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A Living System - Discursive Wall

M. J. de Oliveira
Vitruvius FabLab, ISCTE-IUL, Lisbon, Portugal

A. Paio
Vitruvius FabLab, ADETTI-IUL, ISCTE-IUL, Lisbon, Portugal

V. M. Rato
Vitruvius FabLab, DINÂMIA'CET-IUL, ISCTE-IUL, Lisbon, Portugal

L. M. Carvão
Vitruvius FabLab, ISCTE-IUL, Lisbon, Portugal

ABSTRACT:
We feel and perceive the built environment through our senses and our body's interactive movement (Diniz 2008). In this paper we propose a Discursive Wall that physically responds to movement, interacting spatially and temporally with the environment and its inhabitants. In addition, we intend to solve spatial acoustical issues related to sound reverberation. Based on the theory of Autopoiesis (Maturana & Varela 1980), the discursive wall acts as a self producing system. In response to movement sensors installed in the room, the cork surface elements of the wall move back and forth. Therefore, the inhabitants of the room make the wall mutate continuously, thus redesigning itself. This is produced by several components like sensors, bearing systems and test motors. A set of arduinos processes and distributes the information received from the sensors and receives back the animation data generated by Grasshopper and Firefly (plug-ins for Rhino software). The methodology that supports this prototype explores the real possibility of the architecture to enter into a direct dialog with its inhabitants and surrounding space.

1 INTRODUCTION

> *"If living systems are machines, that they are physically autopoietic machines is trivially obvious: they transform matter into themselves in a manner such that the product of their operation is their own organization."* Maturana & Varela (1979)

Recently, questions of performance and interactions in architecture, as a key factor for the design process, have come into the interest of architects (Hensel and Menges 2008). Traditionally, the approach to new technologies had the objective of creating single pieces (installations). With the development of the digital fabrication and manufacturing technologies, architecture is now on the path to one responsive and discursive approach, enabling the creation of truly living systems. Over the past hundred years, there has been a large body of work over the living systems, the relationship between their components, coexistence and complexity (Hensel, Menges and Weinstock 2010). The autopoiesis theory (Maturana and Varela 1971) seems to contain the necessary knowledge to enable the creation of individual self-producing systems. Although the fabrication parameters were found mainly in the design process, some recent research and experiences went deeper into the prototyping phase, proving the viability of the theory (Hensel *et al*, 2010).

1.1 *Related Work*

During the 60's and 70's Cyber and Kinetic's thinkers, such as Wiener, Neumann and Pask had encouraged architects to think not only about static buildings but also buildings as feedback systems. In 1995, Jonh Frazer in the AA School, creates a new lexicon, based on his fundamental investigation about form-generating processes and the 'morphogenesis' theory. In the same year, Cedric Price, in his never built project "the fun Palace", explores as central idea the belief that through the use of new technology the public could have full control over the environment. This would mean to have a building which could be responsive to its visitor's needs and activities. The project was composed by modular panels and prefabricated elements that could be inserted or removed as an open framework that could be adapted according to different needs.

One of the most relevant projects was built in 2001 by Mark Goulthourpe, the "Aegis Hypo-Surface" system. A metallic surface, composed by hundreds of triangles, that has the ability to physically deform itself, in response to electronic stimuli from movement, sound and light. The dynamic has its base in real time calculations. In 2003 Michael Silver in his ‘Liquid Crystal Glass House’, trying to solve sunlight and heat issues, developed a constantly adapting electronic building skin, enabling an electronic shift from transparency to opacity. More recently, Sachin Anshuman (omnispace, October 24, 2006) developed a smart surface designed to regulate light, solar radiation and views, as well as display dynamic signage called ‘Pixel Skin’. Pixel Skin may also be used to generate low resolution images, low refresh-rate videos, or abstract patterns. Pixel Skin is an electrographic surface which allows the integration of illumination and view controls with real-time communications media.

More than finding architectural surfaces as solutions this “form follows performance” strategy mixes appearance and organization of patterned skins and structures in nature, enabling to explore new materials behaviors and effects - biomimetics and biomimicry (Kolarevic and Klinger, 2008).

1.2 *Our purpose and project*

In order to design a periodic structure to a coffee shop, it seemed very adequate to produce a customized product, using digital fabrication processes to develop and design this acoustical panel. The main focus of this research is the transformation of data, from the discursive wall into the process of the constantly evolving design and re-design process. This type of process is contributing to respond to the particular problem that initially motivated the production of this wall: the excess of sound reverberation.

