets mentioned in section 5.3. via a comprehensive, secure as well as supportive language which can easily cater to issues related to interaction between objects (architectural and technological), networking oriented concerns, ease of installation as well as security oriented concerns. The object oriented aspect further helps in structuring the entire program in a much more comprehensive manner thus allowing one with much more flexibility in terms of adding or deleting behaviour oriented functionalities amongst the objects under consideration. However, considering the time constraints involved in this research, a software development kit which would allow for the rapid development and testing of the proposed Java based program was sought after in order to speed up the programming and evaluation process.

Eclipse[8], a software development kit (SDK), which is both the leading Java™ integrated development environment (IDE) was subsequently decided as an appropriate medium for programming the Java based program for the entire system. Eclipse platform is more than just a foundation for building development environments: it is a foundation for building arbitrary tools and applications. It is being used to build arbitrary applications that have nothing to do with software development in diverse areas that include banking, automotive, medical, and space exploration. Eclipse rich client platform (RCP) also proves to be an excellent platform for building applications that work in conjunction with application servers, databases, and other backend resources to deliver a rich user experience on the desktop and was hence considered to be an adequate medium for the proposed software development.

One of the key benefits of the eclipse platform is realized by its use as an integration point. Building a tool or application on top of eclipse platform enables the tool or application to integrate with other tools and applications also written using the eclipse platform. The eclipse platform is turned in a Java IDE by adding Java development components (e.g. the JDT) and it is turned into a C/C++ IDE by adding C/C++ development components (e.g. the CDT). It becomes both a Java and C/C++ development environment by adding both sets of components. Eclipse platform thus integrates the individual tools into a single product providing a rich and consistent experience for its users.

The Eclipse platform, in a nut shell is designed and built to meet the following requirements which made it an obvious choice for the proposed software development initiative:

- Support the construction of a variety of tools for application development.
- Support an unrestricted set of tool providers, including independent software vendors (ISVs).
- Support tools to manipulate arbitrary content types (e.g., HTML, Java, C, JSP, EJB, XML, and GIF).
- Facilitate seamless integration of tools within and across different content types and tool providers.
- Support both GUI and non-GUI-based application development environments.
- Run on a wide range of operating systems, including Windows®, LinuxTM, Mac OS X, Solaris AIX, and HP-UX.
- Capitalize on the popularity of the Java programming language for writing tools.

After exemplifying upon the object oriented framework, the ideal language and the development platform to be utilized for the materialization of the interactive system, the next section exemplifies upon the manner in which the proposed program will be deployed for binding the various system components together.

b. Usability of the proposed program

The java based program as was proposed in the earlier section will be specifically deployed for conceiving and binding the derived system components (human, local and global) together. A systematized manner of coding the behaviour of each component distinctively as specific objects bearing individual characteristics would formulate the first step in developing the system. The notion of materializing media oriented visual output of certain objects such as the online interface, the interface for the pluggable units as well as simulations which operate in real-time will also constitute a major part to be developed via the proposed language. Hardware entities such as RFID tags, sensors and the controllers involved in the system would also be coded with specific routines written in Java in order to synchronize these entities with other system components.

One of the most important implementation of the proposed language would be to program the global agent, which as mentioned earlier would host the rules for interaction, data exchange, structuring as well as algorithmic space allocation sequences. The Java code developed for such complex behaviour of this singular unit would hence form the main source for developing interconnections amongst the scattered objects constituting the system. Data mining as well as data communication routines within each object per say would need to be defined in order to develop a looped system interaction, in which a change in the status/value of any object would be interpreted in individual ways by the rest of the objects (for some they would serve as triggers to start up computational processes, for some it would imply registering a new set of data etc). A logistical set up appropriated towards the kind of output required of the system should thus be formulated by the manner in which the instructional routines are coded.

The data base (local agent) to be developed as a separate entity using applications most suited for its construction would also need to be integrated as an inherent data store, enriched with the property of being mined and being updated in real-time. This behavioural aspect of the local agent would also need to be programmed via the proposed Java language. In essence, the required system output in terms of graphical, physical as well as simulation oriented aspects would be promoted via the Java codes via instilling an output oriented meaningful information flow amongst the varying components formulating the system.

The manner in which the Java code structures this interactive information flow in the most convenient, time saving manner results in a faster system response and is hence rather crucial to be tested at different stages of its development. Simulation oriented aspects concerning geometric augmentations based on curve fitting and interpolation techniques (exemplified in section 5.5) in order to attain a precision oriented configuration genealogy would also be driven via the proposed programmatic language. It is vital to develop these configurations as test beds for running simulations, gathering the required mathematical (geometric vertices displacement) data and further communicating this data to local controllers in order to check the amount of time required for conducting this manoeuvre. This interconnectedness amongst the soft and hard counterparts of the system informed by a logical set of rules of operation thus formulates a crucial role for the proposed Java based program.

In order to assist the above mentioned computational approach, it was considered quintessential to develop a system architecture diagram mapping the interconnections amongst the various system components. The diagram would further facilitate the development of the Java program in a much more rapid fashion owning to the clarity of interconnections existent amongst the prominent agent categories.

The developed system architecture diagram (Fig. 74) illustrated below is additionally supported by detailed information flow diagrams, which exemplify the manner in which updated data or time oriented constraints provide the foundations for triggering specific computational routines. A thorough mapping of how individual space allocation, temporary space allocation and conference space allocation sequences would be carried out are also extensively illustrated via these sets of flow diagrams. A detailed review of the system components, their degree of interaction with other components and sub-components as well as a detailed review of the flow diagrams is provided in the following section 5.5 which explicitly focuses upon the physical design and prototyping phase of the research work.

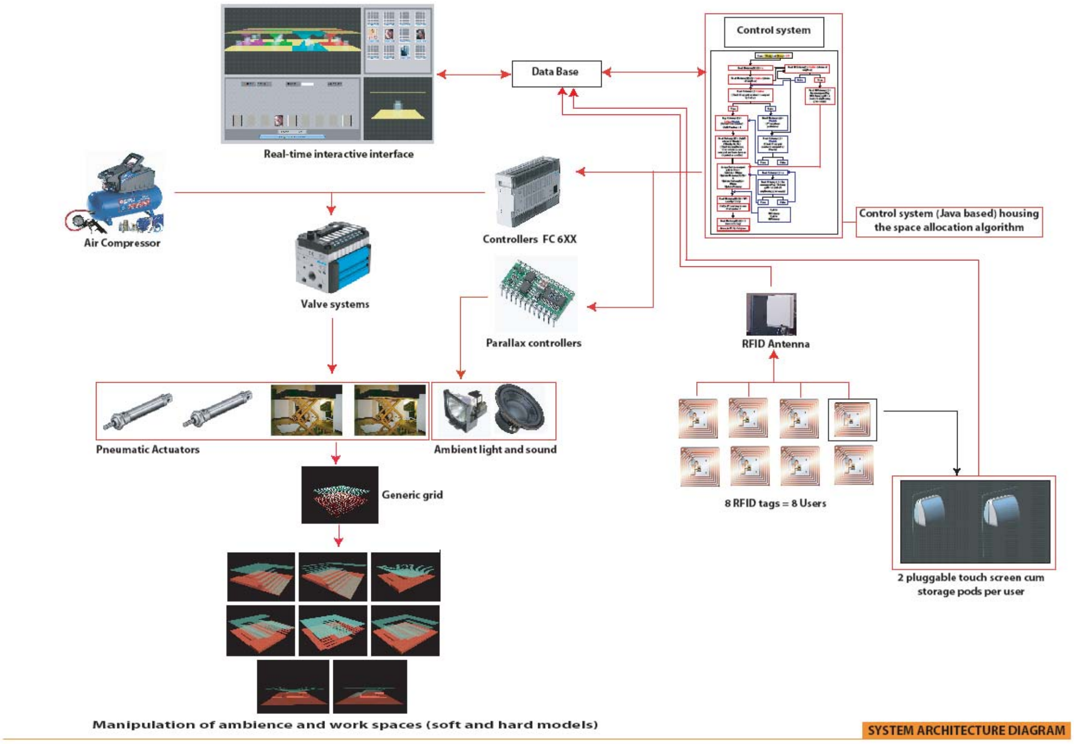


Fig.74.System architecture diagram illustrating componential interconnections amongst the three agent types.

The above illustrated system diagram is thus revisited, dissected and explained in terms of its operational logistics in coherence with the technological inputs associated with each system component.

Owing to the architectural inclinations of the proposed research, the next section before expanding upon the above mentioned intricacies (local level) will exemplify the notion of customization (global level) as an underpinning for the proposed generic pod design, thus outlining a user oriented design perspective for tailoring the proposed generic construct.

5.5. Physical design and prototyping

After getting an insight into the conceptual underpinnings for the proposed system design, this section specifically deals with the development and materialization of the entire system. It is important to note that after much deliberation and constant communication with various industries and organizations, it was difficult to generate funding possibilities to construct the physical working prototype. Under such circumstances, the aforementioned prototypes: The Muscle re-configured and The Bamboostic, are considered as proven exemplifiers of the deployability of the physical constructs with an interactive behaviour embedded within them. The research scope is thus altered to specifically materialize the following components: The global agent or the main control centre for the entire system with all its functionalities for automated space allocation, The local agent, specifically the online real-time Interactive interface, the central real-time updating database, real-time simulations for the actuators and the mechanics involved for the space adaptation purposes, The human agent via developing computation routines which replicate the sensors (RFID tags, the pluggable units and the infra red sensors) via key combinations on a conventional keyboard.

In its totality, the research work hence would cater to the entire category of agents, without the hardware involved in the physical construction of the office environment. Detailed and precise real-time simulations of the generic pod as well as the entire office space adapting and appropriating itself in real-time in accordance with user input is hence attained as a final product through the research. The entire software development stage as was mentioned in the computation section 5.4.2.5 allows for the development of a systematic structure which can readily be plugged into hardware controllers with minimal additions to the code thus attaining the over all goals proposed via the system architecture diagram (Fig. 74).

The next sections will cater to a detailed explanation as regards the development of each agent per say and the role of the global agent in weaving these agents via computational means into a unified operational interactive system. Hardware related information will also be elaborated upon in conjunction with the key combinations (in case of Human agents) corresponding to the role, which each hardware component plays in the successful operation of the system. However, an introduction to the considerations given to customization oriented aspects which resulted in the basic design unit: the generic pod will be elaborated upon as a prelude to the detailed technical descriptions to follow. A systematic manner of connecting the varied component development stages will thus become evident through the following sections.

5.5.1. Customization; an overview

Contemporary society and the inherent nature of every individual constituting this society being unique in terms of his/her personal preferences gives rise to the increasing success of Mass customization as opposed to mass-production. Mass-customization as a strategic tool, according to James H. Gilmore and B. Joseph, in their book Markets of One, has been successfully utilized by a variety of companies throughout the world for producing unique value for their customers in an efficient manner. Backed by an array of technological development and flexible work processes, it is now possible to develop rapid customized products in high volumes at a relatively lower cost. However, in order to be successful in customization oriented product development, the field of customization in itself should be analyzed in order to understand the typologies of customization existent in today's dynamic environment and to carefully adopt the typology or a mix of typologies most suited for one's purpose. The proposed generic pod development idea featured from such investigations into the field of Mass customization, these investigations, in a rather concise manner will be presented in the following sub-sections. The approaches for customization exemplified in the following section are based upon the typological identifications put forth by James H. Gilmore and B. Joseph, in their book Markets of One. A comprehensive review of these approaches and a subsequent hybridized customization strategy driving the conception of the generic pod is thus presented through the following sub-sections.

a. **The four approaches to Customization**

   Customization as a strategic approach towards addressing individual preferences can be sub-categorized into four distinct approaches namely, collaborative, adaptive, cosmetic and transparent. The approaches possess specific characters and can be deployed individually or can be combined together in order to attain a comprehensive solution for attaining a suitable design and development strategy. Specific characteristics of each approach are elaborated in a sequential manner below.

Collaborative customization, as the name suggests demands an active involvement of the customers in order to help them communicate their needs and to identify the precise offerings that fulfil those needs, thus enabling the creation of customized products which fulfil their needs. This category of customization is usually utilized by industries/businesses where the customers are not very sure about what they want and can very often be frustrated if confronted with a huge array of choices/options from which they are supposed to make a decision. Such scenarios can lead to unwanted compromises and trade offs owing to the one-time decisions to be made by the customer thus leading to the inherent dissatisfaction on the user's part. A collaborative customization strategy can hence be beneficial in such a case for determining the user's choice as regards the customization service required by the individual. Such collaborative customization solutions often result in the generation of front end specifications as opposed to back end solutions which would force the users to make changes to a product which they bought.

Adaptive customization deals with the idea of offering one standard, but customizable product that is designed in a manner that the users can easily alter it according to their needs. This approach is often used by businesses whose customers want the same product to perform in different ways in accordance with different occasions. A technological backing behind such designed products enables the users to easily alter the product on their own hence avoiding any direct interaction with the company/business organization. The notion of product value in this case becomes dependent upon each individual who specifically deals with selecting options provided to him/her by the company as an inherent tool. The level of interaction in this case is between the product and the user per say as opposed to the previous scenario. This customization approach proves vital for the development and deployment of products which due to their inherent nature negate time wasting acts of keeping on experimenting with a multitude of choices and can hence help in increasing user efficiency. The adaptive approach hence, at an operational level, provides the users with the power to alter and adapt a product in accordance with their requirements. The collaborative mode, which deals with assisting the users in circumstances involving a wide array of choices, differs from the adaptive approach where possible configurations can be built/programmed into products hence producing efficient, precise and adaptive designed products.

Cosmetic customization on the other hand deals with the presentation of a standard product differently to different customers. This approach is valid when different users use the same product in the same way but prefer the presentation of that product to each individual in a customized manner. This form of customization owing to its cosmetic nature often deals with psychological satisfaction (in terms of generating a feeling of personalization) as opposed to physical alteration of the product per say.

Transparent customization, the last category, provides individual customers with unique goods or services without them being aware that the offering has been customized for them. This approach is specifically used in cases when the requirements of the customers can be easily deduced without bothering the customers by making inquiries as regards their preferences. Such an approach thus involves observing the customers for their behaviour thus predicting their needs rather than directly communicating with them. The time involved in such observations is significant and can only be afforded by companies who have special sectors dedicated for such observational activities. It also entails the prevalence of a standard package/content into which its products customized features can be placed thus proving to be completely opposite to the cosmetic approach mentioned above.

After exemplifying upon the four categories of customization put forth by James H. Gilmore and B. Joseph, in their book Markets of One, the next section specifically deals with the development of a hybrid customization strategy for conceiving the generic pod.

b. Deriving a hybrid customization strategy: the generation of the generic pod

After analyzing the above mentioned approaches of customization and relating it with the interviews and discussion oriented derivation of a set of generic functional and non-functional requirements derived in chapter 04, a strategy which would combine the salient features of three of the above mentioned customization approaches namely; collaborative, adaptive and cosmetic were considered for developing the basic design unit/module: the generic pod. The three approaches owing to their inherent characteristics have been sequentially utilized at different stages for conceiving the generic pod. These stages, specifically cater to gathering of constructive input from the employees for deriving service oriented customization concerns, designing the product/spatial construct in accordance with these concerns in a manner that embeds various possibilities for satisfying the concerns within the product and finally developing personalized representation means for each individual.

Collaborative customization approaches, owing to its inherent nature of engaging the customers/employees in order to help/assist them to better communicate their needs as well as help them in identifying the precise offerings from an array of conceptual options is specifically utilized during the early phases of the research. This approach was also implemented during the case study (of Interpolis) and subsequently for interviewing and informally discussing with a variety of corporate employees in an attempt to derive a set of logical requirements (elaborated in chapter 03) that the product/the generic pod had to cater to. Following this collaborative approach for extracting the most likely service offerings, a series of collages (Fig 58) illustrating activity oriented spatial alternatives as a conceptual response to the services required were presented to these employees so that they could visually relate and identify the configurations most apt for their satisfaction. The process thus proved beneficial not only for developing an understanding of the context and the employees operating within it but also proved vital for gaining a set of spatial options which could be utilized as presets while customizing the design and operation of the product/ the generic pod.

The translation of the collaboratively derived customization options and service requirements is subsequently attained via adopting the adaptive customization approach. This approach specifically comes closest to the proposed adaptive physical reconfiguration oriented behaviour envisioned while formulating the hypothesis of the research. The notion of embedding configuration oriented variations within a standard product, in this case the generic pod, embedding a variety of spatial configurations with a stress upon allowing the users of the product to be able to customize it to suit their individual needs is thus embarked upon. The generic pod with its ability to transform into a set of predefined spatial configurations is also backed by contemporary technological developments through which the manner in which customizing or in this case switching between pre-defined configurations can be easily communicated to the users. The aforementioned development of an interactive user interface can be seen as such a technological tool fostering an easily graspable manner of customizing the generic pod in accordance with every individual's preference. In addition to the interface, readily available sensing and actuation technologies further aid the development of a ubiquitous manner of customizing the envisioned product. The product value as mentioned earlier is hence actively deciphered by each individual by adapting the product for his/her use oriented satisfaction. The interaction promoted in such a case is thus between the object/product and the subject/employee, rather than the company/business in a direct fashion. The adaptive approach was hence considered crucial during the design and development phase of the generic pod, allowing for the subsequent programming of derived configurations onto a set of generic planes (ceiling and floor) constituting the pod.

The inherent character of cosmetic customization related to presentation oriented aspects of a standard product is considered as a detail specifically involving the surface/skin of the generic pod. A manner in which tailored presentation of the pod could be combined with addressing functional usability was considered as a driver for the cosmetic approach. The generic pod adopts the strategy of cosmetic customization via attaining variations in the colour (via electronic means) of the surface of the generic pod itself. This ambient quality of the generic pod works in relation to colour preferences made via the users, hence attaining a personalized status depicting each individual. The functional aspect associated with this cosmetic aid specifically deals with immediate association and recognition of a pod allocated via automated means to an individual, hence avoiding occupancy oriented confusions and an eventual waste of time.

This strategic sequencing of varying customization approaches thus allowed for an intrinsic articulation of the basic design unit: the generic pod (Fig. 75). The strategy also works in coherence with the initial hypothesis of generating a highly adaptive space which caters to activity oriented concerns of contemporary offices and hence propagates a logical tried and tested customization oriented approach adopted by some of the leading businesses around the globe. Another interesting dimension, a resultant of this hybrid approach, points towards a co-existence of mass production and mass customization approaches. This dimension stems from the notion of repetition of the same generic unit throughout the office environment as was mentioned earlier. The population of pods, owing to their capability to be customized, would, despite of the repetitive nature contribute to the creation of diversity and hence the creation of a truly dynamic, highly customizable environment. The repetitive nature allows for the production of individual components involved in the physical construction of the generic pod at a mass scale and via this rapid production aspect contribute to the economic viability of the proposed system.

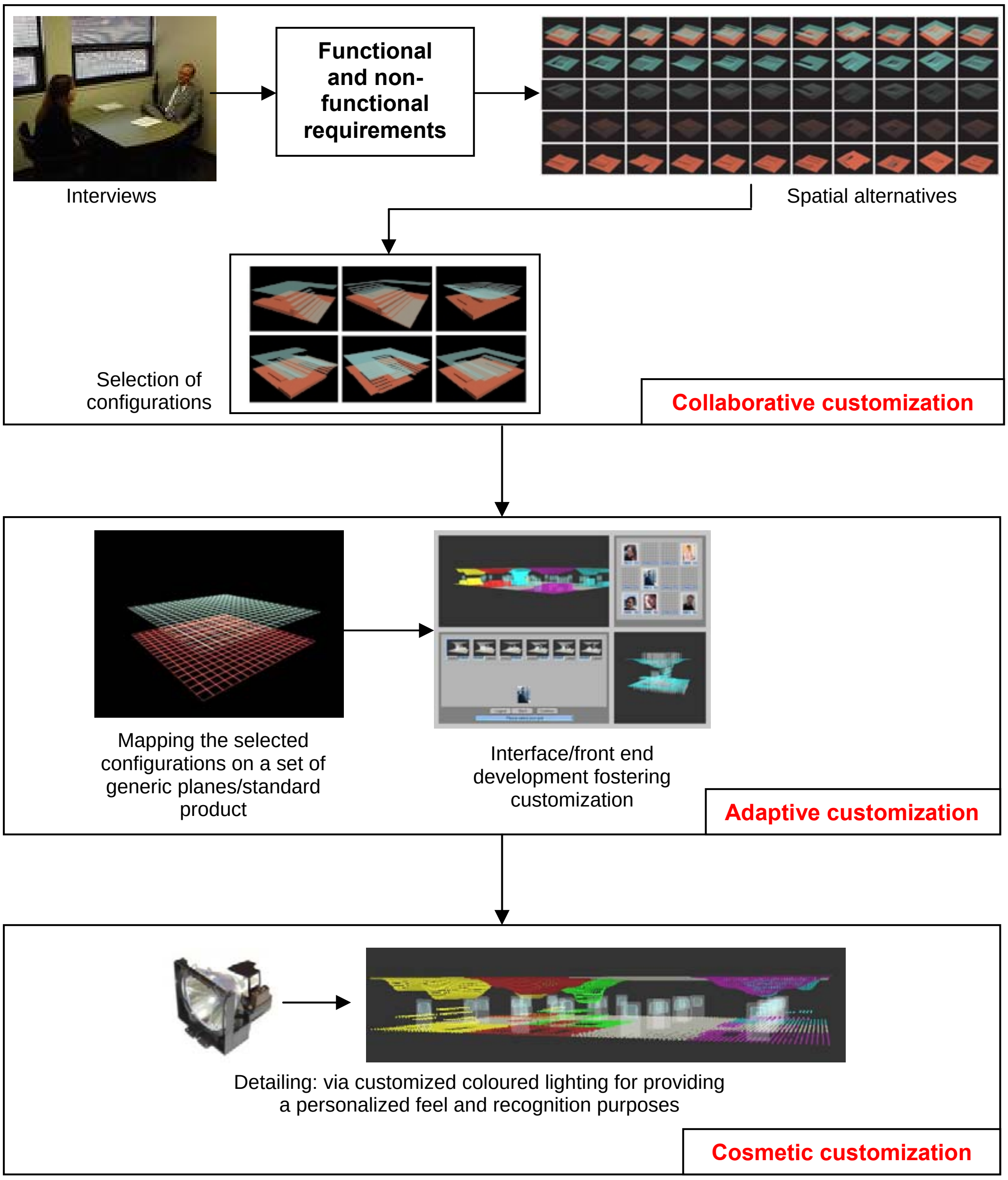


Fig.75.Sequential customization phases.

After elaborating upon customization oriented underpinnings for the conception of the generic pod, the following sections will elaborate upon the computational ideas operating behind the digital prototyping stage of the pod. An active collaboration between the Industrial design department and the Electronics department, TU Delft was sought for attaining precision oriented configuration translations. This collaborative approach for enriching the design output of the proposed interactive system is strongly rooted in the initial conceptual design phase of the research (section 5.4), which specifically dealt with setting up geometric variants (in terms of animations and morphing sequences of the varying configurations) as well as a technological and computational framework for envisioning the interactive system.

5.5.2. The generic pod: dimensionality

The geometric variants of the generic pod, as described in the conceptual sections 5.3, are built upon a standardised template (Fig. 76) in the form of a grid constituting a field of 26 X 26 square units, with each unit being a 20 X 20 cm square. An overall dimension of 5.2 X 5.2 m thus formulates a design unit. However, this dimension also includes half the dimension of a circulation path running along all four sides of the effective working area. A strip of the width of 80 cm along the periphery of this basic unit is hence deducted thus leaving an effective working space of 3.6 X 3.6 m within which the proposed configuration variations can be deployed. Placing the pods together, to populate an office space would hence result in the creation of 1.6 m wide corridor network all along the generic pods, thus providing a comfortable and legible circulation space throughout the office. The aforementioned quality of the circulation space being flexible to accommodate special configurations such as the conference setting is thus easily accommodated in this manner (of conceiving it as a part of the generic unit) by extending the same structural logic being used for configuration variations towards the circulation zone's alterations.

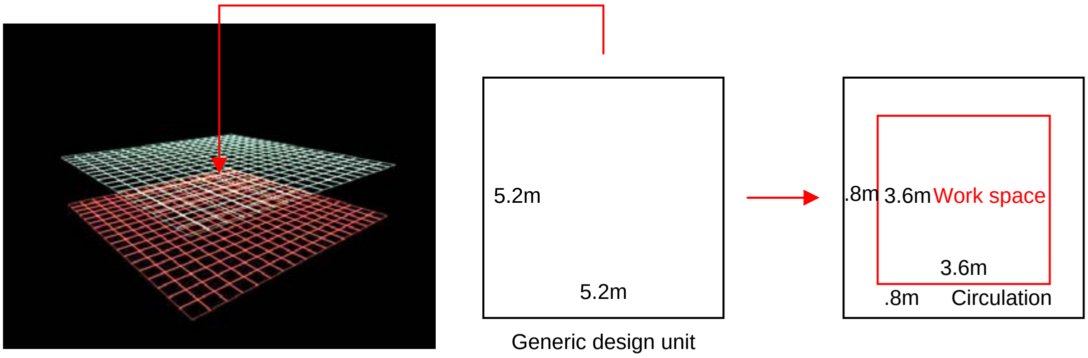


Fig.76.The generic pod: dimensional aspects

A height of 2.85m (which includes the floor and ceiling skins) is maintained between the two planes (could also be limited to 2.5m). Owing to the mechanics (local agents) which would be operational beneath the floor and above the ceiling planes (Fig. 77), an effective height of 3.6m would be required for embedding a finished generic pod within existing office environments. The 3.6m height includes a steel/aluminium housing case, 60 cm in height for the aforementioned pneumatic pistons to be installed behind the ceiling plane and a 25cm high platform/false floor beneath which a mechanism of scissor jacks can be effectively embedded.

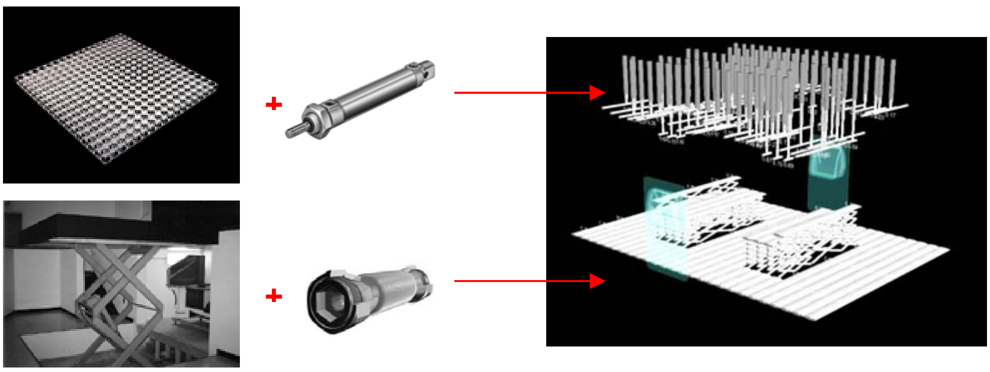


Fig.77.Mechanics operating behind the ceiling and the floor planes.

A simple assembly of the above mentioned components which constitute the height of the generic pod can be materialized rapidly via utilizing pre-fabrication techniques for pre-building the ceiling cage with embedded pistons (attached to rods of variable lengths) and the floor scissor trusses (attached to wooden planks woven together with elastic bands). These assemblies can then be simply placed within existing office buildings to create an organized population of generic pods and can subsequently be wired with individual local controllers per pod. A rapid deployment strategy based upon the pre-fabrication idea can thus result in saving time and can hence prove to be more economic in precisely materializing the dimensional aspects of the pod.

5.5.3. Computational aspects involved in the generation of configurations

The generic pod, as was mentioned in the conceptual design section 5.4.1, is conceived of (in terms of digital models) a set of two grid planes which embed within, the possibility of digitally morphing into varying configurations. These configurations as was mentioned earlier were derived as spatial variants addressing a set of functional requirements based on the PACT analysis of office environments. Collaborative customization via involving typical office employees and keeping in mind the scope of the research, a selected set of activity oriented configurations were derived. These configurations per say will be elaborated upon in the next section. At the conceptual stage, 3d digital modelling and animation techniques (using 3ds max) were deployed for rapidly generating spatial alternatives pertaining to observed as well as desired requirements, these culminated in the communication of digital morphing movies as well as 3d space variation assemblages to the employees. However, after deducing the most favoured alternatives, the need to transform these animations into computer simulations was embarked upon. This translation involved a change in visualizing the generic grid per say and hence a subsequent change in the manner in which the configurations are generated via Java codes.

The digital model of the grid is thus perceived as comprising a field of vertices with specific co-ordinates in the x, y and the z dimension. A cluster of vertices akin to a point cloud[9] is thus generated for representing the ceiling and the floor plane. The vertices constituting the two planes are informed in different manners via the Java code in order to attain a much more fluid topology for the ceiling as opposed to a not-so fluid, rather planar topology for the floor variations (in order to create functional work surfaces). The conceptual design variants play an important role for deciphering the height variations of the vertices involved in the two planes owing to pre-modelled data pertaining to points or a strip of units with the maximum Z axis (height) displacement (Fig. 78).

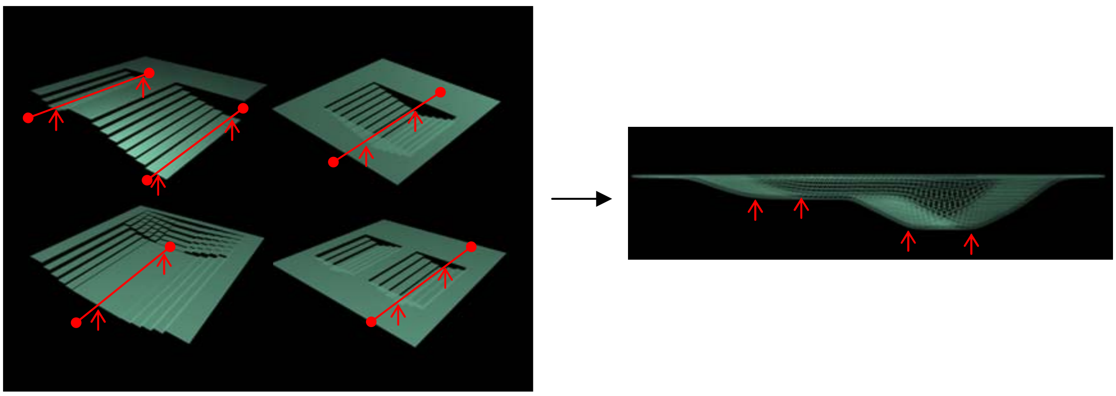


Fig.78.Conceptual ceiling samples with points/strips of maximum Z axis (height) variation.

This information is particularly important for developing an automated sequence for generating fluid ceiling profiles by means of embedding a mathematical algorithm within the Java code responsible for calculating vertex positions. The developed Java code works on the logic of Interpolation; a mathematical method for constructing new data points from a discrete set of known data points. This method is utilized for attaining the height variation of the vertices which fall between a set of known vertex heights, in this case the vertices which correspond to the strip or points with the maximum height (in Z axis) in the conceptual models.

This process involves that the Java code extracts the position of the vertices possessing the maximum height from each of the selected configurations (attained via collaborative customization) and use this data as a set of constants/discrete set of known data points. The heights of the vertices falling between these fixed set of points is derived in an automated manner by using a sinusoid function. For calculating the height of the vertices falling between a set of fixed vertex points the sinusoid function considers the heights of these fixed points as peaks. However, for the vertices falling before and after the first and last set of fixed vertices, the border of the grid (the beginning of the circulation paths in all four directions) acts as the peak[10] value for the sinusoid, which is subsequently used for deciphering the heights of these vertices (Fig. 79). This underlying logic works in both x and y axis directions for attaining an overall fluid curvature for the ceiling plane. Calculation for the height of a piston at a given location (y), between two fixed piston co-ordinates (x1, y1) and (x2, y2) is attained by using the following equation:

$$\mathbf{y = (\sin((x - (x1 + dx / 2) (dx * \pi) + 1) * dy / 2 + y1}$$

(where $dx = x2 – x1$ and $dy = y2 – y1$)

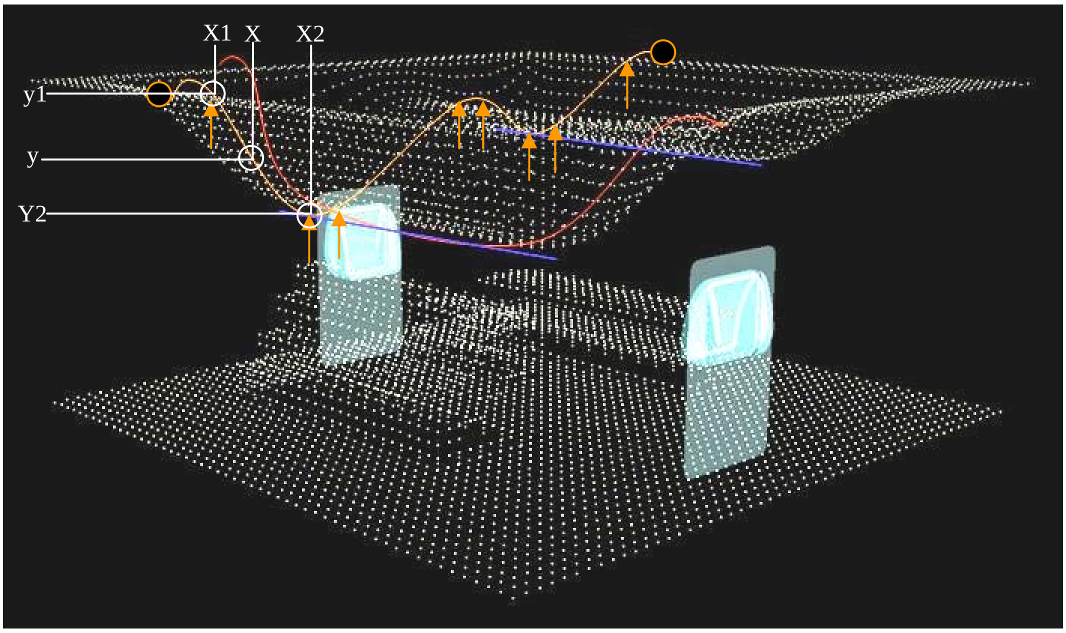


Fig.79. The sinusoidal curve in both directions is developed in sections considering the arrows as peaks for calculating the heights of the points lying between them. The beginning of the circulation zone in both axes always forms the peak points. These points help in generating culminating sinusoidal sections (edge conditions) in the X and the Y directions for each configuration.

The above illustrated example graphically unfolds the manner in which the sinusoidal principle can automate the process of assigning heights to large number of vertices lying between already fixed vertices, thus saving a considerable amount of time involved in the computation process. The resultant output of this computation technique is materialized in the form of fluid curvilinear geometry which, owing to pre-fixing the maximum amount of height variation maintains the functionality of acting as projection screens or light sources for the generic pod.

The floor plane, as compared to the ceiling plane has a much simpler computational routine owing to its inherently planar nature. The height variations involved in the floor plane are directly linked with the conceptual variants where heights are directly related with typical office furniture such as table heights, seating heights shelving heights etc. The computation routines developed per configuration, thus store this information (related to z direction displacement) and apply it to an array of vertices corresponding to the conceptual space variants. A relation between the ceiling and the floor planes is subsequently established so that the automated curvature calculations of the ceiling and the simpler array based height variations of the floor plane work in coherence with each other. A mesh is subsequently generated via the Java code in a manner that it always stays connected to the vertices and re-adjusts itself in accordance with any variation of the vertices involved. A flexible substrate which can, in real-time, adapt its curvature in relation to its constituent vertices is thus simulated. Provisions for visualizing this dynamic surface in the form of a triangulated mesh or a smooth surface are subsequently made via the Java code, hence allowing one to analyze the generated surface in different ways (vertex positions, mesh structure, smooth surfaces). As was mentioned earlier, the systematized nature of formulating the Java code treats each configuration as a separate module, hence allowing one to easily plug-in/embed these specialized coded sequences into any controller (local agent). Local controllers per pod can thus contribute towards distributing the computation load from a centralised system (global agent) and can be rather easily triggered by this central system to actuate specific configurations in real time.

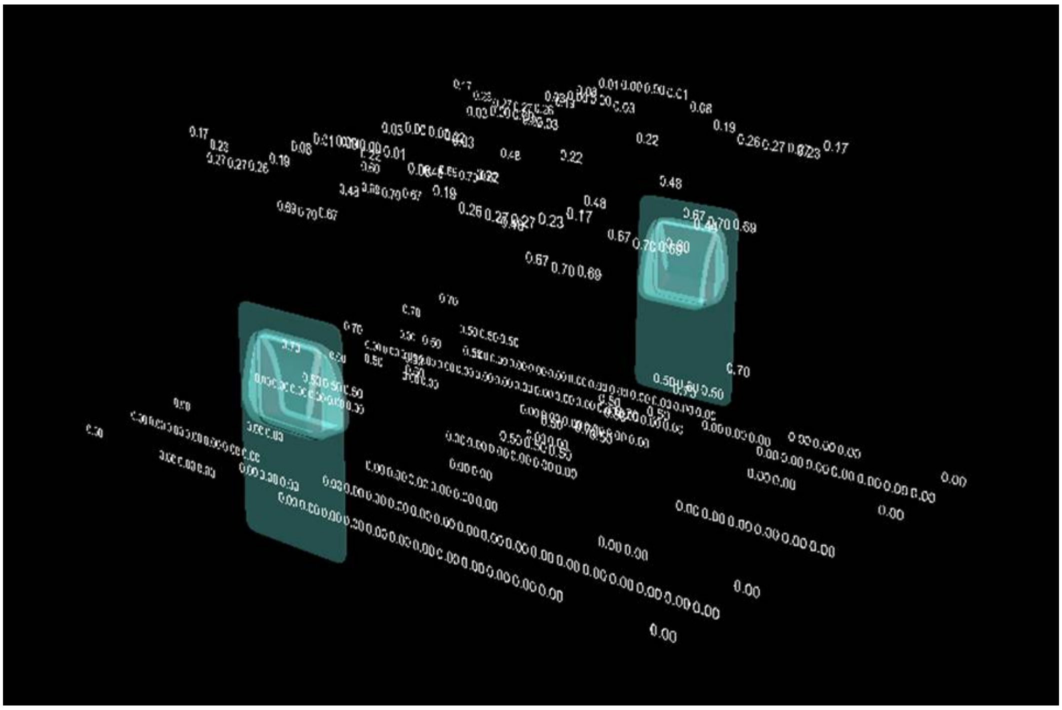


Fig.80. Z axis dimensions (heights) of every augmented vertex in the ceiling and the floor plane.

The Java code developed for the above mentioned generation of vertex heights (in an automated manner) also supports the visualization of the new heights acquired by the vertices. This height variation related data is updated in real-time in correspondence with each configuration update and is conceived as a parallel process for generation of numeric data along side the digital appropriation of vertex positions. A possibility for viewing these height related data without seeing the vertices and the surface mesh, for a clearer perception is also provided via the software (Fig. 80). The height variations acquired in this manner serve a very specific purpose for subsequently informing the actuators (pneumatic pistons and muscles)/local agents as regards precision oriented actuation to attain varying configurations.

This data translation involves the conversion of height related data by local controllers (CPX controllers) into specific time intervals which would eventually control the opening/closing of air valves thus controlling the amount of air pressure being injected/released into/from the actuators. This amount of air pressure is directly related with the amount of thrust and the length of a piston rod (in case of a piston) and the amount of compression/shrinkage (in case of muscle) which can be attained. A direct conversion of digitally produced numeric data into a hardware oriented air pressure regulation is thus attained with utmost precision (Fig 81).

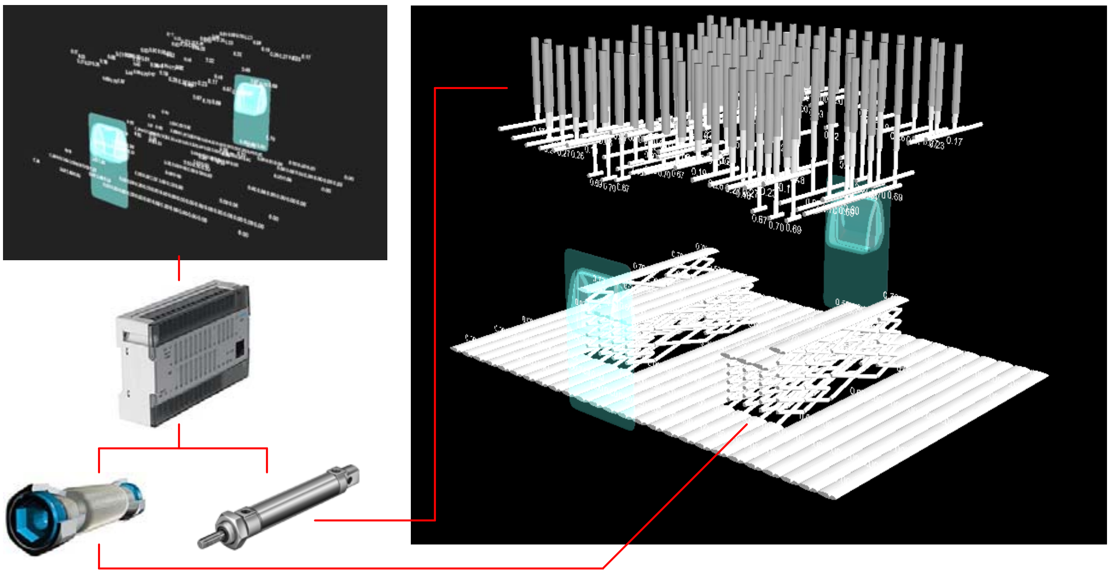


Fig.81.Translation of derived heights via the Java code to Local control agents and subsequently the actuating agents, resulting in precision oriented configuration generation.

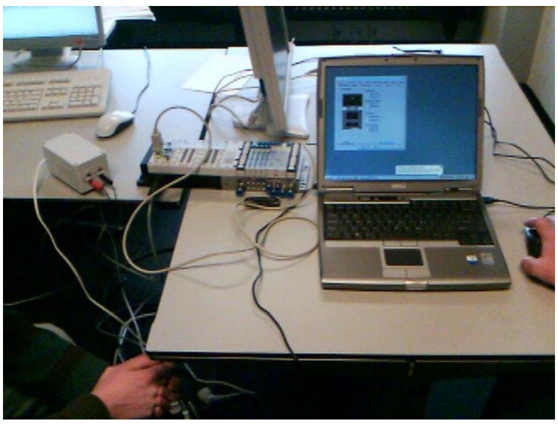


Fig.82.Tests being conducted with the CPX controller for data transmission (simulation-real world) purposes

Despite the fact that a full scale prototype of the generic pod was not constructed (due to financial constraints), tests pertaining to the translation of the simulated numeric data into the CPX controller via Festo's inbred software were conducted in conjunction with Festo engineers (Fig.82). It was concluded that such a precision oriented translation from the simulations can be made possible and can thus be successfully utilized for the proposed pod's adaptive behaviour.

