Living system design Studio: from digital to fabrication process

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Various approaches have been developed to deal with digital tools in architecture design process. The most recent is responsive architecture. This paper presents the results of a design studio based in an interdisciplinary collaboration research at Vitruvius Fablab-ISCTE IUL. The main goal was to explore the new digital technologies to generate a Discursive Wall – Living System that physically responds to movement, interacting spatially and temporally with the environment and its inhabitants.

1. Introduction

"Digital fabrication techniques will certainly play a key role in the affair, but the direction in which they will lead architectural design is still unclear. (...) In context of incertitude, the quest for a new poetics will perhaps represent one of the most enduring legacies of the current experiments" (Picon 2010:7)

The autopoesis theory (Maturana and Varela, 1980) seems to contain the necessary knowledge to enable the creation of new poetics in architecture. Recent discourse on digital and living systems in architecture is exploring number of biological concepts: self-organization and emergency. Going even further several architects argued that, the implementation of locally-sensitive differentiation, achieved through morphogenetic responsiveness, can produce more flexible and interactive architecture (Kronenbur, 2007; Fox & Kemp, 2009). Over the past years, there has been a large number of works over the living systems, and the relationship between their components, coexistence, emergency and complexity (Hensel et al, 2010; Roudavski et al, 2006).

Traditional architecture design process starts from principles that architectural structures are singular and fixed, well integrated and separated from their environment or context. Emergence design processes and technologies require the opposite, complex structures as part of an environment or context. These assumptions associated to development of digital culture are changing the definition of materiality. Materiality is synonymous of resistance, performance, sensation and perception (Malkawi & Kolarevic, 2005). 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 & Klinger, 2008; Diniz & Turner, 2007). However, it is necessary to develop new approaches to design studio involving digital tools. According to Oxman (2010:291) "theories and methods of digital design can no longer be conceptualized as the merging of computational tools with conventional formulation of design.(...) age of digital media presents the need to pioneer a new understand of the nature of designing (...)". It is essential to challenge the supremacy of top-down processes of form-making, and implement bottom-up logic of form-finding. The highlighting is on material performance over appearance and on processes over representation (Leach, 1997). The materializing of a responsive walls need to have multidisciplinary approach towards developing intelligent artifacts (Goulthorpe, 2008). Digital fabrication offers opportunities to produce non-standard elements, which have the potential to create physical spaces with specific characteristics and economically viable (Bonewetsch et al, 2008). Recent research and experiences went deeper into the prototyping phase, providing the viability to these hypotheses (Hensel et al, 2010; Sheil & Glynn, 2011; Burry, 2011).

In order to explore these new architecture challenges, a multidisciplinary group of researchers proposed "a living system" design studio, held at Vitruvius Fablab ISCTE-IUL. The goal was to design an acoustic structure – discursive wall - to a coffee shop, using parametric, generative, programming and fabrication computer supported techniques. Inspired by the performance-based design, the main target was to develop a 3 x 5 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, and 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.

2. Design Studio

The design studio involves three partners: VitruviusFablab-IUL, FabLabEDP and Rhino3DPortugal/DigitaLab. The theoretical and practical design studio (64 hours), was composed of two modules: (1) LS_01, Firefly + Grasshopper + Arduino and Scale Model Fabrication; (2) LS_02, Design Studio – Discursive Wall. The design studio had the participation of students and professionals from different areas of knowledge (architecture, product design, fashion design, sculpture, engineering, electronics, and programming) from different countries. The main scope was to go through