2 OBJECTIVES

2.1 *General scope*

This paper presents the final results of the Lisbon workshop *“a Living system – Discursive Wall”*, held at the VitruviusFabLab-IUL, March 7th-11th and March 29th-April 1st, 2012.

The workshop *“A living System – Discursive Wall”* involves three partners: VitruviusFablab-IUL, FabLabEDP and Rhino3DPortugal. The main assumption was to explore digital technologies and their contribution to solve some of the new challenges architecture is facing.

The workshop has explored the use of Grasshopper, Firefly and Arduino as creative and technical tools in all the design process to simulate and prototype 3D interactive architectural solutions.

The theoretical and practical workshop (64 hours) taught in English and Portuguese, was composed of two modules: (1) LS_01, Firefly +Grasshopper + Arduino and Scale Model Fabrication; (2) LS_02, Design Studio – Discursive Wall. The workshop had the participation of students and professionals from different areas of knowledge - architecture, product design, fashion design, sculpture, engineering, electronics, and programming, and different countries – Japan, Germany, France, Brazil, Portugal and Italy. The main scope was the process of design from ideation to prototyping. Registration was closed at the number of 26 participants with and without previous software knowledge. Participants worked individually and in groups.

2.2 *Main Goal*

The main goal defined for this workshop was to create a wall responsive to human interaction. The fundamental hypothesis supporting this system was the design of an architectural living system constantly being designed and re-designed through its inhabitants and environment. Inspired by the behavior of an organism, the main target was to develop a 3,0 x 5,0 meters wall prototype, that would physically respond to movement, interacting with the temporary space, establishing a direct dialog with the inhabitants, constantly reshaping their perception, minimizing acoustical problems of the space. This acoustical issue was determinant to understand the need of the real scale model, and to establish the material to be used in the model – Valchromat (a variable of MDF) for the structure and Black Cork for the front effect material.

3 METHODOLOGY

The methodology used to develop the ‘A Living System - Discursive Wall Lisbon Workshop’ encompassed five stages. The first one was a preparatory phase led by the trainers. The other four phases included the participation of the attendees to the workshop.

3.1 *Stage 1 – Preparatory Phase*

Led by the workshop trainers, the preparatory phase comprehended several steps. The first one was to establish a clear understanding and direct dialog between the parametric design (using the Grasshopper and Rhino), its translation to a programming language (through the Firefly application) and finally the insertion of data in the Arduino – the open source element that manipulates the physical mechanism. Thus, the greatest challenge in this phase was to develop a parametric structure 1x1m, totally compatible with the selected servo motors and then design a bearing system that could support and provide the fluency of the movement.

After understanding the mechanical system, and taking into consideration issues as friction, weight, effort and robustness, the following structural system was validated:

- Valchromat (a type of MDF) for the vertical and horizontal structure parts; its parameterization allowed (i) for a quick adaptability to the inconstant material thickness (16mm to 16,5mm), and (ii) the manipulation of the assembly parts only with the use of glue and without the need for specific tools, in a simple assembly logic;
- The structure was divided in nine units, each supporting one cork piece and being capable of producing independent movements (Figures 3-6);
- For the bearing system (a total of nine – one for each cork unit), a 3mm MDF was used, cut by laser and assembled by glue for wood providing a 12mm thickness to the bearing structure. This bearing system consists of a sprocket mounted on a comb, allowing a back and forth movement, with controlled and identical rhythms. The physical rotation of the selected motors had to be carefully studied so to get the best possible mechanism and define the minimum and maximum movement of each unit;
- Another relevant issue was the friction between the different components/materials. To avoid as much as possible the friction between the bearing system and the structure a little upgrade was latter on developed: aluminum sash bearings.

  With this programming, structural and mechanical validation, the workshop was ready to start.

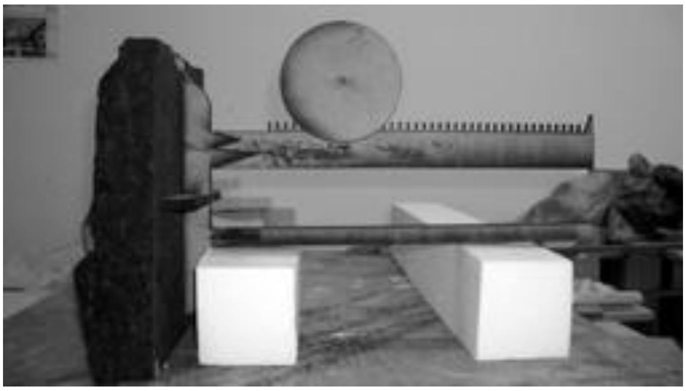

Figure 1. Workshop preparation: Bearing system.