5.5.4. Material Usage

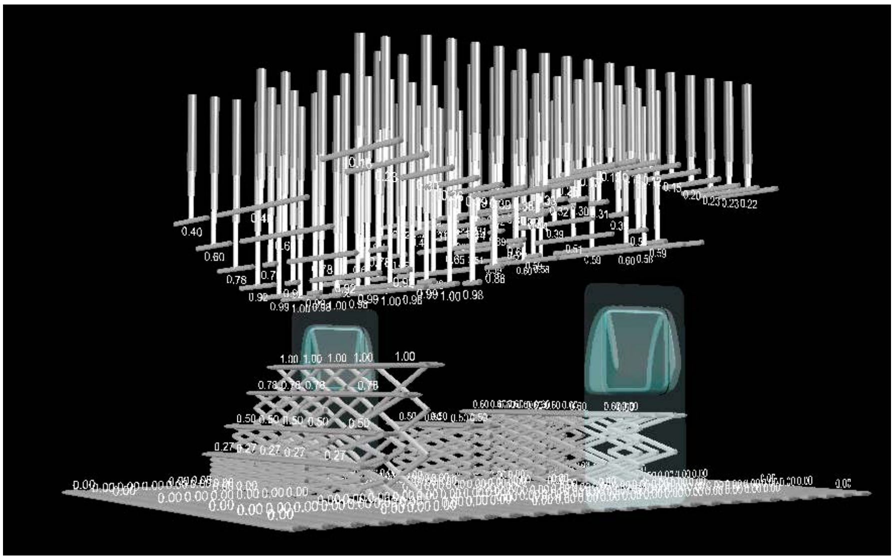
The material usage aspect including the construction proposals elaborated upon in this section are theoretical in their conception and should be considered as one of the various possibilities for constructing the proposed physical prototype. A variety of changes and alterations would be inevitable while manifesting this construction strategy in the physical domain.

A layering strategy is envisioned for the proposed construction of the generic pod:

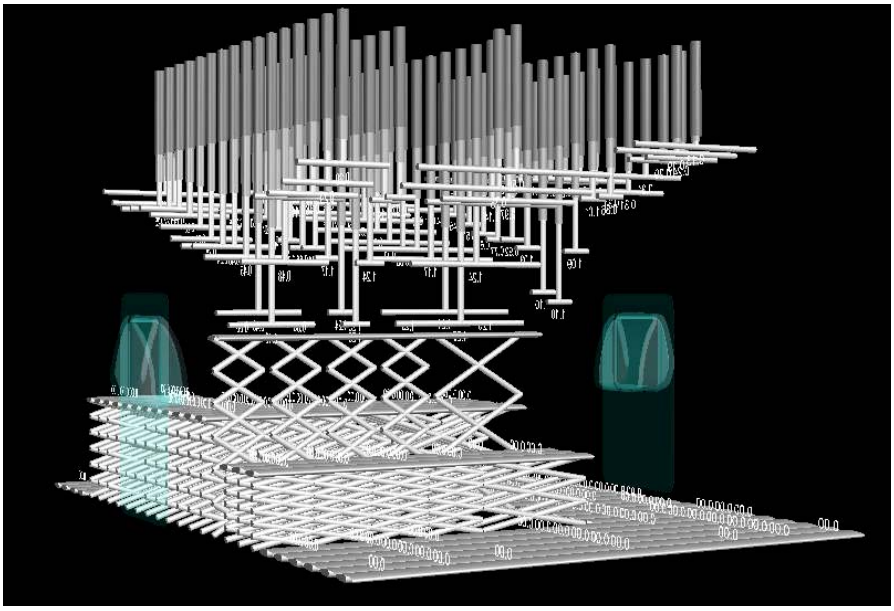
a. Layer 01: The outer most layers in both, the ceiling and the floor planes comprises of mechanical systems utilizing pneumatic actuators. The floor plane owing to its ability to carry load (employees) as well as the restrictions in terms of the mechanism not taking up too much space (height), is proposed to be an arrangement of scissor jacks of variable dimensions. The scissor jacks were specifically chosen after studying the manner in which it is used for lifting heavy loads as well as due to its ability to maintain a rather compressed (in terms of its height dimensions) state when not in use. Scissor jack oriented functional devices such as window cleaning platforms (Fig. 83) were also studied for their ability to unfold the scissor mechanism by means of applying a compression force pulling the bottom-most ends of the jack towards each other.

Fig.83.Scissor jack mechanisms in use for various functional purposes.

The above mentioned actuating principle can be further evolved in order to derive a solution via which a Festo product; the pneumatic muscle could be utilized for applying the compressive force for pulling the two opposite ends of the scissor mechanism towards each other. The property of the muscle to compress proportionately in accordance with the amount of air pressure induced into it could easily be utilized for precision oriented compression power. The strategy described in the previous section for communicating the simulated numeric data (per configuration) to the CPX controller, which subsequently instructs hardware (such as air valves) can be specifically deployed for controlling the compressive force to be applied via the muscle, thus controlling the height variation for each scissor jack (Fig. 84 a, b). A highly precise co-ordinated actuation of a group of such scissor mechanisms per pod can thus be attained in real-time.



a.



b.

Fig.84.a, b. illustrations showing the scissor jack mechanism (floor) and the rod network mechanism (ceiling) in two varying configurations.

The ceiling mechanism layer is proposed to operate upon a similar operational logic as the floor mechanism layer in terms of translation of real-time generated vertex heights via local controllers. However the ceiling mechanism layer owing to its non-load bearing nature and with a stress upon exerting downward thrust can utilize a simple mechanism; a network of pneumatic pistons connected to steel rods of varying dimensions. This simple mechanism would allow for the exertion of a downward force on a specific area (corresponding to the horizontal length of the rod attached to it, Fig. 85). This piston network can in-turn be housed within an aluminium box casing and be securely attached to it in order to hold the pistons in place. This assembly is similar in nature to the one used by DECOI for their responsive wall prototype (Fig. 85).

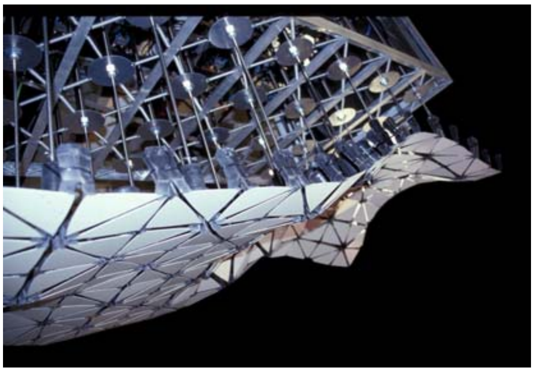


Fig.85. Illustration showing the steel casing within which a set of Pneumatic pistons have been securely positioned (DECOI).

The variations in terms of sizes of the scissor trusses as well as the steel rods are inevitable, owing to the manner in which the floor and the ceiling plane have been subdivided. This subdivision adheres to the conceptual models which were developed earlier with an underlying grid of 20 cm squares. The configurations developed at the initial stage (Fig. 86) are a result of height manipulations of this grid irrespective of the ceiling curvature (which is obtained via the Java codes) in order to arrive at specific heights pertaining to functional work, discussion and relaxation planes. Each configuration thus is envisioned as either a cluster of constituting squares or a strip of planes which are elevated in the positive or negative Z axis to envision furniture or ceiling deformations. The set of conceptual configurations (work, discussion, relaxation, temporary, conference and exhibition) selected via collaborative customization means are subsequently overlapped in two dimensions (ceiling plan and floor plan of each configuration) in order to identify the overlaps as well as unique grid clusters which would need to be treated as individual units in a way that one scheme would suffice for actualizing any of the selected configurations.

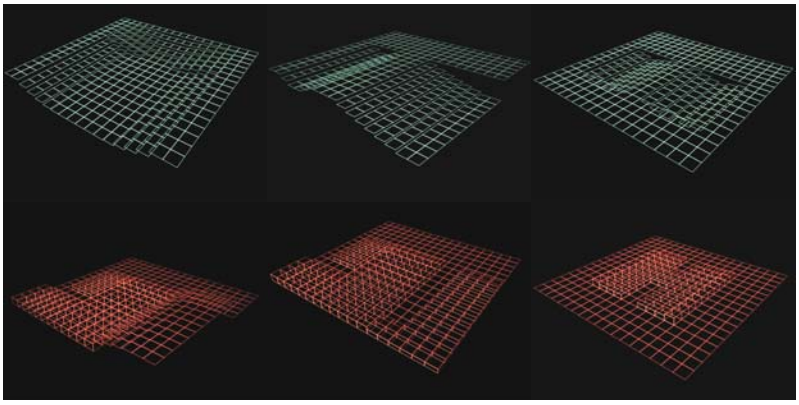
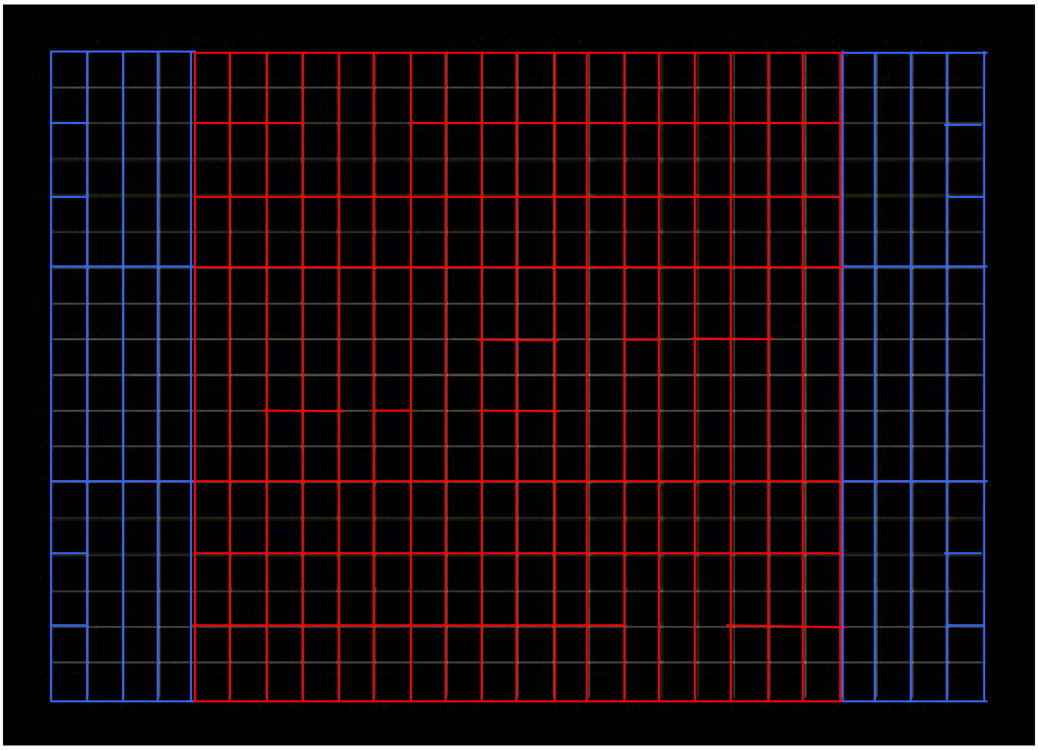
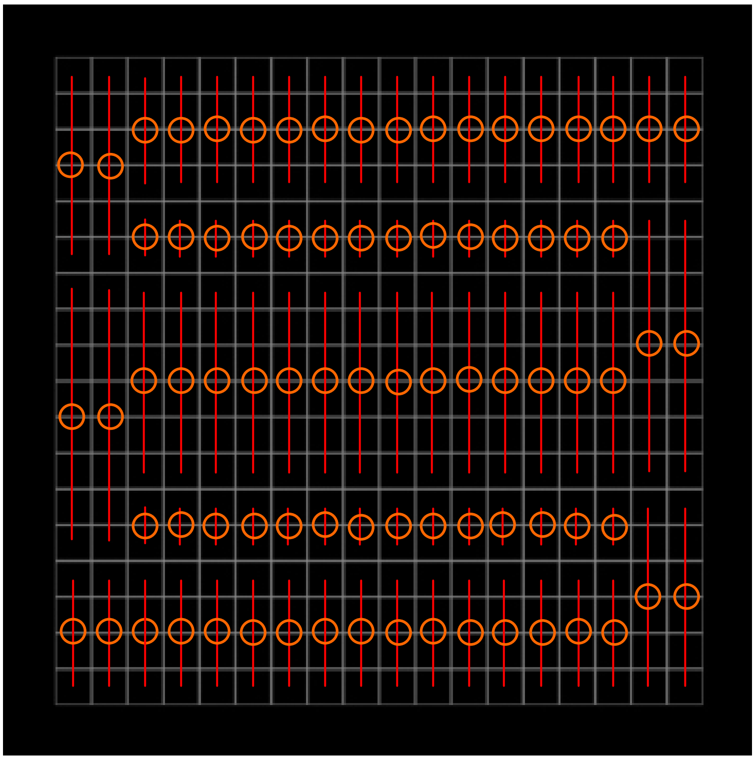


Fig.86. Conceptual space configurations developed by altering a generic grid of 20 cm squares.

As was mentioned earlier, the possibility for providing at least one more orientation option for the employees, necessitated that this generic scheme also takes into consideration the pattern created by the aforementioned layering of the selected configurations in a completely reversed orientation. A generic ceiling and a floor plan with the final scheme of subdivisions is thus developed (Fig 87 a, b). These plans are specifically developed in accordance with the construction strategy proposed for this research. It could differ in accordance with other technological and construction solutions.



a.



b.

Fig.87 a, b. Floor subdivision pattern (a: blue lines demarcate the circulation zones and red demarcate the pod area), beneath each subdivision a scissor jack of the same dimension is placed, Ceiling rod patterns and piston positioning (b: red lines demarcate the rod lengths and positions while the orange circles demarcate the piston positions).

The subdivisions in the floor plane serve as the template under which (under each subdivision) scissor jack mechanisms corresponding to the subdivisions would be installed. The ceiling subdivisions provide for the positioning of the rods, which would be located on the centre line per subdivision and whose lengths would correspond to the lengths of the subdivisions. The mid point of each acquired rod length serves as the exact location where it should be attached to the pneumatic pistons thus providing one with the location of the pistons (Fig 87 b).

b. Layer 02: A second layer which would be attached to the above mentioned mechanism layer is primarily concerned with materializing an appropriate curvature to the ceiling and floor planes once the actuations have been applied. The computational sequences developed for attaining a real-time positioning of vertices constituting the generic pod produce two different kinds of curvature. The simulated ceiling plane is much more smooth and fluid in nature as opposed to the floor plane which remains much more flat for functional reasons. These digital simulations however need to be translated in the material world in a manner that the nature of surface curvature attained in physical reality corresponds with the simulated one. The second layer constituting the pod is proposed to achieve this correspondence in the most economical and easily deployable manner.

The second layer would comprise of two different material systems which are applied to the ceiling and the floor individually. The ceiling plane owing to its demand for mimicking the smooth curvatures will utilize a surface layer of closely woven elastic bands. This surface can be created by means of interweaving (plain weave: A plain weave can be identified by its checkerboard-like appearance. It is also known as one-up-one-down weave or over and under pattern) elastic bands which are 20cm wide (corresponding to the grid dimension) and 3.6m long (the actual length of the pod). An interwoven elastic band surface of 3.6m sq can thus be created and attached to the steel rods of the above described ceiling mechanism (via small loops). Owing to the strong and hardwearing nature of the plain weave pattern of the surface, it can serve the demands of being stretched when external force (thrust applied via the pistons) is applied onto it but still retain its own flat state when the force is withdrawn. The precise translation of numeric data from the simulations to the actuation mechanisms can thus be subsequently mapped onto this flexible surface layer for materializing the sinusoidal curvatures of the ceiling plane.

The floor plane on the other hand owing to its demands for supporting load and serving functional purposes adopts a different strategy for developing the surface layer. For the floor plane a combination of wooden planks woven together with elastic bands is proposed. The wooden planks in the case of the floor planes will serve as a stable platform which is attached to the scissor jacks mechanism mentioned earlier. The plank dimensions in the case of the floor are derived from the subdivision patterns of the floor area. The planks are thus directly positioned above each scissor jack in a precise fashion so that the completed floor pattern is free of any gaps and can serve as a load bearing stable platform. Each plank, in-turn is proposed to be connected to its neighbouring plank (in all four directions) with elastic bands. However as the actuations induced by the underlying scissor truss mechanism could vary the amount of elevation per plank (from 0 to 1.5 m), the elastic bands need to cater to these variations in a manner which allows them to rewind themselves after being stretched (in order to avoid being entangled once the scissor jacks return to their normal position). A solution is proposed by means of deploying a device similar to a chord re-winder (used in conventional vacuum cleaners for winding up electric chord) containing a reel around which the elastic band of a maximum length of 1m can be wound and stored.

This assembly which includes a base, a reel, a spring element and a brake mechanism can be mounted in a slot carved within the four edges of a typical floor plank.

The following definition of a typical cord re-winder device United States Patent 6349808, is provided for better understanding the role of such a re-winding mechanism: *The reel is rotatably mounted to the base and is operative to rotate an axis of rotation in a first direction and second direction opposite the first direction. In the first direction, the flexible cord is wound about the reel for storage within the cord re-winder device. In the second direction, the flexible cord is dispensed from the cord re-winder device. The spring element is connected to and between the base and the reel and is operative to apply a winding force to the reel. The brake mechanism is mounted to the base and is operative to move to and between a reel engaged position and a reel disengaged position. In the reel engaged position, the brake mechanism contacts the reel preventing the rotation of the reel in the first direction while permitting rotation of the reel in the second direction. In the reel disengaged position, the brake mechanism is disengaged from contact with the reel to permit the reel to automatically rotate in the first direction as a result of the winding force. The cord re-winder device is especially useful when used in a horizontal orientation.*

An alternative for replacing the flexible cord with flexible elastic bands would work efficiently for the aforementioned purpose hence enabling one to attain physical surface manipulations akin to the digital simulations generated via the Java code. The difference in arrangement of elastic bands in the floor system as opposed to the ceiling system provides much lesser curvature due to the manner in which the elastic bands are positioned. A composite surface layer which possesses load bearing capacity as well as flexibility (without resulting in the otherwise unavoidable occurrence of gaps in between the planks, when changes in elevation would occur) can thus be materialized.

The above mentioned surfaces as well as mechanical layers formulating the generic pod would also need an appropriate skin to act as the final finishing layer of the generic pod. This skin and the speculated performance aspects of it are further elaborated upon in the following section.

c. Layer 03: A synthetic fibre skin which is extremely elastic in nature and much more durable than rubber conventionally known by the brand name Lycra, is proposed as the finishing skin for the generic pod. This finishing layer is specifically proposed due to the following characteristics it exhibits:

- can be stretched over 600% without breaking
- able to be stretched repetitively and still recover original length
- lightweight
- abrasion resistant
- poor strength, but stronger and more durable than rubber
- soft, smooth, and supple
- resistant to body oils, perspiration, lotions, and detergents
- no static or pilling problem

The above mentioned characteristics address the demands of flexibility and strength considering that the skin will undergo a maximum deviation from a normal (0.0 m) to a maximum of +1.5 m vertically (Fig 88). The skin, despite of constant stretching will be able to retain its original configuration (shape and size) and will be able to create organic curves rather than sharp edges, to provide a fluid free form like continual space.

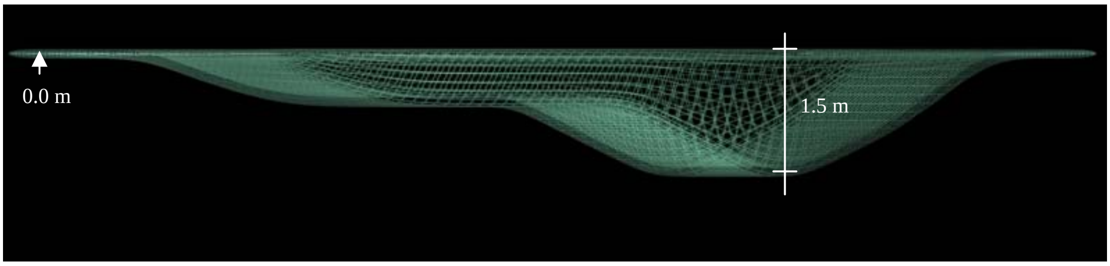


Fig.88. Smooth, organic surfaces as an outcome of the height variation with a maximum height variation of 1.5m.

The network of elastic bands in the ceiling as well as the floor provide the Lycra skin with additional structural strength while at the same time act as guiding layers for directing the manner in which curvatures should be physically materialized. The two layers (02 and 03) can eventually be woven together to form one composite material, thus enhancing the structural performance of the Lycra skin. The characteristic of being abrasion resistant as well as being resistant towards lotions and detergents makes this skin much easier to be cleaned and maintained at a regular basis.

In addition to the above mentioned properties certain other characteristics are also envisioned, which would make the proposed material much more appropriate for the generic pod. However, since no such material exists which hosts a combination of the proposed characteristics in addition to being a flexible membrane, extensive research needs to be conducted in collaboration with the Material sciences industry in-order to make this vision a reality. Two vital characteristics which would be most suited for the finishing skin are the following: The flexible skin should embody a specialized character of becoming softer/cushioned in certain (programmed) areas (Fig 89), hence generating a humane, comfortable feel of the material to the users (considering the floor component, which also includes augmenting seating components).

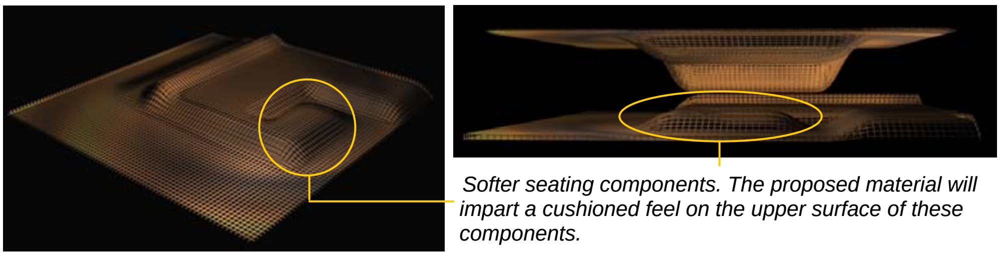


Fig.89. Floor configurations giving rise to a cushioned material property.

The proposed cushioning nature can be generated by embedding self inflating electro-polymer gel based cushions within the surface of the material (or attached between the wood planks and the surface). The inflation of the gel based cushions can be automated by inducing a controlled electric charge to the gels as soon as the scissor jack mechanisms push the surface to a specific height (a programmed height limit suitable for seating purposes, say .45m).

In addition to the above desired character, a self induced transparency gradient manipulation for image projection or emission purposes would be highly desirable. The flexible skin could work on a technology akin to electro-chromic glass, embodying the property of attaining various degrees of transparency. This property will be specifically used for enabling clear projections onto the material's surface. A similar principle of inducing controlled amounts of electricity into specific portions (Fig. 90) of the material will help in transforming appropriate patches of the material into display screens for advertising, exhibiting and presentation purposes.

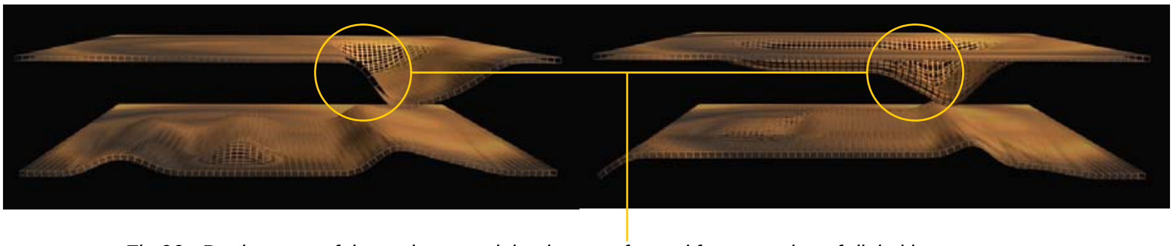


Fig 90. Portions out of the entire material to be transformed for screening of digital imagery.

A programmed value pertaining to a specific height (say 1.5m) can be fed into a control unit for transmitting the required electric current to the material, hence automating the transparency level settings in specific portions of the material. Flexible conductive threads[11] can be integrated within the skin to allow for this mild current transmission. The ability to change transparency levels can be used for various functional as well as aesthetic purposes, thus enhancing the usability aspects of the skin per say.

What could be further interesting is that the skin itself becomes light emitting; this property of the skin will allow for the material to be transformed into an ambience generator and hence could be used in a variety of settings (working environments, relaxing environments, discussion and presentation environments etc). This light emission property can correspond easily with the idea of variable transparency levels: reducing the light emitting capacity in particular areas of the material, could correspond with the property of triggering the transition from transparent to a non transparent corresponding area, hence making it appropriate for projections. However, owing to the extensive amount of research specifically in the material sciences field, required for developing such a material (which does not formulate the scope of this research work), Lycra, as the most probable solution for addressing the demands posed by the proposed finishing surface is thus proposed.

5.5.5. Typologies

After exemplifying upon the computational logics as well as the material structure of the generic pod, the final configurations which were simulated via the Java codes are presented in this section. An interactive user interface (Fig. 91) was developed for visualizing as well as changing the configuration states during the prototyping stage of the research. This interface is used for real-time simulation of a single generic pod as well as for simulating a cluster of pods assembled together to envision an office space.

As was mentioned earlier, after deploying a collaborative customization strategy, two configurations per activity; work, discussion and relaxation, a temporary (informal gathering) configuration and the empty state configuration are first simulated upon a single generic set of ceiling and floor planes for initial testing of the code and the real-time configuration changes. The testing and prototyping phase, apart from being important for checking the operation of the developed codes, is also vital for checking the amount of time involved in simulating the configurations. Once the above mentioned configurations have been successfully simulated by means of randomly selecting any of the configuration buttons provided for, within the user interface and subsequently also testing these configuration's visual display properties (Fig. 92. the configurations can be visualized as surface, wire frame or vertices. These modes of visualization can be combined with viewing the actuation mechanisms operating behind each plane and with the possibility of visualizing the heights assigned to each vertex formulating the configurations), a compilation of 12 generic pods is subsequently simulated.

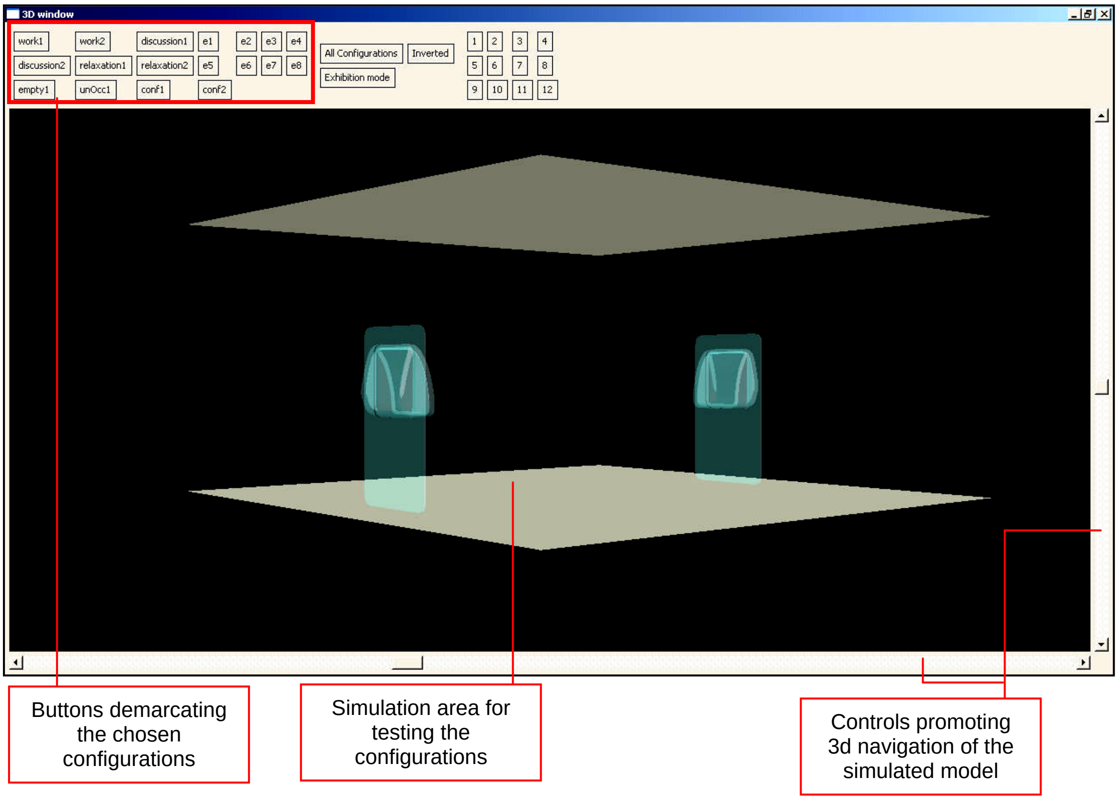


Fig 91.Interface developed for running simulations of various configurations of the generic pod.

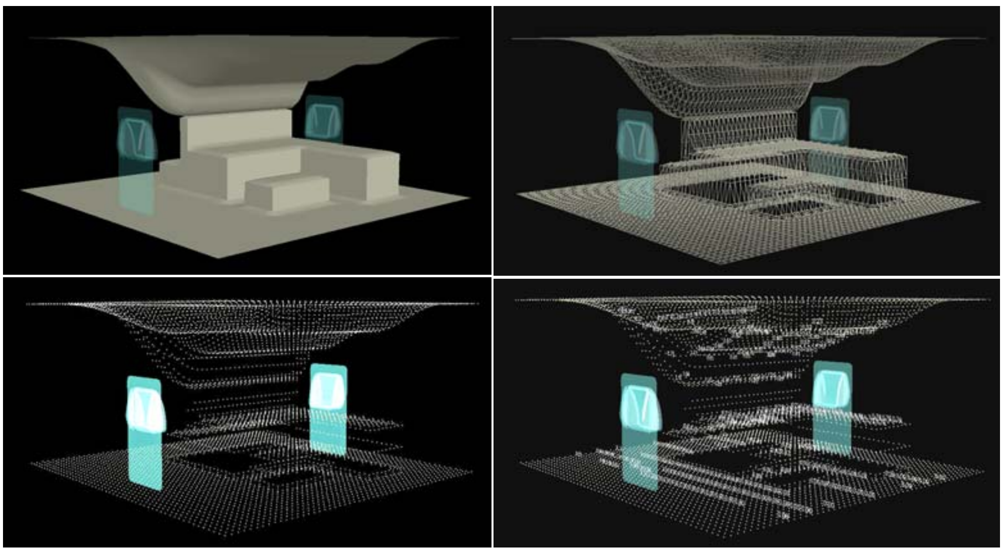
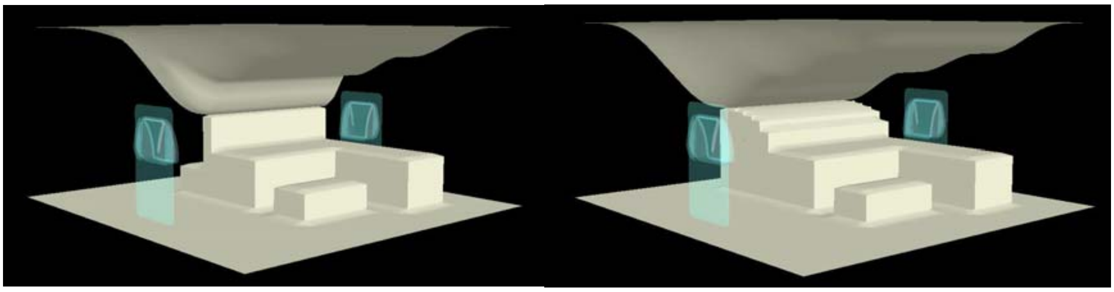


Fig 92.Different modes of visualization: surface, wire frame, vertices, vertex heights.

Two configurations pertaining to work, discussion and relaxation were subsequently chosen for experimental purposes. These configurations, as was described earlier are derived from the prior developed conceptual assemblages and are subsequently simulated using the automated vertex positioning java code.

a. Work: Two work configurations, which are specifically meant for individual, concentrated working, are chosen (Fig 93 W1, W2). These configurations, due to the need for privacy allow for the ceiling and the floor planes to meet at a point in-front of the elevated working surface, thus providing an enclosed alcove like feel to the user of the space. The second alternative (W2) also caters to some peculiar needs expressed by some interviewed office going people as regards their habits of keeping utilitarian objects like watches, cell phones, ID cards, important notes etc in a way that they keep a constant vigil over them while working. This demand is catered to by means of providing gradually ascending steps like planes towards the front of the work areas, thus providing the users with ample space for keeping personal belongings as and when required. The curvature in the ceiling specifically above the work surface is used for lighting purposes (self light emitting) thus providing sufficient lighting for concentrated working purposes. The two work configurations provide the users with two work surfaces which they can use according to their discretion. The power supply needed for laptops etc is housed within the pluggable storage unit provided on either sides of the work area, the role of this specially designed unit will be explained in detail in subsequent sections. The basic provision of this pluggable unit on either side is due to the possibility provided to the employees for completely reversing the orientation in which they would prefer to work. This orientation provision was also derived via collaborative customization means owing to the desire expressed by office going staff as regards their opinions of sitting facing their neighbour/friends or in some cases facing away from them. The pluggable units would thus provide for the power supply requirements in either orientation and are thus positioned accordingly.



W1 W2

Fig 93.W1, W2. Work configurations with pluggable units on either side.

The configurations, including the two work configurations shown above, have an equally vital external surface augmentation. These external manipulations (height gradients and curvature variations) provide for seating as well as advertisement or display of information which could be beneficial for the office e.g. weather forecasts, breaking news, stock market status, schedule of meetings, important dates for specific events etc. The design strategy of assimilating a group of such pods thus results in rather articulated circulation zones which are enriched with seating zones as well as information dispensers, transforming the otherwise rather functional zone into a hybrid information rich informal zone. The configurations should hence be considered as multi-functional, owing to the spatial contributions it makes both towards the inner activity zone as well as the external more public zone of the office. The two work configurations specifically exhibit these qualities, with configuration a. materializing an option where one can sit on the external surface of the pod, combined with the ceiling curvature which serves for visual display, and configuration b. providing an inclined surface to be used for information display of the likes mentioned above (Fig. 94 W1, W2).

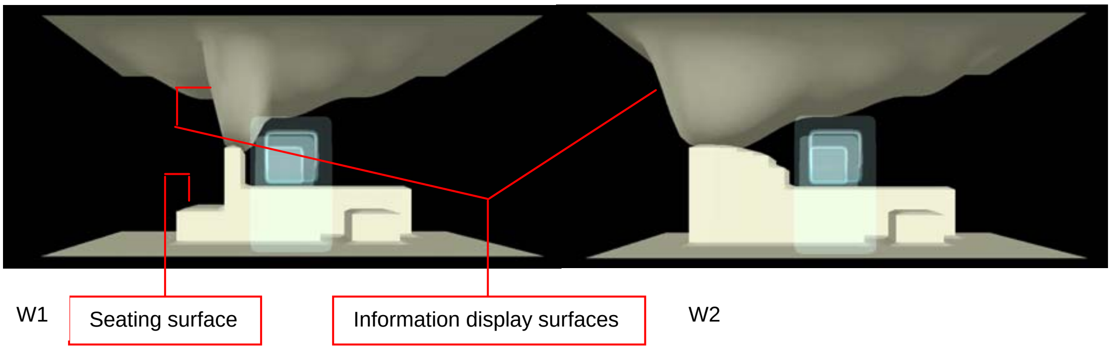


Fig 94.W1, W2. Work configurations displaying multiple usability scenarios

b. Discussion: Two separate configurations (D1, D2) supporting discussion oriented activity are also generated via the Java codes. These configurations can, like any other configurations, be interactively selected by the user as and when wanted, resulting in a simulated morphing or a physical augmentation of the ceiling and the floor planes. The discussion configurations support group oriented activities, formal or informal in nature. The collaboratively deciphered configurations serve two different purposes; D1, is specifically aimed at more informal talks and discussions which can be carried out at regular intervals and do not require specialized presentation oriented input. Activities like meeting friends or other employees, discussing over notes, sketches, exchanging ideas through lap tops, meeting visitors etc can be easily catered to via this configuration. D1 simply involves the change in elevation (in the floor plane) and the change in curvature (ceiling plane) applied to the previously shown W1 and W2 configurations. This implies that the closed alcove like setting for concentrated work is transformed into a much more inviting and open space. D1 deploys another seating area in front of the already actuated work surface, thus catering to visitors in a much more transparent manner (Fig. 95 D1).

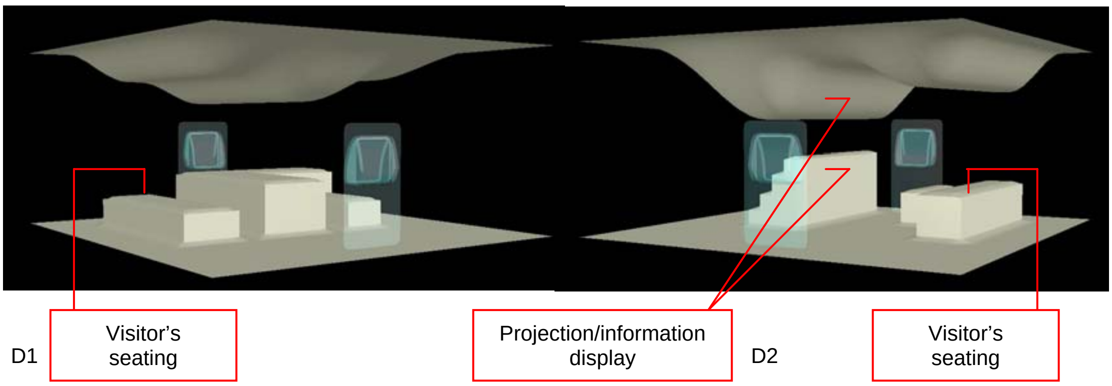


Fig 95. D1, D2. Discussion configurations.

The second discussion configuration D2 arose from concerns expressed by office employees pertaining to presentation oriented informal group discussions as opposed to formal conferencing facilities. This configuration thus provides for both floor and ceiling floor augmentations fostering digital presentations

(Fig 95. D2). A linear seating area for accommodating a group (three people) and a small work-top for keeping laptops/notes etc formulate a part of this configuration. Towards the external/circulation side, D2 provides for a stepped seating area as well as an information display possibility on the curvilinear ceiling profile (Fig. 96).

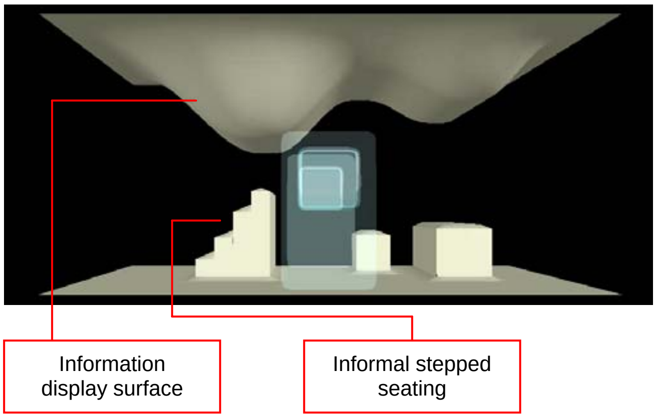


Fig 96. External seating and display properties exhibited by D2

c. Relaxation: Two relaxation configurations (R1, R2) are also developed in a similar manner via the Java based vertex interpolation code. These configurations are also a resultant of numerous studies of contemporary offices which provide spaces for self introspection and reflection to their employees. The need to take some time off from intense work and fuse it with relaxation or a rather informal/relaxed manner of reflection, was one of the strong suggestions derived during the collaborative customization phase. This strategy was also predominantly applied for the design of the Interpolis office and has been enthusiastically received by the staff. A variety of activities, individual or group based such as reading the newspaper, magazines, scribbling ideas on a personal sketch pad, sharing informal talks with a group, conceptualizing strategies, discussing client related issues etc are usually performed within such spaces. R1 (Fig, 97), one of the configurations is thus developed to cater to individual users by means of providing them with a much relaxed seating as well as an enveloping ceiling profile. The ceiling and the wall meet halfway through the height of the pod thus creating a suitable immersive digital display surface onto which content related to ongoing projects, informal but inspiring data etc can be visualized. The comfortable (comparatively wider) seating also serves as a good place for reading in a relaxed manner.

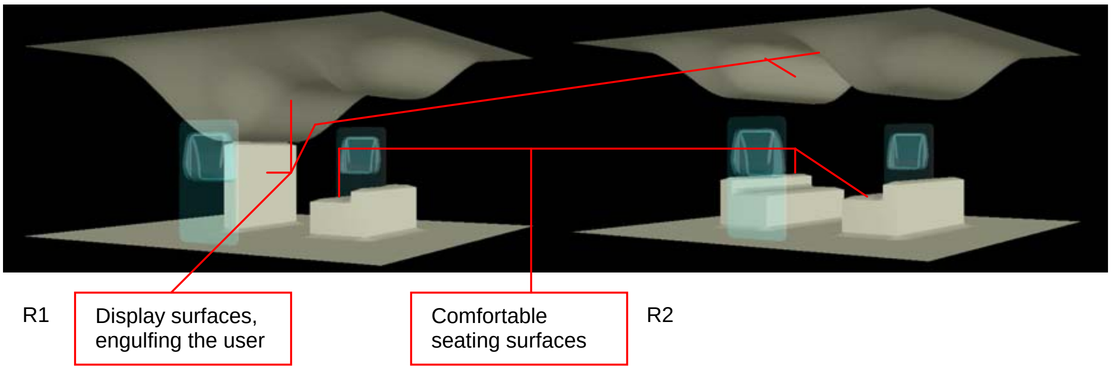


Fig 97.Relaxation configurations

Configuration R2 is designed keeping in mind group oriented interaction, where members from the same team/profession can sit together and share informal talks. It was also found by interviewing people that most vital strategies are usually developed in such informal settings, where psychologically everyone feels free in terms of expressing their own selves. Such settings can also be used for entertaining clients in order to meet them in a much more informal manner rather than heading straight for conference rooms or similar serious settings. The ceiling curvatures in this configuration provide for information/video display surfaces catering to people sitting on either side. These can be used effectively during client entertainment by means of displaying videos related to the office's accomplishments and strengths thus creating an impact on the client without taking any special steps for showing them everything but rather letting him sub-consciously register such background information.

Apart from the above mentioned configurations which can be physically augmented in real-time considering the nature of activity preferred by the user, some other configurations have also been programmed in order to meet some special demands of offices. These, as was mentioned in the Requirements section cater to activities like informal meetings (groups) hosted at places other than the employees own pods, exhibition oriented settings and conferencing facilities. These configurations are elaborated upon in the following sections.

d. Temporary space: A configuration derived from the demands put forth by typical office going employees pertaining to informal gathering nodes where they could meet people spontaneously thus encouraging a better bonding between different professions operating within the office. The configuration is also called as a temporary configuration owing to the manner in which it is assigned within a typical office setting. An automated temporary space allocation algorithm is specifically developed for this purpose, which is executed via the Java codes operating within the control system (global agent). This operational detail will be explained in a subsequent section pertaining to the Global agent's properties. However, as a basic underpinning the goal is to allocate or rather instruct the local agents to actuate this configuration in a position nearest to the most occupied neighbouring pods following one condition; a single temporary configuration will only be activated if three or more people are present within the proposed office environment.

