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Paper: **Generative Tectonics: Environmental performance and parametric design morphology**

Topic: Architecture, Computing

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Abstract:

This paper reports on the collaborative experimental work carried out in the University of London to deploy generative processes to parametric elements of design using environmental parameters to trigger design morphology. The experimentation culminates in the installation of the 3-D parametric model. Subjects' interaction with the 3-D-printed parametric model provides insights inro human interaction with space in its physical and virtual modes. It also provides an insight into the effects of environmental performance on human interaction with space.

The project has three distinctive parts. In the first part, a procedural programming language (C++) is used to develop the interface and inputs that deploys the generative algorithms and activate the access to a pool of 3D primitives that act as the building blocks of the parametric design. It also provides the environmental performance's interlocking loops of environmental inputs. In the first loop the environmental parameters affect the initial process of generating the design, but in the second it affects the design reaction to environmental parameters, which results in the interactive environmental performance. The first part generates real-time parametric structures that are used in the second part.

The second part of this project utilises the parametric design elements of structure by 3D-printing them and assembling them in a physical interactive installation that continuously reacts to environmental variables. The installation forms a technical artistic piece of parametric elements, light sensors, heat sensors and mechanical arms that affect the parametric elements' formation. The installation is in the inner circle of Regent's Park, London, UK.

The third part involves a qualitative study of subject interaction with the installation, and analyses the outcome in an effort to further understand human embodiment and interaction with interactive space. It also evaluates the questions of evolution and continuity through algorithmic events, and the resulting time-based 3D modelling of abstract spaces.

The project is a collaboration between three universities in their effort to address topics pertaining to design morphology, environmental performance, and human embodiment and interaction with space. The team combined researchers from Computre Science, Human-Computer Interaction and Architectural Design.

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Generative Tectonics: Environmental performance and parametric design morphology

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Premise

This paper reports on the collaborative experimental work carried out in the University of London to deploy generative processes to parametric elements of design using environmental parameters to trigger design morphology. The experimentation culminates in the installation of the 3D parametric model. Subjects' interaction with the model provides indicators of human interaction with space in its physical and virtual modes. It also provides an insight into the effects of environmental performance on human interaction with space.

The project has three distinctive parts. In the first part, a procedural programming language (C++) is used to develop the interface and inputs that deploys the generative algorithms and activate the access to a pool of 3D primitives that act as the building blocks of the parametric design. It also provides the environmental performance's interlocking loops of environmental inputs, which results in the interactive environmental performance. The first part generates real-time parametric forms that are used in the second part.

The second part of this project utilises the parametric design elements by assembling them in a physical interactive installation that continuously reacts to environmental variables and users. The installation forms a technical artistic piece of parametric forms, light sensors, thermal sensors, motion sensors and mechanical arms.

The third part of the project performs a qualitative study of subject interaction with the installation, and analyses the outcome in an effort to further understand human embodiment and interaction with reactive space. It also evaluates the questions of evolution and continuity through algorithmic events, and the resulting time-based 3D modelling of abstract spaces.

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1. Interaction, the *'generative'* and *'Technomethodology'*

The development of Human-Computer Interaction (HCI) is founded on the design, evaluation and implementation of interactive computing systems. Interaction came in many different styles that ranged from command line interface to three dimensional ones. The drive behind the development of these interfaces was the need to enhance the interaction between the user and the machine. As a result, the field of Interaction Design (IxD) came to lay the groundwork for intangible human experiences. Many areas of research overlap with HCI, however; arguably the most important element in the development of HCI is the distribution of user-centred design approach to encompass multi-users. The ethnographic studies of the environments in which users participate extended to encompass human experience (Agre 1997). *Technomethodology* (Dourish 1998) came as a result of the amalgamation of these concepts, which in turn shifted the emphasis from the *system* to the *interaction* within the 'interactive system design' (Benyon *et. al.* 2005) (Newman & Lamming 1995).

Technomethodology addresses the context with terms such as *space*, *place*, and *locale* (Dourish 2001). The authors argue that the approach has a significant relevance in the case of generative design; however, the generative process requires a different approach based on the profound understanding of the concept of responsiveness and its implications on immersion and interaction.