3.2 *Stage 2: LS_01 Grasshopper+Arduino+Firefly*

The first two days of the workshop were dedicated to the creative process and the production of the cork units using the Grasshopper. The several participants, organized in four different groups, developed several design logics, like simulated Membranes through the application of fibers over the cork (Figure 3), the Voronois logics (Figure 4), Metaballs (Figure 5) and the simplicity of the Pixel (Figure 6). To argue for their solution, each group had to produce in the CNC machine a 1x1m prototype. In order to provide the basis of programming and open source resources, the third day of the workshop was fully dedicated to Arduino (C/C++). After this creative design process and after providing the open source knowledge the workshop led the participants to create the animation movement that would engage the cork. This was done through the use of Firefly, a translator to integrate Grasshopper and Arduino (C/C++). The tool allows nearly real-time data flow between the digital and physical worlds, and reads/writes data to/from internet feeds, remote sensors and more. Firefly allowed the simulation of the different movements created by the four groups, first in the computer and then in the 1x1m prototypes.

3.3 *Stage 3 – LS_01 Prototyping*

After the virtual test of all the four solutions, the last day of the module LS_01 of the Workshop was dedicated to the construction of the physical 1x1m model. Supported by the pre-designed parametric structure, each cork solution gave rise to specific customized structures so that a best possible match was achieved.

Four different parametric structures were cut by the CNC machine (Figures 3-6) and completely assembled by the participants. After the physical prototype was assembled, and the cork units glued to the bearing systems, the participants proceeded for the electronic connection – harness and wirings, breadboards, arduinos (C/C++), source supplies – everything was inserted into the structure (Figure 2).

After the electronics worked, each group uploaded their definition into the Arduino and all the four prototypes exhibited their full process – parametric design and programming movement in their own physical 1x1m prototypes.

Figure 2. Workshop – testing connection to motors.

Figure 3. Group A: Curves for the membrane support.

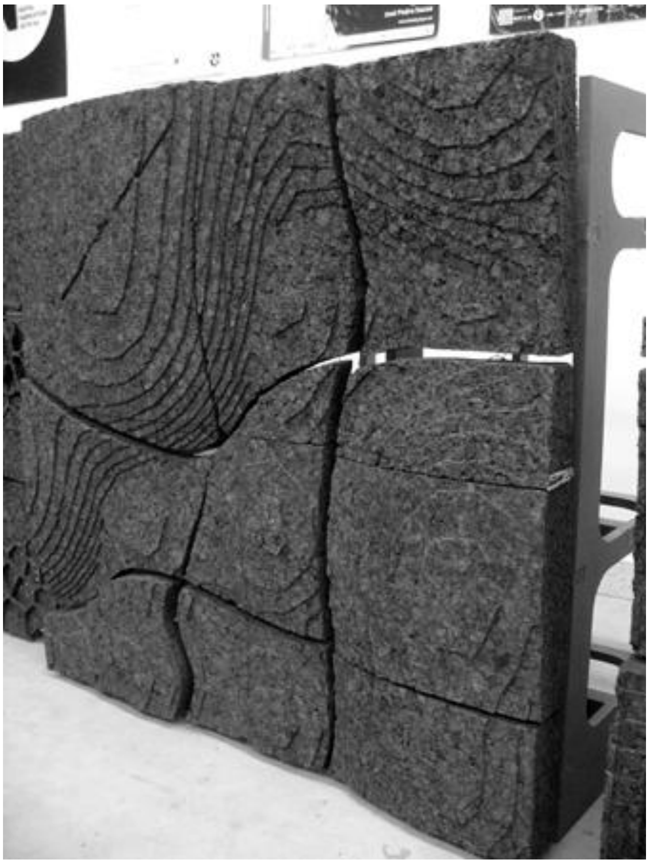

Figure 5. Group C: Metaballs.

Figure 4. Group B – Voronoi.

Figure 6. Group D: Pixel.

3.4 *Stage 4: LS_02 Design Studio*

During the two weeks between LS_01 and LS_02 workshop modules, a vote for the best prototype was held online. Each participant and trainer – in a total of thirty people - was asked to vote one solution. The winner was the group B, with the Voronoi solution and wave movement.