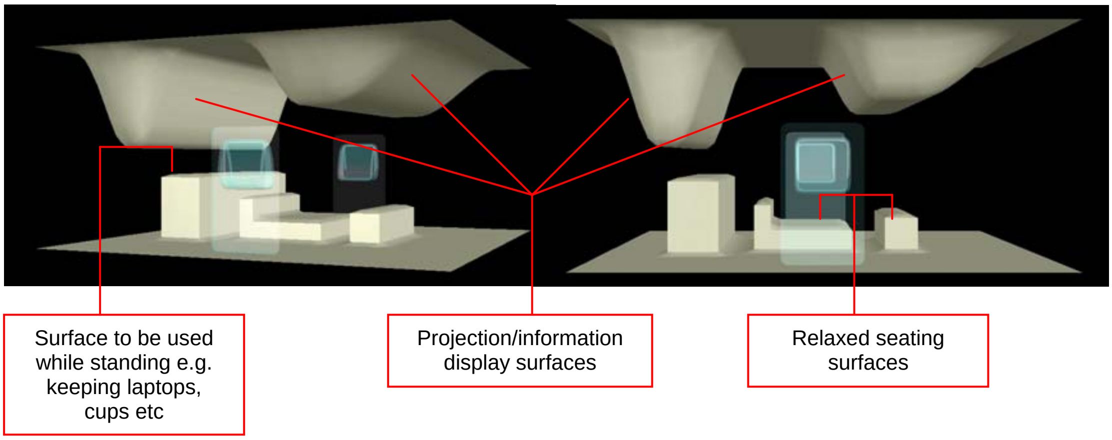


Fig 98.Views of the temporary configuration.

The temporary configuration is also termed as temporary as it is prone to transform into any other configuration e.g. during the automated space allocation sequence, if it is extremely necessary to assign a different configuration to the temporary space then it is mandatory for this new configuration to be actuated in place of the temporary configuration. The intricacies of such allocations will be explained in detail in a subsequent section concerning the global agent (5.5.6.c). The temporary configuration, owing to the collaborative customization phase embodies the following provisions: a surface (comfortably positioned for a standing person) for keeping utilitarian objects like lap tops etc for informal exchange of ideas while conversing with people, a low height relaxed seating arrangement (the back rest for this seating can also be used for sitting purposes), as well as an elevated seating surface. The ceiling surface augments into two smooth curves addressing people in both directions (seating as well as standing) thus providing for information display as well as light sources for the temporary configuration (Fig. 98). The configuration thus specifically caters to the social demands of professional employees by means of providing them with an informal setting for interaction.

e. Conference configuration: the conference configuration, owing to the serious nature of the activity it sustains and the amount of people it involves is the only configuration which occupies two pods at one time. This involves the aforementioned augmentation of the circulation zone in order to bind two pods into one activity oriented unit. The floor surface is thus accordingly sub-divided, as shown in figure 81, in order to incorporate scissor jack mechanisms underneath it.

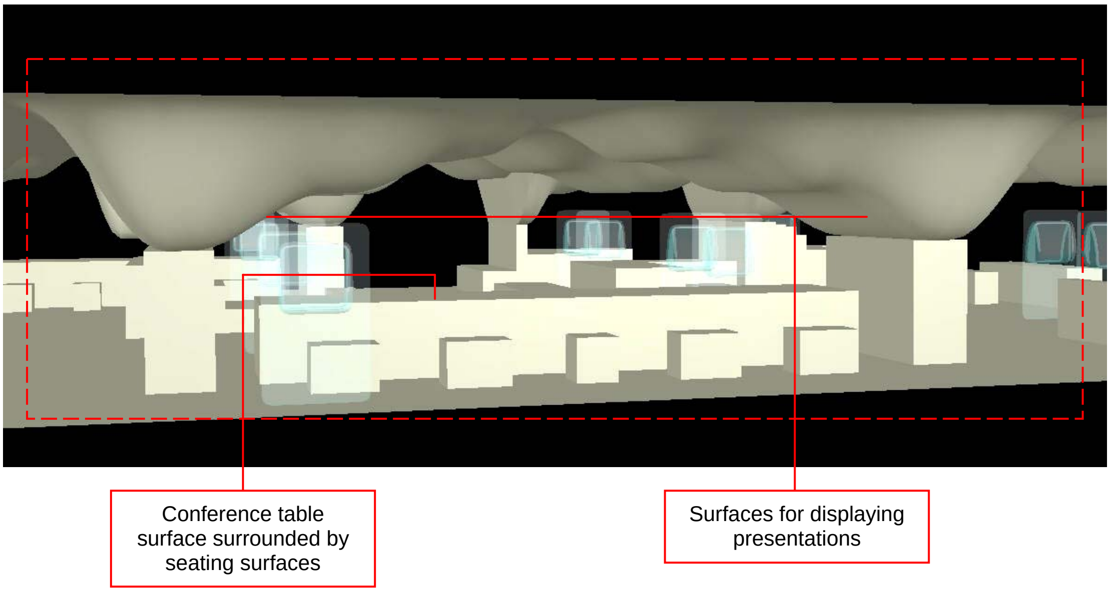


Fig 99.Conference configuration actuated as a combination of two pods.

The conference configuration (Fig 99) incorporates up to ten people to join a single conference session, which is further provided with a linear conference table surface (also incorporates portion from the circulation zone). The ceiling profile offers an engulfing feeling supporting a much more concentrated feeling while at the same time being open towards the other parts of the office. The ceiling curvatures, in turn provide one with huge display surfaces for viewing presentations etc. The ceiling is designed in a manner that apart from the portions where the presentations are displayed, the rest of the surface can provide as an efficient light source for the entire conference area, thus avoiding settings where very less light becomes a hindrance for taking notes etc. during conferencing or presentations. A special provision for entering time frames within which the conference facility needs to be actuated has been developed as a data entry option within the real-time operating on-line interface, this will be subsequently elaborated upon in the section pertaining to local agents (5.5.6.b). In addition to this, as was mentioned earlier, owing to the occupancy of two generic pods for deploying the configuration, a detailed computation routine, which specifically assesses the current occupancy status of the office environment and in real-time iteratively computes the optimal location (based on a set of rules) for the configuration to be assigned is developed as an integral routine within the global agent (control system), this will be elaborated upon in the section 5.5.6.c (global agent). However, it is thus vital to note that the conference configuration is time dependent and is assigned in an automated fashion thus allowing one to be psychologically independent instead of arranging for conference facilities (booking in advance etc).

f. Exhibition mode: the exhibition mode concerns an overall transformation of the entire office space per say. This implies that all the pods constituting the office environment will undergo a physical augmentation and will be assigned differing exhibition configurations per pod. This decision was arrived at after talking to various office managers who expressed the desire for exhibiting the office's achievements at least two to three times a year to the general masses as well as prospective clients. What is also interesting is the possibility of renting the entire office space after office working hours in order to gain economic benefits as well as allow for multiple usability of the space, which would otherwise be unused. A set of eight pre-defined configurations (Fig 100) formulating the exhibition mode are thus generated for the purpose of this research work.

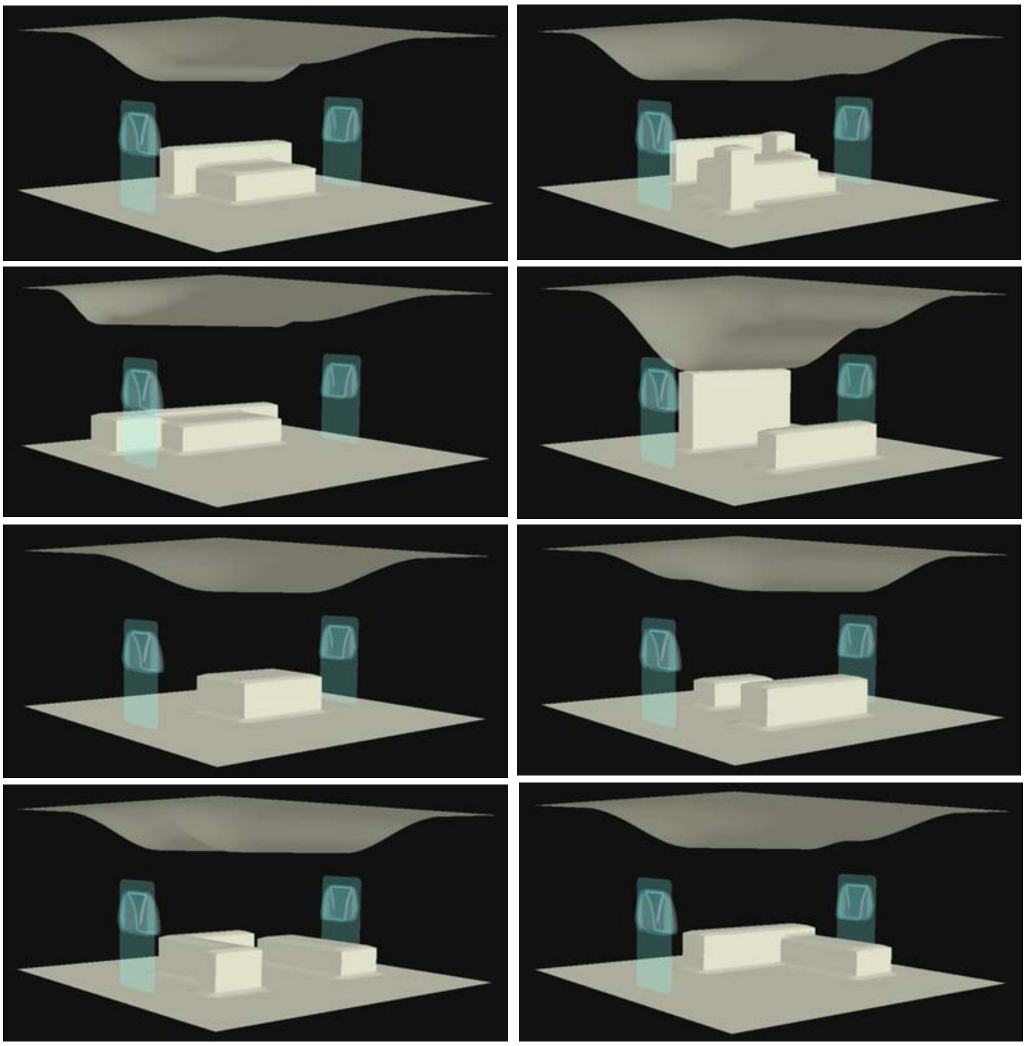


Fig 100.Exhibition configurations illustrating different exhibiting and display configurations.

These are specifically deployed on-to the entire office (consisting of 12 generic pods clubbed together), with some repeating themselves. The exhibition mode, similar to the conference mode works on the basis of time, and thus utilises the data input means provided within the interface. The different exhibition configurations are derived keeping in mind the possibilities for exhibiting models, reports, pictures etc clubbed with the possibility of displaying videos as well as slide shows etc on the ceiling surface. The pluggable storage/touch screen devices for the case of the exhibition mode can be easily removed in accordance with the arrangement, however they can also prove very useful in cases where exhibition configurations need to be modified via the touch screen interface which it hosts. The possibility of converting an exhibition configuration into, say for instance a work configuration for monitoring the exhibition can easily be performed via the pluggable unit's interface thus making the entire office space extremely flexible and adaptable in nature (Fig. 101). The automated re-configuration of an entire office environment is extremely helpful in saving on extra costs incurred for re-arranging the entire office or shifting furniture etc. thus proving the interactive system's easy to operate and economical nature.

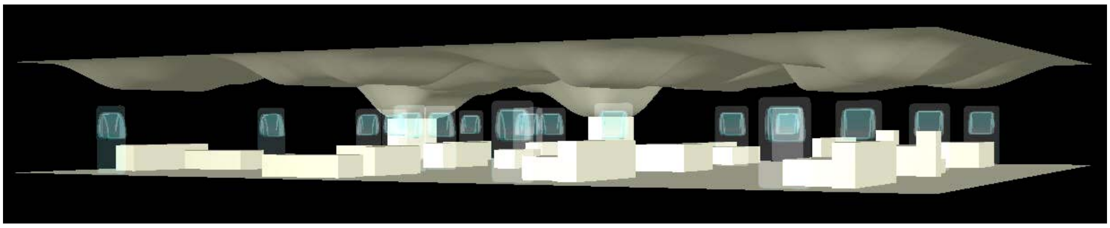


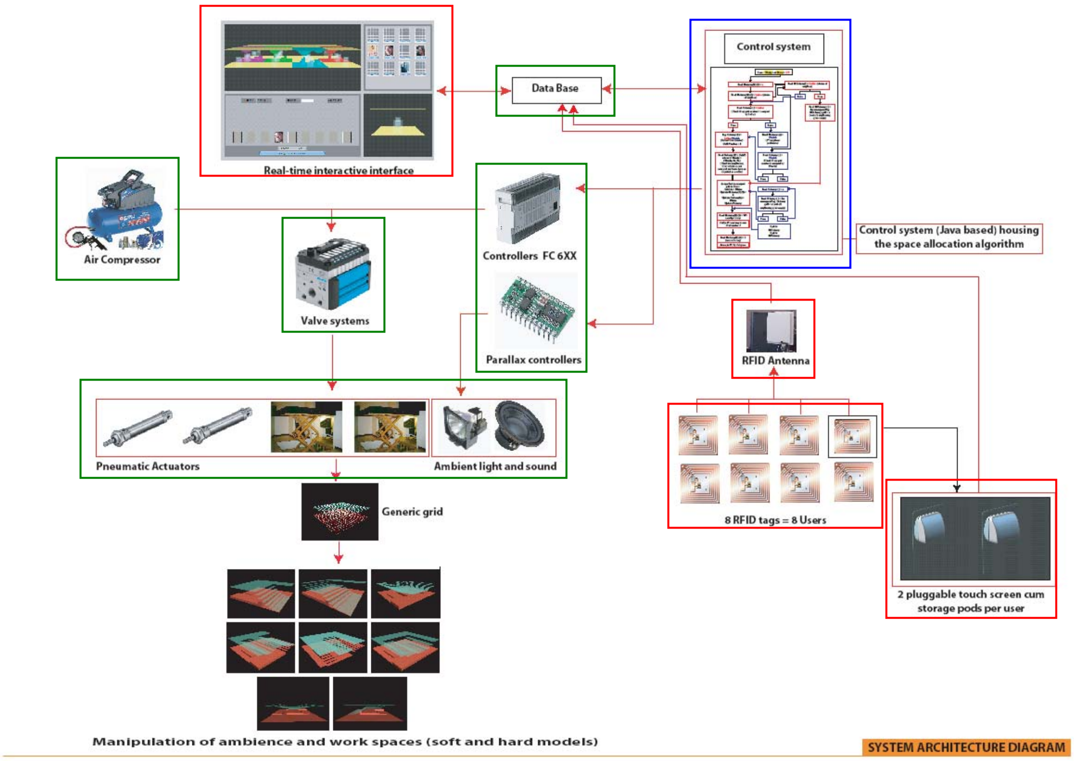
Fig 101.Exhibition configurations applied to the entire office.

The strategy for combining different typologies of customization has thus proven to be extremely valuable in delivering customer-unique value thus emphasizing upon a user centric design development process. The typologies thus owe their individual materialization to the following; the collaborative strategy which builds upon active user participation by means of various interviews and brain storming sessions, the adaptive strategy which harnesses the results attained from the customization phase and embeds it within one singular product (the generic pod) by harnessing technological means, and finally highlights/enriches the product derived from the adaptive strategy using cosmetic customization strategies.

5.5.6. Designing Interactions

After exemplifying upon the manner in which the generic pod is prototyped via incorporating computational and material logistics, the following sections elaborates upon technological aspects involved in the interaction design of the pod. The interaction design phase is quintessential for developing an easy to understand manner of operating the proposed interactive system. Special consideration, owing to the user centric nature of the research, is given towards developing a communicable interface as a front end to the entire system. Aspects pertaining to real-time communication of the occupancy as well as the spatial state of the office, the amount of data and the number of preferences allowed to be inputted as well as the data flow sequences operating within the entire system will be specifically elaborated upon.

The following sections will adhere to the aforementioned typologies constituting the technological counterpart: human agents, local agents and global agent, and will elaborate upon the role played by each agent in the interaction design process. The system architecture diagram (Fig. 102) is revisited, is methodically broken down in its constituent (the three agent types), the constituents are elaborated upon and eventually the diagrammed interconnections (in the system architecture diagram) are explained in detail.



Human agent ☐ *Local agent* ☐ *Global agent* ☐

Fig 102.System architecture showing the Human, Local and Global agents.

5.5.6. a. Role of Human agents

Human agents, as was mentioned earlier are directly associated with employees and visitors of the office. This association relates to tracking/identification, data input and real-time visualization of the office environment. The human agents thus play a crucial role in developing an active connectivity between humans and the interactive system in order to foster an efficient usage of the adaptive generic pods. Human agents, for the case of this research, is the term assigned to the following components: Mobile devices fitted with RFID tags, RFID antennas, Pluggable storage cum touch screen interface units and a real-time interactive user interface. These are elaborated upon in order of global/general usage by the entire staff to a local usage/specific to each user. The elaborations are thus structured in the following order: the real-time interactive user interface, the pluggable units and subsequently the mobile devices.

1. The Interface: The data input provision, which forms the crux of the proposed interaction, takes up the form of an online real-time interactive user interface and is specifically designed and prototyped for this research. The real time interactive user interface provides the users with an easy to understand and operate front end to the interactive system, which is graphical in nature and in essence prompts the users to enter personal preferences as input data for the system to process. The interface is completely developed via Java; the object oriented programming language and can be readily deployed within any office environment today. The interface as was mentioned earlier is directly linked with the database counterpart of the local agents and is thus a vital tool for communicating personal preferences per employee. It is also mandatory that the interface be made available online via the server-client relation developed through the Java code and is thus freely available for data input purposes from any location whatsoever. This possibility for accessing the interface subsequently led to decisions pertaining to the amount of data input in terms of preference options to be made available via the interface. The decisions prove useful for sustaining the interest of the user as well as support the Interface to come through as the least time intensive tool for entering user oriented personal inclinations. The interface, after iterative conceptual and wire frame design stages, eventually attains a composition in which the interface screen (which can be viewed in the full screen and normal mode) is subdivided into four sections (Fig 103); a real-time updating 3d view of the entire office (for spatial feedback), a real-time updating 2d representation of the occupancy status of the office (via images of the users present), a data entry section (graphical in nature) and a real-time updating 3d view, demonstrating the selected spatial configurations and colour preferences onto a generic pod.

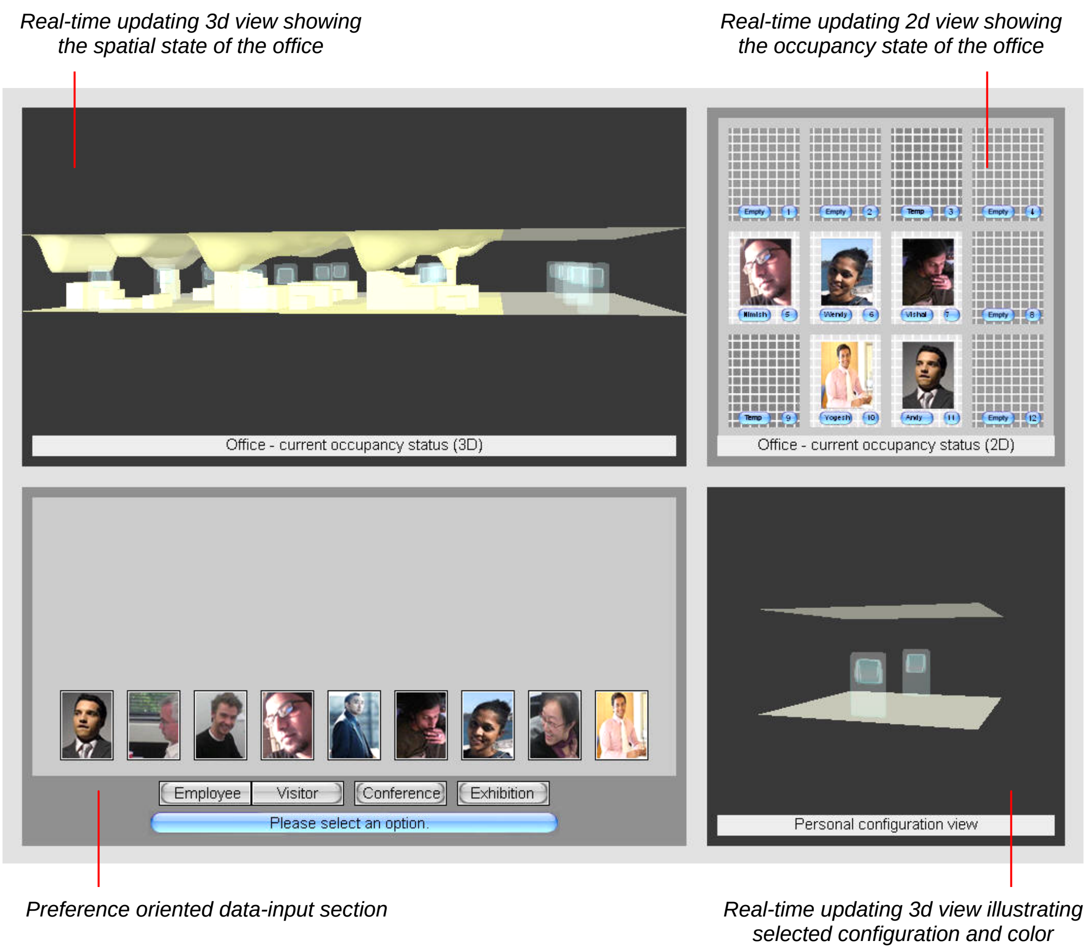
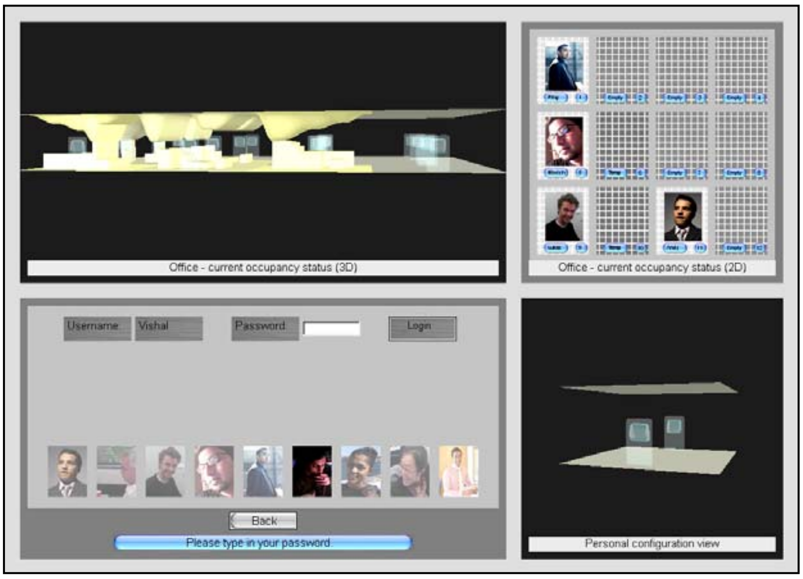


Fig 103.Real-Time interactive User interface illustrating its constituting sections

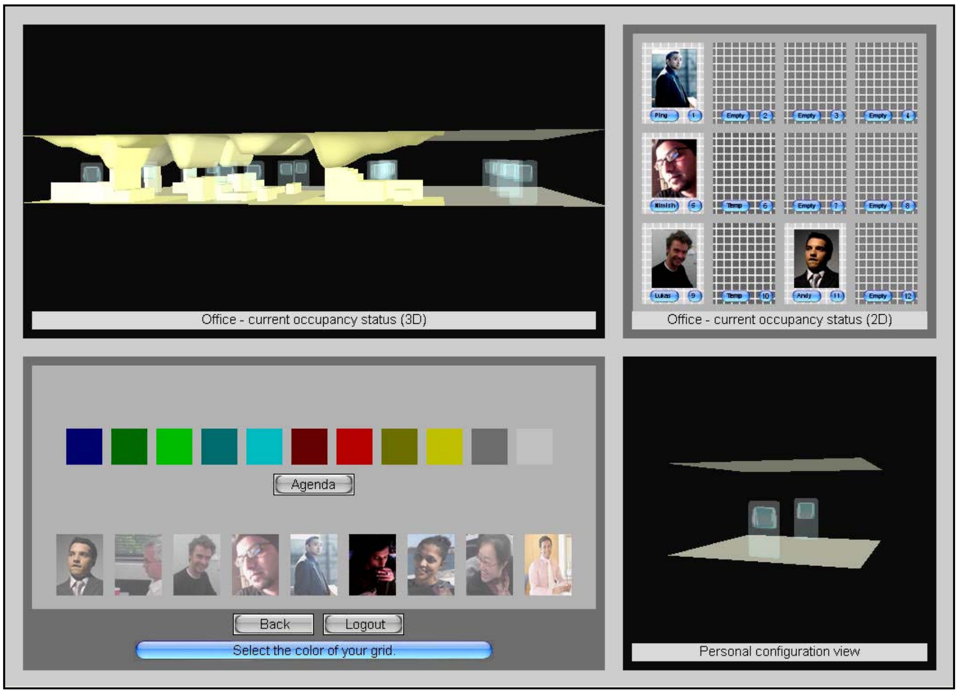
The 3d real-time updating section specifically focuses upon generating the most recent spatial state of the office, which is directly related with the employees present within the office (as each generic pod forming the composition augments itself to attain the configuration desired by the user to whom the pod is assigned). A resultant landscape which is dynamic owing to its adaptive nature is hence visualized in real-time. This 3d view is thus extremely enticing owing to its constantly changing nature. The view, apart from displaying the 3d configuration of the office also mimics the lighting conditions within the office via differing light intensities associated with the activities taking place within the office environment. However, since this view doesn't provide one with information regarding 'who' is present within the 3d space, a parallel real-time 2d visualization pertaining to each pod and its occupant is provided for. This view exhibits a grid structure which outlines the office layout (or the lay out of the pod cluster) and subsequently displays an image of the employee to whom a grid/pod has been assigned thus generating a map of the current occupants of the office. The two sections at the bottom of the interface screen are interlinked; preferences in terms of spatial configurations as well as colour, made in the data-entry section are simultaneously simulated in the section corresponding to real-time generic pod augmentations. This correspondence helps the user to visualize the manner in which his preference will materialize in reality thus making one completely aware of the final selections.

The data entry section gains paramount importance in the interface screen and illustrates the choices that one can enter concerning his/her preferences. The data entry process follows a sequential flow, which is activated once a user enters information verifying if he or she is an employee or a visitor (option visible in Fig 103 left hand bottom). For an employee, data entry sequences are only initiated after he enters the correct password, thus maintaining confidentiality pertaining to entered data and the right to modify entered data strictly to the user. The interface exhibits information in two ways to an employee depending upon if he is already in the office or if he is outside the office e.g. at home etc. In order to illustrate the difference in terms of sequences to be followed for data entry/retrieval in the above mentioned circumstances, the following section elaborates upon the two scenarios independently.
For an employee outside the office the following sequence is mandatory:

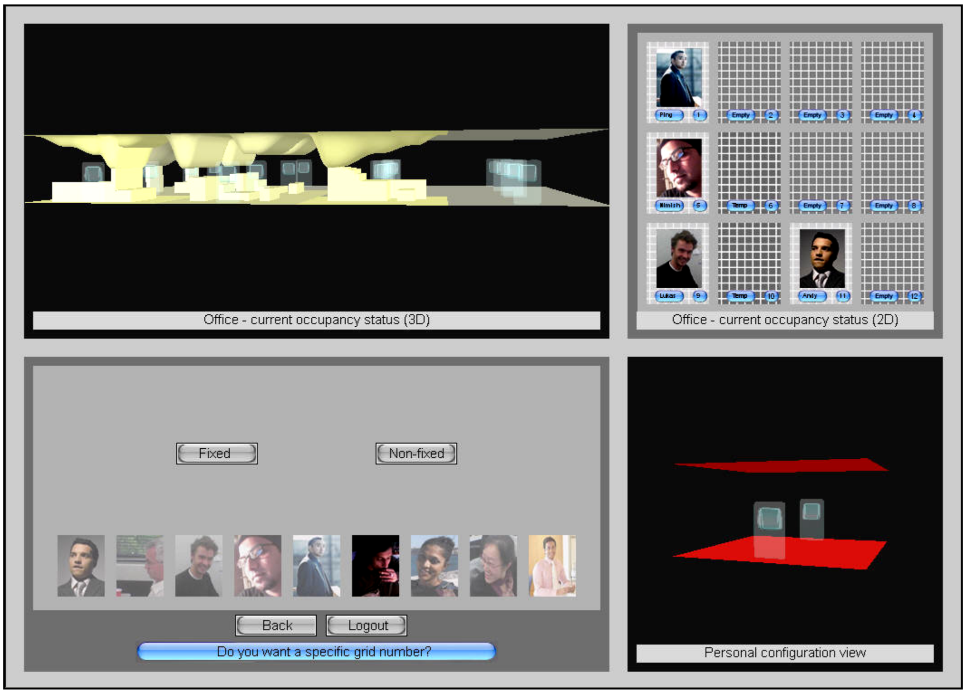
- Select if you are an employee or a visitor
- Click on the image corresponding to yourself/employee
- Enter password



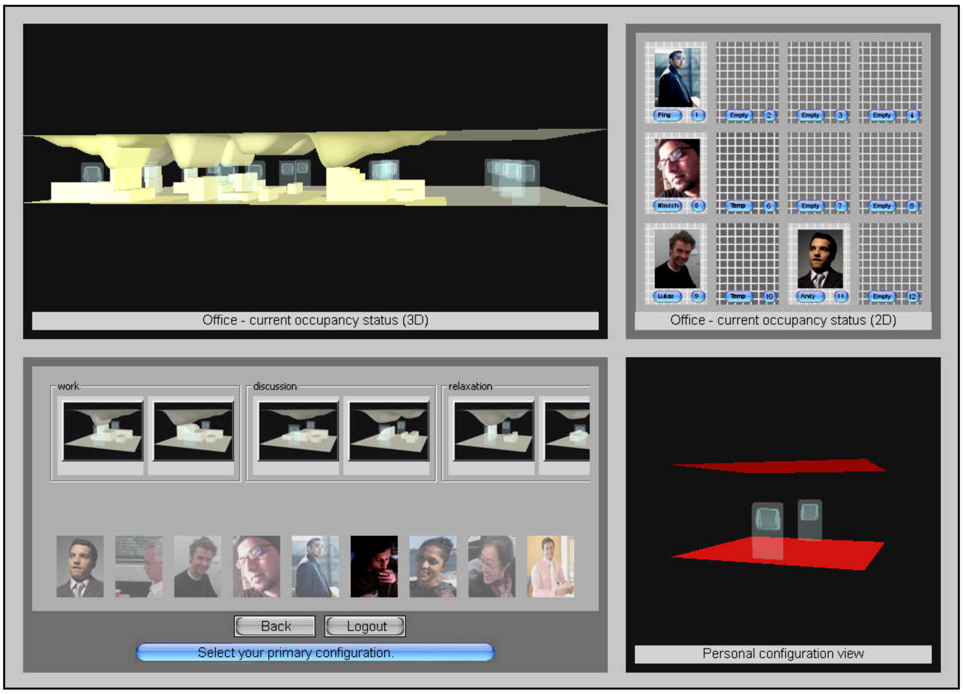
- Select a colour which you would want to be displayed for pod identification purposes (the colour is displayed on the bottom right generic pod update section)
- Click agenda button to view appointments (A choice of viewing the employees agenda is provided within the colour selection screen, thus enabling one to see his/her agenda if he is outside the office)



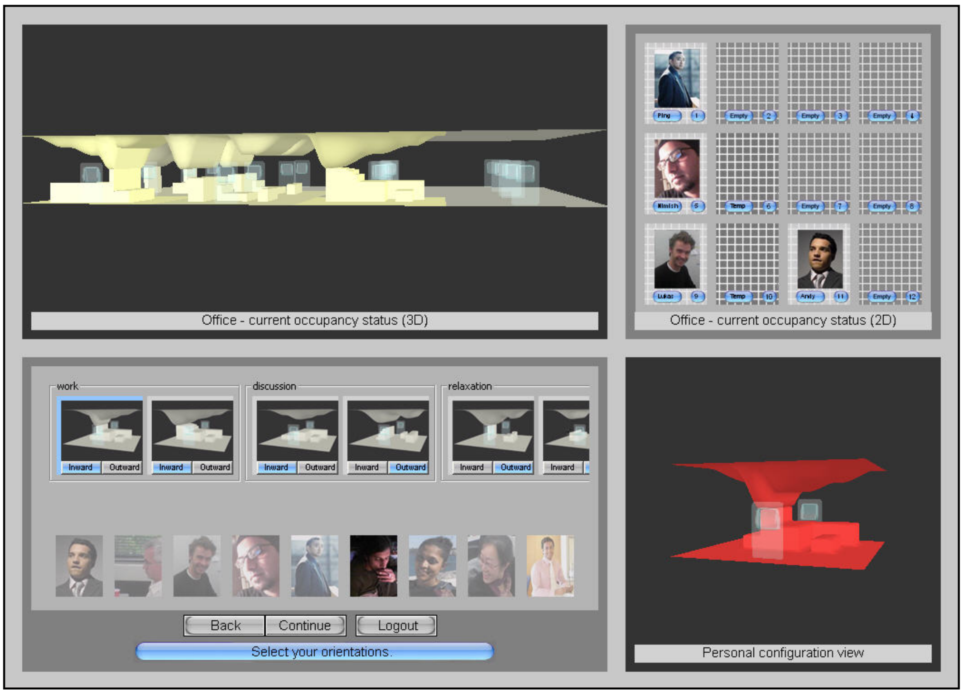
- Select if you want a fixed position or a non fixed position (for fixed position one can select a grid number from the upper right corner 2d grid display of the office layout)



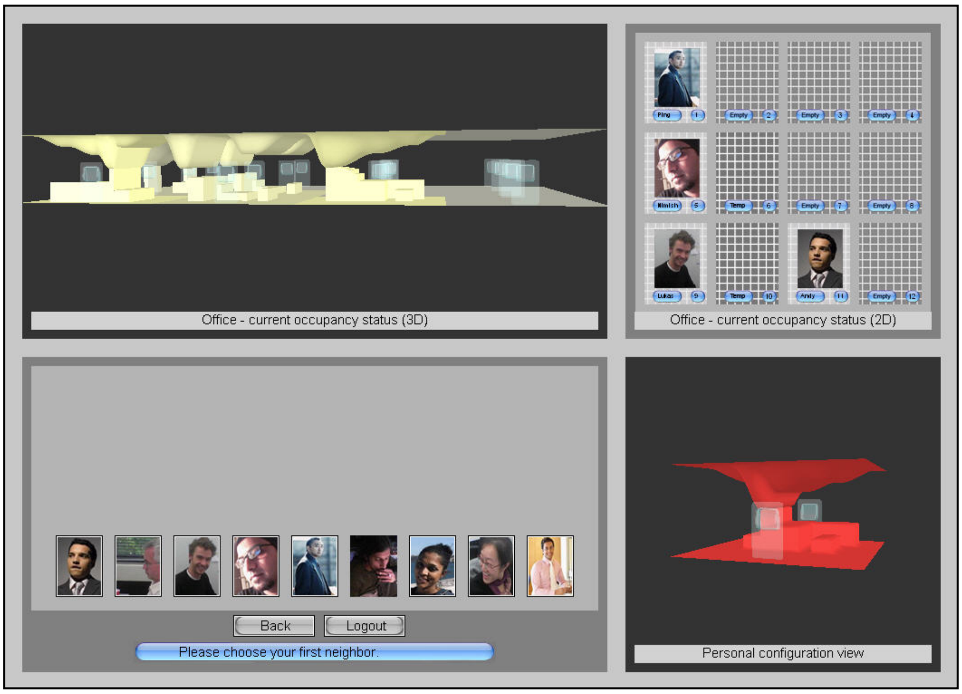
- Select your primary configuration; a primary configuration is the one which you would want to be actuated when you come to your assigned pod. Clicking on any configuration highlights the image of the selected configuration in blue (the selected configuration is simulated in the bottom right generic pod section)



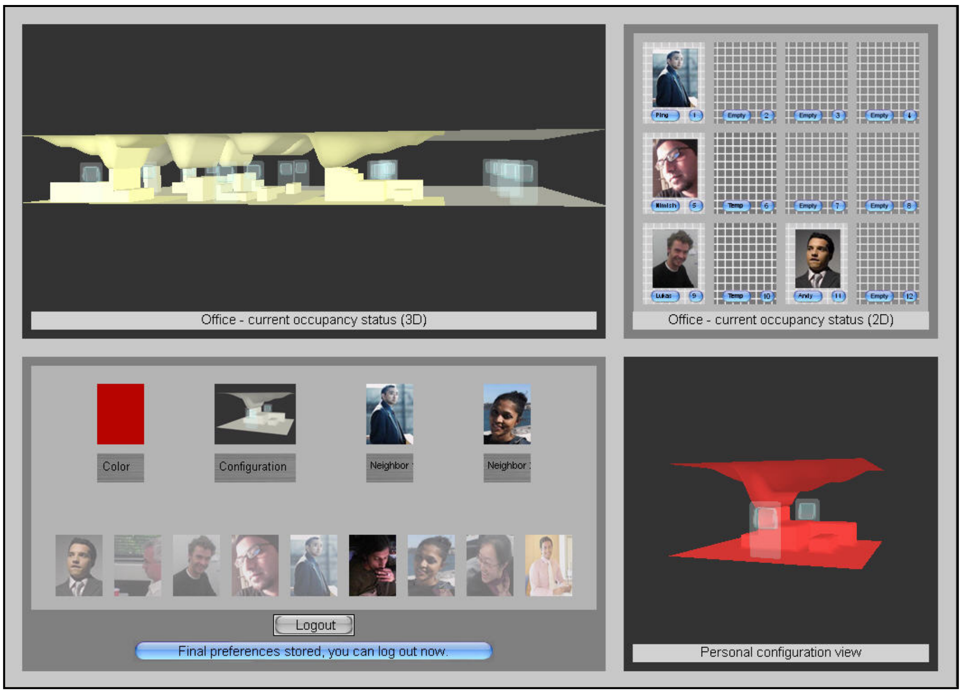
- Select your orientation; by means of selecting the inward/outward buttons situated below the selected configuration image (the selected orientation is simulated in the bottom right generic pod section)



- Select your first neighbour; from the images of the displayed employees (the first neighbour is the person with whom you would like to sit as a first choice)
- Select your second neighbour; from the images of the displayed employees (the second neighbour is the person with whom you would like to sit as a second choice)

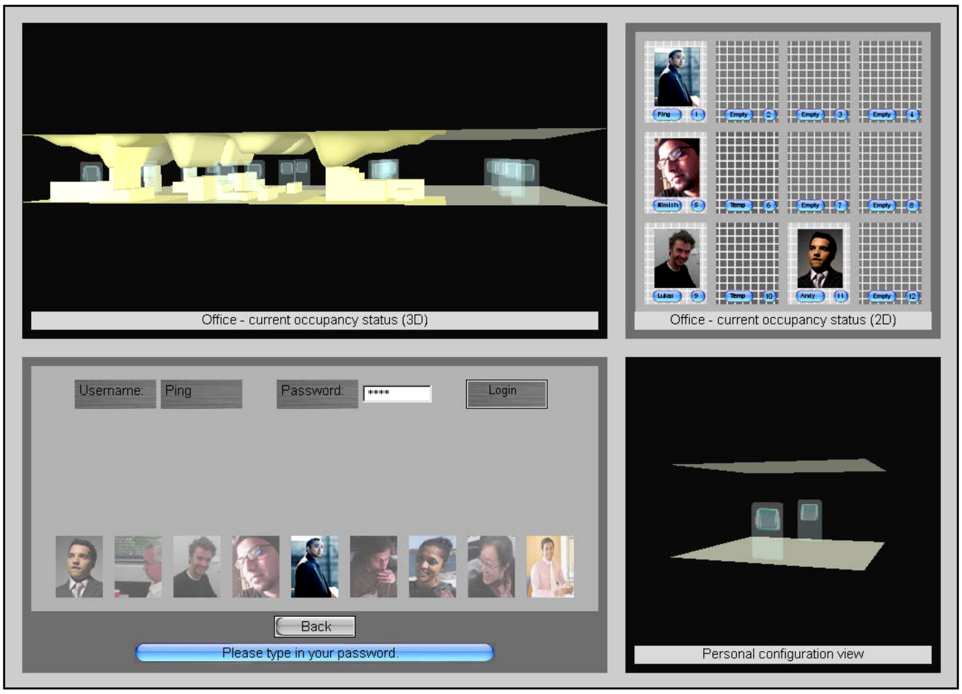


- The data entry screen displays the final selections made by you and asks you to log out.