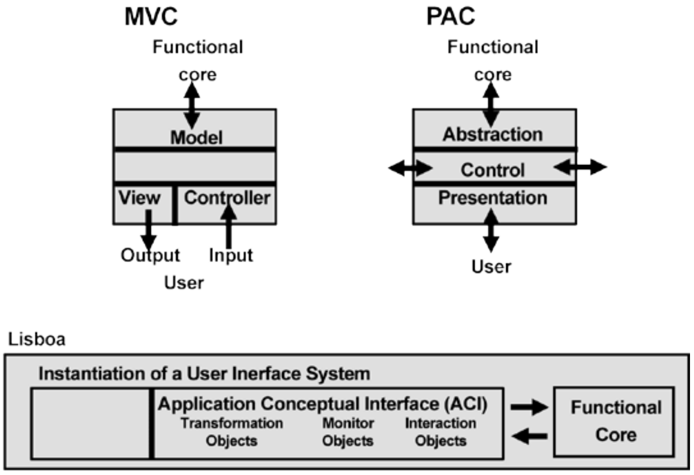
Fox and Kempt explore the notion of interactivity in relation to the built environment with focus on the concept of responsiveness. They argue that the user and the environment are linked through a conversation (2009). The researchers argue that this conversation introduces a 'Husserlian' notion of intentionality on behalf of the generative environment. The duality of action and reaction, Fox and Kemp argue, implies an intermediate stage of processing. In its totality, the implied potential which is incidentally suggested by the idea of 'generative art' is a duality that has the quality of a binary opposition system. Karandinou suggests that the traditional binary opposition of form and matter is changing and she uses Derrida's temporal notion of 'opening up' to indicate new found elements in this binary opposition (2011). The researchers in this paper argue that the simpler schema of sensor's input, processor, active output implies notion of intentionality of action. This implied notion is further pushed forward by the complexity of the algorithm and its responsiveness to human interaction in conjunction with environmental performance.

The project highlights the notion that familiar interaction forms the basis of embodied interaction, which, in turn, triggers the sensors providing them with an input and, therefore, resulting in an output that reflects the original embodied action. A deeper understanding of this interaction may provide a better understanding of the resulting environment. In a way, the project deploys a '*generate and test procedure'* proposed by Rowe (1987).

In order to understand the process, the researchers abstracted the process in an effort to simplify inputs and outputs. What follows will describe the system.

2. System design

An interactive system is designed using a procedural programming language (C++). The system architecture is modelled using collaboration agents such as presentation-abstraction-control (PAC). The system is used for to its hierarchical structure, which naturally lends itself to the processes implicated in this activity. Previous incarnations of this design interface witnessed the use of model-view-controller (MVC) and using the slightly different Lisboa collaboration objects architecture.

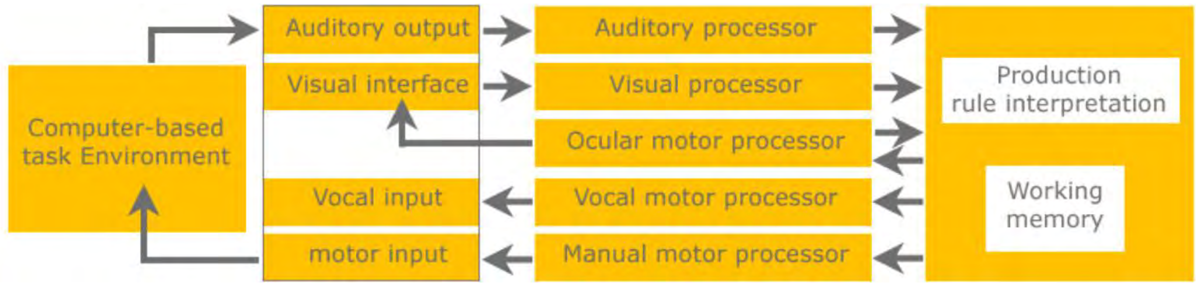


Conceptual architectural models of interactive systems (Palanque et. al., 2000)

The interface deploys inputs to operate the generative algorithms and to activate the access to a pool of 3D primitives that act as the building blocks of the parametric design. Several variations are rendered using the L-system. In its simplest states, the system is composed of:

- Variables (V) = a set of 3D primitives, of which
- Origin (O) = the initial primitive to be deployed
- Rules (R) = the rules that decide which primitive to generate next

The 3D primitives are parametrically linked using rules that adapt width, height and depth in reaction to the inputs. Kieras and Meyer’s diagram of potential inputs and outputs provides a useful summary upon which the researchers relied to experiment with the inputs. The ultimate reason for using this model is the implied intention of enabling HCI capability, if even on an initially abstract level.



