

ADAPTIVE CORPORATE ENVIRONMENTS

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

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Abstract. The research paper illustrates an attempt to envision computation aided architectural responsiveness (spatial and informational) towards contemporary forms of corporate organizations. Architectural substantiations for such corporate bodies embodying dynamic business eco-systems 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. Architectural renditions supporting such emergent forms of organizations hence need to be re-thought: a need to break apart from the inherent closed system typology of architectural materiality needs to be visualized. The research paper, addresses such issues by specifically focusing upon developing intelligent reconfigurable spaces (in accordance with customized activity oriented spatial preferences of its occupants) and an interactive user interface as a front end of the system (for inputting preferences and 3d space visualization purposes). A space cluster, completely user centric, equally dynamic, and flexible, as compared to the dynamic activities which the space sustains is thus developed. The papers content is explicitly based on the output of the authors PhD research work conducted at the TU Delft, Netherlands.

1. Underpinnings

An exhaustive research conducted by the author (via interviews and on site observations as a part of his PhD research) into spatial typologies, the bio-rhythms of corporate offices and psychological associations/dissociations of employees working within such office environments, suggested an increasing desire for customization of individual environments. This customization oriented demand was furthered by a need for the induction of intuitive ambient dynamics within otherwise static, rather insipid office shells. A variety of researches conducted till date (for instance IBM's Blue space, and ambient intelligence oriented research works concentrating on smart surfaces) as regards attempts to envision smart office environments were thus critically analyzed. However, it became increasingly clear that such developments 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, furniture etc. In turn the interactivity that is programmed into the tools of new media is portrayed as developing intelligence into architecture per say. Architecture, on the other hand remains the same closed container bearing such pastiche.

As a consequence of this negation of architectural inclusion within the domain of smart office environments, a dynamic user centered real-time adaptive environment (spatial, ambient and informational adaptability), bound to its contextual logistics is proposed. The research initiative thus involved the development of a customized software/meta-system which specifically binds two co-evolving aspects: conception, design and prototyping of a real-time user activity dependent 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 it 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) meta-system which can re-configure its physical and ambient configuration to cater to varying activities being performed within office environments.

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 (The Muscle re-configured and the Bamboostic installations). 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.

2. 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 by the author) for developing a bottom-up componential understanding of typical office environments. This analysis was utilized for extracting a set of intrinsic user requirements to be considered while 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 well designed interactive interfaces, the choice of media and various spatial configurations that a singular architectural space (the generic pod) could inherit were thus iteratively derived from this analysis. Three broad activity oriented categories of topological space modulations: Work, Discussion and Relaxation were subsequently derived. 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 were decided upon.

3. Developing 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 thus seen as the result of 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 the aforementioned conceptual models and are used for developing automated Java sequences responsible for generating the mathematically computed topology of these surfaces.

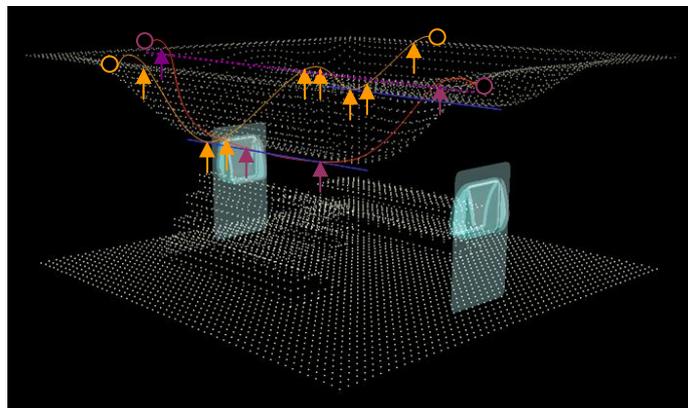


Figure 1. The sinusoidal curve in both directions is developed in sections considering the arrows as peaks (derived from conceptual models) for calculating the heights of the points lying between them.

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 these 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 1). 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.

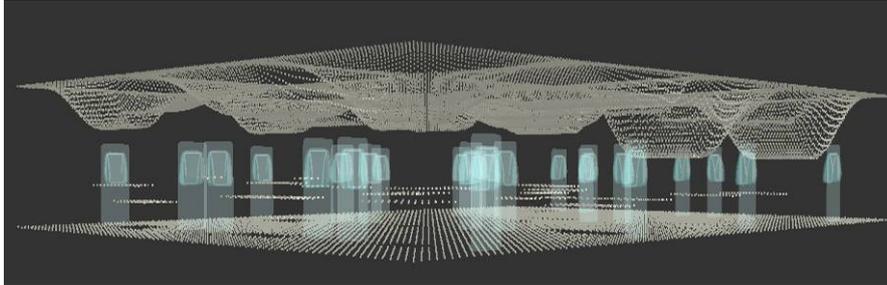


Figure 2. Office environment as a cluster of 12 generic pods.