After the competition, at the end of the second week, trainers were mobilized to adapt and fabricate the parametric structure to the winner 3x5m cork panel. In the first two days of the second module, participants and trainers dedicated their time assembling the five modular 3x1m structures that together would form the 3x5m wall. This strategy (to split the complete wall in five modular structures) was intended to facilitate de CNC fabrication, the transportation and specially to minimize the vibration effect caused by the motors movements. The last component of the wall being mechanized was the 3x5m cork panel, during the first two days of the LS_02 workshop module. The cork panel was mechanized in three parts – two of 3x2m, and one of 3x1m.

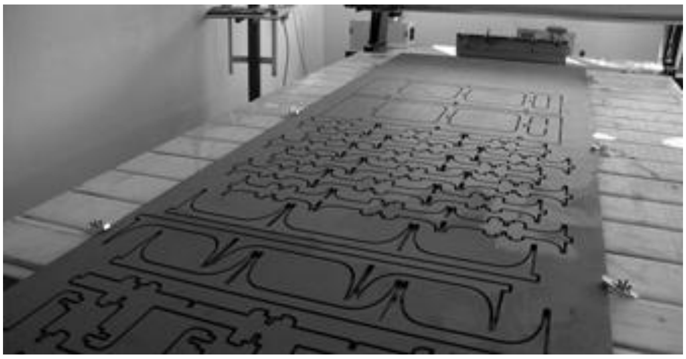

Figure 7. LS_02: CNC prototyping the structure components.

Figure 8. LS_02: 3x1m structures; CNC cork process.

3.5 *Stage 5: LS_02 Discursive Wall - Design Studio*

Resistance, transportability, functionality, operability, and tenacity were all features to be include in the final test to the Discursive Wall idea.

After the two days period of assembling the different components of the living system (Figure 7), in the third day all participants and trainers were invited to transport the five 3x1m modules to the coffee-shop (Figure 8). The modules were fixed in a wall, at 1.50m height from the floor level, providing the idea of suspended panel, enabling the usual use of the coffee-shop space (Figure 9).

All the electronics (wires, Arduino, power supplies) and the cork panel were assembled in loco, after the Discursive Wall structure had been fixed to the coffee-shop wall (Figure 10).

The next question to be answered was to determine the most strategic location of the movement sensors. The obvious chosen locations were frequently used spots, like the payment area and the pizza queue area.

After the movement sensors had been installed in their locations, the 3x1m modules were tested. All were firstly validated individually, making sure that all the motors were responding and working correctly. This motors issue was very delicate. Since these electronic equipment are specific to micro scale tests, their durability and precision were very sensitive within this larger scale model. Basically the solution was to control their velocity and concurrency of movement.

The final challenge was to make sure that all of the five independent structures were able to work together and could produce a unique and continuum movement.

Figure 9. LS_02: Fixing the Discursive Wall.

Figure 10. LS_02: Perspective view of the structure and the electronics incorporation.

4 VIRTUAL-DATA-PHYSICAL

This workshop proved that architecture is no longer a drawing exercise. The multidisciplinarity associated with this big team was the particular characteristic that brought this idea to reality. The electronic system was conceived from basic knowledge, being enriched by the *a posteriori* professional know-how.

Virtually, the exercise consisted in the constant flow of information between the Grasshopper VPL and the Sensor. Firefly made the translation – from VPL to C++ and VS. Arduino was the bridge between the virtual/physical gap. Many adjustments were made from the LS_01 to the LS_02.

In the first four 1x1m prototypes, one Arduino UNO was used with nine entries, one for each unit motor. For the 3x1m modules of the second phase, as the UNO were not sufficient, Arduino MEGA were used (each 3x1m module contains 27 unit motors).

In the first phase 1x1m prototypes, one 12V power supply was used to feed the each set of nine motors. In the second phase 3x1m modules, power supply was optimized, one power supply being used for 20 motors.

The motors' used in phase 2 were also different from the ones of phase 1. In the first prototype, continuous rotation servo motors were applied. However, it was found that this type of rotation was too fast for the movements that were projected. Therefore, in the second phase modules, 180º rotation servo motors were used with key specs at 6 V: 0.14 sec 60°, 240 oz-in (17 kg-cm), 60 g. The greatest difficulty was to improve the motors performance within the bearing system. The plastic-metal link component revealed to be too sensitive to the heat generated by the movement. It did not take long to become too slick to provide the necessary engagement of the parts, and so the motor had no way to move the bearing system. The solution was to improve the continuous movement with a shorter and slower step-by-step movement. This was still able to create the illusion of a continuous movement.