Human-Computer processing and interaction systems (adapted from Kieras and Meyer 1997)

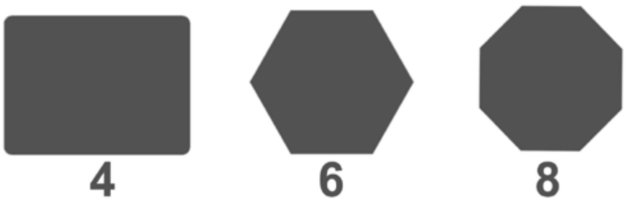
The resulting outcome is an input-enabled software that has the capability of receiving four inputs that are modified by the algorithm to produce the output. The enabled input sensors used are light

- Thermal detection sensor
- Light detection sensor
- Motion detection sensor

The output is in the form of an electric impulse that activates a unit, which contains a linear actuator attached to a set of elements. The unit mobilises the set of shapes that in their totality engulf a primitive shape that mirrors the corresponding generated primitive. The following part describes the primitives and how they are formed.

3. Primitives and variations

The values generated by the sensory inputs, when using hardware, or from manual inputs through the interface, are used to activate the access to a pool of 3D primitives that act as the building blocks of the parametric design. The generated primitives were limited to three levels for the purpose of experimentation. The primitives are: rectangle, hexagon and octagon.

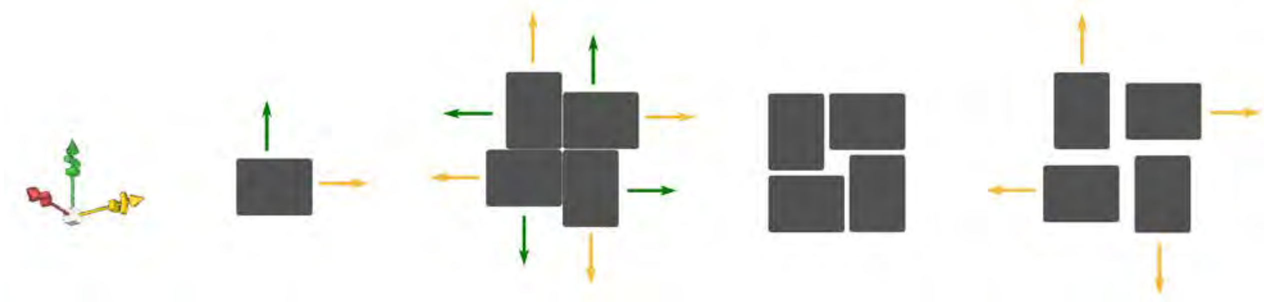


The three primitives that can be generated: Rectangle, Hexagon and Octagon.

The dimensions of the primitive is decided by the algorithm but is influenced by the sensory input. When transformed into the installation, the *Gestalt's foreground / background principle of* perception is deployed, and the primitive becomes the void which is formed by the surrounding primitives. This transformation facilitates dimensions control and therefore reinterprets the generative capability, which, otherwise, would have been difficult in an installation.

The primitive is the white void appearing in the middle, and is formed by the conjoined dark shapes

The movement of surrounding primitives to form the void is controlled by linear actuators. The distance and direction of movement is delivered through the actuator attached to each shape, but is decided by the algorithm. The shapes are generated inside a 3D virtual environment to provide a point of origin and the corresponding values. Each shape can perceptually move in four directions. By perceptually, we mean that a single shape moves in two directions only since the linear actuators operate in two directions. However, since the panels are aligned in perpendicular position to each other, extra two dimensions can be achieved perceptually by moving the perpendicular panels.



The shapes move in four perceptual directions. The change in location changes the size of the void.

