DEVELOPING AN INTERACTIVE ARCHITECTURAL META-SYSTEM FOR CONTEMPORARY CORPORATE ENVIRONMENTS

An investigation into aspects of creating responsive spatial systems for corporate offices incorporating rule based computation techniques

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Abstract. The research paper exemplifies upon an attempt to create a co-evolving (socio-cultural and technological) programmable spatiality with a strong underpinning in the domain of computation, interaction design and open system typologies for the generation of a constantly informed self-adaptive corporate office space (which addresses the behavioral patterns/preferences of its occupants). Architectural substantiations for such corporate bodies embodying dynamic business eco-systems usually tend to be rather inert in essence and deem to remain closed systemic entities, adhering to a rather static spatial program in accordance with which they were initially conceptualized. The research initiative, rather than creating conventional inert structural shells (hard components), thus focuses upon the development of a meta-system, or in other words the creation of a 'soft' computationally enriched open systemic framework (informational) which interfaces with the 'hard', material component and the users of the architectural construct (corporate offices). This soft 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 in order to create self designed spatial alternatives. 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.

1. Underpinnings

An exhaustive research into spatial typologies and the bio-rhythms of corporate offices, progressive evolution of the so-called generic cell, 'the cubicle' and psychological associations/dissociations of employees working within such office environments, suggested an increasing desire for customization of individual environments and induction of intuitive ambient dynamics to be introduced within otherwise static, rather insipid office shells. A dynamic user centric environment, bound to its contextual logistics is thus proposed. This research initiative, concluded with the development of a customized software entity which specifically binds two co-evolving aspects: conception, design and prototyping of an adaptive office space and the development of a real-time interactive interface as a front end of the entire system. The software is developed using Java in a modular manner, thus leaving itself open for further plug-ins in order to enhance the proposed adaptive behavior of the office space as and when required.

This proposed environment is conceived as an adaptive (real-time interactive) spatial system which can re-configure its physical and ambient configuration to cater to varying activities being performed within office environments. 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 physical augmentation/adaptation is embarked upon. After successfully evaluating the performance of this generic unit for its adaptability oriented aspects, a cluster of the pod units is assembled together in-order to conceive an entire real-time adaptive office environment. These highly adaptive modular units are designed in way that they can be easily inserted into existing office shells, thus converting otherwise static shells into dynamic user centric environments. In order to interact as well as impart information pertaining to the contextual setting of the above mentioned adaptive office environment, an online real-time interactive Interface is subsequently developed. The interface specifically caters to issues concerning data input (by employees and visitors) and acts as a medium for communicating the spatial and ambient state of the office.

The adaptive office oriented research builds upon a substantial amount of physical real-time interactive prototypes built over a period of three years at the TU Delft under the author's guidance. A methodical testing and evaluation of the underlying Multi-disciplinary approach binding design, computation, electronics, control systems and kinetics is thus already conducted in order to arrive at the proposed adaptive system.

1.1. A FRAMEWORK FOR USER-CENTRIC DESIGN

The research work specifically operates on the outcome of PACT analysis (People, activity, context and technology framework, conducted through interview sessions, on-site observations and literature reviews) for developing a bottom-up componential understanding of typical office environments. This analysis was utilized for extracting a set of intrinsic requirements for designing an appropriate interactive system for the corporate species. Issues related to 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 (the generic pod) could inherit were thus derived from this analysis. Three broad activity oriented categories of topological space modulations (Figure 1): Work, Discussion and Relaxation were subsequently derived.

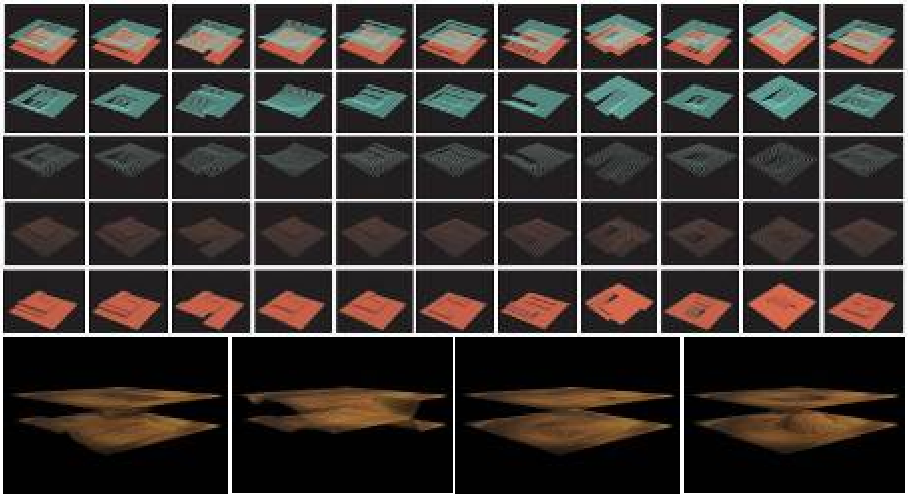

Figure. 1. Work, discussion and relaxation related initial configuration variants.