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 (Figure 2) is eventually simulated by means of clustering together 12 generic pods, each embedded with the computational logic explained above (real-time adaptable nature derived from vertex positions).

4. The Interface: building interaction between users and the pods

After developing the adaptive behavioral aspects of the generic pod and formulating a cluster of the aforementioned 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 3) 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. A choice of neighbors, currently limited to two degrees of preferred neighbors can be specified by each employee; this option can, besides providing 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).

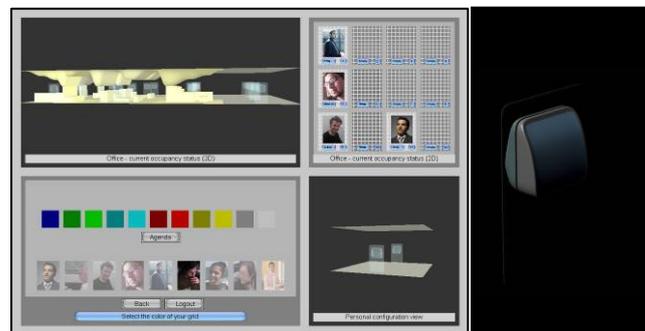


Figure 3. *Real-Time interactive User interface and the pluggable units*

At a local control level, Pluggable units (Figure 3 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.

5. 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.

6. Control system: data processing for outputting actuation protocols

The control system (Java based) module specifically deals with 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 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. 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.

7. 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 sensors: 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 4) 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 and 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 manufactured 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 communicates 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.

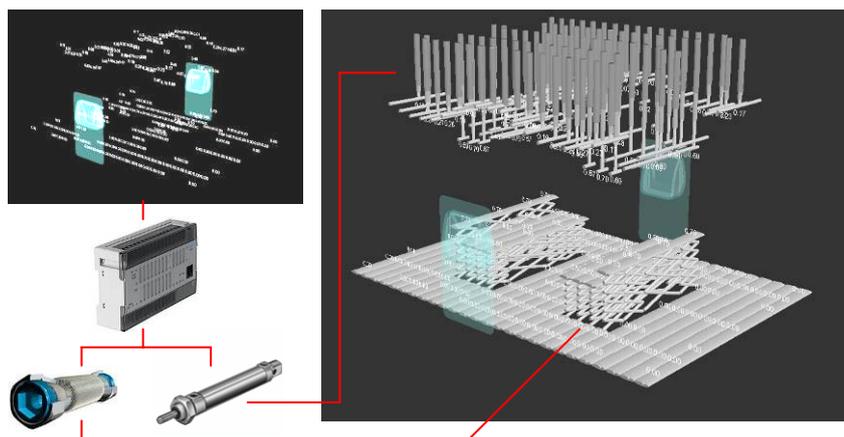


Figure4. *Translation of derived vertex heights via the Java code to the CPX controller and subsequently the actuating agents, resulting in precision oriented configuration generation.*

8. System architecture

The system architecture (Figure 5) 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 (DB). Every DB update acts as a trigger event for the Control system which is inextricably linked with the DB, subsequently triggering the aforementioned space allocation sequences. The control system additionally outputs data strings for microcontroller networks, hence actuating the mechanics of the physical prototype.

The research initiative embodying this system architecture concluded with the development of a customized software. The software allows for testing the designed meta-system's adaptive nature by means of interacting with it via the online interface. This Java based software can be readily

installed in contemporary office set-ups and is specifically kept open for accepting new plug-ins in order to enhance the proposed adaptive behavior of the office space as and when required.

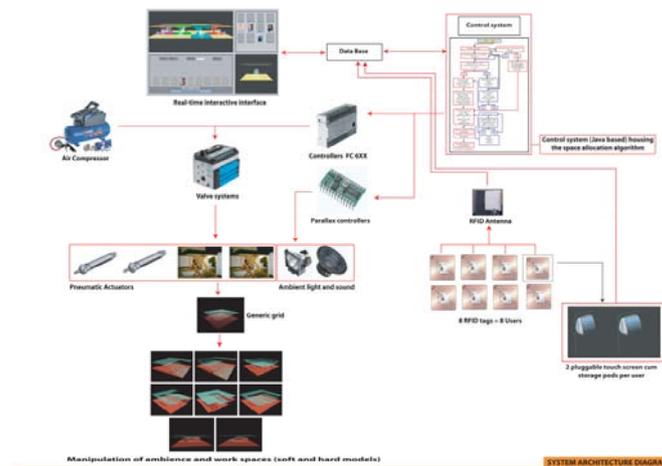


Figure5. *System architecture diagram*

9. Conclusion

The research paper, exemplified upon a co-evolutionary (socio-cultural and technological) approach to create a real-time interactive corporate office space. 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 proposed architectural construct formulates the core agenda of the research. 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. 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 similar open source architectural constructs.

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