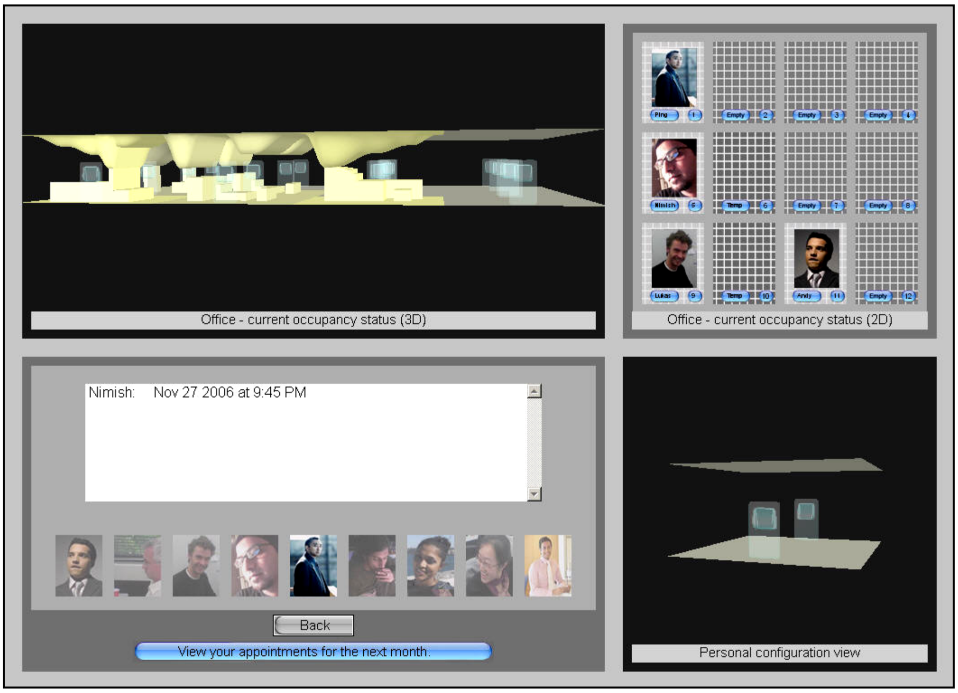


For an employee inside the office the following sequence is mandatory:

- Select if you are an employee or a visitor
- Click on the image corresponding to yourself/employee
- Enter password



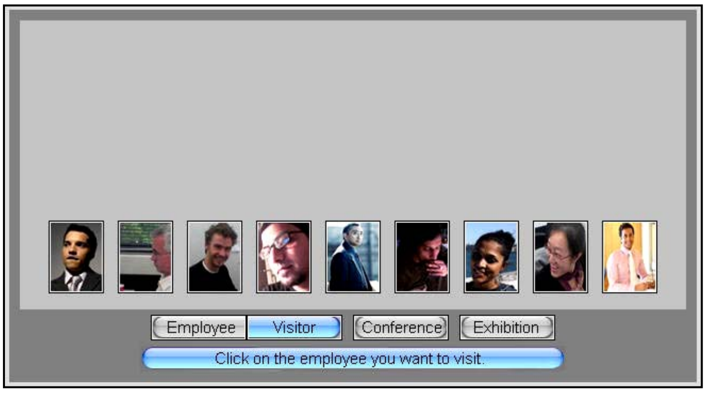
- A screen showing the employee's agenda appears in the data entry section



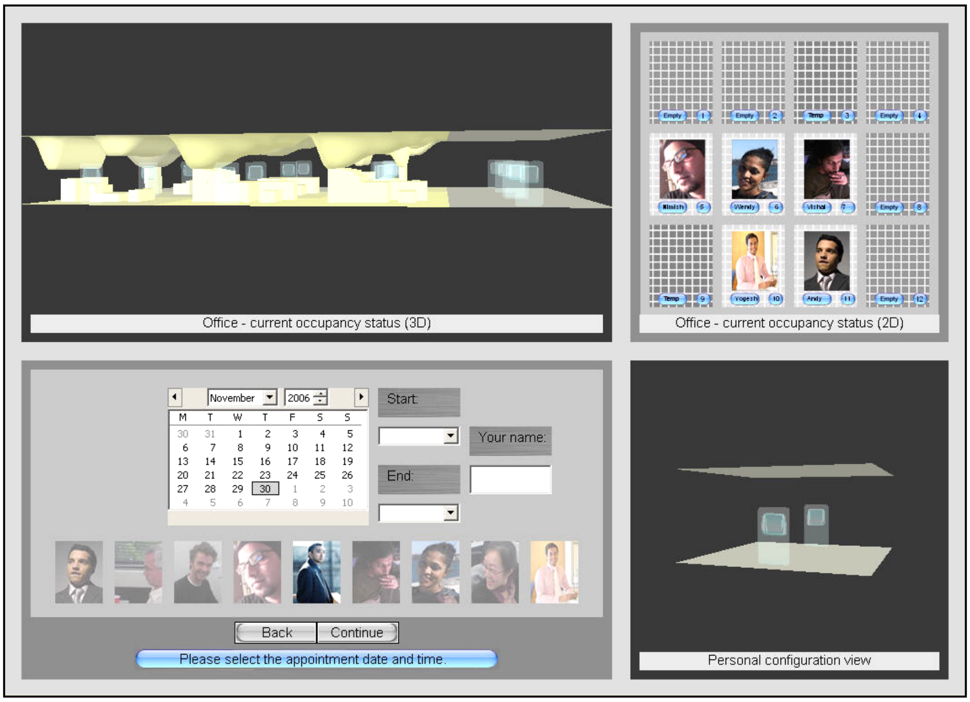
The interface, as is elaborated in the above screen-shots and the sequential mode of data entry presents a rather simplified manner of entering data while limiting the amount of preferences to be entered per user. The preference options were also derived via the collaborative customization strategy by engaging employees in discussions about what they would or usually prefer if they are provided with an opportunity to be assigned a space within office environments.

Apart from the employees, the interface also caters to visitors who would like to meet specific employees. A simple three step procedure allows a visitor to set up an appointment without wasting time in calling up secretaries for looking up agendas of the corresponding employee. The employee can on the other hand, before hand, book the dates/times when he can not be free under his own name, thus leaving the visitor with options of dates and times which the employee is available for meetings.
For a typical visitor, the following sequence is applicable:

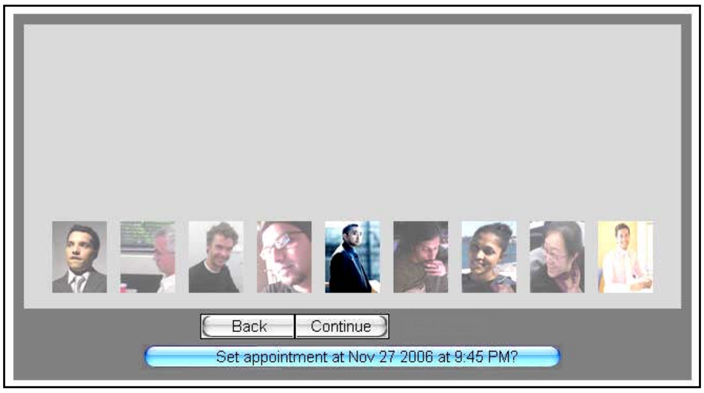
- Select if you are an employee or a visitor (when one selects the visitor option, he is prompted to select the employee he wants to visit)



- After selecting the employee, a screen with data entry pertaining to date, time and personal details needs to be appropriately filled in by the visitor



- Confirm the entered data as a final decision from the visitors end

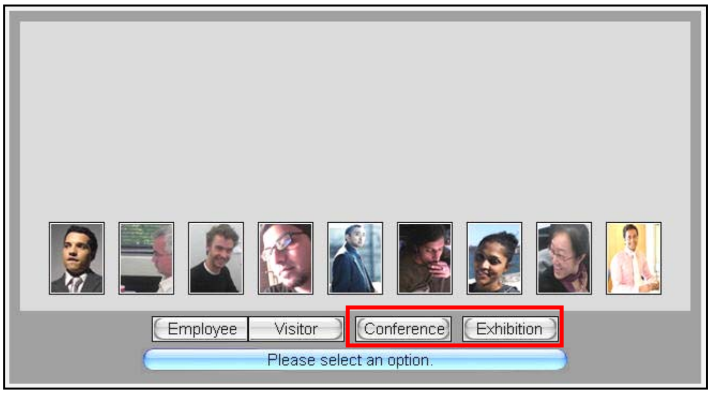


Three simple to follow steps can thus allow a visitor to enter appointment related data. This data is stored in the respective employee's agenda and as was illustrated before can be accessed by him/her either inside or outside the office via the interface thus keeping track of his/her appointments. A sound notification system is also automatically attached with the time entered by the visitor and is instrumental for informing/reminding the employee as regards his appointments in the pod allocated to him (will be explained in the local agents section).

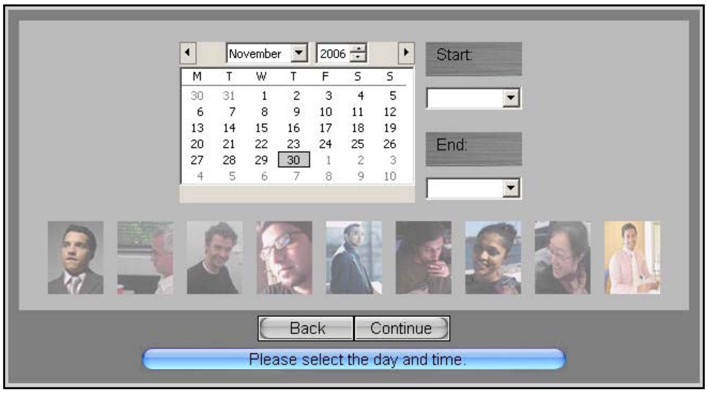
The same interface's 3d and 2d sections apart from displaying the occupied space and people oriented data, also display where temporary configurations, conference configurations and exhibition configurations have been deployed. As opposed to the automated deployment of the temporary configuration, the conference and the exhibition mode actuation completely depend upon the time frame within which these configurations are required to be allocated. The online interface also caters for such data entries by means of set sequences for entering day and time related data for the conference and exhibition mode. Data entries pertaining to these modes can be entered by anyone in the office, but is usually preferred to be done by team managers or directors.

A typical conference/exhibition mode related data entry is conducted by the following sequence:

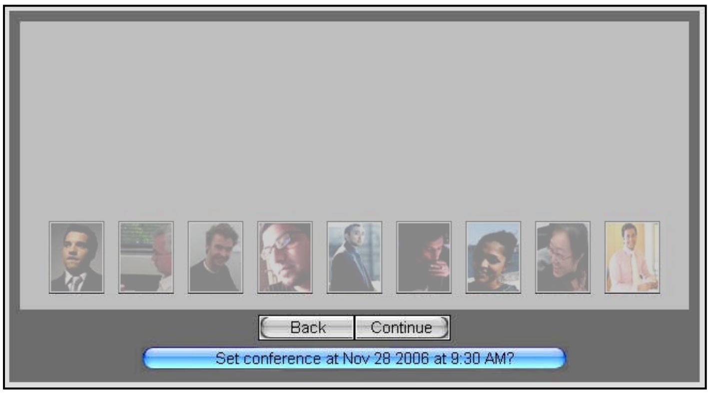
- In the interface start up screen click the conference or the exhibition button



- Enter data pertaining to date and time for the conference/exhibition to be scheduled



- Confirm the date and time for the proposed conference/exhibition



The data entered for the conference and the exhibition modes is subsequently stored within the real-time updating database (local agent) and is instructed to be deployed in accordance with the date and time frames via the control system (global agent). The conference configuration, owing to the requirement of two pods to be clustered together, is assigned on the basis of a set of internal rules which the control system iteratively follows in order to pick the optimal location for the conference. These rule sets will be elaborated upon in the section pertaining to the global agent.

2. Pluggable pods - local control oriented interface: the pluggable units contribute to the Interface category of human agents. The pluggable unit, a conceptual construct, is essentially a multi-purpose mobile furniture unit which apart from serving the purpose of a touch screen interface also serves the purpose of a storage unit. This combination was considered essential due to the dynamic nature of the space; the complex adaptive behaviour in terms of structural reconfigurations necessitates a need for a static counterpart where utilitarian everyday use objects can be stored. The unit is thus conceived as having two faces: the face oriented towards the inside of the pod serves as a storage means with shelving on the inside, the face oriented outwards bears the touch screen interface via which instant configuration changes can be initiated. The unit can be plugged in (docked) akin to a computer being docked into a docking port, at the borders of each generic pod. Every pod would thus carry two pluggable units considering the orientation preference for the configurations. The height for the pods is also decided upon in a way that the shelving/storage unit aligns with the top of any actuated working surface thus making it easily accessible for storage purposes.

Unlike the online interface illustrated above which is predominantly used by employees outside the office to input elaborate user preference, the pluggable unit's interface is specifically meant to be operated within the office. The derivations from the PACT analysis as regards the amount of information to be inputted via an interface is specifically considered during the interface design of the pluggable unit. Owing to the fact that the users would have busy schedules as well as times when they would want to alter an existing configuration to better cater to the kind of activity to be performed, the interface design for the pluggable unit is reduced to the bare minimal data entry options (Fig. 104). The data entry options in the touch screen interface are limited to configuration selection only.

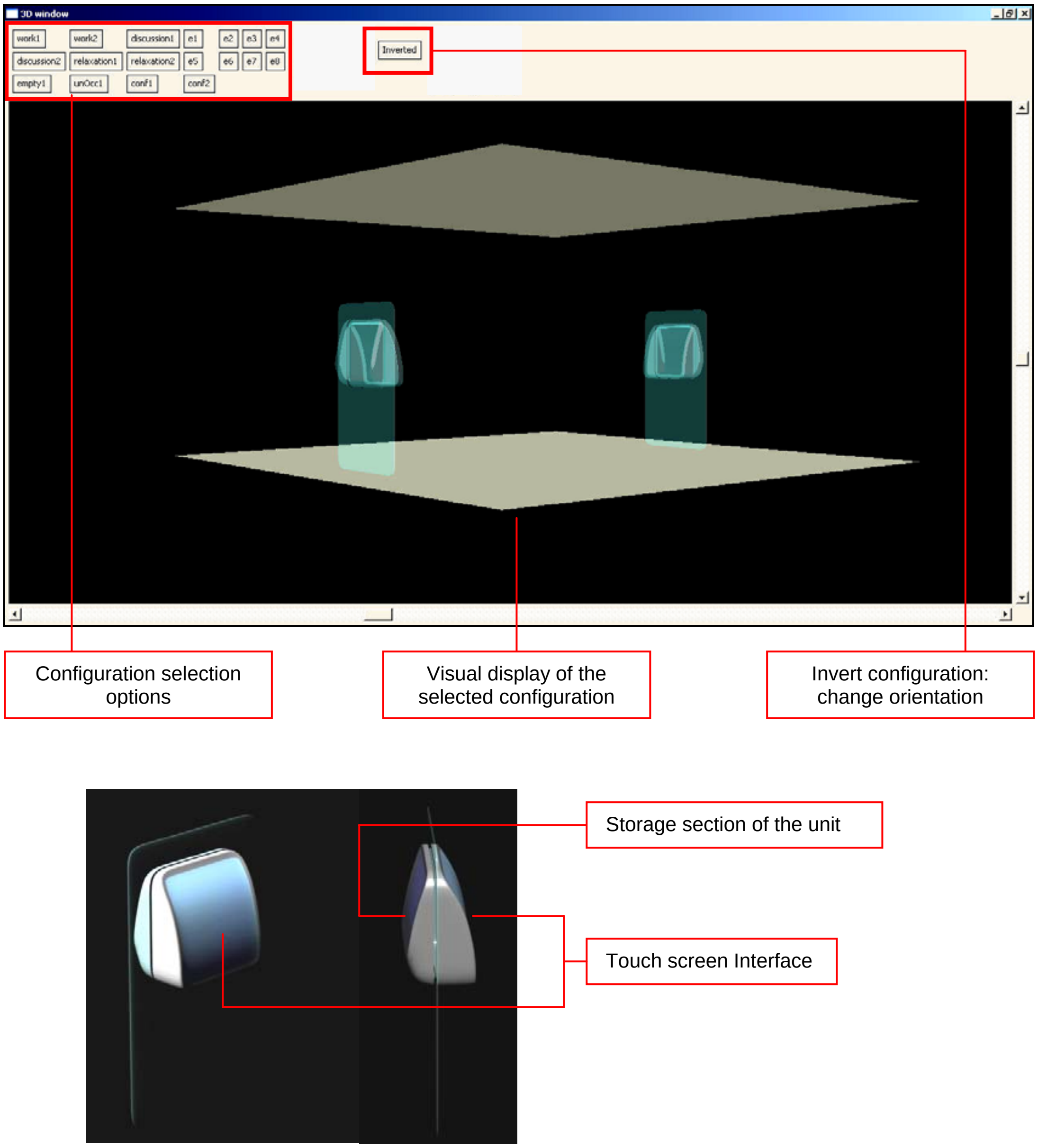


Fig 104. Top - User interface displayed on the touch screen of the pluggable pod, Bottom – The pluggable pod showing the storage and the interface sections.

An invert configuration button in the pluggable unit's interface further provides the option by which one can change the orientation of the selected configuration. The interface thus provides the user with the most essential data entry options via an easy to understand and operate front end to the system.

The pluggable unit owing to its mobile nature can be easily removed if not needed especially in cases where the exhibition mode is set as the current configuration. Pluggable units in such cases can be removed from the pods where they are not required, however a possibility of loading videos/images pertaining to the exhibits onto the touch screen section for converting it to an additional information unit for such occasions can also be provided for.

3. RFID tags: the third category of Human agents, rather than acting as a tangible data input medium, is intrinsically linked with the employees of the office. This category specifically deals with radio frequency identification, an automatic identification method which relies on storing and remotely retrieving data using devices called RFID tags. This radio frequency identification tags as the name suggests is specifically used for ubiquitously tracking the position of employees in real-time. A passive RFID tag (Fig 99) is specifically used as they do not need any internal power supply thus enabling them to be made in small sizes which can be easily embedded into a variety of things, in the case of this research, a mobile device.

Turning an everyday utilitarian device into a ubiquitous traceable entity without the need for expensive tracking devices can thus be easily attained. A RFID reader (Fig 105) can be positioned at the entrance of the office in order to track the RFID tags/mobile devices/employees. The minute electrical current induced in the antenna by the incoming radio frequency signal (given out by the reader) provides just enough power for the CMOS integrated circuit in the tag to power up and transmit a response. The response could be in the form of a digit which in an abstract manner denotes the employee. This digit, once read by the RFID reader is translated as a tick mark (connotation) to an activity column corresponding to each user in the real-time updating database (local agent), which eventually serves as the basis for triggering computational processes for preference oriented space allocation via the control system (global agent). An extremely simple and efficient means of communicating the presence of each employee in the vicinity of the office is thus instrumented.

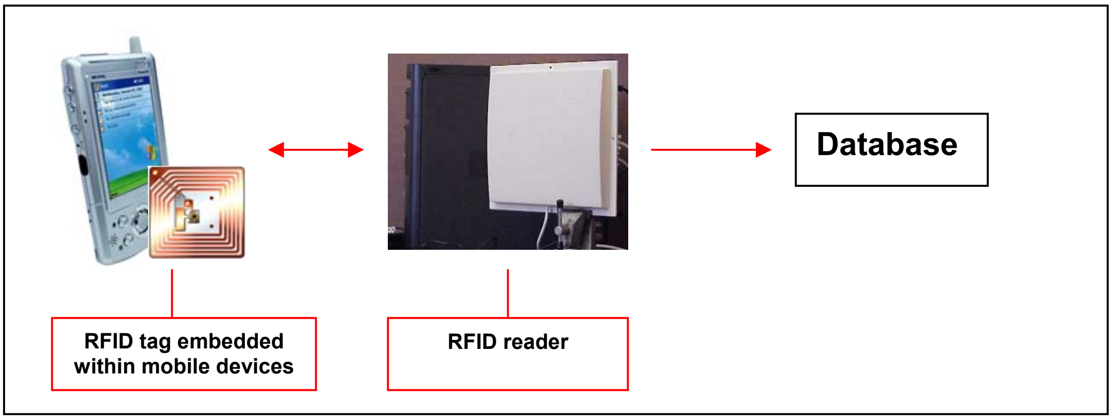


Fig 105. Diagram showing the data flow between the RFID tags, the RFID reader and the Database

The tracking enabled via the RFID tag embedded mobile device only serves the purpose of peripheral tracking (global level) which is eventually translated into the following via the control system: automated space allocation, activating the preferred colour light per user (for visual identification). At a local level though (for identifying the employee's entering the allocated pod), another category of identification oriented Human agents: IR Sensors plays a vital role. This category of sensors is elaborated upon in the following section.

4. Infra Red Sensors: this category of human agents, specifically serves the purpose of local detection of employees of the office. The local, here is considered as a condition pertaining to the employee's entering the pods which have been allocated to them via the control system. An Infrared sensor is embedded in one edge (where the pluggable units are positioned) of the ground surface of each pod. The sensors specifically track motion related to any infrared emitting source: in this case, humans. An employee who recognizes the pod allocated to him/her via the aforementioned ambient colour lighting displayed by the pod is thus tracked via these sensors. The tracking is denoted via an update (tick mark connotation) in the database, which subsequently is mined via the control system. Once tracked via the sensors, the preferred colour based ambient lighting mode actuated via the control system, is translated into a white light of pre-defined intensity (activity based configuration dependent). These lighting modulations will be described in detail in sections elaborating upon local agents. The infrared sensing is thus closely linked with human counterparts, the key system triggers for the case of this research.

5. Keyboard combinations: the above mentioned sensors and their behaviours have already been tested via the aforementioned 'Muscle' research and design prototypes built under the author's guidance at the Hyperbody Research Group, TU Delft. However, owing to lack of funding facilities for the office prototype, key board based key combinations have been developed in order to simulate the above mentioned sensor based triggers. The numeric keys on a keyboard (1 – 9) represent the RFID sensors attached to nine individual employees of the office environment (Fig 106). The numbers correspond (in an increasing order) with the images of employees displayed in the online interface's data entry section.

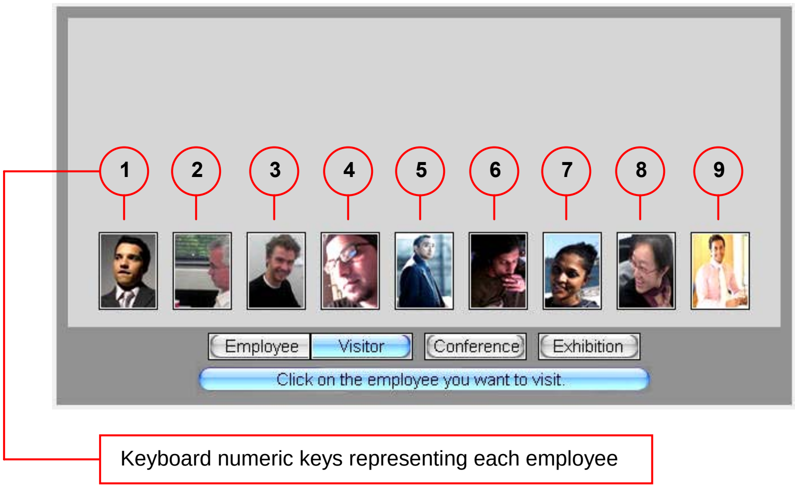


Fig 106. Diagram showing keyboard based representation per employee

A numeric key pressed on the keyboard thus signifies the detection of the corresponding employee at the entrance of the office (similar to an RFID tag being tracked via a RFID reader) and is immediately updated in the database for initiating the space allocation, ambient colour lighting and the preferred configuration actuation.

The infrared sensor's role is mimicked via pressing the alphabet keys diagonal to each numeric key e.g. for employee represented by numeric key 1, his/her entering the allocated pod is communicated via pressing key Q (diagonally positioned to key 1). The act of entering allocated pods per employee is thus represented as shown in the following table:

Employee (represented by numeric keys)	Key's denoting the corresponding employee entering the allocated pod
1	Q
2	W
3	E
4	R
5	T
6	Y
7	U
8	I
9	O

Pressing the diagonal keys, thus akin to the role of an IR sensor, result in updating the database as regards the employee's entering the pod, thus initiating a change in the ambient lighting conditions of the corresponding pod into a white light of appropriate intensity (according to the activity based configuration actuated for the employee).

The above mentioned alterations in configuration, lighting and space allocation can be viewed in real-time in the 3d and the 2d section of the aforementioned online interface of the system. The 3d section, upon pressing the numeric keys displays the allocated pod via a flashing low intensity white light followed by actuation of the user's preferred configuration and the ambient light corresponding to his/her colour preference (Fig 107). Upon pressing the diagonal alphabet key, the coloured light in the 3d section transforms to white light of varying intensities and the 2d section displays an image of the corresponding employee in the 2d grid view of the entire office (Fig 108).

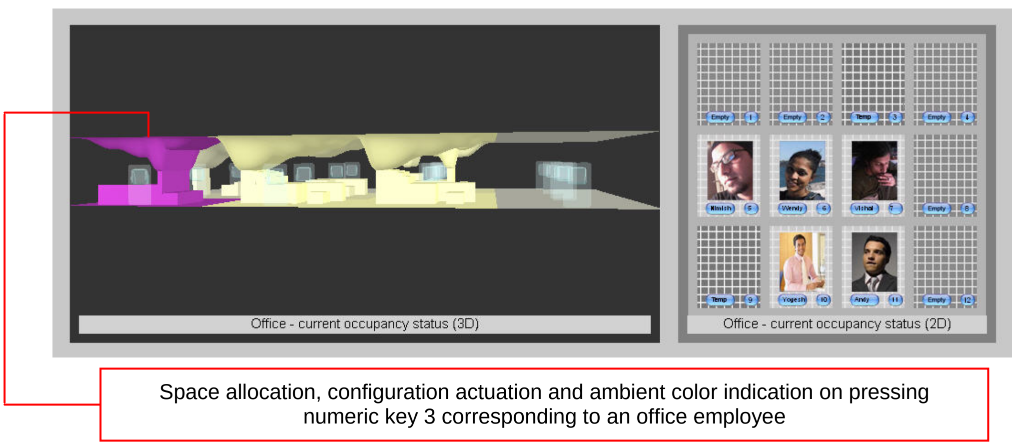


Fig 107. Resultant of a numeric key press akin to the role played by a RFID tag.

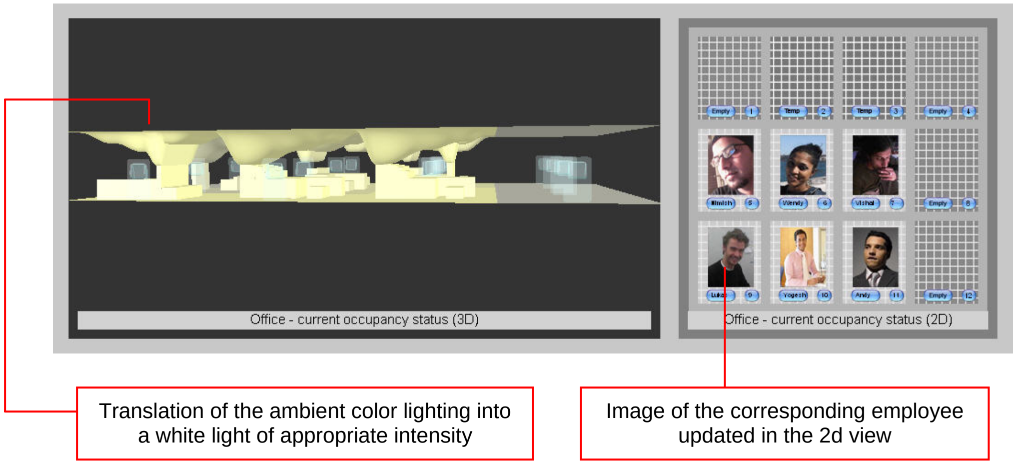


Fig 108. Resultant of the diagonal alphabet key press (corresponding to the RFID signifying numeric key) akin to the role of an infrared sensor.

The role played by the pluggable pods as regards changing a configuration once the employee is already in the office is also substituted via key combinations. For this purpose, a pre defined order for numbering the configurations is set up; the two work configurations are numbered: 1 and 2, the two discussion configurations are numbered: 3 and 4, and the two relaxation configurations are numbered 5 and 6. This pre-defined numbering is of specific importance for the key board combinations and is used in conjunction with the numbers given to each employee (1 – 9). To change the current pod configuration of an employee who is already in the office, the following sequence is thus mandatory:
C + Employee Number (1-9) + Configuration Number (1-6). C in this case denotes Change and is followed by a key press corresponding to the employee number which is subsequently followed by pressing the number corresponding to the configuration one wants to be actuated. Inverting (changing orientation) the chosen configuration can be done by pressing O followed by the employee number (1 – 9). The process thus replicates the function performed by the pluggable pods in order to assist in individual pod configuration changes in real-time.

5.5.6. b. The role of Local Agents

A local agent, for the case of this research is the term given to system components involved with localised (per pod) control, processing and storage processes. The local agent domain thus engulfs micro-controllers, actuators, lighting and sound related hardware components. Another vital component which is termed under this category is the database. Though operating as a central data store in the developed software, the inherent nature of the database of serving as a data store, registering the local state (occupancy, configuration, actuation, ambient colour, lighting level and sound initiation) per pod allows it to be clubbed under the local agent's domain.

Local agents as was mentioned earlier are highly interdependent upon the human agent's sensing and data input processes and the global agent's processed output/instructions in order to be activated. A looped interdependency scenario (as shown in the system architecture diagram) on the basis of which the generic pod's behaviour is regulated is thus formulated. The following sections will elaborate upon the above mentioned local agents by means of categorizing them in accordance with the behaviour they depict.

1. Database - real-time updating data storage and retrieval: this category of local agent specifically deals with the storage of data entered via the online interface, the pluggable pods as well as the two categories of aforementioned sensors. The database also stores data pertaining to lighting levels per configuration as well as date and time frames within which special configurations like conferencing and exhibition need to be deployed. It is quintessential that the nature of this database has to be a real-time updating one in order to update itself of any new data entry as and when entered by the employee. The database is thus developed in Microsoft Access, a relational database management system from Microsoft. This application is often used by software developers for developing application software (like the one developed for this research). One of the benefits of Microsoft Access from a programmer's perspective is its relative compatibility with SQL – queries may be viewed and edited as SQL statements. SQL (commonly expanded to Structured Query Language) is the most popular computer language used to create, modify, retrieve and manipulate data from relational database management systems. Java based SQL query protocols are thus specifically written for establishing a real-time connection enabling reading and writing of data to and from the Access database.

The database contains the following set of tables which are constantly updated via the human agent based data entry procedures:

- **Main Table** (Fig. 109): the main table comprises of data pertaining to all the final preferences selected by the employee via the online user interface (human agent). Information which awaits processing via the control system (global agent) such as the allocation of a grid if the employees preference for his space was non-fixed, is updated in real-time as soon as the employee is allocated a grid. Any subsequent data change (either via the online interface or the pluggable unit’s interface) is also updated in this table in real-time. The main table thus comprises the following set of data:
    - o user name
    - o His/her status (fixed or non fixed preference of space)
    - o Which grid number is he/she assigned (in case of fixed space preference, the grid number is updated immediately in the database, or else it is updated after the control system automatically allocates a gird number to the employee)
    - o Configuration (the preferred configuration selected by the employee, this is updated in case he/she changes the configuration via the pluggable units)
    - o Orientation (pertaining to all configurations: work, discussion and relaxation are updated as and when changed by the employee via the online interface or the pluggable units)
    - o Neighbours (first choice and second choice)
    - o Colour (colour selected via the online interface)

	user	status	gridnumber	configuration	orientation_work	orientation_work	orientation_discussion	orientation_discussion	orientation_relax	orientation_relax	firstneighbor	secondneighbor	color
▶	Andy	F	10	1	I	I	I	O	I	I	Nimish	Lukas	1
	Hans	NF	-1	1	I	O	O	O	O	I	Vishal	Yogesh	7
	Lukas	F	8	0	O	O	O	O	I	I	Ping	Nimish	8
	Nimish	NF	-1	4	O	I	O	O	I	I	Lukas	Wendy	5
	Ping	F	4	4	O	I	I	O	I	I	Nimish	Vishal	9
	Vishal	F	6	0	O	I	I	O	O	O	Lukas	Wendy	5
	Wendy	F	5	2	I	I	I	I	I	I	Nimish	Ping	6
	Xia	F	11	0	I	O	O	O	O	I	Hans	Ping	8
	Yogesh	NF	-1	1	I	I	I	I	I	I	Lukas	Nimish	3
*			0	0									0

Fig 109. Screenshot of the main table

- **Agenda table (Fig 110):** the agenda table caters to the data entered by visitors in order to fix meetings with employees of the office. This table is thus updated in real-time when a visitor enters the preferences put forth via the online interface. The agenda table comprises the following data:
  - o Time (regarding when the appointment starts and ends)
  - o Employee (whom the visitor wants to meet)
  - o Visitor (the name of the visitor)

time	employee	visitor

Fig 110. Screenshot of the agenda table

- **Conference table and the exhibition table (Fig. 111):** the conference and the exhibition tables specifically store data pertaining to the time frame of a proposed conference or an exhibition. Data pertaining to timings of these events is entered via the data entry section of the online interface and is immediately recorded in this table. The conference and the exhibition table thus contains the following data:
  - o Time (regarding when the conference/exhibition begins)
  - o Duration (the total amount of time the conference/exhibition configuration needs to be active)

time	duration
	0

Fig 111. Screenshot of the conference table

- **Sensor table (Fig 112):** the sensor table maps the status of the sensors (RFID and IR which are simulated via key combinations) in real time. The sensor trigger is divided into two sections; the RFID triggers are mapped as activity based tick marks (connotation for an active sensor reading) in the first section of the table, subsequent IR triggers are denoted by tick marks too but are only mapped in front of the activity section corresponding to the preferred configuration which has been actuated. These subsequent IR sensor mappings, replace the previous tick mark connotations of the RFID sensors as soon as the employee enters the allocated pod.

ID	user	configuration	activity
1	Andy		☐
2	Hans		☐
3	Lukas		☐
4	Nimish		☐
5	Ping		☐
6	Vishal		☐
7	Wendy		☐
8	Xia		☐
9	Yogesh		☐
10	Andy	1	☐
11	Andy	2	☐
12	Andy	3	☐
13	Andy	4	☐
14	Andy	5	☐
15	Andy	6	☐
16	Andy	7	☐
17	Andy	8	☐
18	Andy	9	☐
19	Andy	10	☐
20	Andy	11	☐
21	Andy	12	☐
22	Hans	1	☐
23	Hans	2	☐
24	Hans	3	☐
25	Hans	4	☐
26	Hans	5	☐
27	Hans	6	☐
28	Hans	7	☐
29	Hans	8	☐
30	Hans	9	☐
31	Hans	10	☐
32	Hans	11	☐
33	Lukas	12	☐
34	Lukas	1	☐

Fig 112. Screenshot of the sensor table

The sensor table contains the following data:

- Employee ID (the ID section is structured in the following manner: ID no. 1 – 9 represent the RFID sensors, subsequent ID's denote the IR sensor's not in terms of their physicality but in terms of denoting an employee's entering the allocated pod which inherits his preferred configuration)
- User (employee names are structured in the following manner: the names corresponding to ID no. 1 – 9 represent the employee's activity of being detected near the office entrance, subsequent ID's per employee pertain to the configuration e.g. ID 10, 11, 12 and 13 represent 2 work configurations and 2 inverted orientation work configurations etc activated for him/her).
- Configuration (represent the three main configurations work discussion and relaxation and their inverted orientation e.g. ID 10 to 21 represent 4 work, 4 discussion and 4 relaxation configurations)
- Activity (denotes the sensor status/keyboard entry per employee, activity sections corresponding to ID 1 – 9 represent RFID/keyboard counterpart triggers, subsequent ID's represent aforementioned configuration oriented IR sensor/keyboard counterpart triggers)

- **Content table (Fig 113):** the content table is a static data table which marks out the positions of the pods, which in this case are denoted as grids. The table thus contains the following data:
    - Grid number (denoted the 12 pods which are clustered together)
    - X position and Y position (denote the X and Y co-ordinates for each pod)

	gridnumber	xposition	yposition
▶	1	1	1
	2	18	1
	3	36	1
	4	54	1
	5	1	18
	6	18	18
	7	36	18
	8	54	18
	9	1	54
	10	18	54
	11	36	54
	12	54	54
*	0		

Fig 113. Screenshot of the content table

- **Configuration table (Fig 114):** the configuration table is also a static table which marks out the property of each pre-configured configuration in the system. These configurations are denoted via the following data:
    - ID (is the numeric value given to each of the 7 configurations)
    - Type (the typology of configurations)
    - Count (represents the variants each configuration has e.g. work configuration has two main configuration variants W1 and W2)
    - Main (denotes the three main category of configurations: work, discussion and relaxation)

- o Multiple and single (denote the possibility of the same configuration being actuated in different pods)
- o Light (denotes the activity dependent lighting level per configuration)

	ID	type	count	main	multiple	single	light
▶	1	empty	1	☐	☑	☑	1
	2	unOcc	1	☐	☑	☑	
	3	conf	2	☐	☑	☑	
	4	work	2	☑	☑	☑	1.3
	5	discussion	2	☑	☑	☑	1.2
	6	relaxation	2	☑	☑	☑	1.1
	7	e	8	☐	☑	☐	
*	0		0	▣	▣	▣	0

Fig 114. Screenshot of the configuration table

- **Occupancy table (Fig 115):** the occupancy table is updated in real-time with data pertaining to the pods/grids occupancy status. Each new space allocation instruction provided by the control system (global agent) is updated in this table. Data pertaining to employees who opted for fixed spatial positions via the online interface is immediately updated within this table as a constant value. The table is also updated as regards an employee's entering and leaving the office, thus constantly displaying the most updated space occupancy status of the office. The occupancy table thus contains the following:
  - o Grid number (denotes the 12 pods)
  - o Occupant (displays the name of the employee to whom the pod is allocated)

	gridnumber	occupant
▶	1	none
	2	none
	3	none
	4	none
	5	Nimish
	6	Wendy
	7	Vishal
	8	none
	9	Lukas
	10	Yogesh
	11	Andy
	12	none
*	0	

Fig 115. Screenshot of the occupancy table

- **Password table (Fig 116):** as the name suggests contains a log of the passwords entered per employee. The password table thus contains the following data:
  - o User (the employee's name)
  - o Pass (the password for the user)

	user	pass
▶	Andy	andy
	Hans	hans
	Lukas	lukas
	Nimish	nimish
	Ping	ping
	Vishal	vishal
	Wendy	wendy
	Xia	xia
	Yogesh	yogesh
*		

Fig 116. Screenshot of the password table

- **Size table (Fig 117):** the size table is a static table which denotes the ceiling and the floor surfaces as a collection of rows and columns of a 2d grid. It thus denotes these two surfaces in terms of the rows and columns

	part	rows	columns
▶	ceiling	18	18
	floor	26	18
*		0	0

Fig 117. Screenshot of the size table

The above mentioned database tables are subsequently mined via the Java code specifically written to develop a connectivity with the control system's data processing. The java code specifically includes functions for sending SQL queries to the database and enabling the java code to listen to incoming database calls. Different java code functions thus perform the following operations in order to develop a real-time interaction:

- DB package: creates a handle to access the database and establishes a connection with the interface
- DB control: develops a specific connection with the database by means of including functions to send SQL queries to the database
- DB server: listens to incoming database calls
- DB server connecting thread: is a class to start a thread for receiving incoming database calls and returning back a value

An elaboration of the code written for the database server connection thread can be seen in the figure 118 shown below.

```
import java.io.IOException;
import java.io.ObjectInputStream;
import java.io.ObjectOutputStream;
import java.net.Socket;

import calls.Call;

/**
 * Class to start a thread for receiving a database call and sending de return
 * value back.
 *
 *
 *
 */
public class DBserverConnectionThread extends Thread {
        private Socket socket = null;

        private Database db = null;

        private ObjectOutputStream out = null;

        private ObjectInputStream in = null;

        public DBserverConnectionThread(Socket socket, Database db) {
                super("DBserverConnectionThread");
                this.socket = socket;
                this.db = db;
        }

        public void run() {
                try {
                        out = new ObjectOutputStream(socket.getOutputStream());
                        in = new ObjectInputStream(socket.getInputStream());
                } catch (IOException e) {
                        message(e.getMessage());
                }
                try {
                        Call call = (Call) in.readObject();
                        Object back = call.call(db);
                        out.writeObject(back);
                        socket.close();
                } catch (IOException e) {
                        message(e.getMessage());
                } catch (ClassNotFoundException e) {
                        message(e.getMessage());
                }
        }

        private void message(String message) {

        }
}
```

Fig 118. Screenshot of the DB server connection thread java code

2. Micro-controllers – regulating the behaviour of the pods: two types of microcontrollers are proposed for physical actuation of the mechanics as well as for controlling the ambient light and sound oriented aspects of each pod. The two proposed controllers are Festo's modular electric terminal CPX which is linked directly with MPA valves and Parallax's Basic stamp 2. The two controllers would be embedded with each pod and would specifically act upon the instructions they receive from the control system (global agent). The main aim of regulating such embedded control per pod is to develop a distributed computing scenario, thus avoiding information processing overload on the global agent. The two controllers play very specific roles and thus receive specific actuation instructions from the control system (global agent). The roles played by the two controllers are elaborated upon in the following sections.

- **The CPX terminal:** is specifically developed by Festo to attain an optimal synthesis of pneumatics and electrics. The electric terminal (CPX) is modular in nature and can be easily coupled together with a highly modular valve terminal (MPA). This combination (Fig 119) provides one with a highly robust and economic solution for controlling the actuation of pneumatic actuators (connected to the MPA valves) via an integrated system comprising the electronic CPX terminal and the MPA valve system into one comprehensive unit. The CPX would be delivered information pertaining to the height variations of the vertices constituting the two surfaces (floor and ceiling) by the control system. The role of the CPX terminal would thus specifically be to relate these vertex heights to corresponding actuators and most importantly to instruct the MPA valves corresponding to these actuators to open or close for specific time intervals. The time intervals for opening or closing the valves is specifically derived from the aforementioned vertex heights thus precisely regulating the amount of air pressure (via a central air compressor) to be induced within each piston. The CPX thus via its electronics and processing functions informs its integrated pneumatics counterpart, the MPA valves to carry out the control system's instructions.

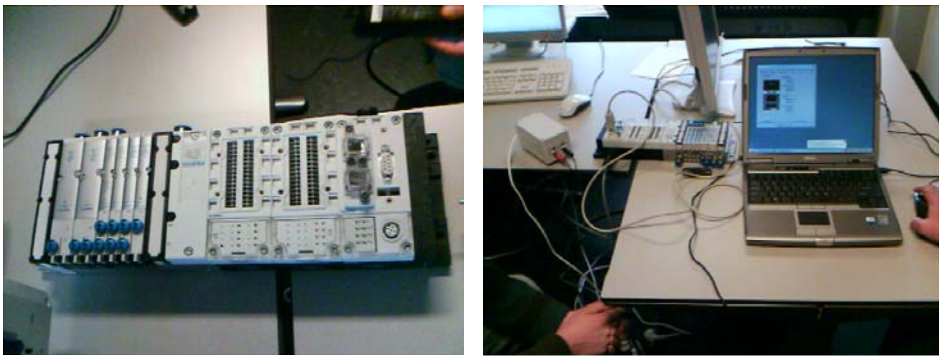


Fig 119. The CPX terminal combined with the MPA valves being tested for integrated data communication purposes together with Festo engineers.

- **The Basic stamp 2 controller (Fig 120):** the basic stamp controller is a microcontroller designed to be used in a wide array of applications it is essentially used for developing embedded systems which require some level of intelligence. The Basic stamp controller for the case of this research serves the purpose of regulating ambient lighting and sound within each pod. The Basic stamp also receives specific information pertaining to coloured lighting (the preference entered by the employee), lighting levels (pre-programmed light intensity per configuration) and information regarding sound (in the form of beeping sounds for informing an employee about appointments and meetings). The Basic stamp controller thus regulates connections with appropriate hardware such as lighting systems and multi-channel speaker systems per pod in order to support the control system's instructions. A java code specifically built within the current software can interface with the Basic stamp API in order to transmit messages from the control system (global agent) to the P Basic language which the stamp follows.

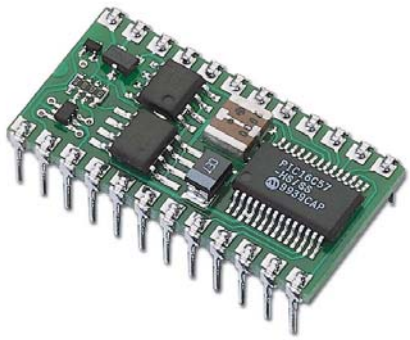


Fig 120. Basic stamp 2 controller

- **Substitutions:** as was mentioned earlier, the lack of funds for conceiving the entire office environment, lead to embedding the codes developed for the above mentioned hardware within the control system (global agent). However, the earlier exemplified muscle projects proved to be a testing ground for prototyping the aforementioned pneumatic control systems. Successful tests conducted with Festo's engineers specifically aimed at testing the translation of the control system's output pertaining to vertex heights into piston actuations by the CPX and MPA combination further assured the plausibility of the concept. Data communication pertaining to the vertex height translations into actuation simulations for this research is eventually computed internally within the control system. The control system per say thus embeds a data processing routine which communicates piston height variation as well as light and sound modulations directly to the online interface's 3d section. A scenario akin to the proposed physical operation of the pods is thus simulated in real-time. The modular nature of the java code further makes it possible to extract the data translation codes from the current application and embed them within the Festo controller as well as interface them with the Basic stamp controller.