Each of these topologies is further broken down into two configuration variations per mode (as a research scope limitation). Apart from the above stated configurations, a temporary space for informal meetings, an over-ride configuration (partially customizable) capable of converting the entire office environment to an exhibition/entertainment space for image building and public interaction occasions (open days) and a conference configuration for converting a set of adjoining pods into a conference setting are decided upon.

2 The Generic pod: mapping conceived configurations

The above mentioned conceptual spatial configurations are subsequently conceived as the resultant of an alteration of a set of two surfaces (floor and ceiling). Any configuration formation is seen as the result of varying height variations of the two surfaces at specific co-ordinates. Data pertaining to the maximum and minimum height variation co-ordinates per configuration is eventually retained from these conceptual models and are used for developing automated Java sequences responsible for generating the mathematically computed topology of these surfaces.

The two planes in the java environment are represented as a set of point clouds or vertex clusters. Owing to the fluid nature of the ceiling surface, an automated interpolation sequence using a sinusoidal function is utilized by the Java code responsible for calculating respective vertex positions constituting the ceiling plane. The maximum height variations derived from the aforementioned conceptual models are used as peaks for the sinusoid function. The entire ceiling profile is thus generated in sections, by taking the peak points into consideration. This logic works in both x and y axis directions thus attaining an overall fluid curvature for the ceiling surface (Figure 2).

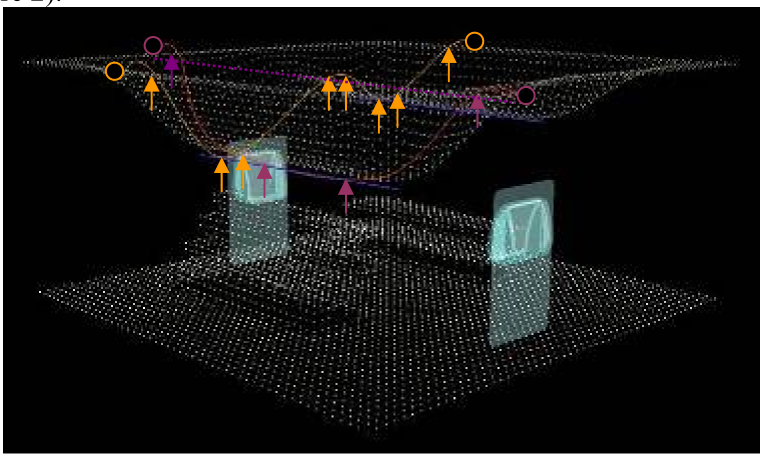

Figure 2. The sinusoidal curve in both directions is developed in sections considering the arrows as peaks (derived from conceptual models) for calculating the heights of the points lying between them.

Calculation for the height of a vertex at a given location (x), between two fixed vertex (peaks) co-ordinates (x1, y1) and (x2, y2) is attained by using the following equation:

$$h(x) = (\sin((x - (x1 + x2) / 2) * \pi / (x2 - x1)) + 1) * (y2 - y1) /2 + y1$$

The floor surface, 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. An office scenario is eventually simulated by means of clustering together 12 generic pods, each embedded with the computational logic explained above (Figure 3).

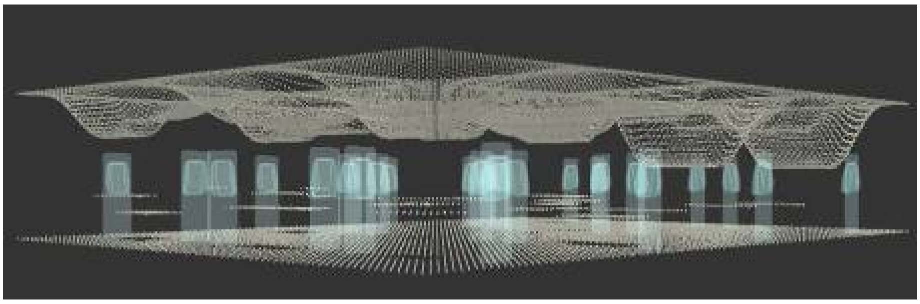

Figure 3. Office environment as a cluster of 12 generic pods.

