Emergent Technologies and Design

An investigation into biotic processes, material technologies and embedded computation for developing intelligent systemic networks

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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 experiments conducted by the author: Developing concept prototypes for electronic media augmented spatial skins. The augmented skin project exemplifies a synergetic merger of scientific investigations into the fields of bio-mimetics, control system, material technology and embedded computation techniques.*

Keywords. *Control systems; real-time interactivity; bio-mimetics; embedded computation.*

1.0. Underpinnings

The systemic prototype, developed as an electronic media augmented skin demonstrates an automated kinetic response with respect to parametric changes (Light, wind and ergonomics) concerning its immediate context. Such automaton is conceived via multidisciplinary studies in the field of natural systems immersed in open typologies, concerning phenomena of embedded control, communication, self-organization and self-renewal. The paper exemplifies the dynamism inherent in biotic systems, and applies the study of such complex systems through a synergetic merger of the fields of electronics, material technologies, embedded computation, control systems (for developing sensing and actuating properties) and Kinetic structures (for developing a dynamic skeletal framework with variable resolution: both interior and exterior structural frameworks). The designed system is an active contribution to the much-researched field of information driven, real time processing responsive architecture. The proposed prototype exemplifies information exchange by means of tactile variations of physical entities, generated as a resultant of human/environmental intervention. Tangibility is further manifested by integrating physical materials with the realm of digital, electronic and information media in order to create an interactive and responsive (real time) interface that can be used in architectural applications as innovative claddings and intelligent surfaces.

2.0 Developing the electronic media augmented spatial skin

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, 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 01.). 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 (any one of a number of alternative forms of the same gene occupying a given locus (position) on a chromosome) 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.

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 visulise 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 02.). 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. These structural agents, acting as connector elements have been exemplified upon in section 2.0.3.3.

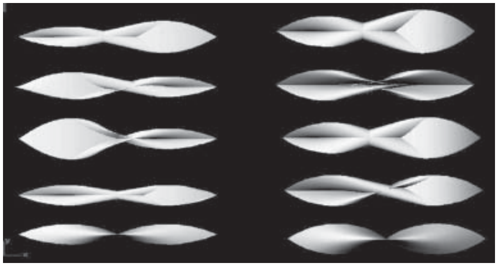

Figure 01. Genotypes: developed from the same two dimensional curvature networks

The next section will deal with the sequential break up of the genotype into its sub-components. A bottom up approach was induced at this 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.

System components

The system is perceived as a network of components working in coherence with each other to generate the desired tectonic variations. The further sections will elaborate upon the system components, exemplifying dimensional variations, material allocation and performance criteria of each component individually.

The system component demarcation is induced from the initial 3d surface component it-