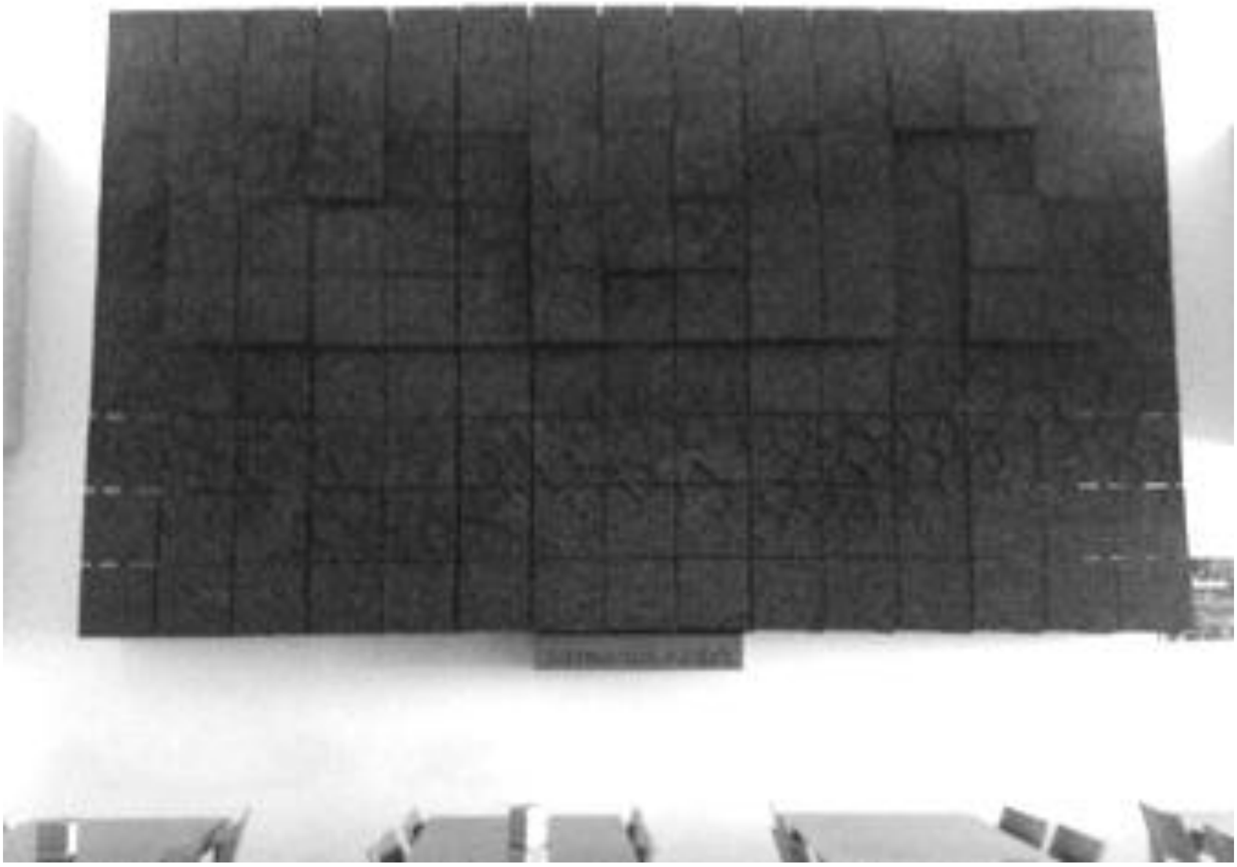

Figure 11. Discursive Wall

5 CONCLUSIONS

The challenge was overcome (Figure 11). The Discursive Wall is real, the 3x5m cork panel reacts to the inhabitants and visitors of the coffee-shop, responding to their passage and proximity, establishing a real time dialog. The acoustical problem seems to have been mitigated. Giving continuity to this experience, this team aims at exploring and creating new wall systems that will respond and solve different issues related to solar radiation creating an autonomous input/output organism. The creation of systems able to respond to exterior stimuli will certainly contribute to an adaptive and evolving context of contemporary architecture. This premise has been experimented with the discursive wall described in this paper.

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Figures 3-10 by Bárbara Varela.

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