3. The Interface: building interaction between users and the pod

After developing the adaptive behavioral aspects of the generic pod and formulating a cluster of the pods, the notion of Interaction between the computationally driven space and the users of this space is focused upon. A real-time interactive interface (Figure 4, left) for communicating user oriented preferences to this inherently adaptive space is thus developed. The Interface can be accessed over the internet by the employees of the office for customizing a fixed set of preferences (entered via bottom left section of the interface). A color preference for his/her work pod can be made by each employee; this color (ambient light) will be activated for visual identification of the workspace allocated to individual employees as and when their spatial positions (entering the office) are detected via sensing devices.

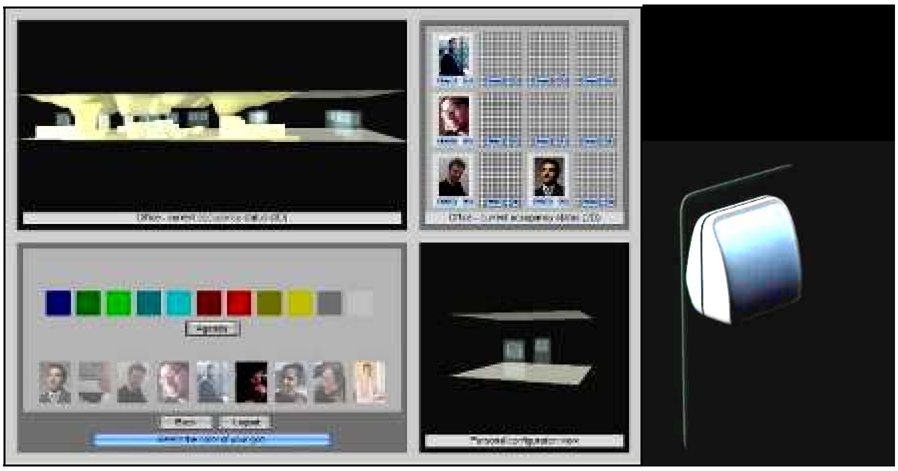

Figure 4. Real-Time interactive User interface and the pluggable units.

A choice of neighbors, currently limited to two degrees of preferred neighbors can be specified by each employee; this option can, besides gratifying psychological comfort, can also be an active mode for organizing groups (teams) operating within the office space (This setting could also operate at an organizational decision making level for inducing a top down grouping option). Choice of spatial configurations is another preference which the employee can select out of the given set of aforementioned activity based spatial alternatives; this selection will be activated once the employee's proximity is detected within the vicinity of the office space. The employees are also given the freedom to specify their desire to sit at a fixed location or a flexible location within the entire office space; this flexibility option allows one the freedom to be allocated a space (automated space allocation sequence) which satisfies all of his/her aforementioned preferences.

The interface also incorporates a visitor's section, via which they are able to book appointments which are directly updated in a database table corresponding to the employee's appointments (the appointments can be viewed by the employees as soon as they log into the system). Data entry options pertaining to day and time as regards when conferences or exhibitions are to be scheduled are also provided via the user interface. These, time based configurations are deployed in an automated fashion via the control system component in optimal locations within the office environment. The interface apart from providing the employee with customization tools also provides a visual feedback of the current occupancy level (real-time updated) within the office in a 3d as well as a 2d manner (top left and right section of the interface).

At a local control level, Pluggable units (Figure 4, right) are developed as mobile/portable storage cum touch screen interface units. These, have the possibility of being connected at borders of each work pod (via docking ports embedded in the floor), hence in a tangible manner attaching its functionality to every individual pod per say. Such portable units, on one hand operate as the much needed storage space per employee as well as act as a touch screen for the employee to change his configuration.

4. Database: organized storage of inputted data

A real-time updating database developed (ODBC using MS Access) for storing the above mentioned preferences per employee as and when inputted through the interface is subsequently developed. The Database also incorporates tables concerning a list of microcontrollers (associated with specific actuators: lights, speakers, pistons) pertaining to each workspace. It also incorporates set values of lighting levels per configuration as well as stores data for each sensor and actuator status involved in the physical prototype. The database is hence envisioned as a central layer of the entire system which receives data, is updated in real time and acts as a trigger for initiating data mining/structuring initiatives fostering spatial augmentations. This database is thus fed in with data via the interface, the plug in pods and the sensing devices and is actively mined by a Control system module for data processing and outputting actuation protocols.