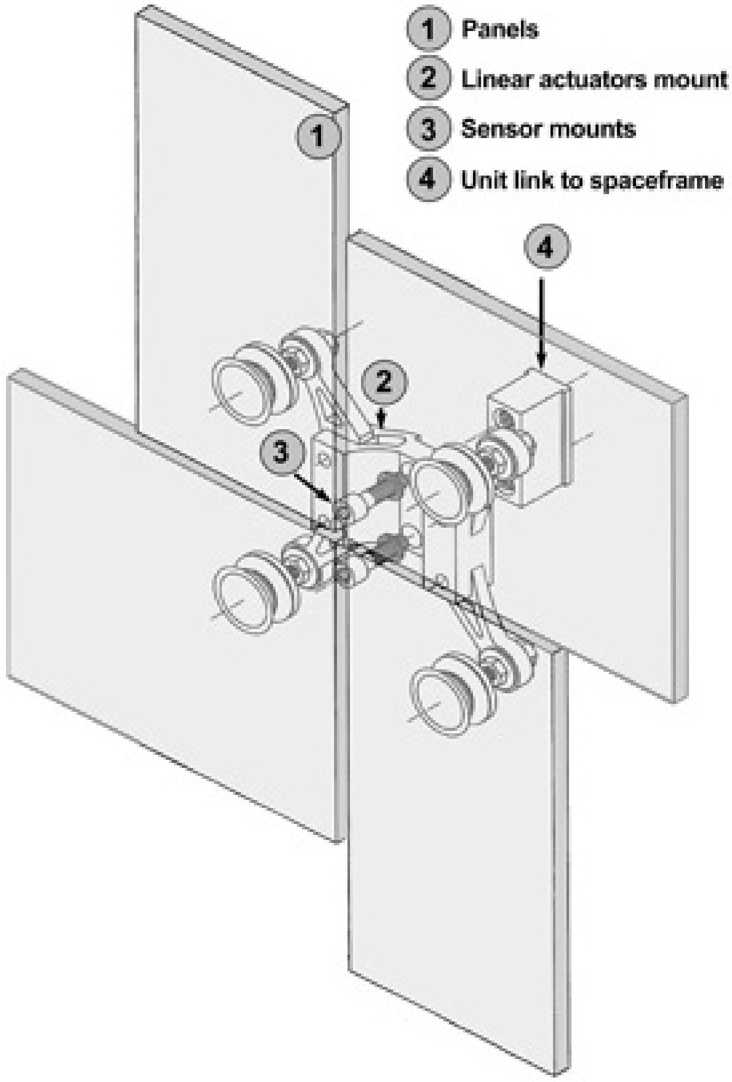
The design of the system and the algorithm that runs belong to the realm of the theoretical, however, to realise the design in reality is a different challenge. The following section will address this side of the project.

4. Enacting a generative process

The set of processes implied in realising an installation are different than those encountered in the design stage. To assemble a physical interactive installation that continuously reacts to environmental variables requires a prototype modular unit, which can be replicated. What follows will describe the modular unit.

4.1. Mechanisms and sensors

The isometric figure, which follows below, illustrates the composition of the elements that form the unit of structure in the case of the rectangular composition. Each void is formed by four shapes, which form a unit. Each unit, of four shapes, is equipped with three input sensors and four linear actuators. Upon the receipt of an output, each shape reacts in an identical manner, but in a different direction. As such, each of the four linear actuators belonging to one unit, behave in an identical manner, however, and depending on the way they are positions, the resulting movement is different. It is possible to utilise the same unit output to control other units. This suggests that sensors can be attached to one unit for input, but the output can be utilised for more than one adjacent unit. It is also possible to interpolate the output of two units to have variations in the formations.

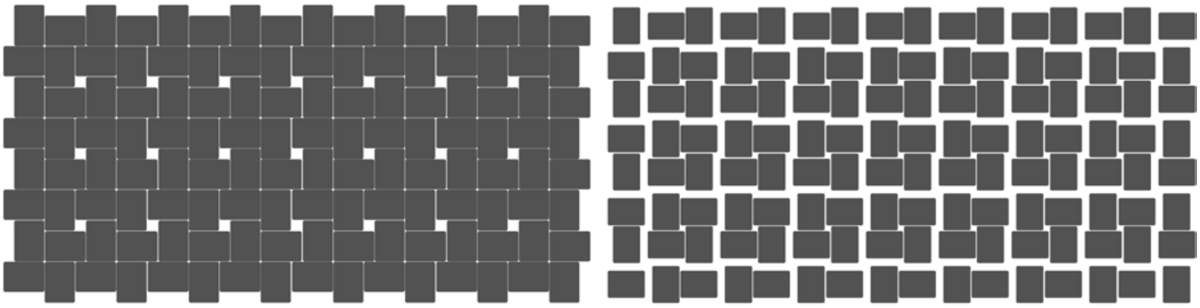


The shapes move in four perceptual directions. The change in location changes the size of the void.