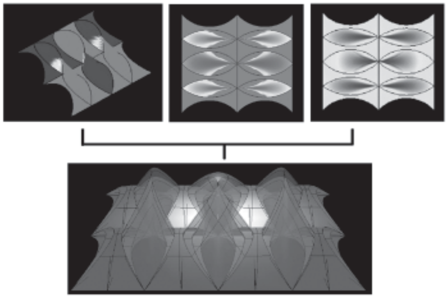

Figure 02. Curvature and wind analysis of the generated genotypes

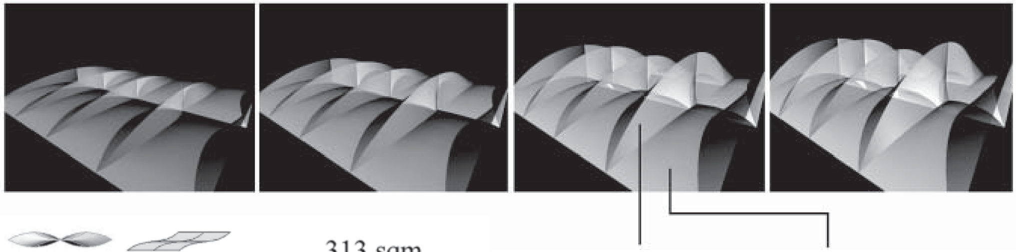

Figure 03. The surface assemblage: the Membrane, the Strata

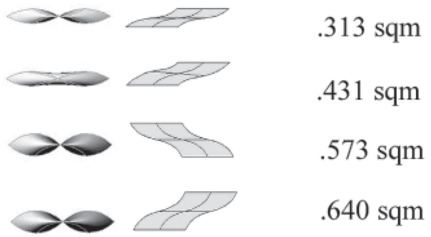

Figure 04. The surface assemblage: the Membrane, the Strata

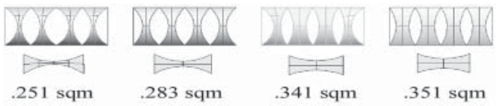

Figure 05. The surface assemblage: the Membrane, the Strata

Figure 06. a. Arch shaping the strata, b. Arch shaping the membrane

self (Fig 03.), which was generated in the earlier stages. The surface is subdivided into two distinct entities: the membrane and 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 initial network of 2d curve geometry) The animation stages also take into account these corresponding curvilinear entities (as they in essence are the chromosomes influencing the genotype) hence creating the underlying guiding framework of the skin. Exemplification of the structural system involves breaking it into its sub-parts in accordance with the surface elements (the membrane or the strata), which is affected by the kinetic behavior of the system. The connector element hence has two categories (Fig 06):

- The arch shaping the strata
- The arch shaping the membrane

Both categories witness different cumulative angular variations during the different stages of surface actuation. These variations, along with material and performance criteria elaborated upon in this section.

- 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.

- Cumulative change in length in each individual arch: 162.05 mm

- Increase in the opening size (horizontal): 127.51 mm

The cumulative 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 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 09), 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.

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 07).

- 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

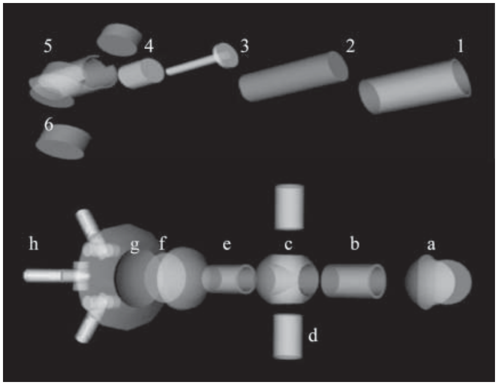

Figure 07. The active part of the (Actuators) positioning element consists of a stack of polymer gel disks separated by thin metallic electrodes. The maximum operating voltage is proportional to the thickness of the disks. The stack actuators are manufactured with layers from 0.02 to 1 mm thickness.

with connector hollow tube, as an outlet for data cables, f. micro controller and motor mechanism, g. housing element for the actuators, h. actuators

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 08)

a. Strata with the embedded sensing device - b. the sensing device registers the amount of sun and light intensity falling on an individual panel and transfers the information via - 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.

3.0.2. Phase 2: (Figure 09)

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. this data is transmitted to the I Cube digitizer - g. the digitizer receives the analogue signals and

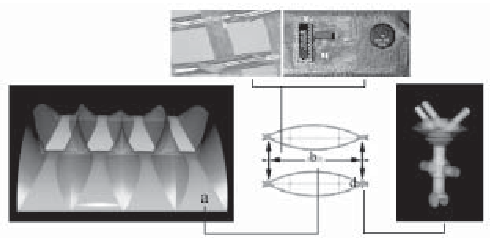

Figure 08. Information sensing and routing sequence (phase 1)

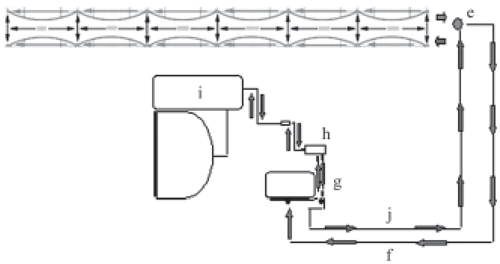

Figure 09. Information sensing and routing sequence (phase 2)

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.

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 10. These actuators are directly linked with the system of flexible connector elements, which

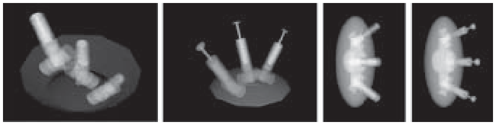

Figure 10. State changes in the actuators involve 3d movement control and generating electric impulses to activate the electro active gels.