5. Control system: data processing to output actuation protocols

The control system (Java based) module specifically deals with issues of processing the preferences laid down by each employee (in the database) via a space allocation algorithm which specifically deals with allocation of an appropriate workspace to an employee whose presence is detected in the office's vicinity. The space allocation sequence incorporates a series of data-structuring routines that operate on a set of rules; for mining the database, developing interconnections between datasets, checking for conditionalities and allocating grid/workspace to each employee while satisfying his/her preferences.

The space allocation algorithm also incorporates a sub-routine based on an a triangulation algorithm responsible for allocation of the temporary space configuration, which is triggered at 10:00 am and is responsible for activating this informal configuration in an unoccupied pod nearest to the workspaces which are occupied at that point of time. This, temporary space is modified only under circumstances when no other pod but the temporary space allocated pod would satisfy an employee's preference or in case when the need for adjacent empty pods for conferencing facilities necessitates the temporary configuration to be altered.

A conference mode and an exhibition mode (Figure 5) are also catered to via the control system wherein overriding scripted routines are responsible for converting the entire/selected office pod clusters to the desired spatial mode.

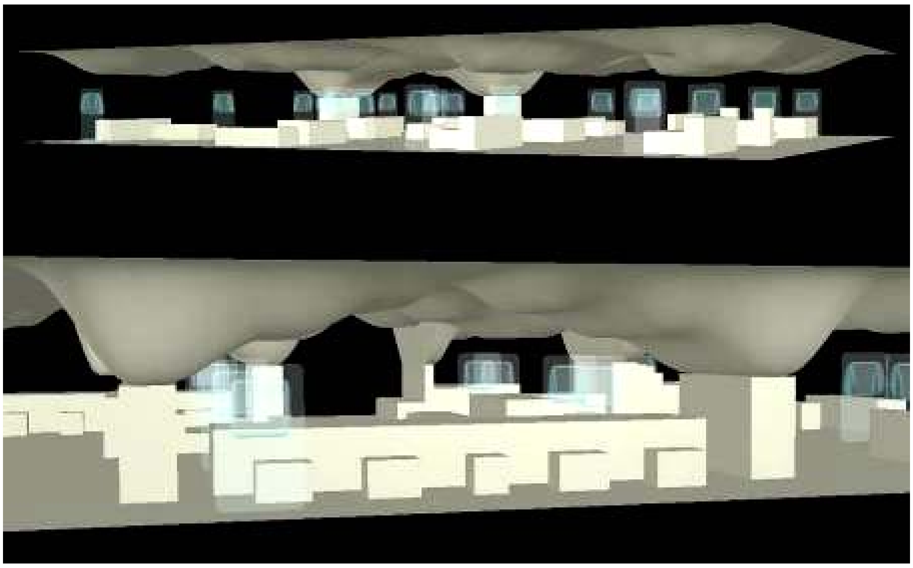

Figure 5. Views of the Exhibition mode (above: converting the entire office space to an exhibition scenario) and the conference mode (below: combining two adjacent generic pods) simulations.

The conference mode owing to its requirement of engulfing two pods is allocated by the control system after iterative rule based analysis of the most recent occupancy status of the office space. The aim of this iterative search is to optimally allocate the conference configuration in a manner which least disturbs the occupants already present in the office. The control system apart from implementing spatial configuration oriented changes also instructs the database as well as the real time 3d and 2d visualization section of the interface to incorporate these new states.

The output is also used as a trigger for micro-controllers with built in sub-routines responsible for actuating different configurations and corresponding hardware (Pistons, Lights and Speakers) accountable for configuration-related augmentations. The control system also caters to the possibility of changing configurations by means of an employees mobile device (if he isn't in his workspace), hence re-enforcing the employee with a psychological feeling of being in control of his space.

6. Sensing and actuating systems: tracking and augmenting

In order to facilitate the tracking of an employee's vicinity to the adaptive office space RFID tags are embedded within personal mobile devices per employee. This personal ID is tracked by a RFID antenna located at entry points to the office. Any ID tracked by the antenna is immediately updated in the database which in-turn triggers the control system for conducting data processing. This tracking thus initiates the allocation of space as well as the actuation of the employee's color (ambient lighting) and configuration preferences. Another set of IR sensors mark the boundary of the pods, this boundary when intercepted by the employee triggers a change in the colored lighting to the lighting level (pre-programmed) corresponding to the activity based configuration actuated for the employee.