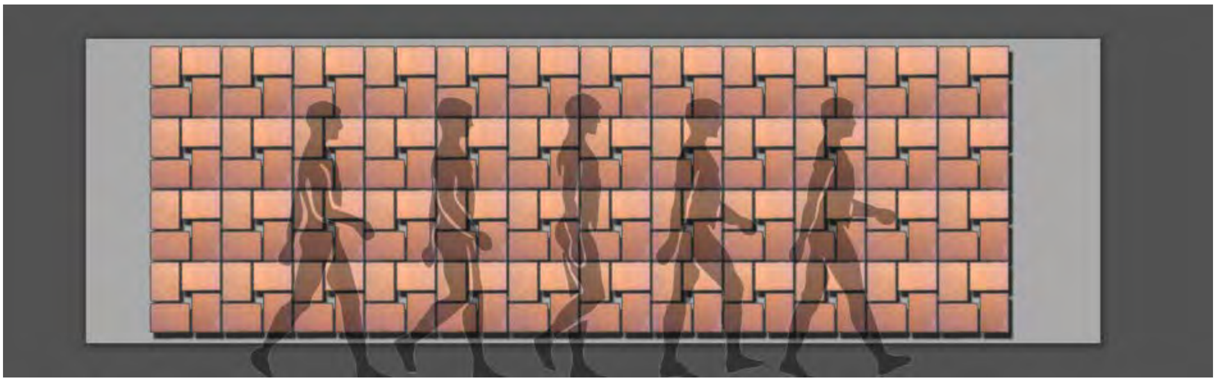
The figure above constitutes a unit in the installation. The unit is mounted into a spaceframe that holds other units. The link to the spaceframe is equipped with the technological wiring in order to connect the sensors and to connect the linear actuators. The panels are mounted on adjustable revolving screws in order to fine tune the panels and to change the alignment as necessary.

4.2. Assembled structure

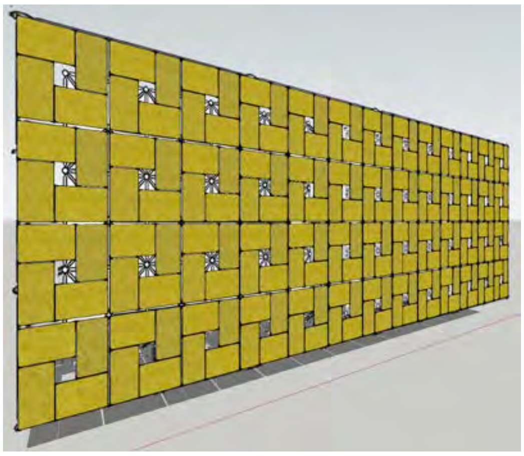
When the units in the diagram above are joined together and mounted on the spaceframe, the result is a wall that seemingly has a similar pattern. The centre point of each pattern contains the sensors and therefore, they are exposed to changes in the environment only when a human user passes by, or is visible to the centre of the unit.



The assembled units displaying two different behaviours reacting to two sensory inputs.



The assembled units in relation to human scale.



A 3D rendered scene of the assembled units.

The figures above demonstrate the different behaviours in reaction to sensory inputs triggered by human or environmental factors. While the environmental factors triggered light and thermal sensors, human factors triggered light and motion sensors. To measure interactivity a qualitative study was prepared with random subjects picked from the visitors of this installation. This was done using an unstructured interview where the main objective was to explore the theme of interactivity. In this process of exploration, other themes that either supported interactivity, or opposed it were probed. Several themes relating to interactivity emerged from the interviews. One of the major themes was the sense of the installation being ‘alive’. Subjects expressed the sense of dealing with a ‘conscious’ or an intelligent entity. Along these lines several expressions were used, such as ‘*smart* wall’, ‘motors were *breathing’*, ‘is *it feeling* hot?!’ and ‘I don’t want to *annoy it*. *It* might decide to *swallow me*!’ (italics for emphasis)

5. Discussion and conclusion

Minsky proposes a frame of reference that is used by humans in their perception and interaction with the environment. He suggests that this frame of reference is representative of knowledge (1975). We cultivated this sense by introducing a modular unit that acts as a frame of reference for the user’s and the system’s knowledge. In this process we rely on the nature of the parametric design which equally relies on the concept of the reference point, albeit for different reasons. Subject’s ability to recognise patterns and associate knowledge to the behaviour suggests more complex processes taking place at the same time. Simon characterises these by their iterative nature (1973). The researchers characterise the behaviour of the system as being generative, which is not due to the algorithms deployed, but due to the environmental factors and human behaviour affecting the output. The characterisation finds resonance in Steadman’s problem solving approach (1979). Accordingly, subjects viewed the installation as an entity. This characterisation of an object is due to the subject’s ability to attribute the qualities of an entity to the installation. The installation did not have the image of an entity, but had the qualities of an entity. The qualities were evidenced by the themes expressed by subjects. The qualities were generated by the system, and the randomness of reactions applied an element of familiarity. The value of familiarity is preserved through interaction; therefore, interactive objects are familiar objects. Familiarity when expressed by subjects appeared to be an abstract feeling; however, when experienced, appeared to take place with a tangible object.

The researchers realise the limitations of this experiment since it is still far from providing a formal testing procedure. They also note that this is the nature of experimental work.

6. Notes

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