3. Actuators – physical and ambient augmentation: this category of local agents specifically deals with structural as well as ambient augmentation of each pod constituting the office. The actuators for structural modifications are pneumatic in nature and are controlled via the aforementioned CPX terminal and MPA valve combination. The actuators are linked with the mechanics assembly per pod and are thus selected in accordance with the performance they need to deliver. These local actuating agents are of two kinds; the pneumatic muscle (developed by Festo) and the pneumatic piston (developed by Festo). Apart from these typologies of structural actuators embedded lighting systems and speakers per pod are also termed as local actuators since they specifically contribute towards ambience actuation. These local actuators are specifically controlled by the aforementioned Basic stamp 2 controllers. The above mentioned local actuators are elaborated upon in the following sections.

- **The pneumatic muscle actuators:** also known as Fluidic Muscles Type MAS is a flexible tube actuator manufactured by Festo (Fig 121). These tubes are made up of reinforcing fibres woven together in the form of a lattice structure. The muscles tend to contract 20 percent of their initial length with the induction of air pressure owing to this lattice structure, hence making it act as an actuating device for the aforementioned scissor jack mechanism embedded in the floor plane. The data array (pertaining to each fluidic muscle) calculated via the CPX controller updates in real-time with every configuration change and acts as a generic procedure for actuating these muscles as well as pneumatic cylinders (explained below).

Fig 121: Pneumatic Muscle manufactured by Festo.

- **Pneumatic pistons:** also known as Round cylinders Type DSNU manufactured by Festo (Fig 122) are utilised in the ceiling plane for augmentation purposes. The cylinders (piston rods) are attached at their ends with cylindrical rod sections, which are in-turn connected to the lycra based skin. Every configuration change instructed via the control system is translated via the CPX and MPA components resulting in a precision oriented programmed piston rod actuation, which pushes down on the flexible skin, hence creating formal augmentations. This bed of pistons is further embedded in a steel casing which incorporates all the wiring as well as the pneumatic tubes per piston.

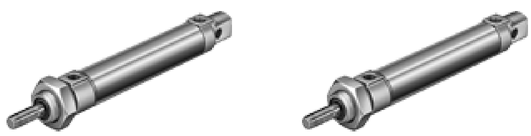


Fig 122: DSNU type cylinders manufactured by Festo.

- **Lighting system:** the proposed lighting system as mentioned earlier is controlled via the Basic stamp 2 controller. The lighting hardware in the form of a programmable luminescent tube spanning the length and the width of each pod will be embedded along the circulation pathways per pod. The ceiling surface is thus fixed at these circulation junctions (devoid of any kinetic mechanism behind it) to allow for these fixtures to be attached. Each grid of the proposed lighting hardware is subsequently controlled via the Basic stamp 2 controller which specifically regulates the hardware as regards lighting level changes. A variety of off the shelf programmable lighting controllers[12] usually used for controlling ambient lighting conditions within domestic environments can also be utilized for the proposed lighting.

An alternative solution in the form of flexible lighting surfaces can also be embarked upon. A recent product from lighting pioneer CeeLite[13] is highly compatible with the proposed flexible ceiling surface of the pod. CeeLite inc. by harnessing a revolutionary light emitting capacitor technology (LEC), in collaboration with lighting leader Osram Sylvania has recently produced flat flexible light bulbs (Fig 123). This new development is specifically apt for the proposed ceiling surface of the pod owing to its flexible nature. CeeLite panels are comprised of an LEC structure with higher quality Sylvania phosphors sandwiched between a series of electrodes. The application of AC voltage generates a changing field within the phosphors which causes the phosphors to emit light. CeeLite 7501 panels create an all new level of white for LEC panels with a whiter appearance to the naked eye.

Fig 123: CeeLite flat flexible light bulbs.

The CeeLite flexible light bulbs have the following properties which make it a viable lighting actuator for the generic pod:

- Constructed using screen printable polymer thick film compositions similar to shrink-wrapped polymer-based laminate products
- Fabricated with very environmentally friendly and degradable chemicals
- Powered by CeeLite proprietary Inverters, which convert the electrical current, either DC or AC, to the required voltage and frequency to power the panel
- Typically consume minimal quantities of electricity relative to incandescent, neon and fluorescent lighting
- Enables more vibrant graphics for true flesh tones, appetizing food images and anything printed on clear, backlit media
- Thin
- Flexible and bendable
- Uniform illumination
- No heat generation
- Lightweight
- Vibration and impact resistant
- Durable
- Can be incorporated into clothing

- Sequencing for strobing or flashing effect
- Can be powered with low voltage batteries

The Basic stamp 2 controller, used for actuating programmed lighting and ambient lighting variations can thus work in conjunction with the CeeLite inverters to precisely produce light variations corresponding to the activity driven configuration settings.

- **Sound actuators:** this category of local agents specifically caters to the production of beeping sounds via embedded speakers within each pod for a time frame of 2 to 3 seconds. The emitted beeping sounds serve as reminders for the employees and are actuated via the Basic stamp controller five minutes before a meeting is scheduled. The control system (global agent) via the built in Java routines mines the database's agenda table for deriving the aforementioned time schedule for meetings. The control system subsequently instructs/triggers the Basic stamp controller embedded in the pod corresponding to the employee (with whom the meeting has been scheduled), exactly five minutes prior to the meeting time thus actuating the set of speakers embedded within the pod to produce the beeping sounds.

- **Substitutions:** the above mentioned actuations are eventually visualized as a real-time simulation in the online interface's 3d section. The actuations concerning the Pneumatic pistons and the pneumatic muscles are simulated in real time via computational routines operating within the control system. The resultant of these actuations can be seen in the form of height variations of the mechanics; scissor jacks and rod networks (connected to pistons). Each configuration thus initiates an overall restructuring of the mechanics operating beneath the ceiling and the floor surfaces owing to the compression and thrust exerted by the two pneumatic actuators. As was mentioned earlier, the java codes for communicating vertex height variations to the CPX terminal have been tested successfully with Festo engineers thus establishing the success of the code communication meant for actuating the pneumatic actuators. However due to the lack of sufficient funds for constructing the office environment, the codes currently embedded within the control system initiate an automated routine for translating vertex heights into real-time height variations of the simulated mechanics (Fig 124).

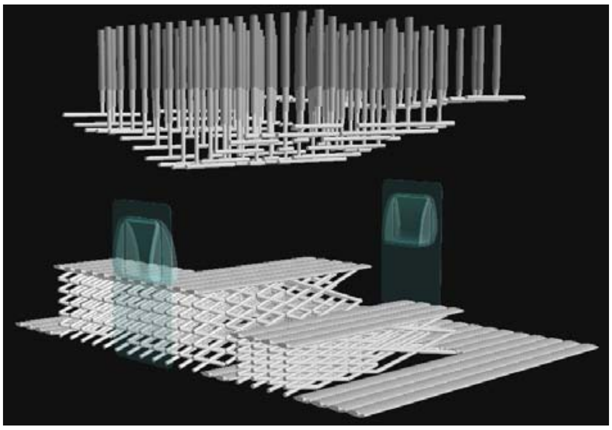


Fig 124: Real-time simulation of underlying Mechanics via the control system.

Lighting level variations are subsequently derived from the database's lighting table, and are simulated in real time as and when a configuration update is initiated. Upon space allocation to an employee via the control system, light flashes corresponding to the employees preferred colour are initiated. These flashes appear four times (four seconds) and serve as a sign for notifying other employees (for either vacating the grid in case it is being used as a temporary configuration, or for stepping out from the boundary of the pod's grid) as regards a probable state change. After the four flashes, the coloured lighting remains static ((for visual identification purposes) until the corresponding employee enters the pod thus triggering the IR sensors (simulated by the diagonal keyboard key). The IR sensor trigger translates the coloured lighting into white light of an intensity corresponding to the intensity of the configuration being activated as specified in the light table. An automated routine operating from within the control system thus supplements the role of the light actuators in order to simulate the desired ambient conditions (Fig 125).

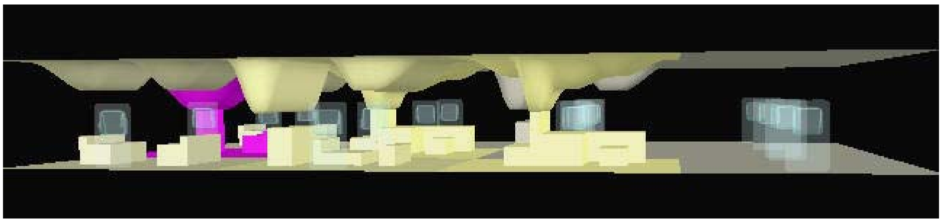


Fig 125: Light level variations displayed in the 3d section of the interface. Light levels are simulated in real-time via the control system.

The role played by sound actuators is also substituted by an automated routine via the control system. The control system mines the database's agenda table and stores the specified time for meetings in the system's memory. The employee name, with whom the meeting is scheduled is also registered in the memory in order to channelize the sound output to the pod corresponding to the same employee. The control system's (global agent's) automated routine (which was specifically developed for instructing the Basic stamp controller) via its internal timer/clock synchronization (with the server computer's clock) activates beeping sounds exactly five minutes prior to the specified meeting time. These sounds as opposed to the speakers embedded within the pods are actuated via speakers of the computer on which the client end of the developed software is running. The employee's are thus informed well in advance about the meetings they have to be engaged with and leave them with sufficient time to collect data, set up projectors etc for the proposed meetings.

5.5.6. c. The Role of the Global agent

Global agent is the terminology used for addressing the control system component of the entire interactive software. The control system is specifically responsible for initiating rule based automated computational routines in order to systematically impart actuation (spatial and ambient) oriented instructions. As was mentioned earlier, the global agent works in conjunction with the human and the local agents in order to develop a closed loop in terms of information flow amongst the three components of the system. The global agent is indirectly linked with the human agents including the RFID tags, IR sensors as well as the online interface and the pluggable pods which serve as tracking as well as data entry tools for the entire system. The aforementioned roles played by each human agent is directly linked with the database counterpart of the local agent which essentially serves as the main trigger for the global agent hence making it the primary source of automation routine trigger for the global agent (and establishing the role of the human agent's as indirect but vital in the triggering process). Any data input registered via the human agents in terms of an employee's entering or leaving the office, the employee's entering the corresponding allocated pod, data related to preferences of the employee via the online interface, data pertaining to a change in the existing configuration via the pluggable pods is directly updated in the real-time updating database's (local agent) corresponding tables. The control system specifically mines the aforementioned sensor table in order to mine data pertaining to the entry/exit of an employee. A tick mark indication in any of the first nine columns of the sensor table (representing the entry of any of the nine employees) acts as a trigger for initiating space allocation routines by the control system.

The control system, as regards space allocation, deals with the deployment of the following: grid/pod allocation per employee in accordance with his/her preferences, allocation of the temporary space, allocation of conference space and the allocation of the exhibition mode. As was mentioned earlier, the control system communicates actuation instructions pertaining to the above mentioned space allocations to a set of micro-controllers (local agents), updates the online interface's (human agent) 3d and 2d sections as well as updates the database's (local Agent) occupancy table in real time. The control system in order to simultaneously deal with these real-time updates is built in a modular fashion to channelize the information update (pertaining to space allocation) to the human and the local agents. The modular nature further leaves the control system with a degree of open-endedness, thus allowing it to become scalable and prone to additions/subtractions of functionalities. Preliminary system diagrams outlining the information flow within the control system were developed (Appendix D, E, F) and were subsequently communicated to the Java programmer with whom the collaborative software development was being carried forth. These initial diagrams assisted in a rather rapid development of the control system owing to the clarity of the iterative steps needed for data structuring as well as data processing amongst the human and the local agents involved in the system. The control system development in accordance with the above mentioned space allocations are exemplified in the following sections. Each section specifically elaborates upon the linkages between human and local agents involved in triggering corresponding space allocations.

1. **Automated space allocation sequence:** the global agent is responsible for allocation of space per employee as and when their presence is detected in the vicinity of the office. This space allocation operates as an automated routine programmed into the control system component. As was mentioned earlier, this routine is triggered owing to the detection of an employee via tracking his/her mobile device which has an embedded RFID tag (human agent). The tracking results in a real-time update of the database's (local agent) sensor table, which is responsible for triggering the control system (global agent) on. Upon being triggered, the control system mines the main table of the database, which carries information pertaining to the space oriented (fixed or non-fixed) preferences entered by the corresponding employee via the online-interface. If the space preference displays a fixed space option, then the following routine is followed for space allocation:
    - Read corresponding Grid/Pod number specified by the employee as his preferred fixed position
    - Read corresponding Colour preference entered by the employee

- Read corresponding configuration (work, discussion or relaxation variants) the user prefers to be actuated when he/she enters the office.
- Read the lighting level table of the database to register the light level corresponding to the preferred configuration.
- Inform the Basic Stamp controller corresponding to the grid/pod number as regards the ambient coloured lighting to be actuated immediately.
- Instruct the Basic Stamp to initiate the blinking of the ambient colour three times and then retain the coloured lighting.
- Inform the CPX controller embedded in the grid/pod number selected by the employee as his fixed position as regards the vertex height variations involved for materializing the configuration (The CPX controller would then convert the height variations to specific air pressure regulations to be imparted in corresponding pneumatic actuators and actuate the configuration as soon as the blinking of the coloured lights stop)
- Represent the above mentioned spatial and ambient changes in the online interface's 3d section in real time
- Continue reading the database's sensor table to track the actuation of the IR sensors lining the boundary of the corresponding pod till the table updates with a positive/tick mark feedback suggesting that the employee has entered the allocated pod.
- Instruct the Basic stamp controller to change the ambient colour lighting to the light intensity corresponding to the configuration (already registered by the control system earlier)
- Represent the above mentioned ambient changes in the online interface's 3d section and update the 2d section with an image of the corresponding employee in real time

The above mentioned sequence currently operate in conjunction with the online Interface, the front end of the system and update the 3d and the 2d sections of the interface in real time as regards the space allocation. However another scenario for the automated space allocation, which involves a much more elaborate rule based process concerns a situation where the tracked employee has indicated that his space preference is non-fixed. This implies that the employee would want the system to allocate him a space which satisfies his/her preferences, specifically preferences dealing with the choice of neighbours or whom they would like to sit with. An automated sequence which involves many more additional data structuring rules is thus developed in order to allocate an optimal spatial location to the employee under speculation. This sequence takes up the following form:

- Read the database's main table for extracting the corresponding employee's first neighbour preference
- Read the database's occupancy table for establishing the presence of the extracted neighbour in the office
- If the corresponding neighbour is present then do the following
    - Check iteratively (starting clockwise) if the neighbour's surrounding grids/pods are empty (surrounding grids/pods are the grids/pods which share at least one common boundary with the neighbour's grid/pod)
    - If any of the surrounding grids is empty then *allocate* the first empty grid/pod obtained via the iterative search to the tracked employee

    - If none of the surrounding grids is empty then check iteratively if any of the surrounding grids/pods has a Temporary configuration
- If the first neighbour is not present in the office then do the following:
    - Read the database's main table for extracting the secondary neighbour preference entered by the employee
    - Read the database's occupancy table for establishing the presence of the second neighbour in the office
    - If the second neighbour is present is present in the office then
        - Check iteratively (starting clockwise) if the neighbour's surrounding grids/pods are empty (surrounding grids/pods are the grids/pods which share at least one common boundary with the neighbour's grid/pod)
        - If any of the surrounding grids/pods is empty then *allocate* the first empty grid obtained via the iterative search to the tracked employee
        - If none of the surrounding grids/pods is empty then check iteratively if any of the surrounding grids has a temporary configuration
- If any of the surrounding grids has a temporary configuration then *allocate* the first iteratively found grid possessing the temporary configuration to the tracked employee
- In case none of the surrounding grids has a temporary configuration then iteratively search for a condition where the grids/pods diagonal to (a grid sharing one point as opposed to one boundary) the first neighbour's and the second neighbour's grid/pod have an Empty or a temporary configuration
- Create a combined array of the empty or temporary grids/pods found diagonal to the grid/pod of both neighbours
- Check for recurring grid/pod number in the array
- If the recurring grid/pod is empty then *allocate* it to the tracked employee or else
- If the recurring grid/pod is not empty then check if the grid/pod has a temporary configuration
- If the recurring grid/pod configuration is temporary then allocate the temporary grid to the tracked user
- If the recurring grid/pod does not have a temporary configuration then read the database's occupancy table for extracting grids/pods having an empty configuration
- Iteratively check the neighbouring grids/pods of each extracted empty grid/pod having an empty or a temporary configuration
- *Allocate* the first grid/pod whose neighbouring grids/pods are empty or have a temporary configuration to the tracked user
- If no extracted empty grid/pod has all its neighbours either having an empty or a temporary configuration then *allocate* the first empty grid to the tracked user at random.

In the above mentioned process, it is mandatory in any of the instances where the ***allocate*** command would be activated to follow the following sequence immediately and not to embark upon any further steps which precede the allocation:

- Read the database's main table for extracting corresponding colour preference entered by the employee

- Read the database's main table for extracting corresponding configuration (work, discussion or relaxation variants) the user prefers to be actuated when he/she enters the office.
- Read the lighting level table of the database to register the light level corresponding to the preferred configuration.
- Inform the Basic Stamp controller corresponding to the grid/pod number as regards the ambient coloured lighting to be actuated immediately.
- Instruct the Basic Stamp to initiate the blinking of the ambient colour three times and then retain the coloured lighting.
- Inform the CPX controller embedded in the grid/pod number selected by the employee as his fixed position as regards the vertex height variations involved for materializing the configuration (The CPX controller would then convert the height variations to specific air pressure regulations to be imparted in corresponding pneumatic actuators and actuate the configuration as soon as the blinking of the coloured lights stop)
- Represent the above mentioned spatial and ambient changes in the online interface's 3d section in real time
- Continue reading the database's sensor table to track the actuation of the IR sensors lining the boundary of the corresponding pod till the table updates with a positive/tick mark feedback suggesting that the employee has entered the allocated pod.
- Instruct the Basic stamp controller to change the ambient colour lighting to the light intensity corresponding to the configuration (already registered by the control system earlier)
- Represent the above mentioned ambient changes in the online interface's 3d section and update the 2d section with an image of the corresponding employee in real time

A parallel sub-system process which runs in conjunction with the above mentioned automated space allocation sequence is the allocation of temporary configuration within the office. A preliminary system diagram concerning data flow pertaining to the operational logistics of this configuration can be seen in Appendix E. The following section will elaborate upon the role played by the control system (global agent) in terms of articulating this configuration.

2. **Temporary Configuration allocation:** the global agent apart from the above mentioned space allocation sequences deals with the allocation of temporary configurations. The term temporary refers to the nature of this configuration, which in itself is developed to aid social gathering of an informal nature with the sole purpose of bringing people from different disciplines together. The temporary configuration operates considering two factors: time and the current spaces/pods allocated to the employees and is prone to change or be re-deployed in real time in different grids/pods throughout the office hours. The re-deployment aspect specifically caters to the need for deploying this configuration where it could be most beneficial, for instance in a place which is convenient for the currently present employees. However, owing to the fact that the office environment should maintain a balance between concentrated work and social, informal activities, a decision to restrict the number of these configurations to be actuated was arrived at. The configuration, based on the above mentioned criteria thus operates upon four rules which are integrated as an automated sequence within the control system;
   - Start the automation process at 10 am and end the process at 6 pm

- The temporary configuration should only be activated if the number of people present in the office is equal to or more than three.
- The configuration should be deployed onto a grid/pod which is nearest to the currently occupied grids/pods
- A maximum of 2 temporary configurations (for nine people) should be activated throughout the office in order to maintain the balance between concentrated work and informal gathering.

In order to implement the temporary configuration based on the above mentioned rules the following sequence is adopted by the control system:

- Check if time on the server's clock is 10 am
- If No then check if the time on the server's clock is 6 pm
- If yes then stop all temporary space allocation processes
- If no then check if time on the server's clock is 10 am
- If yes then do the following or else loop back to step 2
- Read database's occupancy table and extract all occupied and temporary configuration grid/pod numbers
- If the number of temporary configuration grids/pods is equal to 2 then re-check the occupancy table or else (if the number of temporary configuration grids/pods is 0 or 1) do the following
- Check If the number of occupied grids/pods is greater than or equal to 3
- If they are not greater than or equal to three then keep on checking the occupancy table for any new occupancy status and recheck for the number of occupied grids/pods
- If the number of grids/pods is equal to or greater than 3 then extract the neighbouring grids/pods (grids which share a common border with the occupied grids/pods) of all occupied grids/pods
- Create an array of all the neighbouring grids/pods of the extracted occupied grids/pods and check for recurring grid/pod numbers within the array
- If there are one or more recurring grids/pods in the array then do the following
- *Allocate* the first grid/pod which is recurring, the temporary configuration
- Update the 3d and the 2d sections of the online interface in real time as regards simulating the 3d configuration as well as demarcating the corresponding grid/pod with a Temp. notation
- Update the occupancy grid and recheck if the total number of temporary configuration grids/pods is equal to 2
- If yes then re-loop to step 1
- If there are no recurring grids/pods in the array then do the following
- Check iteratively for each neighbouring grid's/pod's proximity to the all the occupied grids; *For each unoccupied grid/pod, the distance to the occupied grid/pod is measured cumulatively; the grid/pod with the minimal cumulative distance is chosen to be assigned the temporary configuration. The calculation of distance between the unoccupied grid/pod and the other occupied grids/pods is based on the Euclidian distance: the length of a line going from the centre of an unoccupied grid/pod, to the centre of the occupied grids/pods.*

For two 2D points, $P = (p_x, p_y)$ *and* $Q = (q_x, q_y)$*, the distance is computed as:* $\sqrt{(p_x - q_x)^2 + (p_y - q_y)^2}$

- *Allocate* the temporary configuration to the grid/pod with the minimum cumulative distance to the other occupied grids.
- Update the 3d and the 2d sections of the online interface in real time as regards simulating the 3d configuration as well as demarcating the corresponding grid/pod with a Temp. notation
- Update the occupancy grid and recheck if the total number of temporary configuration grids/pods is equal to 2
- If yes then re-loop to step 1
- If No then re-calculate the grid/pod with the least cumulative distance and *allocate* a second temporary configuration grid/pod with the least distance.
- Update the 3d and the 2d sections of the online interface in real time as regards simulating the 3d configuration as well as demarcating the corresponding grid/pod with a Temp. notation
- Update the occupancy grid and recheck if the total number of temporary configuration grids/pods is equal to 2
- If yes then re-loop to step 1

In the above mentioned sub-process for automatically allocating a temporary configuration, after each ***allocation***, the following communication with the Local agents is mandatory:

- Inform the Basic Stamp controller corresponding to the grid/pod number as regards the ambient coloured lighting to be actuated immediately (in this case the ambient light is white light of the least brightness as compared to all other configurations).
- Instruct the Basic Stamp to initiate blinking of the ambient light (for informing people as regards the actuation of a new configuration) three times and then retain the ambient lighting.
- Inform the CPX controller embedded in the grid/pod number as regards the vertex height variations involved for materializing the configuration (The CPX controller would then convert the height variations to specific air pressure regulations to be imparted in corresponding pneumatic actuators and actuate the configuration as soon as the blinking of the ambient lights stop)

As was mentioned in the earlier exemplified automated space allocation sequence, a temporary space can be allocated at any point in time to an employee if the preferences put forth by him/her can be satisfied best if he/she is allocated that grid/pod. In such a scenario, the above mentioned Temporary configuration allocation process, owing to its operating as a continually running sub-process immediately senses an update in the occupancy table and thus continues the search for an optimal grid/pod to be allocated the temporary configuration. The sequence mentioned above as regards the deployment of the temporary configuration upon recurring grids/pods or upon grids/pods with the minimum cumulative distance insures the maximum usability and convenience in terms of utilizing this informal configuration. The time based trigger for initiating the above mentioned sequence further insures an optimal deployment of the configuration throughout normal working hours of a typical office environment.

Apart from the above mentioned space allocation categories, the control system (global agent) is also responsible for the allocation of the conference and the exhibition configurations. These configurations are also time dependent and are strictly actuated in accordance with the time frame entered via the online interface's data entry section. The following sections will elaborate upon these configurations with an emphasis upon the manner in which an optimal automated space allocation (specially for the conference configuration) is attained.

3. **Conference configuration allocation:** The conference configuration, owing to the fact that it occupies two adjacent pods within the entire office is actuated on the basis of a set of rules in order to insure an optimal space allocation of this configuration. The term optimal, in this case refers to a scenario where least disturbance is incurred upon the occupants of the office in terms of altering currently occupied grids/pods for creating an ideal situation for the conference configuration. For allocating the conference configuration the following sequence is embarked upon:
   - Read the system memory for extracting the date, start time and end time of the proposed conference
   - Trigger the control system to start the conference allocation procedure ten minutes before the conference start time
   - Upon initiation iteratively check all rows for the following:
   - For each row check if any grid/pod lying in that row is unoccupied/empty or has a temporary configuration
   - If a grid/pod is unoccupied/empty then check if its immediate neighbour (which shares a common boundary to the left/right of the grid/pod in the same row) is also unoccupied/empty
   - If yes then *allocate* the two adjoining unoccupied/empty grids/pods the conference configuration
   - Update the 3d and the 2d sections of the online interface in real time as regards simulating the 3d configuration as well as demarcating the corresponding grid/pod with a conference notation
   - Update the occupancy grid
   - If there are two unoccupied/empty or temporary configuration grids/pods in the same row but are not adjoining each other then do the following
   - Save row number and check the next row for a similar condition where two unoccupied grids/pods or temporary configuration grids/pods are adjoining each other
   - If there is a condition where two unoccupied/empty grids are adjoining each other then *allocate* the two adjoining unoccupied/empty grids/pods the conference configuration
   - Update the 3d and the 2d sections of the online interface in real time as regards simulating the 3d configuration as well as demarcating the corresponding grid/pod with a conference notation
   - Update the occupancy grid

- If two adjoining grids/pods are not found then continue the search for all other rows and save the rows which have two unoccupied/empty or temporary configurations (not adjoining each other)
- Recall the saved rows (in terms of an array) and check iteratively if any of the rows has the following:
    - Two unoccupied/empty grids/pods
    - One unoccupied/empty grid/pod and one temporary configuration grid/pod
    - Two temporary configuration grids/pods
- Iteratively check in all the rows for a condition where one unoccupied/empty and one temporary configuration are adjoining each other
- If yes then *allocate* the conference configuration to these grids/pods
- Update the 3d and the 2d sections of the online interface in real time as regards simulating the 3d configuration as well as demarcating the corresponding grid/pod with a conference notation
- Update the occupancy grid
- A new temporary configuration oriented grid/pod will be automatically allocated as was mentioned in the previous section's sequence
- If the aforementioned condition is not met then iteratively check all rows for a condition where two temporary configuration grids/pods are adjoining each other
- If yes then convert these grids to a conference configuration and perform the updating sequence and re-allocation sequence for the temporary configuration grids/pods
- If none of the above conditions holds true then an occupancy status where there are intermediate work, relaxation or discussion configuration grids/pods between the unoccupied/empty or temporary configurations in the saved rows exists
- in such a scenario recheck per row for the following:
    - Select each unoccupied/empty or temporary grid (per row) and check its neighbours (grids/pods who share a common boundary on the right and left side of the selected grid/pod) for extracting the active configuration they possess.
    - Check iteratively in each row for a condition where the neighbouring grid's configuration is a relaxation configuration
    - If any of the rows has such a condition then *relocate* the employee with the relaxation configuration and *allocate* the conference configuration to the two adjoining grids
    - If any of the rows does not exhibit the aforementioned condition then check iteratively each row for a condition where the neighbouring grid's/pod's configuration is a work configuration
    - If any of the rows does not exhibit the aforementioned condition then check iteratively each row for a condition where the neighbouring grid's/pod's configuration is a discussion configuration
    - If any of the rows has such a condition then *relocate* the employee with the discussion configuration and *allocate* the conference configuration to the two adjoining grids

The discussion configuration is the last one to be relocated as it might involve clients engaged in active discussion sessions with the employees. The later part of the sequence involving *relocation* of employees is however the last resort that the system engages in, thus causing the least disruption in the employee's activity unless extremely necessary. Under such circumstances the *relocation* process (for employees) involves the re-allocation of grids/pods to employees in a manner which causes the least movement of the employee from his pre-allocated grid/pod.

In order to attain this, the control system firstly analyses the row within which the employee's grid/pod lies for an empty or a temporary configuration. If this condition holds true then the employee is relocated to another grid/pod within the same row. However if this is not the case then the second option is to check for the grid's/pod's immediate neighbours for a similar condition (for locating unoccupied/empty or temporary configuration grids/pods). If this condition is met then the first preference is given to an empty neighbouring grid or else a neighbouring grid/pod with a temporary configuration is allocated to the employee. If the above two conditions also do not hold true then the control system initiates a diagonal search (grids/pods lying immediately diagonal to the employee's grid/pod) for extracting any unoccupied/empty or temporary configuration grid/pod. The first preference for relocating the employee in this case is again given to an unoccupied/empty diagonal neighbouring grid/pod and is followed by a second preference for the temporary configuration grid/pod. Only in circumstances when none of the above conditions are met then the employee is allocated a random grid/pod nearest to his/her current location via the same euclidean distance calculation between the centres of his occupied pod and an unoccupied/empty or a temporary configuration grid/pod. A grid/pod irrespective of its unoccupied/empty status or having a temporary configuration is thus allocated to the employee strictly based on the calculation of the least cumulative distance from his present grid/pod.

In the above mentioned process for automatically allocating a conference configuration, after each ***allocation*** of the configuration or the relocation of an employee the following communication (additional to the updating of the online interface and the Occupancy table) with the Local agents is mandatory:

- Inform the Basic Stamp controller corresponding to the grid/pod number as regards the ambient coloured lighting to be actuated immediately (in this case the ambient light is white light of a pre-specified intensity for a conference configuration).
- Instruct the Basic Stamp to initiate blinking of the ambient light (for informing people as regards the actuation of a new configuration) three times and then retain the ambient lighting.
- Inform the CPX controller embedded in the grid/pod number as regards the vertex height variations involved for materializing the configuration (The CPX controller would then convert the height variations to specific air pressure regulations to be imparted in corresponding pneumatic actuators and actuate the configuration as soon as the blinking of the ambient lights stop)

The above mentioned sequence for automated allocation of the conference configuration thus insures the actuation of this configuration ten minutes prior to the actual conference time. This allows ample time for the employees to set up necessary projectors as well as gather conference related data in advance as well as insures the relocation of employees (if needed) before the intended conference starting time thus avoiding any disturbances during the entire conference session. The conference configuration returns back to its normal state (the original configuration if the process involved the relocation of a user or the displacement of a temporary configuration) ten minutes after the intended conference end time to insure the provision of a comfortable buffer zone for concluding the conference. The next configuration to be elaborated upon is the exhibition configuration. This configuration as was mentioned earlier involves the conversion of the entire office space (for the case of this research) into an exhibition space or an advertising and informal gathering environment thus completely transforming the spatial outlook of the entire office.

4. **Exhibition configuration allocation:** the exhibition mode falls in the same category of time based configuration allocation as the above mentioned conference configurations. However, what makes this configuration radically different than any other configurations is the fact that it affects the entire office set up as opposed to one or two grids/pods within the office. This configuration holds within a set of eight pre-defined configurations which are apt for display as well as exhibiting objects. The control system (global agent) thus specifically allocates these eight configurations (Fig 126) throughout the office's twelve grids in a pre-defined sequence which deals with combining them with empty as well as repetitive and inverted (orientation) exhibition configurations.

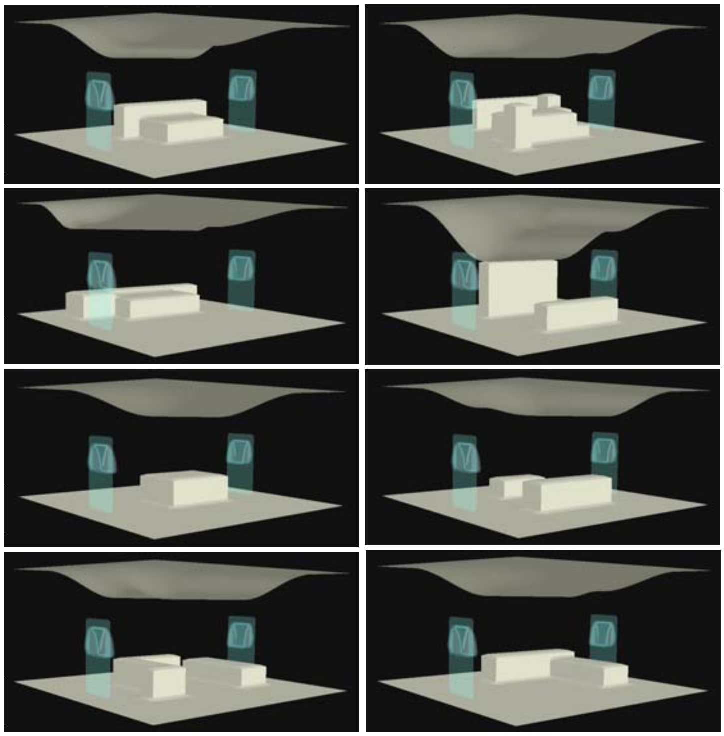


Fig 126. Eight pre-programmed exhibition configurations.

The twelve grids/pods composition depicting the office space is specifically used as an experimental field within which the configurations are deployed in the following order: Grid 1 = E1 inverted, Grid 2 = E3 inverted, Grid 3 = E6, Grid 4 = E8 inverted, Grid 5 = E2, Grid 6 = E5, Grid 7 = E6, Grid 8 = Empty, Grid 9 = E5, Grid 10 = E3, Grid 11 = e4, Grid 12 = E4 inverted. This pre-configured order (Fig 127) of allocation of the exhibition configurations is initiated by the control system ten minutes prior to the time frame entered as regards the exhibition timings.

01 = E1 Inverted	02 = E3 Inverted	03 = E6	04 = E3 Inverted
05 = E2	06 = E5	07 = E6	08 = Empty
09 = E5	10 = E3	11 = E4	12 = E4 Inverted

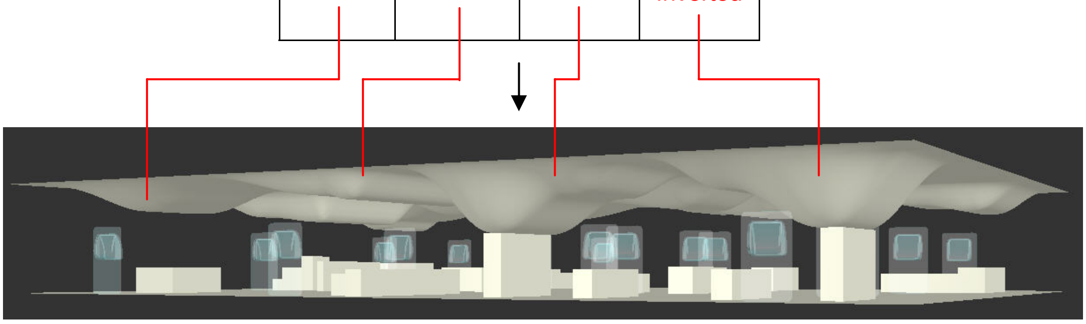


Fig 127: Configuration assembly to create the exhibition mode.

In order to actuate the exhibition mode the control system follows the following sequence:

- Read the system memory for extracting the date, start time and end time of the proposed exhibition
- Trigger the control system to start the exhibition mode allocation procedure ten minutes before the exhibition start time
- Inform the Basic Stamp controllers corresponding to all the grids/pods as regards the ambient coloured lighting to be actuated immediately (in this case the ambient light is white light of a pre-specified intensity for each exhibition configuration).
- Instruct the Basic Stamp to initiate blinking of the ambient lights (for informing people as regards the actuation of new configurations) three times and then retain the ambient lighting.
- Inform the CPX controller embedded in all the grids/pods as regards the vertex height variations involved for materializing the configuration being assigned per pod (The CPX controller would then convert the height variations to specific air pressure regulations to be imparted in corresponding pneumatic actuators and actuate the configuration as soon as the blinking of the ambient lights stop)

The configurations once assigned can easily be changed by using the pluggable storage cum touch screen unit's interface thus allowing for an easily understandable space augmentation scenario. The exhibition space can thus be tuned at a local level (per pod) to best suit the need and the demands of the event. The exhibition configuration as of now is pre programmed to switch over to inherit an unoccupied configuration for the entire office after twenty minutes of the proposed exhibition end time. In case the exhibition ending time is after 18:00 hrs, when the office staff has either left the building or would not be resuming routine office work once the exhibition is over, the empty configuration is retained till the point the control system allocates a new configuration to any of the grids/pods (usually on the next day). However, in cases where the exhibition end timing is before 18:00 hrs, a scenario where the last saved state of the office configuration is re-actuated after twenty minutes of the exhibition end time is materialized. This time buffer between configuration switch over allows ample time for removing the exhibits and for comfortably retaining the usual office biorhythm.

The global agent, as was mentioned earlier, apart form the above mentioned space allocation procedures, is also equally responsible for communicating its output to a set of two microcontrollers (per pod) in order to trigger the physical actuation of mechanics constituting the prototype. Though the physical prototype is not built owing to financial constraints, the control system embodies routines specifically written for the transmission of actuation related data (in terms of vertex displacements, ambient lighting and sound triggers) to the CPX and the Basic Stamp controllers. These routines are however modified in the developed software in order to integrate the control system's data output with real-time simulations of the entire office environment. The real time simulations in-turn imply a visual and auditory feed back as regards configuration translations, light effects as well as beeping sound based reminders. The control system thus specifically uses the online interfaces 3d and 2d sections to communicate configuration and light levels related output and uses computer speakers to communicate reminders five minutes before a scheduled meeting to the corresponding user. A highly controlled and precision oriented real-time contextual information update is thus attained via the control system/global agent.

The above mentioned agent characteristics as well as the manner in which they communicate with each other is materialized in the form of a software (the meta-system), specifically developed as a resultant of this research. The software, best exemplifies upon the above stated systemic nature of interactions amongst the agents via being installed and run in any office environment. The results, in terms of attaining appropriate spatial and ambient adaptation can be verified in real-time via the software's internal interaction amongst its client and server ends. The outcome, as regards real-time configuration, ambient lighting as well as sound augmentations in real-time can be experienced via the online interface (part of the client end) and a set of speakers attached to a computer on which the client end is operating. A detailed review of the developed software is provided in the following section.

d. Resultant Software: The aforementioned system architecture operates in a highly inter-dependent fashion by means of constant data exchange amongst the human, local and the global agents. Each agent contributes in a specific manner in order to maintain the proposed interactive behaviour of the system hence portraying the whole or the entire office environment as an intelligent body constantly adapting and adjusting its physical and ambient nature to best serve its occupants. The software developed in Java (attached with this thesis) embodies the above stated agent interactions and can be installed by following the instruction guidelines provided in the read-me file of the software.

The software itself constitutes three main sections: the server end (bkprotoServer), the client end and a database section (hosted within the server end - bkprotodb). In order to initiate any computational procedures, it is mandatory that the database hosted within the server end be connected internally to the computer which would be used as the server or rather which would host the server end of the software. In order to set up the database the following procedure needs to be followed:

- Adding the database to a computer (running Windows XP):
  Press Start > Settings > Control Panel > Administrative tools > Data Sources (ODBC) > Select tab “User DSN”, press button “Add…” > Select “Microsoft Access Driver (*.mdb)” > press button “Finish” > In the Data Source Name field, type “bkprotodb” > Press button “Select…” and locate the file “bkprotodb.mdb” in the server section of the software > Press “OK” and close the windows.

Once the database section has been connected, the server, which in this case takes up the form of an internal start/stop computational engine, can be installed in the same computer by means of double clicking on the executable Jar file (bkprotoServer) in the server end. This installs the server and adds a small icon representing the server in the task bar (bottom right portion of the desktop). Right clicking the icon provides one with options for stopping, starting or reviewing on-going computing processes. The server, once installed, is immediately attached with the database counterpart and starts data exchange/data mining and data updating procedures in real-time. In order to input data in real time the client end of the software is required.

The client section can be run on either the same computer which hosts the server or on different computers. However, it is important that any computer on which the client end is operating should point towards the server computer’s IP address. The client end, in order to facilitate the inputting of the server’s IP address, hosts a text file by the name: address. One can simply enter the new IP address (of the server computer) as the top most/starting line of the text file (as the software only reads the first/starting line) in order to establish the connection to a server computer. In order to demonstrate the real-time simulations as regards testing configuration changes on a singular pod as well as the entire office space, the Client section hosts the following options: Demo Multiple, Demo Single and Interface. These options can be operated in two versions: the full screen or the non – full screen versions.

The Demo (demonstration) versions are specifically developed as a part of the prototype testing phase of the research. However, owing to the academic nature of the research these demonstration versions are provided with the final software in order to better understand and test the proposed configuration transformations. The Demo single section illustrates the manner in which the pluggable pod based interface operates by means of making selections as regards the configuration one wants to be actuated. Double clicking the Demo single executable jar file (within the client folder) opens a real time interactive interface (Fig 128) via which it is possible to select the configuration one wants to be actuated. These configurations are mapped upon a single unit/generic pod, thus the name Demo single. As was mentioned in section 5.5.5: Typologies, it is possible to visualize the demonstration of the adaptive generic pod in the following forms:

- Surface
- Vertex (point cloud)
- Wire frame
- With pneumatic actuators and attached mechanics
- With heights of the vertices displayed

Each of these forms of visualization acts independently, updating in real time in accordance with the configuration currently active. One can thus visualize the generic pod as a combination of the above, say for instance, view the pod as a point cloud, with the mechanics and actuators and the heights displayed at one time or can simply view the pod as a surface depending on his/her preference. In order to activate the above mentioned visualization forms the following keyboard entries are mandatory:

- Surface: **S**
- Vertex (point cloud): **D**
- Wire frame: **L**
- With pneumatic actuators and attached mechanics: **J**
- With heights of the vertices displayed: **H**

The above mentioned key connotations can be used in any combination desired. Pressing any of the above keys will enable the corresponding visualization mode and re-pressing the same key will disable the visualization.