Two kinds of actuators, coupled with mechanics (Figure 6) are used for physically augmenting the pods. Festo (Pneumatics Company) made pneumatic Muscles are coupled together with scissor jacks topped with an elastic band knit framework of wooden planks are placed under the floor surface; a layer of latex based fiber material. The scissor jacks are actuated via compression of the muscles which in turn creates a vertical thrust causing surface augmentation. The ceiling surface utilizes a network of Festo made Pneumatic pistons which are encased within aluminum box casing and are connected at their actuating ends to a network of steel rods of varying lengths. The steel rods are in-turn connected to a dense intertwined layer of elastic bands which are subsequently connected to the Lycra based surface of the ceiling. The java routines for generating the vertex heights in turn communicated these new heights to a Festo CPX controller which translates the heights to the amount of air pressure to be induced into corresponding pneumatic muscles and pistons.

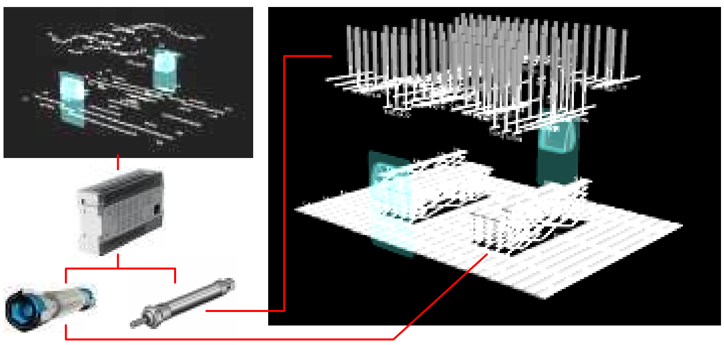

Figure 6. Translation of derived vertex heights via the Java code to the CPX controller and subsequently the actuating agents, resulting in precision oriented configuration generation.

7. System architecture

The system architecture (Figure 7) conceived to bind the above mentioned components operates on transmitted contextual data by means of the system's sensing capabilities (RFID's and IR sensors) and user preferences via the interactive interface of the system. These sets of data are updated in real time in the database (the central data collection/exchange layer). Every database update acts as a trigger event for the Control system which is inextricably linked with the DB, which subsequently triggers the space allocation sequences. The control systems, as mentioned earlier, apart from operating in the virtual domain by means of computing and updating the database and the 3d and 2d views in the interface, also outputs data strings for microcontroller networks, hence actuating the mechanics of the physical prototype.

The employee, unaware of the complex codes running behind the front end of the system, is hence intuitively tracked by the space and via the control system's data output is allocated a space (if his preference of space was non-fixed). The allocation criteria are based on the choice of neighbors provided by the employee, thus contributing to group dynamics and eventually the satisfaction of the user. This allocated space is indicated to the employee in a visual manner via an ambient color light setting (user preference). A data-output stream in parallel is communicated to the controllers responsible for activating the pneumatic mechanisms running behind the two surfaces, hence actuating the customized (primary choice) configuration of the employee.

A network of infra red sensors bordering each allocated space, are triggered as the employee enters the pod boundaries, hence registering an update in the database, which consecutively, via the control system updates the lighting conditions (in accordance with the pre-set light settings per configuration). The employee can further manually over-ride any configuration via the pluggable storage unit bordering his pod, which again follows a similar data routing to materialize the selected configuration and for updating the ambient lighting conditions (Figure 8) corresponding to the chosen configuration.

The inherent dynamic nature of the generic pods (local level) constituting the office body, renders an unpredictable though completely user centric topological nature to the entire office (global level) hence making it akin to a live, understanding entity, co-evolving with the socio-cultural dynamics inherent in corporate environment.