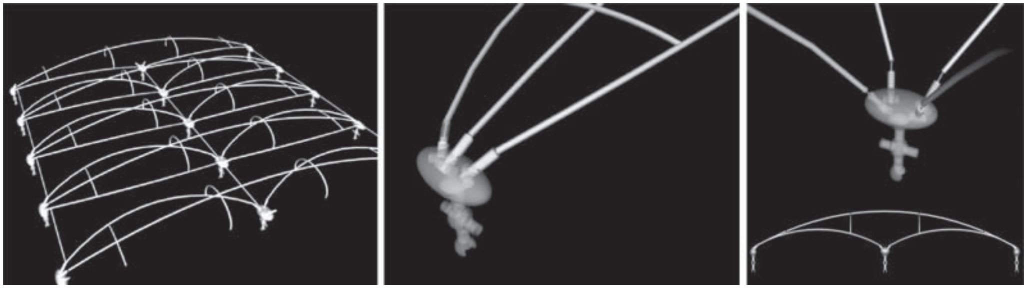

Figure 11. Actuators linked with the carbon fiber connector framework: A distributed processing embedded element actively linked with a flexible superstructure mechanism.

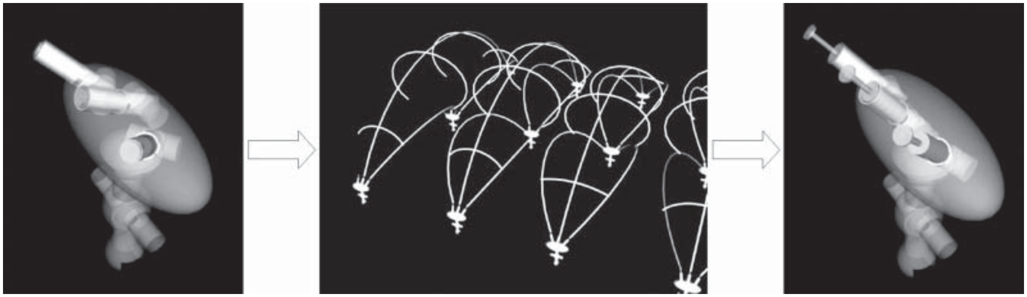

Figure 12. The modular grid of actuating cum processing devices accurately registers data that the sensor embedded strata delivers to it, and outputs readings to an external device, in this case the Midi Digitizer.

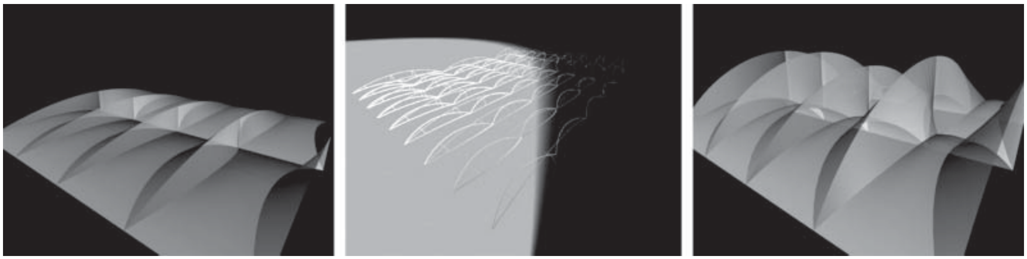

Figure 13. The resultant: real time responsive architectural system.

alter their geometry in accordance with the actions of the actuators, hence altering the networked systems overall form.

3.0.4. Real time responsiveness: (Figure. 11, 12, 13)

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 behavior is materialized through the skin experiment.

Conclusion

A Multidisciplinary approach towards architectural thinking is emphasized upon in the research work. Breaking apart from the static conception of space and the classical database guiding architectural processes is seen as a prelude to developing a responsive whole. An alternative Conception of appropriating architecture as an open systemic network possessing emergent behavior is propelled through the design research, with Computation, networking and kinetic behavior formulating a rational to the much-speculated issue of responsiveness. 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.

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