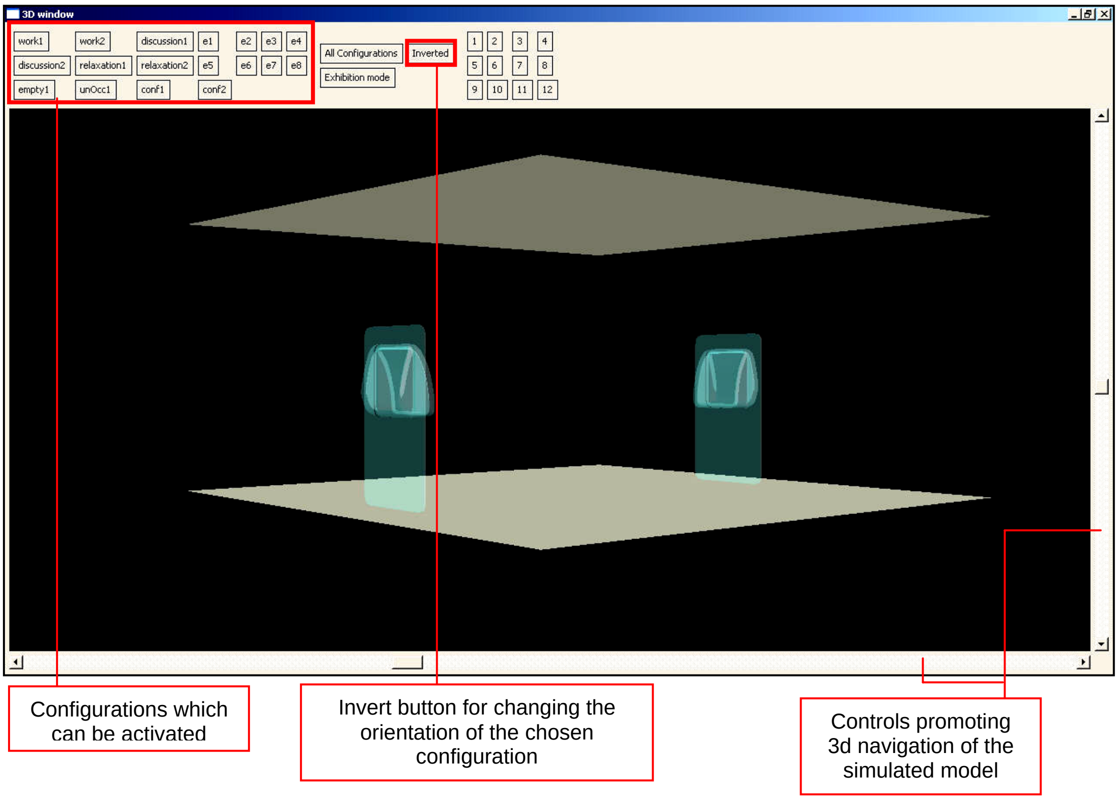


Fig 128: Interface for the Demonstration versions (the buttons illustrated by the red boxes are used for testing configuration translations in the Demo single version)

The interface (Fig 128) remains common for the Demo single and the Demo multiple versions. However, as is illustrated in the figure above, the configuration buttons (marked by left red box) can be specifically used for altering configurations. The resultant generic pod simulations can be seen transforming in the main window and the angular manner in which one wants to view the pod can be controlled by the control sliders at the bottom and the right side of the interface window. In addition to the configuration buttons, one can press the Invert button (marked by the right red box) for changing the orientation of a configuration. In order to do this, one needs to press the Invert button first and subsequently press the configuration button which he/she needs to be actuated. The Demo multiple option is more illustrative of the entire office per say and it thus displays all the pods (a total number of 12) in the visualization window. The Demo multiple can be tested in the following ways:

- Activate all the configurations (W1, W2, D1, D2, R1, R2, temporary and conference) by pressing the All configurations button
- Activate the Exhibition mode by pressing the exhibition button

The results of the above mentioned testing options are illustrated below (Fig 129). The two buttons: All configurations and exhibition are clearly outlined in the interface (outlined by the left red box).

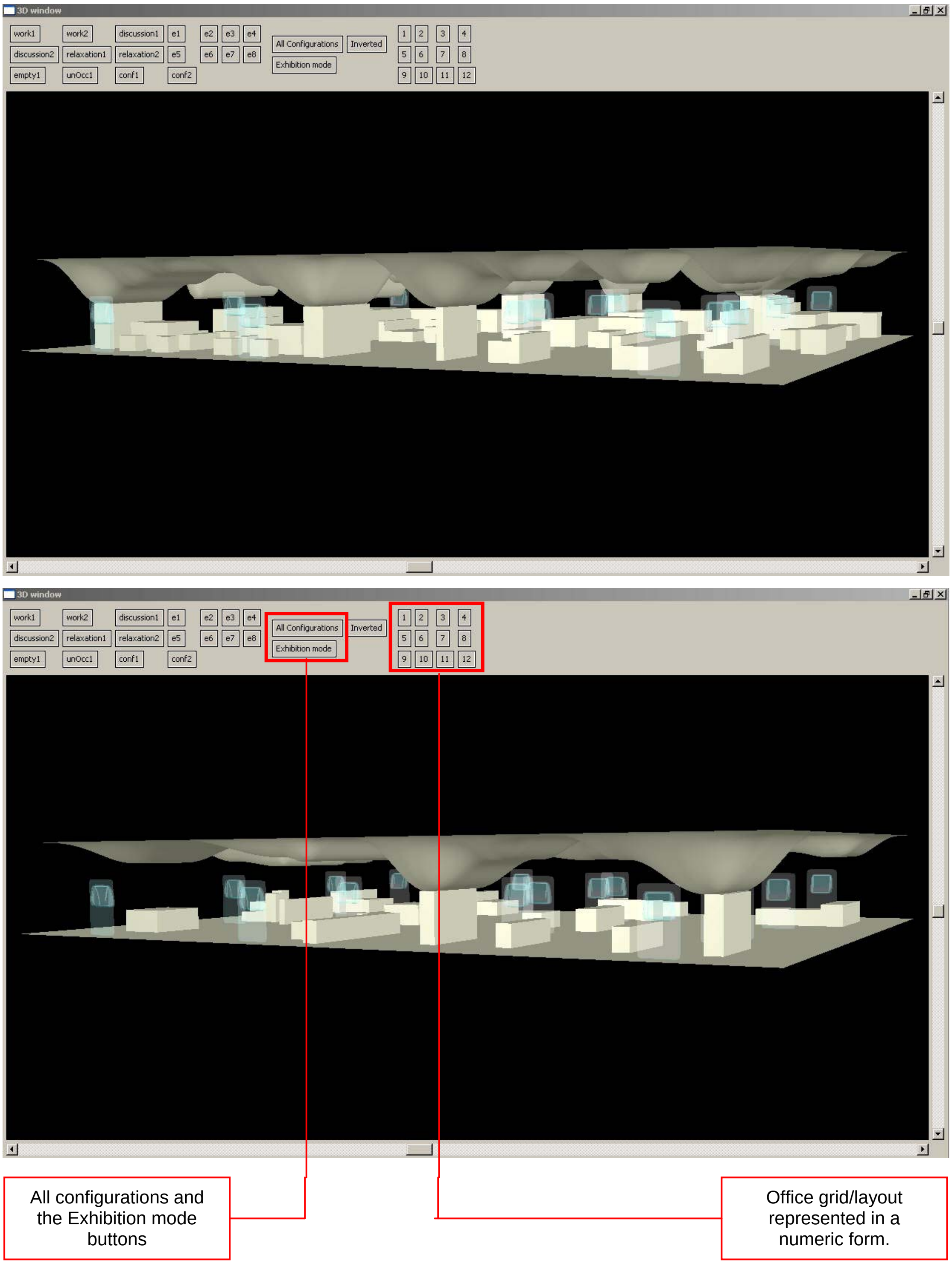


Fig 129: Interface for the Demonstration versions displaying all configurations (Top) and the exhibition mode (Bottom)

The Demo multiple option apart from the above mentioned pre-set configuration settings can also be manually tested via the numeric buttons (buttons outlined by the right red box, Fig 123) which represent the office layout. Upon activating the Demo Multiple executable java file the cluster of pods which appears on the visualization screen corresponds with the numeric button layout e.g. girds/pods 9, 10, 11 and 12 are visually represented as the first row facing the user in the 3d visualization of the office. One can thus select any grid number from the numeric button pad and can subsequently alter any existing configuration by selecting a new configuration from the aforementioned configuration buttons on the left corner of the interface. For changing the orientation of a configuration the aforementioned Invert button can be pressed followed by the configuration one wants to be actuated. Owing to computational capacity limitations, the Demo multiple option does not allow one to visualize the pneumatic actuators and associated height variation of vertex points operating behind the pods. However, one can still view the entire office cluster in the other remaining visualization forms (via the same keyboard entries): surface, vertex and wire frame.

The Interface, as was mentioned in the human agent's online Interface section is used specifically for data entry purposes by all employees of the office. The Interface executable Java file can be activated on any computer running the client end of the software by double clicking the file name in the full screen or the non-full screen options provided for in the software. The resultant Interface window will display the latest spatial and ambient configuration of the office in the 3d real time updating section of the interface. The 2d section also akin to the 3d updated view, presents an updated occupancy status of the office space by demarcating the office grid with images (of employees) as well as labels (temp, conference, empty). One can easily enter his/her preferences via the data entry section of the interface, which is automatically fed into the server computers database (as the network communication IP address points towards the server computer). The aforementioned keyboard entries representing RFID as well as IR sensor detections can be subsequently carried forth in order to trigger the server's inbuilt control system (global agent) to resume space allocation sequences. Conference and exhibition related data entries are automatically stored in the server's memory and are appropriately actuated in accordance with the aforementioned time based pre-programmed space allocation rules. Reminders (for meetings with visitors) in the form of beeping sounds are also actuated via the server and can be heard via the computer speakers (running the client end) corresponding to the user with whom a meeting is scheduled.

5.5.7. Conclusion

The real-time interactive software system has been tested for the above mentioned performance at various stages and has proved to operate successfully adhering to data structuring rule sets, spatial configuration creating algorithms as well as space allocation routines. Owing to the java based software development, the resultant software can be readily installed and run on a variety of operating systems without un-necessary need to download special plug-ins or additional software in order to insure its smooth performance. The software thus not only showcases the real time space augmentation scenarios but also presents a highly precise space allocation and ambience regulation system which proficiently establish the successful accomplishment of research goals and the simulation of an user centric, real time adaptive, multiple usability oriented office space. Parallel hardware oriented tests conducted in collaboration with Festo engineers (testing the CPX terminal) as well as the Hyperbody Research Group, TU Delft culminating in the successful materialization of real time interactive space installations also demonstrate the ability to eventually translate the resultant simulations into the physical realm.

Both, corporate culture and technology thus became intrinsic elements of the research focus evaluating user needs and demands, patterns of social processes in corporate communities, prevalent communication habits, future needs and Institutional space/character/vocabulary in context of its cultural traditions. Socio-functional aspects of contemporary culture and the manner in which real-time interactive technologies can be deployed for addressing projected trends are thus manifest in the research endeavour. In the process of developing interaction based adaptive spaces, the project outlines possible functionalities, parametric product dimensions, form-studies, real-time simulations and interface designs, additional to its major textual research component. The research output thus successfully led to the production of an interactive user interface, a dynamic database, an intensively programmed control system and real-time responsive simulations of the designed spatial solution in the form of the developed software. In addition to the above mentioned output, the research work also actively proposes the manner in which hardware components such as sensing and actuation systems along with their respective controllers can be linked with the informational domain (control system and sensing/actuating agents) to weave together the proposed performative system architecture.

The next chapter reflects upon the intensive research and design experience which went into materializing this thesis and marks the conclusion of this research thesis. The conclusion itself summarises the generic ideology as regards conceiving architecture as a symbiotic process, binding the fields of explorative design and cutting edge technology into a real-time interactive spatial construct.

Endnotes

[1] Designing interactive systems people, activities, contexts, technologies, David Benyon, Philip Turner, Susan Turner, Pearson Education, Harlow, 2005.

[2] Morphing: Transforming one image into another; for example, a car into a tiger. The term comes from metamorphosis. Morphing programs work by marking prominent points, such as tips and corners, of the before and after images. The points are used to mathematically compute the movements from one object to the other - "morphing." Computer Desktop Encyclopedia. Computer Language Company Inc., 2007. *Answers.com* 04 Mar. 2007. http://www.answers.com/topic/morphing

[3] Bio system: A living organism or a system of living organisms that can directly or indirectly interact with others - "biosystem." The American Heritage Stedman's Medical Dictionary. Houghton Mifflin Company, 2002. *Answers.com* 04 Mar. 2007. http://www.answers.com/topic/biosystem

[4] An autonomous agent is a system situated in, and part of, an environment, which senses that environment, and acts on it, over time, in pursuit of its own agenda. This agenda evolves from drives (or programmed goals). The agent acts to change the environment and influences what it senses at a later time. Non-biological examples include intelligent agents, autonomous robots, and various software agents, including artificial life agents, and many computer viruses - "autonomous agent." Wikipedia. Wikipedia, 2007. *Answers.com* 04 Mar. 2007. http://www.answers.com/topic/autonomous-agent

[5] RFID (Radio Frequency IDentification): A data collection technology that uses electronic tags for storing data. The tag, also known as an "electronic label," "transponder" or "code plate," is made up of an RFID chip attached to an antenna. Transmitting in the kilohertz, megahertz and gigahertz ranges, tags may be battery-powered or derive their power from the RF waves coming from the reader. Like bar codes, RFID tags identify items. However, unlike bar codes, which must be in close proximity and line of sight to the scanner for reading, RFID tags do not require line of sight and can be embedded within packages. Depending on the type of tag and application, they can be read at a varying range of distances. In addition, RFID-tagged cartons rolling on a conveyer belt can be read many times faster than bar-coded boxes - "Radio Frequency Identification." Computer Desktop Encyclopedia. Computer Language Company Inc., 2007. *Answers.com* 04 Mar. 2007. http://www.answers.com/topic/radio-frequency-identification

[6] Touchscreen: A display screen that is sensitive to the touch of a finger or stylus. Touch screens are very resistant to harsh environments where keyboards might eventually fail. They are used with custom applications and on-screen buttons large enough to be pressed with the finger. Applications are typically very specialized and greatly simplified so they can be used by anyone. However, touch screens are also very popular on PDAs and full-size computers with standard applications, where a stylus is required for interaction with tiny screen objects - "touchscreen." Computer Desktop Encyclopedia. Computer Language Company Inc., 2007. *Answers.com* 04 Mar. 2007. http://www.answers.com/topic/touch-screen

Touchscreens, touch screens, touch panels or touchscreen panels are display overlays which have the ability to display and receive information on the same screen. The effect of such overlays allows a display to be used as an input device, removing the keyboard and/or the mouse as the primary input device for interacting with the display's content. Such displays can be attached to computers or, as terminals, to networks - "touchscreen." Wikipedia. Wikipedia, 2007. *Answers.com* 04 Mar. 2007. http://www.answers.com/topic/touch-screen

[7] Object oriented programming (OOP): Computer programming that emphasizes the structure of data and their encapsulation with the procedures that operate upon it. It is a departure from traditional or procedural programming. OOP languages incorporate objects that are self-contained collections of computational procedures and data structures. Programs can be written by assembling sets of these predefined objects in far less time than is possible using conventional procedural languages. OOP has become extremely popular because of its high programming productivity - "object-oriented programming." Britannica Concise Encyclopedia. Encyclopædia Britannica, Inc., 2006. *Answers.com* 04 Mar. 2007. http://www.answers.com/topic/object-oriented-programming

[8] Eclipse: an open source Java-based platform for integrating software tools for application development. Running under Windows and Linux, it provides a universal platform for tools created as Eclipse plug-ins. IBM started the Eclipse consortium in late 2001 with $40 million and donated a large amount of code. In 2004, it was spun off as an independent foundation. For more information, visit www.eclipse.org - "Eclipse." Computer Desktop Encyclopedia. Computer Language Company Inc., 2007. *Answers.com* 04 Mar. 2007. http://www.answers.com/topic/eclipse-software

[9] Point cloud: In computer science, a point cloud is a set of three-dimensional points describing the outlines or surface features of an object, such as that produced by a 3D digitizer - "point cloud." Wikipedia. Wikipedia, 2007. *Answers.com* 04 Mar. 2007. http://www.answers.com/topic/point-cloud

[10] In geometry, a peak is an (n-3)-dimensional element of a polytope. In three dimensions this corresponds to a vertex of a polyhedron, in four dimensions an edge of a polychoron, in five dimensions a face of a polyteron, and so forth. At least three facets (and, accordingly, at least three ridges) must meet at any peak in a convex polytope - "peak." Wikipedia. Wikipedia, 2007. *Answers.com* 04 Mar. 2007. http://www.answers.com/topic/peak-geometry

[11] A review of conductive threads and fabrics: http://itp.nyu.edu/physcomp/sensors/Reports/SoftSensing

[12] A short review on programmable lighting controllers:
http://www.flashtracklighting.com/programmable_lighting_controllers.htm

[13] Ceelite's flexible light bulb sheets: http://www.ceelite.com/

06

CONCLUSIONS AND RECOMMENDATIONS

06

Conclusions and recommendations

6.1. A progressive view on architecture

"Architectural design that emphasises "softspace" over "hardspace" is a little like "software" design rather than "hardware design" in computer terminology, where "hardware" refers to the physical machine and "software" refers to the programs that animate the machine. In an architectural context, technology is used to provoke interactions between people, and between people and their spaces. If soft-space encourages people to become performers within their own environments, then hard-space provides a framework to animate these interactions. The idea of an architectural operating system lies in the design of the systems that integrate the two. One model of operating system that is particularly relevant to architecture (since the design of space is always a collaborative process) is an open source system"…… Usman Haque, www.haque.co.uk.

This research work, with its inter-disciplinary underpinnings and intensive focus on user centric design conceives architectural substantiations for the corporate domain as an open source system akin to the above statement, promoting a continual interaction between the built form and its inhabitants. Such an interaction oriented design ideology combined together with a socio-cultural understanding of information communication, technology as well as computational tools brought forth a distinct understanding of the role that architects/designers can offer, in today's information intensive era. The research initiative, after an intensive stage of developing sufficient knowledge about the corporate domain (via the PACT framework) interfaced with this evolved role of architects/designers, which, rather than creating inert spatial shells, is much more involved with the design of a meta-system which binds the spatial, ambient and informational domains into an inter-activating comprehensive whole. The creation of such a meta-system for the case of this research specifically involved the design of a computationally enriched open systemic framework (soft-space developed via the produced software and its extensions for data input) which actively promotes user interaction and interfaces with the architectural grammar (hard-space) constituting corporate offices for spatially responding to these interactions. User interaction in the case of this research is attained by provoking the users of this meta-system to input their social, spatial and ambient preferences via the systems front end (interface). This soft data is subsequently interfaced with the hard-space (architectural grammar) in order to actuate the resultant user-customized social groupings, spatial configurations and associated ambient conditions. This soft information input thus serves as a medium for triggering real-time spatial adaptability to accommodate the user's activity based programmatic needs thus developing an inherent interconnection between the soft and the hard space domains. The otherwise static/inert hard-space, enhanced with contemporary technology and computational logic thus attains the role of a physical interface prone to customized spatial augmentation hence transforming architectural space into a real-time multiple usability platform.

The user's in such a scenario thus become the central pivot of the entire designed construct, owing to their role as regards the formulation of customized social, ambient and spatial programmes, thus strengthening the user centric premise of this research. The hard and the soft designed counterparts of the meta-system, in conjunction with the role of the user, thus attain a new dimension of an interdependent highly dynamic spatial construct. The role of the author, through this research and design initiative hence primarily concerned the design of a meta-system which allows users to shape their own spaces subsequently leading to the collaborative creation of a dynamic spatial field (in this case a corporate office environment). A truly performative space which is highly adaptive in nature and the architectural character (in terms of its topological variation) of which is the resultant of activity based performance (within the meta-system) of each individual of the environment is thus materialized.

The meta-system in the case of this research is realised as an interactive software system which can be readily installed within office environments eventually allowing users to customize their spatial settings or in other words perform within this meta-system, thus generating specific personalized architectural renditions. The office environment per se becomes an interactive participatory field which specifically augments its physical, ambient and informational composition via interacting with the users of this dynamic field. The pre-conception of form becomes redundant in such dynamic environments, since the main mode of discourse shifts from the mundane-ness of such artificiality towards real-time appropriation of space to programmatic needs and a plastic conception of internal flexibility. A change of the operative scenario both physically and organisationally is thus dwelt upon, resulting in the development of an interactive spatial system, which has the ability to register contemporary needs and to interactively trigger spatial adaptability. Initial design conceptions/abstractions which formulated the design process of this research are translated as demonstrative, real-time interactive architectons by acquiring a collaborative design strategy which binds the domains of education, practise and industry into a comprehensive whole. This process allows one to develop quintessential contemporary technology oriented knowledge (IT, smart materials, sensors, actuators etc) in coherence with visions of adaptive architectural constructs and hence allows for effectively simulating as well as physically demonstrating a logical co-evolutionary (design + technology) approach towards generating innovative constructs. This inherently dynamic character (simulated and visualized via the developed software) combined together with the knowledge of mechanics, electronics and control systems is proposed to be physically constructed as a real-time interactive spatial prototype (1:1 scale) of the entire office environment (subject to funding).

Architectural constructs through this research initiative are eventually visualized as subjects for real time information processing, thus displaying a continuous state of interaction and spatial re-appropriation, representative of contemporary socio cultural dynamism. This research and design initiative by means of engulfing the above described progressive view on architecture conceives spatial interventions as inter-disciplinary constructs, focusing on a synergistic merger of science, technology, art and architecture, eventually transcending the discipline of architecture into a participatory meta-system which successfully performs in contemporary information intensive contexts.

6.2. Reflections on the research agenda

“Historically spatial metaphors have been the most fundamental source of concepts of order and organization. This semi conscious process of concept formations persists as long as society exists in and through built space. But if this dialectic of spatial, social and conceptual order is raised to the level of conscious reflection, it allows architecture to ‘translate’ organisational concepts into new effective spatial tropes while in turn launching new organisational concepts by manipulating space”…Patrik Schumacher, Corporate Fields, 2005.

This research initiative in its attempt to experiment with the above stated notion of manipulation of space for realising new organisational concepts specifically adopted an inter-disciplinary framework for understanding the corporate species. As was elaborated upon in the earlier section, the underlying theoretical premises and ground research on corporate organisations was conceived as the study of systems per se. Architectural concepts and resultant typological variants of the corporate species were thus scrutinized in accordance with the degree of performance or in other words the level of interactivity they yielded. The 'building for profit' ideology, which the design of corporate spatial entities traditionally adopted was thus at once understood as a factor resulting in the production of stereotype floors with equal rentable value stacked on top of each other. This inclination towards profit oriented architectural conception as opposed to client or even more so, user centric conceptions led to the creation of closed systemic spatial substantiations. Basing the research inclinations within the contemporary information rich, technologically advanced, interaction supportive and customization oriented context (in chapter 01) thus highlighted the desire to translate such conventional organisational concepts through augmenting the spatial, informational and ambient constituents of space from a user centric perspective. This approach towards manipulation of space driven by the user's activity oriented needs thus formulated the core of the research undertaking. A highly dynamic and performative environment is thus proposed by means of addressing the basic unit: the user's needs and comforts. The entire research thus is a bottom-up approach towards conceiving a spatial system which is inherently open in terms of its interactive nature.

The resultant of a synergistic merger of expertise ranging across the academic and the professional sectors, this research work is an active experimentation with the interior landscape of intensive corporate environments. Architecture, engineering as well as interiors are eventually fused together to envision a seamless hard-spatial counterpart. Office furniture and its affordances itself became the interface for defining ergonomic spatial contours leading to a bottom up mediation of interior elements dialectically opposed to the conventional location of such interior elements within constructed space. An important aspect of this furniture oriented tangible interface was understood in the interactive interface it could manifest in the regulation of corporate as well as social organizational structure. Architectural space (hard) is thus contrived, is made much more intuitively suggestive and personal by means of conceiving conventionally inert spatial shells housing office infrastructure as interactive infrastructure within itself. Furniture and architecture, eventually fused via engineering precision are bound into one synthetic substrate, performing in real-time in accordance with the user's preferences, hence rendering a dynamic architectural quality to the proposed office environment. Intuitive creation of form, in the case of this research is thus negated for a highly deterministic approach of deriving form. Form per se is in turn subject to constant change akin to biological organisms in order to best suite/accommodate and provide comfort to the human inhabitants who are responsible for triggering topological articulation of individual physical skins (the pods).

The user-centric inclination throughout the research body is also reminiscent of the emphasis placed upon the changing nature of corporations. The transition from the Fordist production systems, which based their success on the prevalence of an essentially stable environment (persistence of routine operations) to the contemporary dynamic environment characterised by highly networked global production logistics, information technology oriented economies of scope and innovation, a rapid evolution in organizational structures eventually resulting in the formation of knowledge-based economies. The use of knowledge for the production of economic benefits subsequently leads to an increased importance being extended towards the knowledge worker (in the case of this research, the User) per se. In order to cater to the productivity and comfort of such knowledge workers (via their active interaction with the meta-system) this research work embarked upon appropriating territorial articulation, ambient conditions and customization possibilities, thus imparting a sense of liberty for creating one's own interactive domain. A symbiotic relation between space and its users, for the effective generation of knowledge and thereby attaining the prime corporate concern of generating economic profit hence underlies the primary concern of this research. In doing so, the research agenda further adheres to the notion of multiple usability of space, thus enabling to same spatial components to cater to a diverse range of activities being performed within the office at any point in time. Supporting hybrid programs such as conferencing, exhibition facilities etc can thus be materialized within the same space, via technologically enhanced, automated spatial transformation capability of the same spatial components. A singular architectural space can thus host a variety of programs via this manipulation of space; each manipulation resulting in the generation of a spatial variant appropriated for the activity being performed within.

The resultant meta-system operating on the boundaries of information technology, control systems, robotics as well as electronics is essentially an architectural undertaking which outlines the aforementioned evolutionary role of designers in the contemporary. The collaborative design basis for the research further exemplifies this changing role via opening up architectural conceptions to non-professional designers (users), specialists from multiple fields as well as co-researchers. Understanding the subtle linkages and deriving logical underpinnings from multiple fields rather than looking at them as facilitary attachments to a constructed space was a natural outcome of this inter-disciplinary approach. The research agenda adhering to this user centric, collaborative design oriented inter-disciplinary approach thus lead to a fruitful conjunction of the professional (industry) and institutional (academic) realms for materializing the resultant real-time interactive spatial system.

6.3. Applicability of the system

The system in its current developed state can be readily installed within offices for experimentation purposes. Owing to its current operation on the basis of real-time simulations, the software can be specifically tested for virtual allocation of space in accordance with the user's preferences only. Though, this performative aspect of the software has already been successfully tested by the author and close colleagues, it would be much more informative to test the system in a realistic office environment so as to comprehend certain unaccounted needs of the office staff. This would further help in enriching the system via feedback from these intensive testing grounds. The system per se, owing to its java based modular development structure can be easily enriched by means of adding new plug-ins in accordance with the observed/reported demands. The developed system is one of the first of its kinds to specifically serve office environments, the research endeavour should thus be considered as an evolving process which will be subsequently enriched in accordance with the intensive usage the system is put through.

Eventual development of the physical prototype (the details of which have already been laid out in the research body) will further enhance the real potential of the system by means of adding a tangible dimension to its processed output. The manner in which the physical prototype/generic pod has been conceptualised would simply imply the technologically enhanced pods to be inserted within existing office structures, thus doing away with extensive refurbishment tasks in order to realise a responsive setting. This insertion idea simply put, deals with the assembly of a kit of parts, and can thus be deployed in very less time for actively testing the software's output. The idea of conceiving the office as a collection of such adaptable pods, further allows offices to experiment with a few number of pods, test and analyse the suitability of these pods for their offices and then invest in setting up the entire office field. This approach will help in avoiding the otherwise inevitable input of considerable investments into office re-design initiatives without being able to assess the actual performance of new proposals. Testing the meta-system (software) for its ability to efficiently handle organizational structuring as well as imparting a sense of comfort and satisfaction (spatial, social and ambient) to the employees of an existing office would thus prove to be useful for envisioning a successful application of the system.

The repeated testing of the interface by the author and typical office workers for its ease of data entry as well as effective data communication abilities further assures its success in a professional environment. This user friendly aspect of the interface will thus help in considerably reducing the amount of time required to train/familiarise any office staff with the available preference entering options via the interface. The aim of the research, to develop an easy to comprehend, highly performative user centric meta-system is thus productively accomplished by the developed software.

6.4. Recommendations for future work

As was mentioned in the earlier section, the user centric research output in terms of conceiving a meta-system specifically for office environments is an experiment which is developed for linking spatial adaptation with the informational (user preference oriented) domain. The developed system apart from being rigorously tested and subsequently enriched would also need to be supported with the creation of the physical prototype. The inter-disciplinary framework adopted for this research brings forth the need for conducting specific research and development accompanied by prototyping in the material industry sector in order to develop the proposed smart skin. Small scale prototype developments for initial performance testing of developed material samples, in terms of their image and colour emission properties, flexibility and shape retention, embedded electro-active polymer gel infill actuation as well as exploring the properties of wearable computing for data communication within a flexible substrate would thus become vital. This material oriented research could be further enriched by extensive explorations in the field of biomimetics (appendix G) in order to develop physical augmentation properties devoid of any mechanics. Extensive research into developing the micro-structure of the proposed skin in a customized manner for generating desired physical properties upon external stimulus would thus need to be undertaken. The formulation of inter-disciplinary teams for the totalitarian conceptual, scientific and articulative development of such novel research endeavours would be a prime requisite for insuring a readily applicable research and development output.

Though successful interactive constructs like the Muscle re-configured and the Bamboostic have already been constructed under the author's guidance, a rigorous testing of the proposed physical prototype of the generic pod (for safety and performance issues) would be quintessential before it being induced within professional office set-ups. Its also important to note that the research work through its experimental agenda, only presents a generic user centric research of corporate organizations, however, in order to develop similar interactive constructs for highly specific environments (nature of activity oriented), an extensive data base pertaining to the needs as well as contextual requirements of corresponding users should be appropriately analysed for each case. The technological enrichments proposed for physical augmentation purposes within this research, considering the rapid growth of the information technology and engineering sectors are prone to become obsolete in time with the development of better, much smaller as well as more powerful engineering solutions. It should thus be noted that the co-evolution of design and technology based upon user requirement (analysed and speculative) exemplified through this research, rather than any one of these components looked at individually, is the most vital strategy to be considered for the future development of such real-time adaptive constructs. What could be further interesting is the induction of an artificial Intelligence based learning and reasoning capacity within the control system of the developed meta-system. This quality would further enrich the system to not only accept and organize inputted data but to become a suggestive tool for developing social organizations amongst the office staff. An intricate user profile matching via a set of evolutionary algorithms, combined with a progressive systematized tracking of user preferences (in order to learn every user's preferences and hence develop a pattern which can then be compared with user profiles for developing the proposed match) would be one of the few tasks to ponder upon in such a scenario.

Apart from the successful evaluation of the space allocation sequences being performed by the developed software, a physiological test outlining the direct impact of the interactive system upon the users should be specifically conducted. For this purpose, a physical 1:1 scale prototype of at least two pods should be constructed in its entirety; with the mechanics, the Lycra based skin, the actuators (lights, speakers, pneumatic muscles and pistons) and microcontrollers installed within the pods. Physiological sensor based (as was planned for this research were to be developed by the TU Delft's Industrial design department) measurement of stress levels of user's occupying these physical pods should thus be systematically conducted over a stipulated period of time. The results of this evaluation can thus be of utmost help in further enriching the research output by adding, modifying or removing the functionalities provided by the developed meta-system.

The operational logistics and the performance of spatial constructs conceived for the future of corporate office environments or for that matter any work intensive social structure should be carefully derived from the nature of needs/demands of the users who would be interacting with these constructs. This user centric notion of conceiving holistic spatial systems will undoubtedly result in the creation of meaningful, highly participatory and analogous (as opposed to hierarchical) democratic constructs. The notion of interaction as the core concept behind the formulation of such designed meta-systems would further benefit from diligent research in the areas of human-computer interaction advancements, technological advancements in electronic devices (enabling ubiquitous interaction) and scientific evaluation for measuring the impact of such meta-systems upon the well-being of the people it serves. The motivation and desire for conceptualizing architecture as a democratic construct which not only performs in order to best assist its user but also persuades one with an opportunity to be united with the system for manifesting space thus opens up an entirely new arena for creating such open source architectural constructs and should be actively researched upon in the future.

APPENDICES

Appendices

APPENDIX A

Going Post-Corporate- The re-urbanisation of business in the knowledge economy

Neil Leach: 5th Graz Biennial on Media and Architecture 07-11 November 2001
Session: Structural Changes and Urban Realities

Postmodernity is marked by the simultaneity of multiplicitous diverging tendencies. This also applies to patterns of urbanisation: The tendency of extensive sprawl exemplified in exopolis L.A. (Edward W. Soja) continues in parallel with processes of metropolitan concentration (Saskia Sassen). No overriding paradigm dominates the scene. As architect one might choose one's research focus where one presumes a viable potential for innovative architectural engagement. The tendency of choice explored here is the business-led reclamation of the historic urban centres after many years of suburbanisation and urban decline.

The reclamation of the historic city has many facets. I am neither concerned with tourism nor with the way corporations seem to brand and privatise the urban domain or use iconic architecture to advertise their presence on the urban skyline. What I am focussing on is the city as an authentic and effective place of work. The density, diversity and service intensity of urban centres has been rediscovered as a conducive milieu for the new patterns of corporate organisation and the culture of business relations that mark the emerging era of the post-fordist knowledge economy. Tourism, retail and entertainment are only relevant in as much as they help to financially maintain the various infrastructures (transport, hotels, restaurants) and cultural establishments that support sophisticated business communities. Indeed the rich cultural life (the arts, universities) of the big cities feed directly into the productive capacities of high value "industries" that specialise in areas like the media, IT, design, finance etc.
The appropriate slogans and catch-phrases that could be cited here to circumscribe the relevant cluster of phenomena might be taken from the discourse of management theory: Business eco-systems, loosely coupled networks, de-hierachization, participatory structures, out-sourcing, interdisciplinary team-works, hybridity, self-organisation etc.

The backdrop against which these emerging phenomena stand out is given by the orthodox corporation characterised by clearly set purpose, definite boundaries, strict hierarchy and well-defined internal division of competencies. The orthodox corporation is based on the incorporation of all types of work required for the production of the final service or commodity into its hermetic domain. These nearly autarchic systems withdrew from the constraining and chaotic conditions of the inner cities in order to create their own orderly and centrally planned productive universe on new tabula rasa green field sites. This was indeed the dominant spatial pattern of corporate organisation with respect to both industrial plants and administrative headquarters during the whole post war era until the early 1980s. As paradigmatic examples one might quote the Headquarters of John Deere & Co near Moline, Illinois, designed by Eero Saarinen and Associates in 1956 or Saarinens work for IBM. These developments are at the heart of the degeneration of the historic inner cities in this period.

This spatial pattern has become utterly dysfunctional with respect to the current flow of working relations that moves across multiple corporate boundaries and indeed leads to the blurring of corporate territories through the inflation of alliances and the loose attachment of an endless stream of temporary, independent consultants. While the orthodox system is premised on a rather stable economic environment that allows for long term planning and the build-up of elaborate structures, the self-organising network system is in a permanent state of flux, regroupment and reorientation. Underlying this is a general shift of balance from physical production towards design, the culture industry, research&developement, marketing, management&finance etc. in the most advanced economies. These are all creative and knowledge intensive productive activities that defeat the classical forms of corporate organisation. Inevitably a new organisational paradigm emerges.

The urban expression of this new paradigm can be found in urban quarters like London's Clerkenwell district where dynamic business clusters (design, media, IT) flourish and feed of each other in loft conversions build into the predominantly late 19th and early 20th century fabric that formerly sustained light industry like printing and various types of light manufacturing. Or one might take a look at London's more central Fitzrovia district where a dense web of corporations benefit from each other's expertise and are able to utilise shared resources. Here the AADRL (1) investigated the work/space patterns of two prominent service sector businesses that are world players in their respective fields: The engineering firm Ove Arup Partnership and the advertising agency M&C Saatschi. Both firms occupy multiple buildings (while hardly ever occupying a whole building) within close proximity. Arup has 9 different locations here. This reflects their organisation as a cluster of semi-autonomous groups (companies within the company) that each developed a certain identity and engages in multiple alliances with architects and other professionals around specific projects. The street space between the buildings becomes an informal communication space for the company while the rich choice of various lunch places and restaurants replaces the canteen buried in corporate orthodoxy. The so called "knowledge centre" emerged from the corporate basement library to become a publicly accessible research facility with street-level shop-window. Its video conferencing facility is offered for hire while Arup in turn hires large meeting and conference facilities for its specialist seminar series on demand from a nearby university. Subcontracting, outsourcing and freelancing blur the corporate boundary as internal support services like the IT department start to offer their services to outside customers to fully utilise (develop) its resources. Arup IT even starts to market certain specialised software products and is soon to emerge from the corporate hinterland into the urban surface of interchange. The challenge of ever-changing tasks and permanent competitive innovation requires an ongoing internal as well as external re-routing of the spatial lines of communication while the distinction between in-house vs. out-of-house is sliding.

The patchwork pattern of occupation allows for great flexibility in terms of contraction and expansion into and out of the urban web. Additional pieces of space can be easily acquired or released back into the market. There is always some space readily available. The gain in flexibility afforded here counts for more than the convenience of a unified territory that can not be maintained in this way. Such flexibility is obviously unattainable on the green field site - not to mention the required communication and interface density with external collaborators called for by the new ways of production.

On the basis of these observations and insights one might analyse the upheaval of modern urbanism and the rapid ascendance of postmodern (and then deconstructivist) architecture/urbanism as the superficial/profound expression of that radical transformation of patterns of production that has been theorised as the move from Fordism to Post-fordism.(2) Post-modern architecture found its market in the rediscovery and "detournement" of the historical city as business hot house, catering for the needs of the new forms of business organisation based on clusters and networks of semi-independent units rather than strictly integrated corporations. The new enterprise and yuppie culture could not flourish in suburbia or on secluded green field sites.

Rather than regarding cultural phenomena like individualisation, life-style diversification and branding as primary factors that might explain post-modern architecture, the explanation focuses on the development of the system of production and the attendant re-organisation of the labour process as the generative force of socio-economic and cultural development. Tendencies in architecture and urbanism are to be assessed on the basis of their participation in the overall progress of social productivity. Here in heart of the western metropolis it is a question of facilitating the latest trends and the apparent best practises in the organisation of an advanced knowledge economy. The question of contemporary urbanism can not be what appeals to this or that moneyed audience. Rather the following question must be posed: What does it take in terms of people, infrastructure and spaces of communication to produce a world class newspaper, a cutting edge engineering solution or the hottest trend in web-site design?

Each product produced in the knowledge economy is a new product elaborated in temporary interdisciplinary project teams. This implies a veritable explosion in communication requirements which can only partially be absorbed by the expansion of telecommunication means. A large part of everybody¹s working day is engaged with face to face meetings and the movement between meetings. The office transforms into a conference venue on multiple scales and bleeds out into the urban field (business meetings in restaurants, hotel lobbies etc.). Here the difference between work and entertainment dissolves. Another large part of the working day/week is taken up by research and permanent education. This aspect also escapes the dichotomy of work versus free time. The social principle underlying the modernist zoning - the distinction of working versus leisure time - is subverted as both are transformed into an equally relevant "gathering of experience" as aspects of the "continuous self-development" that elaborates personal skill-sets as the building blocks of the productive networks of self-organisation. The urban environment starts to reflect this rhizomatic seamlessness. The dense and porous spatial texture of these urban quarters offers a fertile matrix of interface surfaces and the rich articulation of degrees of semi-enclosure and intimacy for the various subunits woven into the otherwise continuous web of production.

Post-modern aesthetics - the (unheard of) rejection of the aesthetic values of homogeneity, coherence and completeness - and the celebration of diversity, collage and fragmentation signals the departure from the fordist regime of bureaucratically organised mass-production and heralds the beginnings of the new urban complexity. Deconstructivism and Folding are extensions of this fundamental break with modernism rather than signifying a further break. Here we find the further radicalisation of pertinent conceptual and formal repertoires that might be able to organise and articulate the new spaces for the knowledge economy with respect to their complex network patterns, their organisational hybridity, their smooth transitions and multifaced identities.

APPENDIX B

Robotic fields, Designing for a digital world, edited by Neil Leach

ROBOTIC FIELDS: Spatialising the Dynamics of Corporate Organisation in: Designing for a Digital World, edited by Neil Leach, 2002, based on the conference E-Futures: Designing for a Digital World, RIBA, London, June 2001.

"Robotic fields" is a chapter within a 3 year design research effort "Corporate Fields" conducted at the AA Design Research Lab(1). This research experiments with architectural responses to emergent forms of corporate organisation. With respect to recent patterns of corporate management a number related tendencies stand out that concern our attempt to offer architectural translations:

1. The enormous increase in communication density translates into an insatiable need for spatial connectivity and points toward deep, porous spaces.
2. A momentous acceleration of organisational restructuring translates into an insatiable request for flexibility with respect to the spatial distribution of domains and activities, pointing towards kinetic systems.
3. The tendency to move from management by means of command and control to strategies of self-organization implies an open, under-determined environment that allows for an ongoing aleatoric play of interpretation and appropriation.
4. A new level of organisational complexity calls for strategies of super-position, hybridization and multiple affiliations.

Architectural solutions to these challenges might be enhanced by robotic capabilities. The possibility to augment architecture by means of electronic intelligence has been investigated in the context of the overall expansion of spatial repertoires that emerged from the discourses of deconstruction and folding in architecture. For example: an under-determined and formally excessive "space of becoming might be further "virtualized" by means of augmenting various architectural elements with an electronically engineered kinetic spontaneity which allows the variously activated spatial features to participate in the aleatoric play of (re-)appropriation.

Identifying an emancipatory project: non-hierarchical work patterns:

We live in a period of political reaction. The political arena has been eroded by the frustration of national politicise in a globalised world. The eighties suffered the neo-liberal[1] reversal of earlier social reform programmes. This continued in the nineties combined with a further erosion of civil democracy. The co-optation and disintegration of any organised left opposition implies that an architectural commitment to progress and emancipation can no longer be guided by a straightforward political agenda.

But while politics proper stagnates, one can identify progressive tendencies within the process of corporate restructuring. The modern strategy of rationalisation based on the rigid segmentation and routinised specialisation of work within clear-cut functional hierarchies is failing today in respect to the complexity and dynamism of the overall socio-economic process. New ways of organising the labour-process are emerging in organisation-theory. A glance at the booming literature in management theory will suffice to capture the ongoing frenzy of restructuring: "Welcome to the Revolution", "The new Paradigm for Business", "Liberation Management - Disorganisation for Nanosecond Nineties", "The Post-modern Organisation", "Deconstructing Organisations", "Catching the wave", "The One Minute Manager", "Thriving on Chaos", "The Complexity Advantage", "Competing on the Edge Strategy as Structured Chaos", etc.

Although the word democratization is not among the slogans circulating around the management 'revolution', democratization seems the repressed logic of recent (and future) productivity gains, a necessity for the corporation to be able to cope with permanent re-orientation and innovation. The renunciation of command and control is forced upon the capitalist enterprise by the new degree of complexity and flexibility of the total production process within which it has to function. The more information-based, the more dependent upon research & development production becomes, the less can it proceed autocratically. These hard facts of production - more than ever seem to confirm left intuitions about the effectiveness of radically democratic, participatory relations on an advanced level of socio-economic complexity.

The left wing organizational paradigms (e.g. the rhizome), which Deleuze & Guattari elaborated in the late seventies, in dialogue with the new left forms of revolutionary struggle and organisation, seem to become the very paradigms of corporate restructuring: Deleuzian de-territorialisation is dissolving the rigid departmentalisation of competencies and the aborescent pyramid of classical corporate organisation is mutating towards the rhisomatic plateau upon which the leadership is distributed within a permanently shifting multiplicity of latent centres.