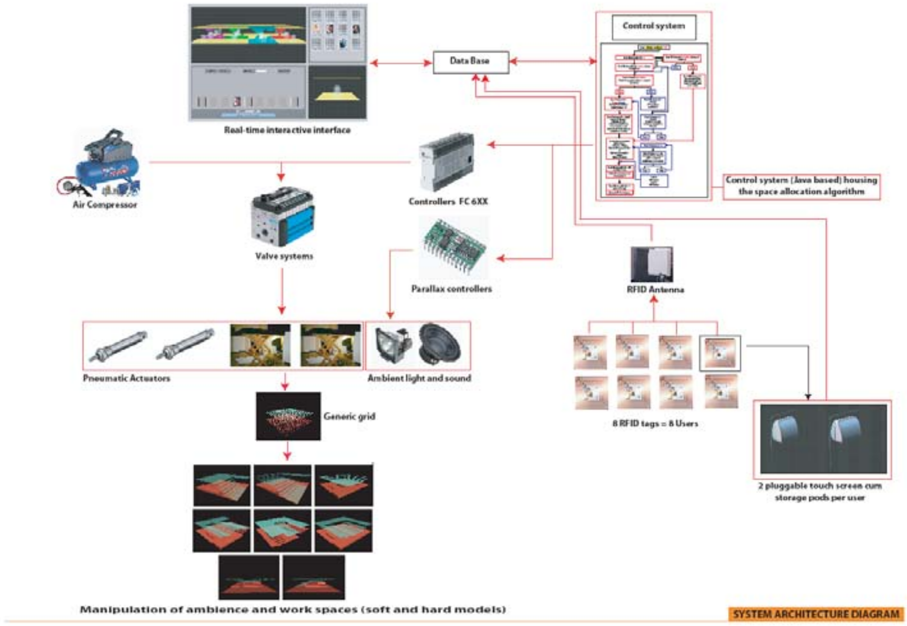

Figure 7. System architecture diagram

Figure 8. Lighting/Ambient variations simulated in accordance with the nature of activity (directly linked with the active configuration per user) and for identification of allocated space (by displaying the preferred color per user)

8. Conclusion

The research work, owing to its inter-disciplinary framework and an intensive focus on user centric design tries to understand architectural substantiations as open systems which allow for an active interaction between built form and the inhabitant as opposed to the manifestation of traditional, static enclosures akin to closed systems. However, this conceptual shift in design ideology combined together with a parallel socio-cultural understanding of human interaction and supportive technological as well as computational tools brings forth a different understanding of the role that designers would, in the contemporary world of information era offer.

The research initiative, after an intensive stage of developing sufficient knowledge about the corporate, organizational domain (Glasson et al., 1996) and (Turner and Myerson, 1998) interfaced with this new role of designers, which, rather than creating hard structural shells, were much more involved with the development of a meta-system, or in other words the notion of creating a 'soft' computationally enriched open systemic framework (informational) which bears its roots within the aforementioned (PACT analysis based) corporate/organizational research data. This soft space/meta system serves as a platform providing the users with a framework, within which users can manifest their own programmatic combinations in order to create self designed spatial alternatives. The fact that this meta-system per say is designed considering the needs and demands of the users (in the case of this research via the PACT analysis), it thus already possesses the ability to materialize essential programmatic variants, if called upon by the users.

The otherwise static/inert hard architectural counterpart, enhanced with contemporary technology becomes a physical interface prone to spatial/structural augmentation to optimally serve the above mentioned user's programmatic initiations. The user's become the central pivot of the entire designed construct, owing to the truly interactive role they play in terms of formulating customized spatial programs for initializing the hard space/architectural counterpart thus strengthening the user centric premise of the research. The hard and the soft designed architectural counterparts work in coherence with the user thus attaining a new dimension of inherently dynamic interactive architectural constructs.

Based upon the above mentioned reflection on the progressive view on architectural design in the contemporary, the role of the designer/the author, through this research and design initiative was to design a system which allows people to shape their own spaces subsequently leading to the collaborative creation of a dynamic social space (in this case a corporate office environment). A truly performative space which is highly adaptive (structural, ambient, informational) in nature and the architectural character (in terms of form) of which is the resultant of activity based performance of each individual of the environment is thus materialized. The space thus created, attains a participatory nature in stark contrast to conventional subject-object discourses within which the architectural built entities were reduced to objects and subsequently closed systems.

The aforementioned meta-system in the case of this research takes up the form of an interactive software (developed by the author) which can readily be installed within office environments eventually allowing one to customize his/her spatial settings or in other words 'perform' within this meta-system thus generating specific personalized architectural renditions. The hard space, architectural counterpart, is enriched via the mechanics embedded within the generic pod and readily responds to the soft set of information per user. The office environment per say is thus considered as a responsive field which specifically augments its physical, ambient and informational composition via interacting with the user of this dynamic field.

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.

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