Today there is no better site for a progressive project than the most competitive contemporary business.

Spatialising organisational knowledge:

Contemporary business processes are more about the generation of knowledge than about producing immediate material values. More and more work takes place in the realm of ideas and information rather than immediate physical production. Thus the structure and pattern of economic activity in general is assimilated to the processes of science. This is the hallmark of the new economy as knowledge economy.

As an organisation shifts from being straightforward manufacturer or provider of a standard service to become a creative innovator, it no longer just utilizes a given knowledge, but needs to operate as original producer of knowledge. The new discipline of knowledge management takes account of this situation. Management theory offers concepts like "the learning organisation" or "the intelligent enterprise". Here learning, knowledge and intelligence are attributed to organisations rather than individuals. For us this is just the first step towards the further expansion of the notion of organisational intelligence to include the various spatial systems that structure and facilitate the vital communication processes within the business.

Knowledge becomes the most precious resource within the organisation. But this resource can not be bought in from outside like energy or labour. It can not be aquired readymade. Knowledge involves much more than information, it is the right information employed at the right time and place, evaluated and adapted within a complex praxis. Organisational knowledge, again goes beyond individual knowledge. Organisational knowledge resides within the organisational pattern itself, in the corporate system of communication and collaboration, i.e. in the distribution and dynamic integration of competencies, in the mechanisms, forms and modes of interaction between the various knowledge workers. The spatial distribution and the nuanced articulation of territories, boundaries and spatial interfaces has an important role to play here. Those architectural patterns contribute to the constitution of the collective intelligence that transforms information into vital operative knowledge.

One might ascribe intelligence/knowledge to every organisation that integrates a series of individual intelligent agents/knowledges into a larger, more complex intelligence/knowledge. Within a beaurocratic hierarchy all organisational knowledge is condensed and fixed within the proper procedures to be followed at every specific position within the administrative machine. Here learning can only take place at the top in the form of adjusting and re-writing the system of rules. Within a non-hierarchical network organisation the system of rules can evolve only if the organisation is at the same time based on self-organisation rather than a fixed constitution. The organising and orienting spatial structures, i.e. team-spaces, have to co-evolve alongside the determination of the social system of collaboration, its temporary division of labour, its groupings and channels of communication. The potential advantages of kinetic systems and the attendant possibilities of utilising artificial intelligence - in the form of life-game rules or flocking scripts etc. - are to be investigated with respect to specific corporate scenarios.

In contrast to the hype about the supposed collapse of space and the end of architecture in an age of tele-communication our working hypothesis is that the desired production of operative knowledge can be catalysed and sustained by built architectures which remain the indispensable spatial substratum of organisational life. Architecture increases its impact as the content of corporate production undergoes a process of progressive dematerialisation. This hypothesis does not deny the increase of tele-communication. Rather it assumes that this increased capacity of communication is swamped by an exponential demand for business communication that can only be addressed by means of new levels of spatial complexity and connectivity - further augmented by kinetics and electronic intelligence embedded within the spatial organisation.

From (animated) diagram to (animated) space:

The translation of organisational patterns into space utilises the organigramme as a spatial (2D) medium of articulation that architecture shares with organisation theory and the practise of management consultancy. The graphic repertoire employed determines the scope of organisational patterns that the consultancy business is able to work with. This repertoire is currently limited to two-dimensional Venn-diagram's operating with boxes within boxes and network diagram's operating with lines connecting nodes. The combination of the two formalisms is utmost of complexity that has been achieved within the domain of corporate organisation design. Therefore graphic representation does not really play an innovative role within this discourse.

In contrast, the expansion of graphic diagramming repertoires has been a key aspect of our research.

This includes the systematic incorporation of layering, the articulation of gradients, the employment of morphing to produce morphological series and matrices of similitude, the move to complex three-dimensional diagram's and the computer animation of 4-dimensional time-figures. These time-figures are geared to capture, model and manipulate the dynamics of organisational life on various time scales: the daily patterns of movement and communication within the company, the formation and re-formation of team-structures across the cycle of a project, as well as more long term corporate growth/re-structuring scenarios.

Each design language is dependent on a given or chosen formal a priori, i.e. graphic language or "design world"(13): a certain set of graphic primitives and attendant rules of aggregation and transformation. While the computer expands available repertoires it nevertheless represents a strictly bound design world, further constrained by the choice of tools and specific ways of building up the formal structures in each project. While this reduction of complexity is unavoidable it is all the more important to choose on the basis of comparative experimentation with various formal systems and to be aware of the contingency of any argument/result upon the initial formal choices. For example: when it comes to articulating an organisation in terms of the grouping of individuals various formalisms might be considered. One might start with rectangles next to/within rectangles to express relations of division and subsumption. Alternatively one might operate with circles next to/within circles.

At first sight these too formalisms might seem functionally equivalent. But the formalism on the basis of circles has a number of important iconographic advantages: The circular system allows the hierarchical level of a domain to be read off locally from its radius and the distinction between inside and outside can be read off the difference between concave and convex while the orthogonal system remains mute in these respects. In the case of overlapping domains the orthogonal intersection between two rectangles might be read as just another rectangle, while the intersection of various circles can not be mistaken for just another circle. It clearly reads as a domain of intersection, revealing as well the number and size of the intersecting domains.

The move from 2D to 3D, from intersecting circles to interpenetrating spheres has the further advantage of allowing for the articulation of a more complex pattern of overlap than can be managed within a two-dimensional plane. At an even higher level of complexity the diagram might have to resort to deformed 3-D blobs to avoid accidental/unintended intersections.

This comparative evaluation demonstrates how formal decisions might be rationalised within a functional context that poses the semantic dimension of architecture, i.e. orientation through articulation, to be crucial. This also shows why - once an articulate level of the visualization/spatialisation of organisationsal relations has been achieved within the diagram - the directive for the translation of the diagramme into an architectural space can only be: as literal as possible in order to maintain the orienting features of the formalism.

If this slogan is applied to the animated time-diagrammes which claim to model and articulate the temporalisation of organisational complexity as an essential component of the organisational system, then the literal translation of the respective time-figures into robotic fields is called for. The hypothesis is that animated, kinetic spaces will have a critical advantage with respect to facilitating and orienting the dynamic life of the organisation.

Layers of transience - furnishing the dynamic of social communication:

The first step in making this vision of an animated architecture tangible is the recognition of the total mass of furnishings - fixed as well as mobile as the crucial space-making substance rather than regarding it as an accidental filling of an already constituted space. The dichotomy of space versus furniture is dissolved into a layers of transience that start with the most ephemeral flux of light or images on computer screens, the movement of people and paper across the space of the office, files, mobile chairs, trollies and the semi-mobile swarm of light-fixtures, the more stable tables, shelfs and cabinets, the semi-fixed partition walls ect. all the way to the supposedly permanent structural shell and external envelope. The tendency of our design research has been to blurr these typologies and to aim for an overall increase and acceleration of transience and mobility within all of these strata (including structure). On the other hand the attempt is made to increase the space-defining power of each system with the result of dynamising what is phenomenologically recognised as the space. Once the substance of spatial articulation is thus put in motion the electronic augmentation and steering of the behavior of these substances can be elaborated. The invention/refinement of behavioral patterns and their dynamic spatial coordination is the challenge of this new paradigm of animated design. The consideration moves from mere form to morphology in relation to behavior: types of movement, modes of transformation, and the agglomeration into collective organisms.

The organisational function of corporate headquarters depends heavily on interior furnishings, both in terms of the diversity of types as well as with respect to the coherent inter-relatedness of the various typologies. A closed semantic universe is constituted subject to a complex matrix of differentiations: formal informal, fixed flexible, individual collective, demarcating connecting etc.

There is an immediate configurational as well as material engagement with the human body and its close range activities, both individually and with respect to the formation of groups and patterns of collaboration. In the final analysis it is the speculation about new social configurations and patterns of communication that we are concerned with.

APPENDIX C

DEVELOPING CONCEPT PROTOTYPES FOR ELECTRONIC MEDIA AUGMENTED SPATIAL SKINS

An investigation into biotic processes, material technologies and embedded computation for developing intelligent systemic networks

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(Research paper presented at the CAADRIA 2004 Conference)

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Abstract. The recurrent issue of materializing a responsive architectural spatiality, emergent, in its conception and the need for collaborative substantiation of the design process, utilizing a multidisciplinary approach towards developing intelligent architectonics are exemplified upon in this research paper through a design research experiment conducted by the author: Developing concept prototypes for electronic media augmented spatial skins. The skin is conceptualized as a synergetic merger of scientific investigations into the fields of Bio-mimetics, control system, material technology and embedded computation techniques.

1. Underpinnings:

The reality in which we situate ourselves reveals that the contemporary environment is increasingly being engulfed in the domain of digital information exchange and the interfaces that trail this new paradigm are almost entirely confined to the conventional graphical user interface comprising of a keyboard, monitor and a mouse. Bearing in mind that about eighty percent of information is non-verbal, the real challenge however lies in the notion of re-envisioning the physical environment as an interface to this very digital medium. It is in this milieu that the paper explores means of enriching architectural spatiality by incorporating the dynamics of information regulation, control systems and kinetic behavior to aid the generation of the much-speculated responsive architectons.

A systemic prototype (Figure 1) was developed to exemplify such responsiveness, as an electronic media augmented skin. The skin demonstrates an automated kinetic response with respect to contextual parametric changes (Light, wind and ergonomics). A synergetic merger of the fields of electronic media, material technologies, embedded computation, control systems and self-organization principles is instrumentalised in order to envision the responsive adaptive prototype. The Skin: an intelligence aided cladding system, is an active contribution to the much-researched field of real time data processing responsive architectural systems.

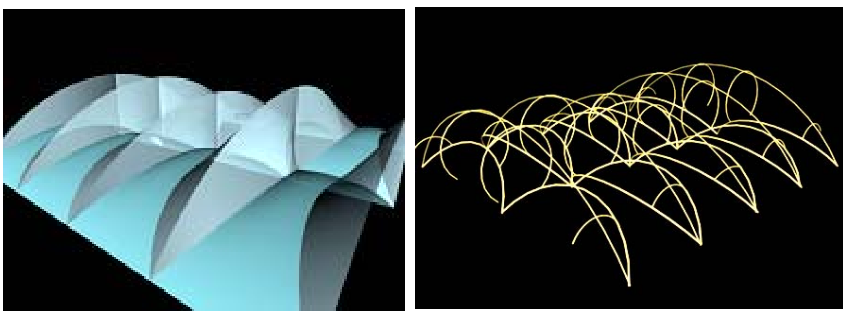


Figure 1. Images of the electronic media augmented skin

The prototype reacts to contextual changes by means of tactile variations of physical entities (system components, 2.0), hence regulating a comfortable interior environment, by maintaining optimal light and visibility conditions. Architecture, hence becomes a subject for real time calculation (Kerkhove 2001) possessing a continuous state of activation, representative of contemporary socio cultural dynamism. The project is conceived as a Multi-disciplinary construct, focusing on a synergistic merger of science, technology, art and architecture.

2.0 Developing electronic media augmented spatial skins

2.0.1 Overview

The skin is conceived as an external cladding system, modular in nature with the capacity to actively sense dynamic changes in its macro context: the environment within which it is embedded (sun angle, light variation, wind flow). The modular panel system is assembled together as a networked whole, hence developing an active information transfer possibility within the complete system. The skin is programmed to respond to contextual variations by means of actuating real time structural modulations to its network of panels. The modulations simulated, depend entirely upon parametric inputs on each single panel locally, creating a non uniform but highly specific alteration required to be made at an individual level in the systemic network. Each individual panel, since being intrinsically connected to its neighbors, generates a swarm like infrastructure, inducing relative alterations to its immediate neighbors. Hence, while working interdependently, the skin possesses a capacity to morph a highly orthogonal façade into an organic, highly efficient filter of environmental data.

Sunlight, sun angle, shadow patterns and thermal gain data are also considered in relation with the location and the orientation of the built form on which the skin has to be applied. The project aims at simulating a scenario where the cladding system can be deployed directly on the existing façade, or could form the external skin independent of the existing façade constraints and hence provide a breathable environmental control envelope for the interior.

2.0.2. Conceptualizing the skin

Analyzing the external façade of a typical modernist office block for opening heights, sill levels, lintel levels etc aided the basic dimension of the modular panel component. These initial geometric façade restrictions, in terms of two dimensional height and width diagrams were further striated in accordance with the corresponding subdivisions and opening patterns that could be generated for the same geometry (Fig 2.), resulting in a module of 2m x 2m which is striated into strips of .5m x 2m. These two-dimensional networks of curves attained from the striation process of the initial geometry are further utilized in the generation of three dimensional panel constituents (Fig 3.). This process was looked at from the point of view of generating a genetic make up (genotype) of an individual panel. A number of allele are experimented with, by lofting the same network of boundary curves, but considering different limits: Normal, Loose, Tight, developable, and Straight segments to arrive at a singular genotype for an individual panel.

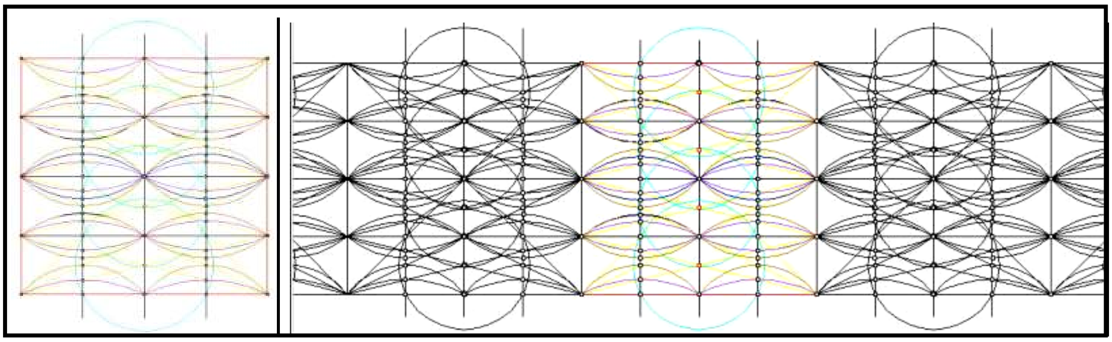


Figure 2. The 2d striated diagram illustrating the network of curves corresponding with the anticipated opening patterns of the skin. The curve network is generated as a result of an emergent continual striation process of the 2d geometry.

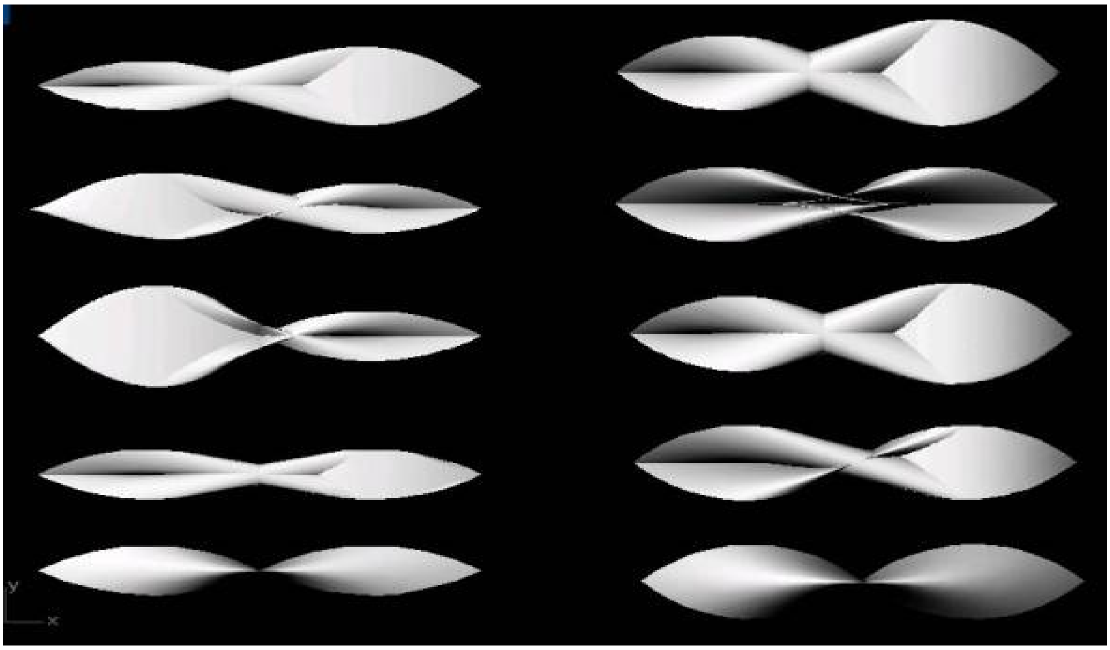


Figure 3. Genotypes: developed from the same two dimensional curvature networks

The genotypes selection is based on a thorough analysis of the external and the internal form, which is generated from the curvature loop process. The surfaces generated were subjected to curvature and wind analysis in order to visualise the stress and strain conditions that the surfaces inherit. This process was also partially conducted in order to approximate the constructability of these surfaces using CNC milling machines. The fittest genotype was hence arrived at by using the process of elemination based upon the analysis and various stages of its actuation were experimented with (Fig 4.). This process not only aided in the simulation of the surface at the digital front using animation techniques but also helped in generating a network of curvilinear entities that aid the kinetic behvaior at the structural front (Fig 5). These structural agents, acting as connector elements have been exemplified upon in section 2.0.3.3.

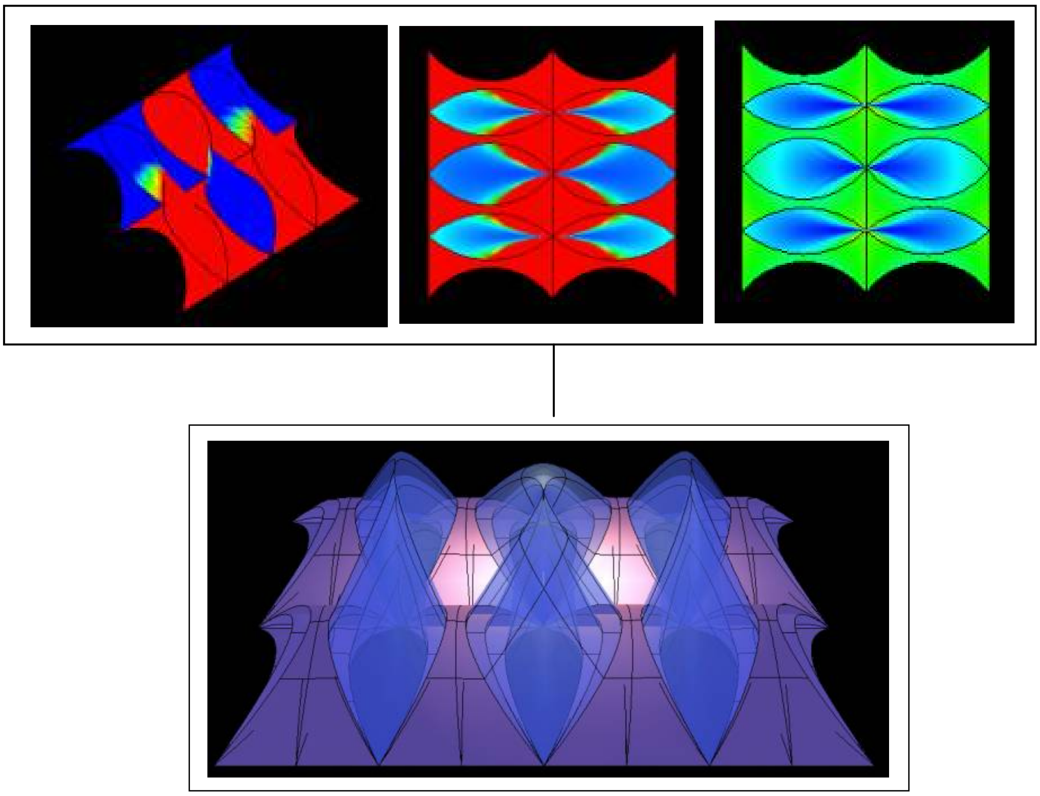


Figure 4. Curvature and wind analysis of the generated genotypes, as an eliminating principle leading to the selection of the fittest.

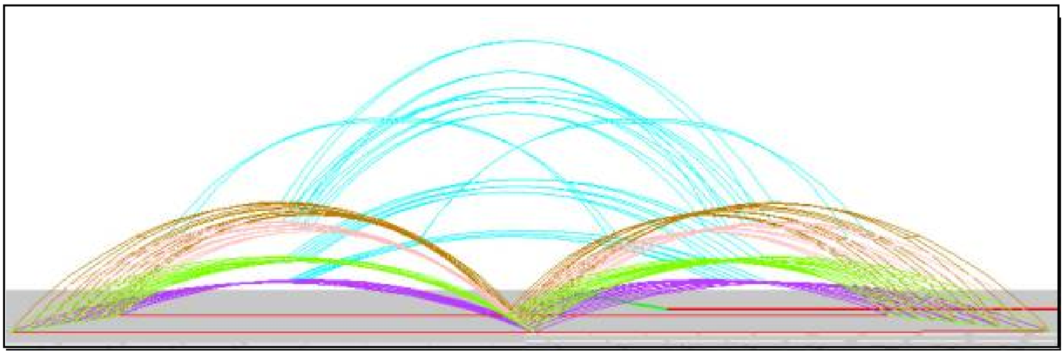


Figure 5. 3d network of curves that makes up the selected genotype. The curves correspond to a sequential stage of the networks opening mechanism.

A bottom up approach (for breaking up the genotype into its sub-components) was induced as the next level in order to develop parametric relations between the sub-components in accordance with the operational alterations that were witnessed during the animation phase in the system as a whole.

2.0.3. System components

The system is perceived as a network of components working in coherence with each other to generate the desired tectonic variations. Sections 2.0.3.1 – 2.0.3.7, will elaborate upon the system components, exemplifying dimensional variations, material allocation and performance criteria of each component individually. The surface is subdivided into two distinct entities: the membrane and the strata (Fig.6).

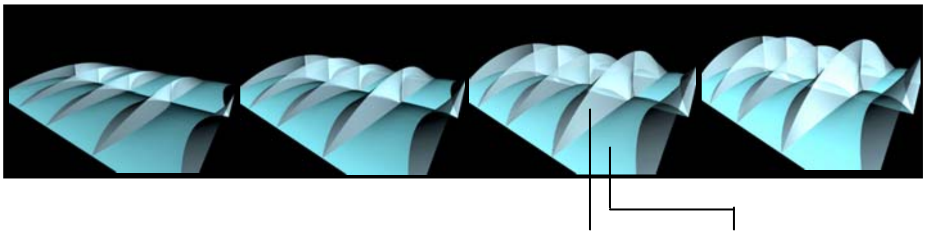
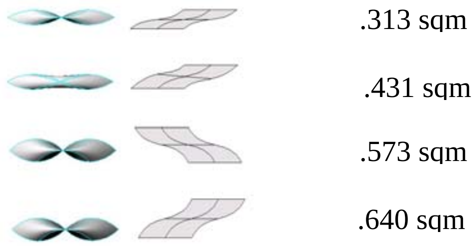


Figure 6. The surface assemblage: the Membrane, the Strata

2.0.3.1. The membrane

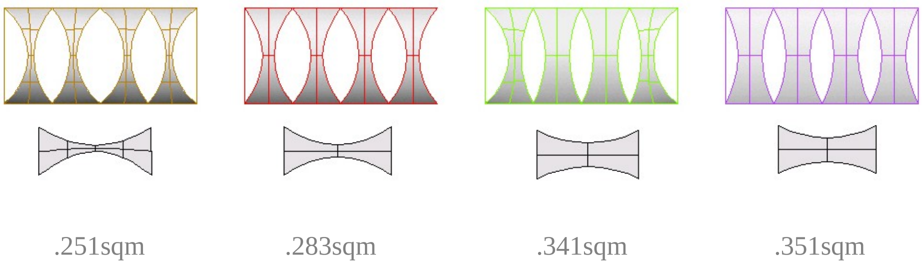
Area variation at different stages of expansion:



- Material allocation: Flexible perforated latex/resin
- Transparent in nature.
- Performance criterion: Allowing the skin to be breathable (for hot air circulation and ventilation)
- Expansion and contraction in the Pores will in turn result in varying gradients of transparency.

2.0.3.2. The Strata

Area variation at different stages of expansion



- Material allocation: Woven elastic latex double skin, with embedded elastic conductive threads and light sensors

- Translucent in nature
- Performance criterion: Flexibility, and Durability with an ability to retain the original shape, Ability to sense Sunlight data from the surrounding environment and transmit the data through the conductive threads
- Nature of the conductive threads: Elastic in order to shrink and expand with the modulating fabric

2.0.3.3. The Connectors

The connector elements are derived from the network of three-dimensional curvilinear elements, which constitute the genetic make up of the surface. The animation stages (Fig 7) also take into account these corresponding curvilinear entities hence creating the underlying guiding framework of the skin. The connector element is categorized into two typologies, owing to its direct connectivity with the two surface variants: the membrane and the strata (Fig 8): the arch shaping the strata, the arch shaping the membrane.

- Material allocation: Connected network of Carbon fiber tubes, Hinge joint at critical junctions to allow for movement, according to the stretch induced by the membrane
- Connected to the Strata as well as the Membrane.
- Performance criterion: Be able to adjust its shape according to the movement of the membrane fabric, Be able to simulate change in the Strata by being able to drag and stretch it along the X and the Z coordinates.

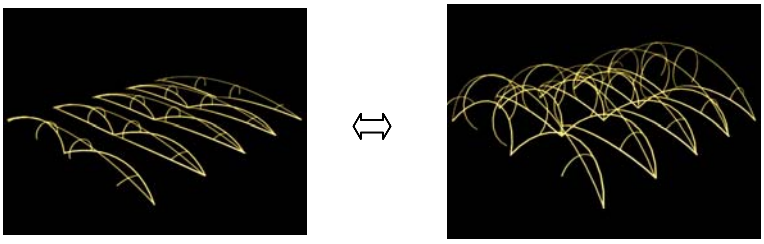


Figure7. Connecting framework exhibiting the initial and the final stages of expansion that is witnessed during the actuation process.

a. b.

Figure 8. a. Arch shaping the strata, b. Arch shaping the membrane

Both categories witness different cumulative angular variations during the different stages of surface actuation. These changes in the arch network are calculated by means of comparing the dimensional variations (both angular and linear) at different stages of expansion and contraction that the whole systemic network witnesses:

- Cumulative change in length in each individual arch: 162.05 mm
- Increase in the opening size (horizontal): 127.51 mm.
- Cumulative change in the angle of the arch shaping the strata: 16.75 degrees
- Cumulative change in the vertical dimension of the strata: 162.58 mm
- Cumulative change in the angle of the arch shaping the membrane: 28.65 degrees
- Cumulative change in the vertical dimension of the membrane: 398.93 mm

2.0.3.4. Analogue to digital converter

The I-Cube digitiser (Fig 9), is used to convert the analogue signals received by the sensors into digital data and to convert the digital signals given out as a response of these received values from the Central processing unit into an electrical field to activate the polymer gel actuators.

*Figure 9.*The I-Cube digitizer and the distributor of inputs from the digitizer

2.0.3.5. Sensing devices

Woven into the weave of the strata, the sensors are proposed to be thin solar cells (about 1.5mm thick). These work based on the principle of silicon releasing electrons in response to photons in the sun's rays. If one layer of silicon is treated to make it rich in electrons, and the other treated to make it contain far fewer, then a flow or electric current can be produced between the two. Alternatively some devices like the PVC-1 from Remote Measurement Systems (a 1 cm by 1 cm square photovoltaic cell) could be utilized directly in order to activate the polymer gel actuators since they have the capacity to produce a high degree of voltage. Amorphous thin film prototype module manufactured by Solarex in the 1990s was also found to be an efficient film that could be used for the solar sensing purposes.

2.0.3.6. Electro active polymer gel Actuators (distributed processing)

An electro active gel polymer based actuating system was developed as the actuating agents for the system. The actuator system is divided into two components: the actuator and the connector (for connecting the networked system to the building façade) (Fig 10).

- Actuator Components:
  - 1. External stainless steel casing tube 5cm radius with the voltage cable connection
  - 2. Internal casing housing the active polymer gel layers 4.8 cm radius
  - 3. Piston connected to the active polymer gel layers 8 to 10 cm length
  - 4. Layers of active polymer gels, with an expansion capacity of four times their original thickness
  - 5. Bottom piece with housing for attachment of rotary motors
  - 6. Motors attached for rotating the mechanism to accommodate the required deformation.

- Connector Components:
  - a. stainless steel connector (attaches to building facades: I beams or Mullions)
  - b. connector rod
  - c. junction element, catering to wiring, distribution, and data transfer cables
  - d. connecting hollow tubes
  - e. cap element with connector hollow tube, as an outlet for data cables
  - f. micro controller and motor mechanism
  - g. housing element for the actuators

- h. actuators

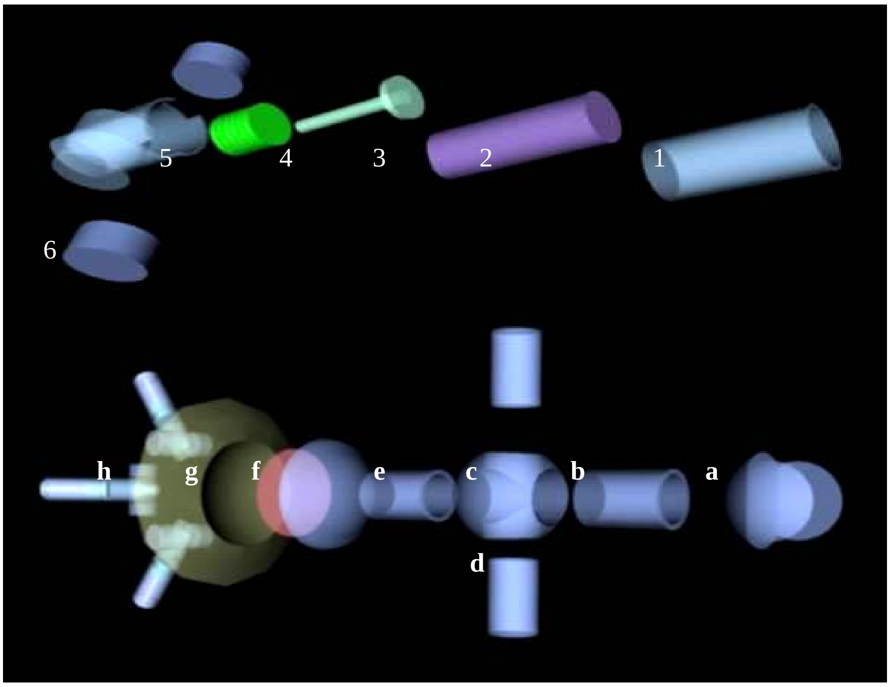


Figure 10. The active part of the (Actuators) positioning element consists of a stack of polymer gel disks separated by thin metallic electrodes. The maximum operating voltage is proportional to the thickness of the disks. The stack actuators are manufactured with layers from 0.02 to 1 mm thickness.

2.0.3.7. Central Processor

A central data processing unit that calculates and sends out impulses based on various inputs from the sensors implanted in the membrane skin. The unit will be in turn connected to the I-Cube system for receiving the digitized sensor inputs. A systemic layout is worked out in accordance with the rows and columns arrangement that the interactive panels will be subjected to and the manner in which the data is sent/received will also be charted out accordingly.

3.0. System Architecture

The creation of a self-organizing automaton, inherently involved visualizing system components as individual data processing entities, capable of processing data in real time while being actively linked with other elements of the system. This implies a continual variable data output with respect to the data scapes with which the elements are in constant communication (the environment). The skin is visualized as an organismic whole with all the components as members of the swarm, working constantly to generate activity patterns. A cohesive and interdependent relation is hence accomplished in real time, with the capacity to process both external and internal forces with equal emphasis on both. The networked behavior of the system components is elaborated upon in a sequential manner in the following sections:

3.0.1. Phase 1: (Figure 11) sequential flow representation

a. Strata with the embedded sensing device b > b. the sensing device registers the amount of sun and light intensity falling on an individual panel and transfers the information via c > c. the silk organza weaving (connecting the sensor in the strata) with embedded computation to the actuating nodes d > d. as discussed earlier possess distributed processing with each node having an embedded micro controller.

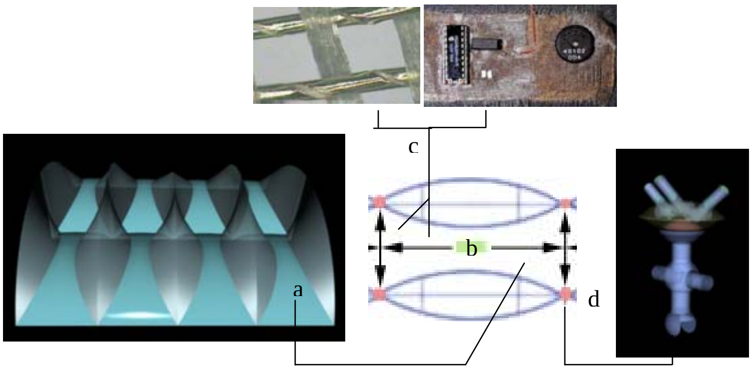


Figure 11. Information sensing and routing sequence (phase 1)

3.0.2. Phase 2: (Figure 12) sequential flow of data

The Actuators d. through the shortest route transmits the data to a central node e > The signals received at e. are still in analogue form f > f. this data is transmitted to the I Cube digitizer g > g. the digitizer receives the analogue signals and processes it further via the midi converter h. into a digital format > h. feeds this digitized information into the CPU i > in the CPU, MAX, the data processing software generates actuation information in a digitized form > This data is transferred back to the CPU from where it follows the reverse route > i. to h to g, where the digitized data is converted to an analogue form and is redistributed j. to the main node e.

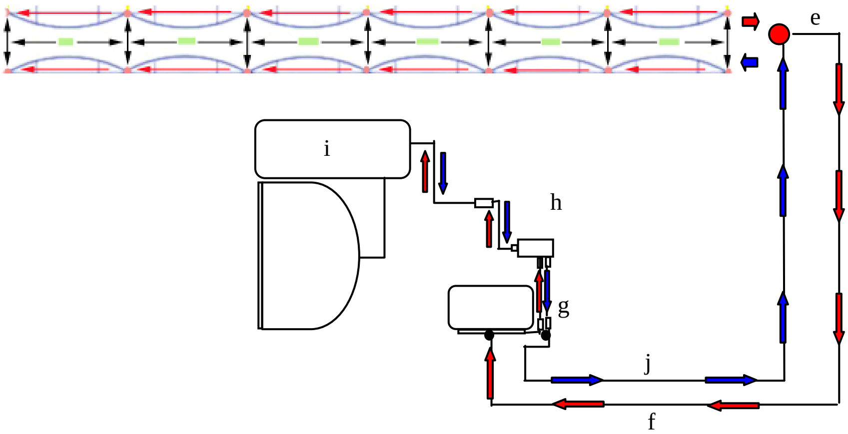


Figure 12. Information sensing and routing sequence (phase 2)

3.0.3. Phase 3: Actuation

This re-routed data reaches individual nodes, which in turn through their embedded microprocessors, compute the electrical impulse needed to activate the electro active polymer gels in the actuators and set the motor actuations to generate the required positioning changes in the actuators Figure 13. These actuators are directly linked with the system of flexible connector elements, which alter their geometry in accordance with the actions of the actuators, hence altering the networked systems overall form.

Figure 13. State changes in the actuators involve 3d movement control and generating electric impulses to activate the electro active gels.

3.0.4. Real time responsiveness: (Figure. 14, 15, 16)

The system thus conceived performs in real time with respect to the environment within which it is embedded to provide optimal lighting conditions in the built form where it is deployed. An open system working in coherence with the swarm's behavior, completely autonomous and emergent in its performance is hence materialized through the skin experiment.

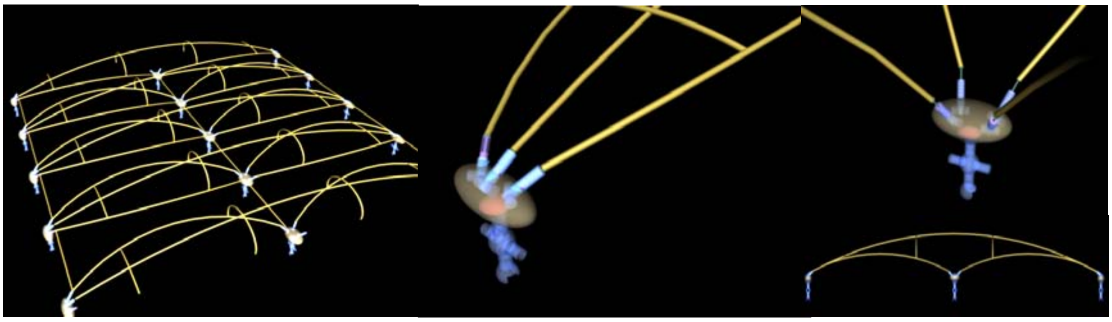


Figure 14. Actuators linked with the carbon fiber connector framework: A distributed processing embedded element actively linked with a flexible superstructure mechanism.

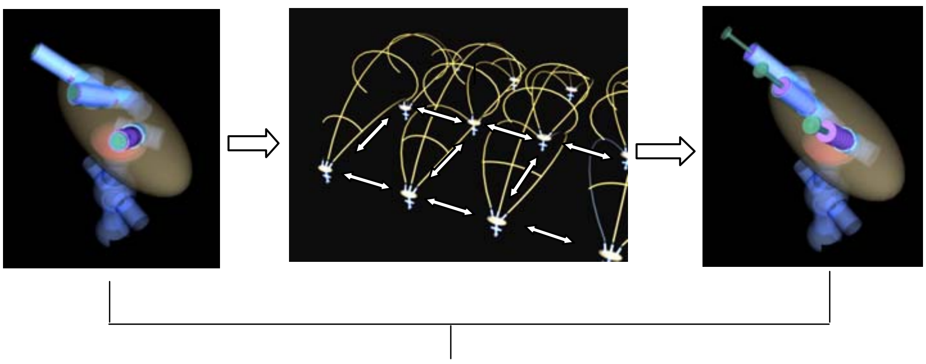


Figure 15. The modular grid of actuating cum processing devices accurately registers data that the sensor embedded strata delivers to it, and outputs readings to an external device, in this case the Midi Digitizer. It also acts as a distribution node in the network of data flow for transmitting data from one such node to the other.

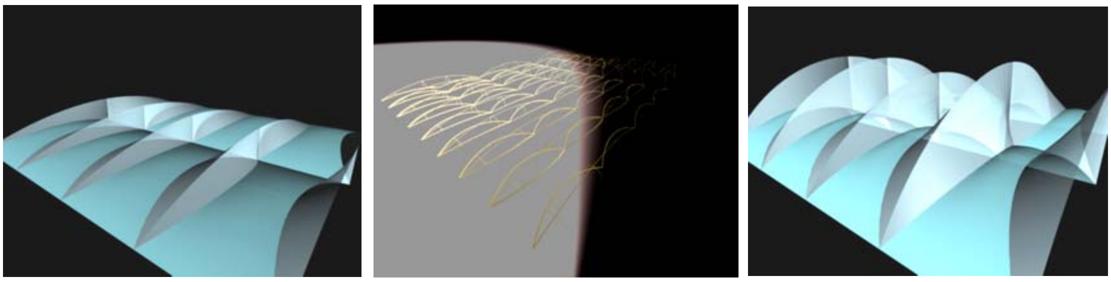


Figure 16. The resultant: real time responsive architectural system.

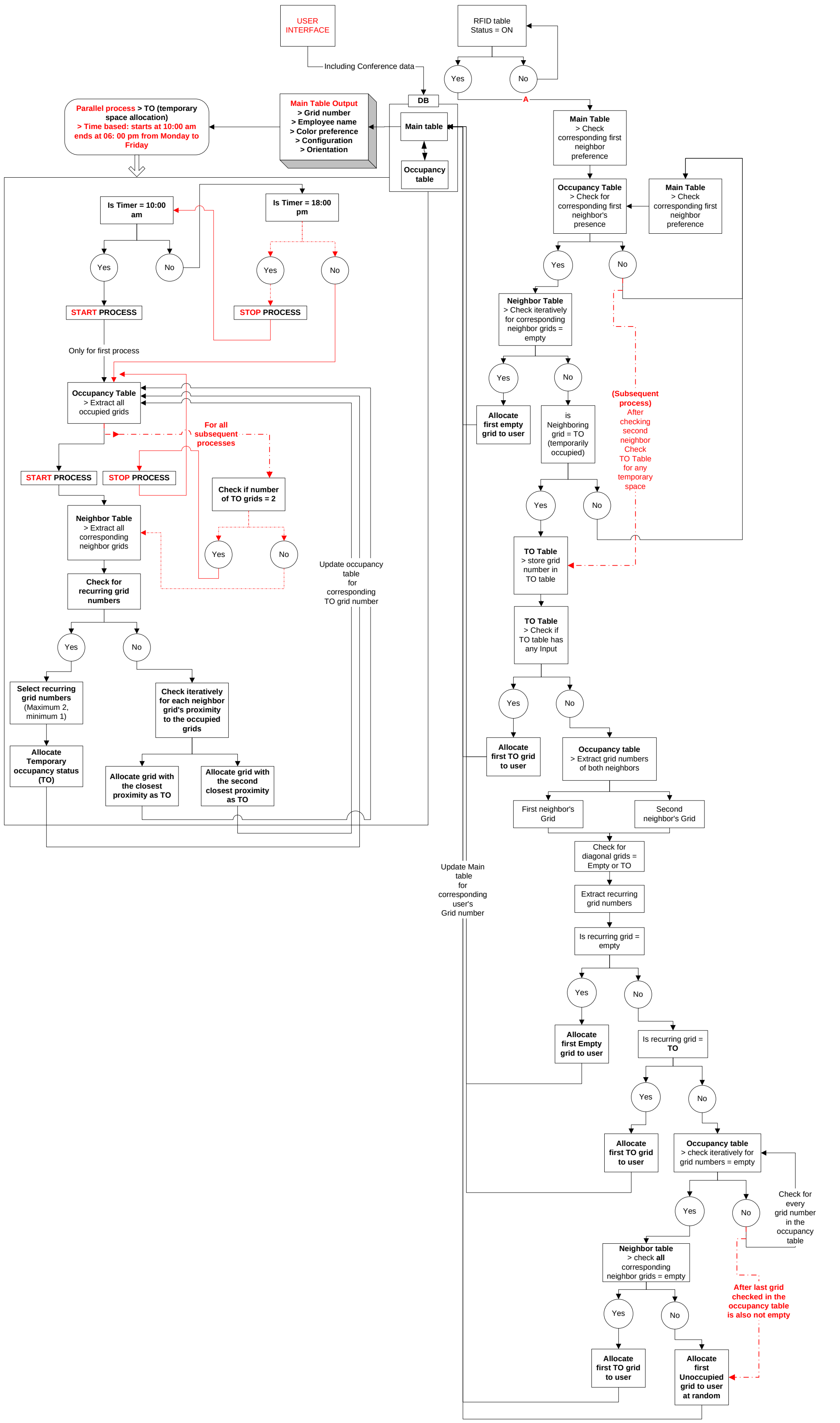
4. Conclusion

A Multidisciplinary approach towards architectural thinking is emphasized upon in the research work. Appropriating architecture as an open systemic network possessing emergent behaviour is propelled through the design research, with computation, networking and kinetic behaviour formulating a rational to the much-speculated issue of responsiveness.

The project embodies the conception of the Architectural whole as an organism, which is in a continual state of data exchange and actuation and hence employs a collaborative instantiation of processes and concepts of a variety of fields such as electronics, biology, physics and material sciences. The future of architectural space is visualized as a transient, real time behavioural body, by means of the illustrated project. Development of such inter-activating cohesive bodies can be taken further to develop a system of networked ecologies, hence developing completely parametric relational societies, which, in a continual state of attuning themselves, contribute to the dynamics of architectural form and functionality.

APPENDIX D: SPACE ALLOCATION PROCESS

25 January 2007



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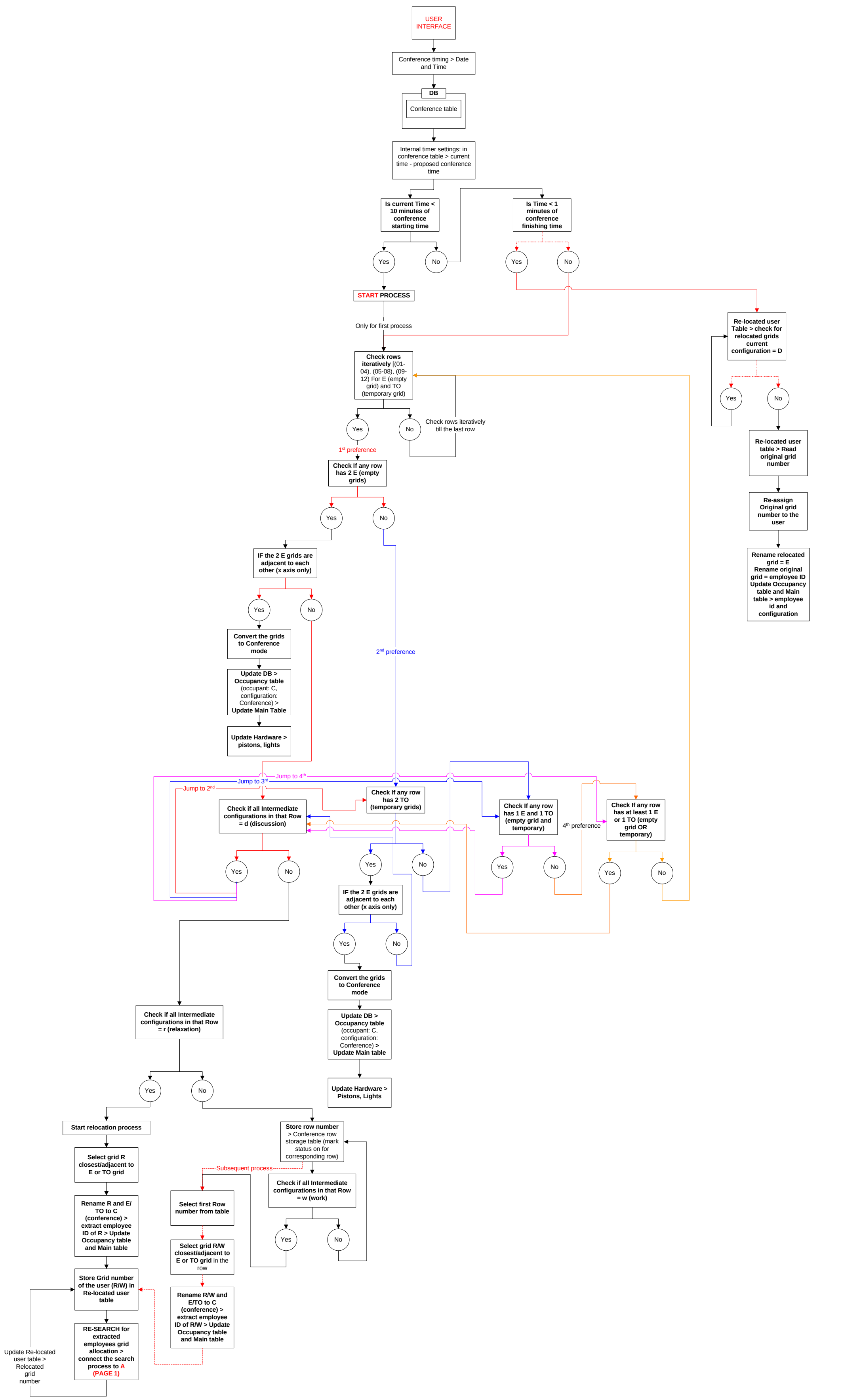
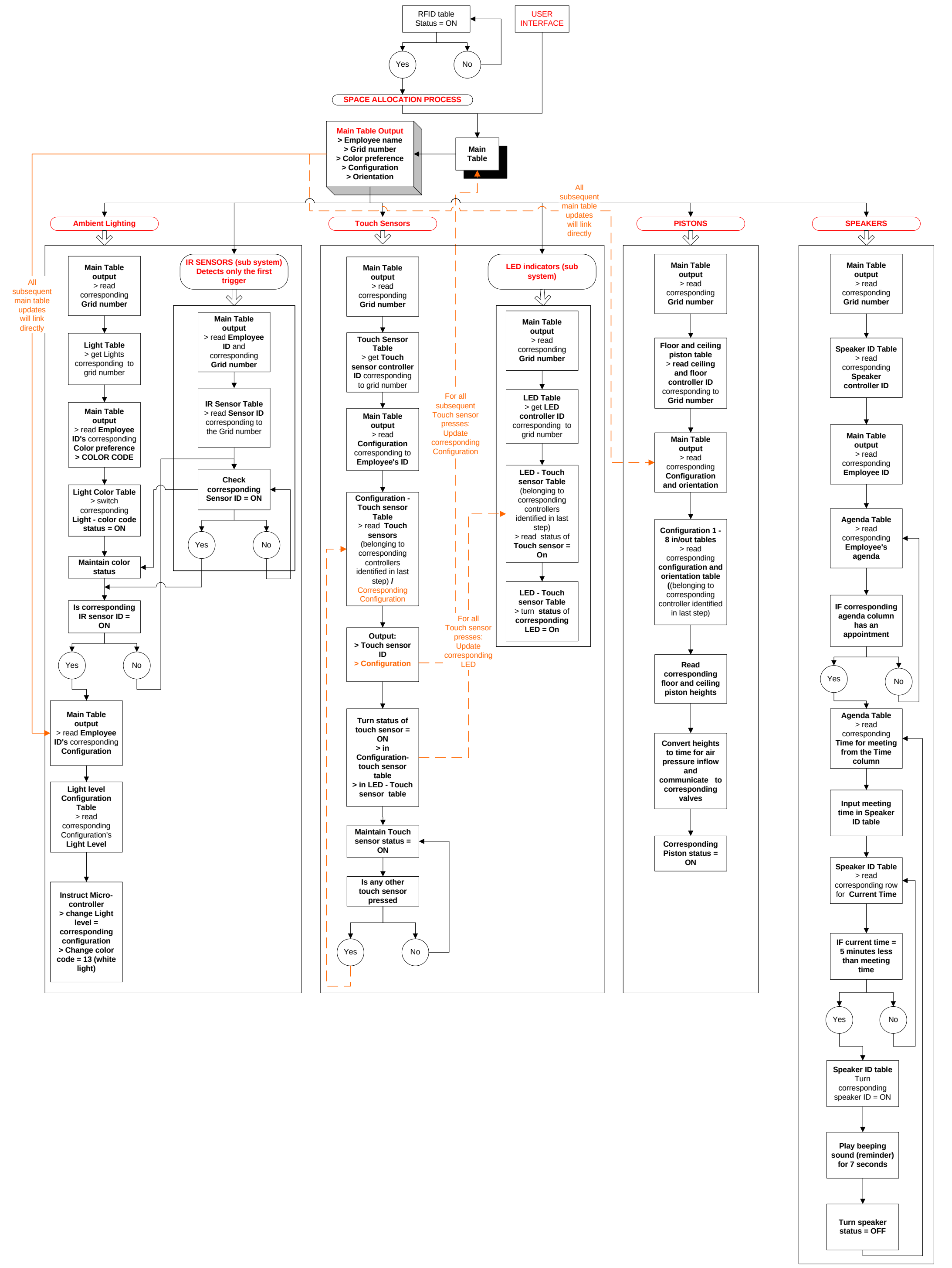
APPENDIX E: SPACE ALLOCATION PROCESS > Conference mode

25 January 2007



APPENDIX F: System diagram, Hardware communication

25 January 2007



Page 1

APPENDIX G

Nimish Biloria: Excerpt from Biomimetics and its application (understanding the contemporary), essay submitted for the history of technology seminar AA, London 2002.

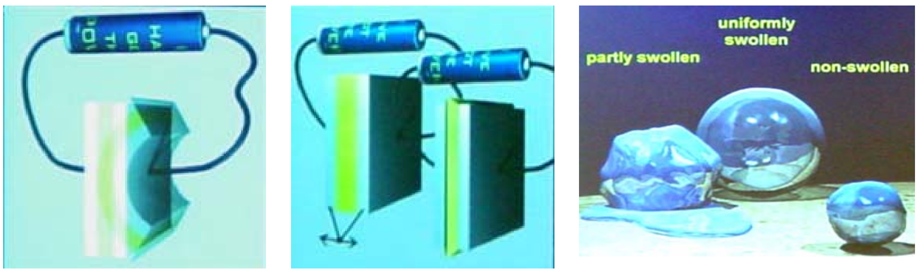
The material world:

The developments in the field of biomimetics and allied material researches brought forth many interesting behavioural characteristics which nature has in store. An interesting observation reveals that the bulk of the mechanical loads in biology are carried by polymer fibres which are bounded together by various substances, and the manner in which they are organised highly depends on the properties that the organism needs to possess. Materials produced by organisms, on the other hand, have properties that usually surpass those of analogous synthetically manufactured materials with similar phase compositions. Biological materials are assembled in aqueous environments under mild conditions by using bio macromolecules. Organic macromolecules both collect and transport raw materials and consistently and uniformly self assemble and co assembles subunits into short- and long-range ordered nuclei and substrates. The resulting structures are highly organized from molecular to nano, micro, and macro scales, often in a hierarchical manner, with intricate nano-architectures that ultimately make up a myriad of different tissues. They are simultaneously ``smart,'' dynamic, complex, self-healing, and multifunctional, characteristics difficult to achieve in purely synthetic systems. Therefore, biomimetics, the use of biological principles in materials synthesis and assembly, may be a path for realizing nanotechnology.

It was analysed that almost all load bearing materials in nature essentially constituted fibrous composites of some sort or the other, which mankind has tried to interpret in the form of high performance fibres like nylon, aramid and highly oriented polyethylene. The idea of using fibres to construct load bearing materials has undergone a lot of research and debates since such discoveries.
For instance in nature, the notion of adaptive mechanical design is extremely sophisticated and highly self organised, the magnitude and the loads that the organism develops become a guiding principle for the fibres to arrange themselves to resist and sustain the organism from collapsing, as a result this phenomenon is now being tried to be replicated by means of various finite element analysis techniques to simulate the possibilities in which materials could react under estimated loading conditions. In nature an abundance of patterns of fibre architecture can be found depending upon the mechanical conditions and performance criteria to be satisfied. As a result it can be seen that though the principles on which these systems act are general though the solutions will be highly individualised in each case. In the book lightness, Adrian Bukeers suggests that ‘the most obvious implications of composing efficiently are that constructions shouldn’t suffer under the burden of their own weight. Materials should be able to transfer as much energy as possible relative to their density. There are several ways of expressing this property… efficiency of course also involves making materials do what they do the best. Wood is not very good at taking pressure. Concrete is. Steel and fibres made from glass, aramid, polyethylene and carbon are extremely good at withstanding tension. The wise thing to do, if you want to build something light, is therefore to take care that the construction leads to a clear differentiation between tension and pure compression and that the materials are chosen according to their best abilities to deal with these forces’.

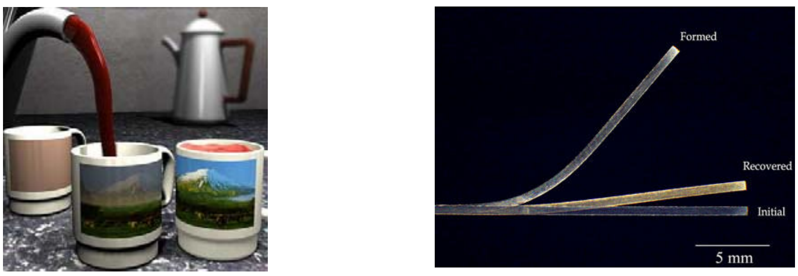
The introduction of fibre mechanisms to develop composites is highly regarded in today's times, however the world of composites itself suffers a set back in terms of dealing with the issues of compression, since the fibre network of the composites are good in terms of tension as was observed with natural systems as well. However steps are being taken now to study further the systems employed by nature to overcome such situations, for instance the notion of pre-stressing the fibres in tension, introduction of high modulus mineral phases intimately connected to fibres to help carry compression, heavily cross linking the fibre network to increase lateral stability, and by changing fibre orientation to avoid the compressive loads to be distributed along the fibre. We will further in the document see the manner in which some of these ideas are applied in creating successful building skins and composites for cladding the built form.

Another interesting development that is taking place is the development of smart materials. A smart material essentially interacts with the environment, responding to the changes in various ways. The developments of smart materials however as compared to the materials in nature, do need to be formulated as a system: with the presence of receptors, processors and effectors. One can see many developments in terms of materials like: electro chromic glass, thermo chromic materials (colour change with temperature change), conducting/dielectric polymers, shape memory alloys, electroluminescent (polymers become fluoresces when electricity is applied), polymer gels (having the capacity to grow unto a thousand times their own volume), hydrophilic materials etc. Each of these have found distinct applications in either the product design industry or architectural construction and many systems like sensor systems are now even used to check the stress, strain values and the failure and shear values in ongoing construction works as well.



a. b. c.

Conducting polymer (a), Dielectric polymer (b), Polymer gels (c), with the tendency to swell 1000 times the original volume.



d. e.

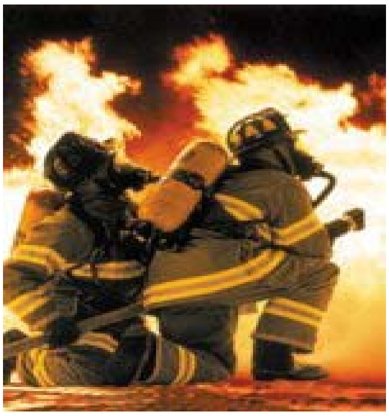
Thermocromic material (d) application: Change in the colour according to the heat sensed by the material, Shape memory alloys (e).

Biomimetics: an overview

The biological world has evolved novel materials essential for survival that can provide blueprints for new directions in materials and environmental research. Biosynthesis and bio-processing methods used to form these materials offer new insights and opportunities with regard to their design, synthesis, and fabrication. In the contemporary context and bearing in mind the fact that the next century is essentially assigned the title: the age of the new materials, the focus of bio mimetic research is essentially extracting a number of unique biological polymers and systems in an effort to gain fundamental insights into their biosynthesis and self assembly, and to engineer useful new materials for materials science applications.

An interesting proposition which the bio mimetic field has to offer is that the materials in nature are made under very benign conditions (tough ceramics such as bone and shell made at ambient temperatures; polymers such as collagen and silk produced from aqueous solvents), and since both nature and technology are limited by energy cost - that's why biomimetics can be utilised to deliver efficiency. The varied researches that have been taking place in the field of biology have been framing many ideas and suggestions, but it's rather recently that the contemporary performance requirements for built forms has attracted interest of material researchers and biologists to develop techniques needed to realise the practical values of the field. The bio mimetic science itself involves studying the various aspects of biological materials in depth taking into consideration the manner in which they are processed, their constitution, their structure, the chemistry itself, which could be analysed in great depth.

The distinction between structures and material itself becomes highly illusive in biology since between the polymer macromolecular chains and the functional organ there exists a multiplicity of structures defining different levels of aggregation of load bearing materials. This occurs usually due to the growth of fibres by successive deposition and other materials. This kind of an integrated sub structured arrangement is highly organised and ordered when it comes to distributing the loads and attaining strength, stiffness, toughness etc. by the manner in which it interacts at various levels. Many engineering materials have been developed with the idea of the microstructure that is prevalent in nature, even recently the development of man made polymeric fibres like aramid, do portray similar sub structures that can be seen in natural materials, and do share the same pros and cons which the biological fibres possess.



Firemen wear clothing that can withstand temperatures above 400oC without burning. The material is high-temperature polymer based on aramid fibres.

Polymers have an immense range of properties; some have fibres strong enough to stop a bullet and some are soft and stretchable like rubber bands. Polymers usually consist of hundreds, perhaps thousands, of covalently bonded units (called monomers) to form string-like macromolecules. These can be used as strings or they can be "stitched" together into a network, as in vulcanized rubber in automobile tires. Polymers can conduct electricity and emit light, and be used to produce transistors. They are the basis of the nanotechnology revolution through their use as photo resists. They are used in medical devices and are vital elements in the coming revolution in nano-biotechnology. In the future, polymers can be expected to play a role in almost all technological advances, since we can now control their molecular structure, atom by atom, to form synthetic polymers with uses limited only by our imagination. Dramatic recent developments in polymer science and technology are described in other sections of this document, including those on electronics and biomimetic materials.

However the bio mimetic sciences are still hunting for solutions and possible alternatives that could be developed that could overcome the fact that these biological fibres are extremely good at taking tension but inherit poor compression qualities. Multi-functionality of biological structures is another important aspect worth looking into. The whole idea of integrating various design disciplines, including engineering, architecture, mechanical design, product designing, aeronautical and ship building industries etc. hold great importance in the field of biomimetics, since it would be highly improbable to mimic the systems prevailing in nature without a thorough understanding of the various complexities it involves. The development of various smart materials is in a way the outcome of such integration. The recent researches even show that the biological sensing systems seem to operate to quite different principles. The sensors are non-linear, their responses can be very history dependent, they seem to sense multiple factors and large numbers of sensors are used in tandem to control behaviour.

The generation of motion and force are a result of the unique interaction of materials, structures, energy sources and sensors. Stemming from an overall interest in bio mimetic materials, there have been various explorations for embedding sensors in synthetic systems for instance the usage of embedded optical fibres for cure monitoring, the usage of piezoelectric stress sensors etc. which will surely be of great importance in the construction industry.

Perhaps the most striking difference between man made and biological materials is the number of components that they use. If we carefully observe certain natural systems it is clear that most of natures designs revolve around two main types of ceramics, a single type of fibrous protein, and a number non fibrous structural proteins, and several space filling polymers. The variety and versatility of their application lies in the structure at a molecular level. In the Domus magazine in January 1997, Frida Doveil, stresses upon the importance of mono-material systems: Single component materials have much less impact on the environment as compared to more complex systems which are harder to separate. Polymers can be constructed in the laboratory to fulfil a wide range of functions by genetically altering their structure at a molecular level. Doveil cited polypropylene as an example. It can be cloned depending on the function required and can be soft like a rubber or resistant like a techno polymer.

It seems that nature can serve as a model not just for passive materials and structures, but also for systems that can respond. The difference between this concept and robotics is autonomy. A "smart" material decides what to do without referring to any central controller (when did you last make an executive decision about healing a wound in your skin?). Once again nature leaves us trailing behind, but at least we are on the trail: University of bath (biomimetics department)

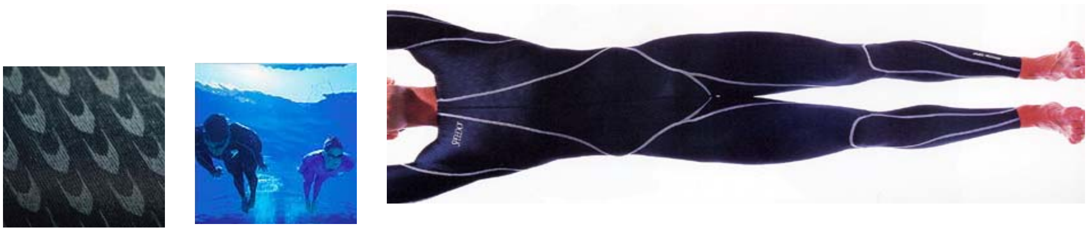
Bio mimetic research and the material industry:

The field of bio mimetic research is increasingly finding its applications in many contemporary material researches, which could essentially be applied to create products with specific requirements. These could be looked at from the point of view of component design, which incorporates the idea of focussing carefully on the parts which could help in building the whole, in an efficient and per formative manner. It usually involves the notion of combining materials with different physical properties to create a single entity. The biological systems are one of the best examples portraying this phenomenon and the manner in which an effective and responsive system could be created by the careful arrangement of the constituting elements.

The textile industry and the degree to which it is possible to engineer textiles today are truly astonishing. As a matter of fact textiles have now been considered as an alternative to heavier materials such as metals. To remain competitive in today’s fast growing markets materials must serve as many functions as possible such as strength, rigidity, alongside a soft surface texture and pattern. Let us focus on some products developed specifically keeping in mind some interesting features of the biological systems:

The Speedo Fastskin:

The shark, a creature that is fast in water but not naturally hydrodynamic, was used as a model for the Fastskin™ swimsuit. The shark's quickness is attributed to V-shaped ridges on its skin called dermal denticles, which decrease drag and turbulence around its body, allowing the surrounding water to pass over the shark more effectively. The fastskin fabric essentially duplicates the height, width and the exact proportions of the shark’s dermal dentricals. Due to the drag effect that occurs when an object travels through water, Fastskin™ fabric was constructed with built-in ridges emulating sharkskin. Fastskin™ is composed of "super stretch" fabric made to improve the suits fit and compress muscles. The result is a reduction of drag and muscle vibration, which increases productivity. A special gripper fabric on the forearm of the suit mimics the swimmers natural skin, enhancing sensory feedback.



The shark's quickness is attributed to V-shaped ridges on its skin called dermal denticles, which decrease drag and turbulence around its body.

Outlast:

If compared with traditional roofing materials, tensile membranes can offer relatively poor thermal insulation. One American company, addressing this issue is Outlast Technologies Inc. This issue was tackled by them with the development of a fabric called Outlast, which performed to provide warmth in the winter and a relatively cooler atmosphere to be regulated in the built form. At present it is used in the sports and the clothes industry but the fabric is essentially being developed to be used as an architectural membrane. This system uses micro-encapsulated Phase change materials (PCM), which have the ability to store or release heat. Water is one example of a PCM, as it changes from gas to liquid to solid, depending on the temperature. The PCM, in this case is however encapsulated at a microscopic level before being incorporated into the fabric. This can be done either as a coating on the finished fabric or through the fibres, using a wet spinning process. The fibre is expected to find its application in the building industry in the wall and roof insulation.

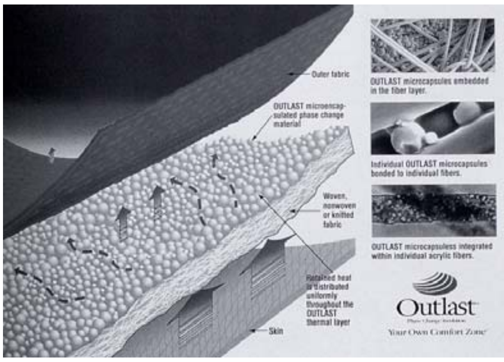


Diagram illustrating the composite structure of outlast, incorporating the unique, micro-encapsulated Phase changing material.

The surface kinetic integral membrane (SKIM):

The SKIM, is an explorative design for a responsive textile composite. The design has three effective layers. The first is a flexible textile, containing piezoelectric sensors. The second, and most complex contains electro-rheological (ER), fluids which are non-conducting fluids, containing polarised particles which stiffen when exposed to an electric field, it also contains localised contact electrodes and current carrying coils. The third layer mirrors the first one, acting as a feed back interface. This system has the capacity to monitor its surroundings and adapt to it, providing a smart or responsive environment.

Velcro:

Velcro as we know it today is based on the principle on which the barb of a goose grass burr acts. The hooked seeds of cleavers or goose grass are dispersed by clinging to animal fur or human clothing. The Velcro system of hook or fastener is based on the same principle. It is essentially a nylon material manufactured in two separate pieces. One has hooks woven into it while the other has a smooth surface made up of loosely woven strands in an otherwise tight weave. This allows the two surfaces to create a strong bond when brought together.

Scanning electron micrograph Images (false colour) showing the system of hooks in Velcro; Barb of Goose grass burr, hooking a strand of wool.

Composites:

The term is used where two or more materials, differing in form or composition, are combined to make a new material with enhanced performance characteristics. They usually contain a base reinforcement material, such as glass fibre prepeg, along with a resin for further reinforcement, filler to improve dimensional stability, and additives for additional functionality such as flame retardency. Composite materials usually employ the same idea as can be seen in the trees and the manner in which they arrange their fibres in the most profitable and structurally efficient manner, to avoid stress, optimize fibre use and building up fibre densities according to the natural forces which the structure would be encountering.

Honey comb structures have been found to add significant strength without gaining much weight to many sandwich structures. Used in commercial aircrafts, such as the airbus A320, the honey combs were found to give a twenty to twenty five per cent weight saving over metallic components. Hexel composites produce Fibrelam, which uses unidirectional cross piled glass fibre skins. These are bonded to an aramid honeycomb core to form structural sandwich panels used for aircraft flooring. Their Aeroweb aluminium honeycomb possesses very good kinetic energy absorbing properties, and has similar applications.

Westwind composites Inc. of the USA produce a range of foam filled honeycomb cells, Weskor. These have the advantage of thermal insulation and sound deadening properties. Kraft paper is used to form the honeycomb structure, which is filled with polyurethane foam and then sandwiched between a fine laminate of granite, marble, wood and an aluminium skin. On similar lines a Swiss company, Tubus Bauer AG, have developed honeycomb based sandwich panels for air filter safety and sports applications, employing a thermoplastic, such as polypropylene or polycarbonate, fusion or adhesive bonded to non woven or glass fibre for stronger reinforcement.

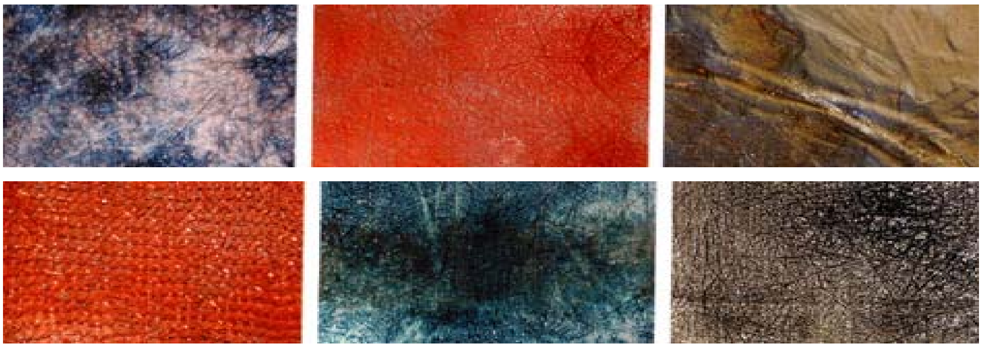
Polymer composite materials:

These materials possess a relatively high strength to weight ratio as compared to many other materials. They are also extensively used to achieve novel aesthetic effects, are highly mouldable and require very little maintenance. A polymer is essentially a combination of two principal elements: reinforcement and a matrix. The matrix materials can be categorised into three broad categories: metal matrix composites (MMC), ceramic matrix composites (CMC), and polymer matrix composites (PMC). The PMC is usually defined as a polymer due to the presence of large molecules which are created from a number of small molecules of the same substance constituting the matrix. Typically polyester and epoxy can be found as the most common matrix materials. The reinforcements are usually fibres that act as adhesives which are embedded in the matrix. A composite can also contain an additive or a filler to add volume with minimum weight gain. These could be in the form of chemical compounds that are helpful in imparting colour or improving the fire resistance quality of the material. Optimising material choices and the composition of a composite allows for weight reduction and can be an economical solution for extreme conditions where the time conditioned non-linear behaviour of composites can be utilised.

Many materials scientists are engaged in developing new ceramic materials and improving existing ones. This involves understanding the properties of the materials so as to tailor them for new applications.

Turbine blades are among parts subject to wear that are made of ceramic material. This prototype gas turbine rotor is made of injection-moulded monolithic silicon nitride.

For example, doping--adding chemical elements that are not present in the starting material--can change the electrical conductivity of a ceramic by many orders of magnitude, or change the type of conduction from electronic to ionic. Such conductivity changes are critical for electrochemical sensors and for materials used in clean energy production in solid-oxide fuel cells.



Material tests exploring different graphical patterns and degrees of light transmission resulting from clear polyester and various reinforcements and additives. Material elements used include: transparent polyester, different mixes of woven polyester mesh, chopped glass fibre roving, glass fibre mats, paper and colour additives.

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SAMENVATTING

Het onderzoek is toegespitst op het nog jonge gebied van interactieve architectuur als een interdisciplinaire systematische aanpak van ruimtelijke vraagstukken die gerelateerd zijn aan de hedendaagse socio-culturele dynamiek. Met name kantooromgevingen, als multi-socioculturele conglomeraten en dynamische ecosystemen vatbaar voor organisatorische herstructureringen en samenvoegingen/mutaties, zijn gekozen als experimenteel werkterrein waarin de grenzen van interactieve architectuur uiterst zorgvuldig onderzocht worden. Het onderzoek, opererend in het hierboven genoemde gebied, wordt geconcretiseerd in een poging tot het creëren van een zowel socio-cultureel als technologisch evoluerend, interactief programmeerbaar ruimtelijk systeem en wordt in grote mate onderbouwd door 'computation', interactief ontwerp en open ruimtelijke systemen. Deze interdisciplinaire benadering wordt in het bijzonder ontwikkeld voor het genereren van een constant met nieuwe informatie gevoede gebruiksvriendelijke, real time interactieve kantooromgeving die zich aanpast aan de gedragspatronen en voorkeuren van de gebruikers. In plaats van het creëren van conventionele inerte structurele omhulsels (harde componenten) gaat het in dit onderzoek om de ontwikkeling van een metasysteem, in andere woorden om het creëren van een 'zacht' door informatietechnologie verrijkt open systemisch kader dat interageert met de 'harde' materiaalcomponent en de gebruikers van de voorgestelde architecturale constructie. Dit interactiverende zachte en harde ruimtelijke metasysteem dient als platform dat de gebruikers een democratisch kader biedt waarin zij hun eigen programmatische (op activiteiten gerichte) combinaties kenbaar kunnen maken en zo op hun eigen behoeften afgestemde ruimtelijke alternatieven kunnen creëren. De anders zo statische en inerte harde architecturale equivalent, wordt zo, verbeterd met behulp van hedendaagse technologie, een fysieke 'interface' die gericht is op het uitbreiden van de mogelijkheden voor een ruimtelijk/structurele real time werkomgeving die optimaal voorziet in de behoeften van de gebruikers. Het onderzoek resulteert zo met name in het ontwikkelen van een ruimtelijk metasysteem dat steunt op 'computation' (eruit voortvloeiende software) en dat geleidelijk ingevoerd kan worden binnen kantooromgevingen die de gebruikers in staat stelt hun eigen sociale en ruimtelijke voorkeuren voor hun werkomgeving in te voeren door middel van een ontworpen interactieve op de gebruiker gerichte interface. Dit metasysteem verwerkt verder de ingevoerde data per gebruiker door middel van het intrinsieke 'computation' programma en algoritmen voor ruimtetoewijzing zodra de aanwezigheid van de gebruiker in real time (via netwerken van sensoren) is getraceerd. Dit intrinsieke proces van dataverwerking resulteert in real time simulatie en fysieke bijsturing wat betreft geautomatiseerde ruimtetoewijzing, ruimtelijke configuratie (real time adaptief vermogen) en verbetering van de werkomgeving (door middel van netwerken van actuatoren) in overeenstemming met de persoonlijke voorkeuren van iedere gebruiker afzonderlijk.

Het onderzoek maakt vooral gebruik van de resultaten van een PACT-analyse (een kader voor de factoren 'persoon', 'activiteit', 'context' en' technologie', gebaseerd op interviewsessies, observaties ter plekke en literatuuronderzoek) om een goed beeld te krijgen van de verschillende componenten van typische kantooromgevingen. Deze grondige analyse van ruimtelijke typologieën, de bioritmes van kantooromgevingen en de psychologische associaties/dissociaties van werknemers in een dergelijke omgeving, duidde op een groeiende behoefte aan een op de individuele gebruiker toegesneden omgeving binnen doorgaans statische en karakterloze kantooromhulsels. Aan deze behoefte wordt tegemoet gekomen door middel van de onderzoeksresultaten: een aanpasbaar (real time interactief) ruimtelijk metasysteem dat een nieuwe configuratie kan produceren voor de fysieke en informationele toestand en werkomgeving om variërende activiteiten binnen de kantooromgeving mogelijk te maken. Een multidisciplinaire aanpak verbindt het werkterrein van 'computation' (voor het structureren en verwerken van data), besturingssystemen (voor het ontwikkelen van sensor- en actuatorcomponenten) en kinetische structuren (voor het ontwikkelen van een dynamisch geraamte van het gebouw) synergetisch en maakt gebruik van de uitkomst van de PACT-analyse en versterkt zo de eerder genoemde co-evolutionele en gebruikersgeoriënteerde aspecten van het onderzoek. Problemen die gerelateerd zijn aan automatisering, gemak in het gebruik, een vrije en transparante inhoud die wordt gerepresenteerd door ontworpen interactieve interfaces, de keuze van hulpmiddelen en de verschillende ruimtelijke configuraties of fysieke vorm die aan een enkelvoudige architecturale ruimte gegeven zou kunnen worden, worden zo onderkend.

Om een dergelijke aanpasbare ruimte te materialiseren wordt een begin gemaakt met een componentgerichte aanpak die de ontwikkeling van een prototype van één generieke werkunit (de generieke 'pod' of schil), met als uitgangspunt afstemming op de behoeften van de gebruiker, automatisering, verlichting, geluid en meervoudig gebruik van dezelfde ruimte dankzij ruimtelijke uitbreiding/adaptatie. De in hoge mate aanpasbare modulaire eenheid wordt zo ontworpen dat hij eenvoudig in bestaande kantooromgevingen kan worden ingevoegd en doorgaans statische ruimtes in dynamische omgevingen veranderd worden. Na het succesvol evalueren van de aanpasbare werking van deze generieke unit wordt een cluster van dergelijke 'pod-units' samengesteld om een experimentele real time aanpasbare kantooromgeving te creëren. Voor het interactieve gebruik en het verschaffen van informatie met betrekking tot de contextuele setting van een dergelijke aanpasbare constructie wordt vervolgens een online real time interactieve interface ontwikkeld. De interface is specifiek toegespitst op problemen met betrekking tot ruimtelijke (op activiteiten gebaseerde) en sociale voorkeuren voor de werkomgeving van werknemers en bezoekers, terwijl de interface eveneens dient als hulpmiddel voor het (in real time) communiceren van de ruimtelijke en sociale toestand van het gehele kantoor. De voorkeuren die door elke gebruiker ingevoerd zijn dienen zo als individuele database waar strikt aan wordt vastgehouden tijdens het automatisch toewijzen van optimale ruimtelijke locaties (zodra gebruikers getraceerd zijn als ze het kantoor binnenkomen) binnen de gehele kantooromgeving die aan de door de gebruikers geformuleerde wensen wat betreft werkomgeving, configuratie en sociale aspecten (buren) voldoen. De gebruikers krijgen ook de mogelijkheid om de automatische toewijzing teniet te doen en onmiddellijk de ruimtelijke configuraties aan te passen aan de door hen gewenste activiteit. Architectuur, techniek en interieurontwerp worden zo samengevoegd om uiteindelijk een real time interactieve ruimte te creëren. Het meervoudige gebruik wordt nog verder gestimuleerd door middel van voorzieningen voor het (tijdsgebonden) omzetten van de hele kantoorsetting in een tentoonstellingsscenario (dat hoewel het voorgeprogrammeerd is om een specifieke ruimtelijke en sociale configuratie aan te nemen door de gebruiker verder kan worden aangepast) zodat een platform gecreëerd wordt voor het uitbreiden van doorgaans niet-flexibele, rigide architecturale fysieke constructies tot in hoge mate dynamische omgevingen.

Tenslotte wordt in dit onderzoek een op de behoeften van de gebruiker toegesneden software ontwikkeld die met name twee in samenhang met elkaar evoluerende aspecten verbindt: ten eerste, het bedenken, ontwerpen en ontwikkelen van een prototype van een aanpasbare kantoorruimte en ten tweede de ontwikkeling van een real time interactieve interface als een buitenschil voor het hele systeem. De software wordt ontwikkeld met behulp van Java en laat openingen voor inpluggen om de mogelijkheden van het voorgestelde aanpasbare gedrag van het kantoor te vergroten op de manier en op elk gewenst tijdstip. De motivatie en de wens om architectuur op te vatten als een democratische constructie die niet alleen functioneert om de gebruiker ervan zo goed mogelijk bij te staan maar die ook iemand ertoe beweegt gebruik te maken van de gelegenheid om zich te mengen in het ontworpen systeem waarin ruimte zichzelf kenbaar maakt, biedt zo uitzicht op een geheel nieuwe arena voor het creëren van 'open source' bouwkundige constructies analoog aan de resultaten van dit onderzoek.

ABOUT THE AUTHOR

Nimish Biloria was born on the 13th of October 1975 in India. After consistently deriving design strategies for materializing a fusion of media, architecture and engineering and being honoured with numerous academic achievement awards during his intensive five year undergraduate education, Nimish was awarded the Diploma in architecture from the Centre for Environmental Planning and Technology, Ahmedabad, India in the year 2000.

He subsequently joined the Architectural Association (AA), London, United Kingdom, where he specialised in the field of Emergent Technologies and Design and was awarded the Graduate design diploma in the year 2002. It was at the AA, that he furthered his inter-disciplinary design and research oriented pursuit and consequently developed substantial interest in the field of real-time interactive architectural constructs as well as the field of Biomimetics.

In order to provide a scientific framework for such an inter-disciplinary outlook, Nimish joined the Chair of Design Methods with the Hyperbody research group, Faculty of Architecture at the Technical University of Delft (TU Delft) as a PhD candidate in the year 2003. He has been actively teaching (design tutor) architecture and urban design studios at the post graduate as well as the graduate level, promoting the integration of digital media to envision innovative design constructs during his four years of association with the TU Delft. He has also been widely publishing and presenting his personal research and design deductions in numerous international computational design conferences and has been a proponent for exchanging informative design oriented knowledge.

Nimish adhering to the inter-disciplinary premise of his PhD has also been involved in developing alliances between professional practise and the academic domains. He developed fruitful alliances with the pneumatics engineering company Festo, the electronics company Philips as well as developed academic linkages with the Industrial design and the electronics faculties at the TU Delft, Netherlands. During his PhD term at the TU Delft, Nimish along with the Hyperbody research group staff was also responsible for developing real-time interactive physical prototypes with his bachelor students; these have been widely published in various international computation conference proceedings. His research interests range from developing real-time interactive spatial constructs, systems design (urban and architectural), kinetics, generative geometry, non-standard architecture and digital design to biomimetics, morphogenetics, smart materials and technology transfer.

PROPOSITIONS

01. Biomimetics, biotechnology and natural systems should be extensively researched for developing sustainable architectural and urban environments.

02. Research in the nano-technology domain needs to be conducted in order to develop smart/intelligent material systems which exhibit high flexibility as well as durability and environmental friendliness.

03. Inter-disciplinary research frameworks should be set up for addressing issues of energy efficiency and glocal (global + local) sustainability oriented spatial development.

04. The fields of architecture and engineering should converge and be taught as a comprehensive course such as 'archi-engineering'.

05. Information technology (IT) is necessary for addressing global warming issues should be enhanced.

06. An artificial intelligence (AI) aided, detailed database of existing materials with their properties (not only the construction sector but also other disciplines such as ship building, aviation, automobile sector) should be created.

07. Interdisciplinary design platforms for efficiently speeding up design and engineering solutions should be pursued.

08. Computation as a design medium rather than computer software as design tools should become the departure point for inculcating IT within the design based academic curriculum.

09. More research should be conducted on the lines of economical viability of computer aided manufacturing.

10. Technology transfer should be conducted with much more transparent frameworks in order to yield successful applied research outputs.

11. A distributed systems approach for developing, implementing, monitoring and evaluating localised development policies which are subsequently scrutinized by a central authority should be a strict framework followed by India in order to insure a sustainable evolution.

These propositions are considered opposable and defendable, and as such have been approved by the supervisors, Prof. ir. Leen van Duin and Prof. ir. Kas Oosterhuis.

STELLINGEN

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01. Voor de ontwikkeling van duurzame bouwkundige en stedelijke omgevingen moet uitgebreid onderzoek worden gedaan op het gebied van biomimesis, biotechnologie en natuurlijke systemen.

02. Om intelligente materiële systemen te ontwikkelen die gekenmerkt worden door een grote mate van flexibiliteit, duurzaamheid en milieuvriendelijkheid is onderzoek nodig op het gebied van de nano-technologie.

03. Kaders voor interdisciplinair onderzoek moeten worden ontwikkeld om vraagstukken aan te pakken van het doelmatige gebruik van energie en ‘glocal’ (global + local) ruimtelijke ontwikkeling die zich richt op duurzaamheid.

04. De vakgebieden van architectuur en bouwconstructie moeten convergeren en onderwezen worden als een curriculum dat beide vakken omvat, bijvoorbeeld onder de naam ‘archi-engineering’.

05. Informatietechnologie (IT) is nodig voor het aanpakken van vraagstukken van ‘global warming’.

06. Er moet een database opgezet worden met behulp van artificiële intelligentie (AI) die bestaande materialen en hun eigenschappen in detail beschrijft niet alleen van de bouwsector, maar ook van andere disciplines als scheepsbouw, luchtvaart, auto-industrie.

07. Er moet worden gestreefd naar een platform voor interdisciplinaire samenwerking om sneller en doelmatiger ontwerp- en constructieproblemen op te kunnen lossen.

08. ‘Computation’ als ontwerpmiddel moet, eerder dan computer software als ontwerpinstrument, het vertrekpunt worden om IT te introduceren in het academische ontwerpcurriculum.

09. Meer onderzoek moet worden geleid langs lijnen van economische levensvatbaarheid van computergestuurde productieprocessen.

10. Om tot een vruchtbare toepassing van onderzoeksresultaten te komen moeten technologietransfers worden geleid langs meer transparante kaders.

11. Wil India zeker zijn van een duurzame ontwikkeling, dan moet het zich houden aan een strikt kader waar vanuit verschillende invalshoeken ‘local’ ontwikkelingsbeleid wordt ontwikkeld, geïmplementeerd, gecontroleerd en geëvalueerd, en dat vervolgens zorgvuldig wordt getoetst door de ‘centrale’ autoriteit.

Deze stellingen worden opponeerbaar en verdedigbaar geacht en zijn als zodanig goedgekeurd door de promotoren, Prof. Ir. Leen van Duin en Prof. Ir. Kas Oosterhuis.