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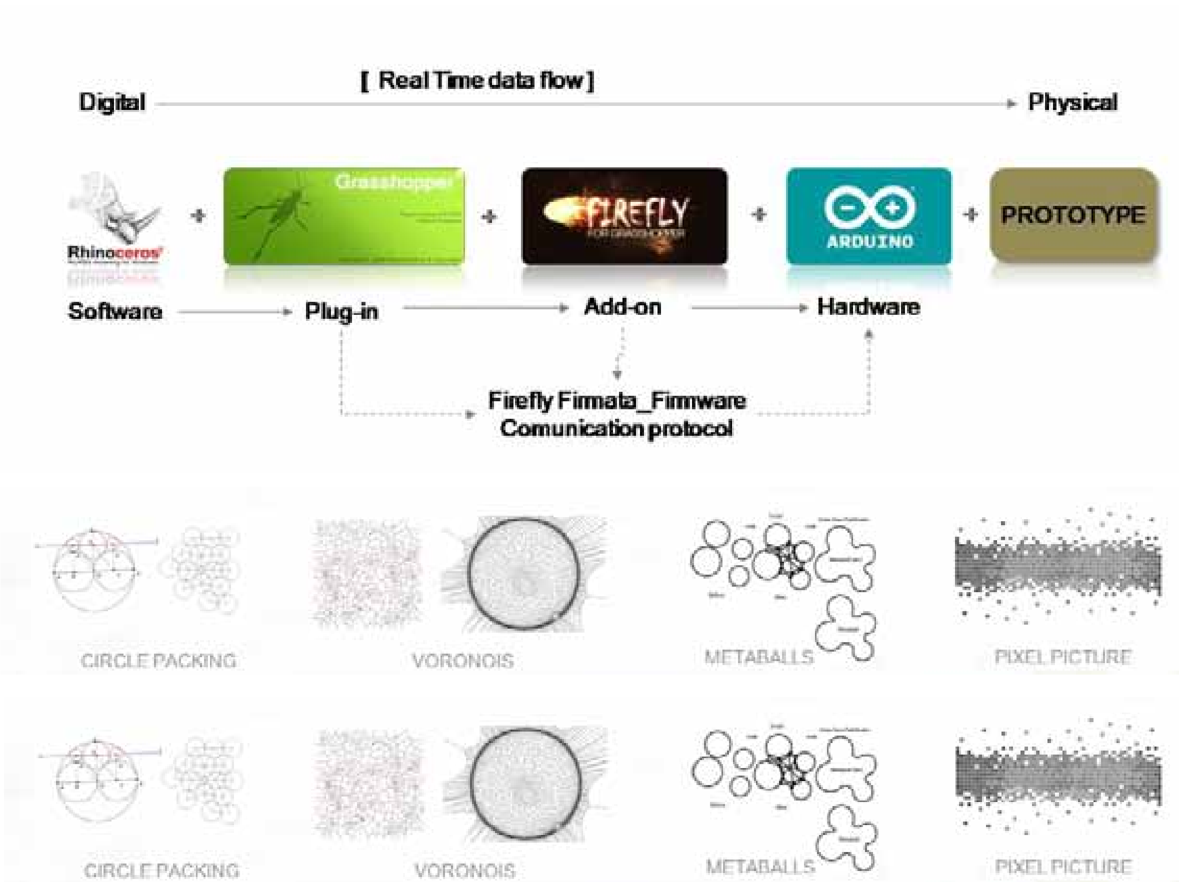

Figure 1. Design Studio Framework

all the lifecycle of the design solution: ideation to prototyping. The design studio explored the use of Rhino Grasshopper plug-in, Firefly add-on and Arduino hardware as creative and technical tools. The design processes used CAD/CAM tools to simulate and prototype 3D interactive architectural solutions (fig.1). The LS_01 was to establish a clear understanding and direct dialog between CAD environment Rhinoceros and programming interface Grasshopper with Firefly and finally the insertion of data in the Arduino – the open source element that manipulates the physical mechanism. The final step was to prototype 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. The LS_02 was to set-up the 3 x 5 meters Discursive Wall in coffee shop.

3. Living System – discursive wall: from digital to fabrication process

The design studio was divided in four phases: (1) LS_01 Grasshopper+Arduino+Firefly; (2) LS_01 Prototyping; (3) LS_02 Design Studio; and (4) LS_02 Discursive Wall set up (fig. 1).

Phase 1: LS_01 Grasshopper+Arduino+Firefly

The first two days of the design studio were dedicated to the creative process and the production of the cork units using the Grasshopper. The participants were organized in four groups, which developed several design logicv=s, like simulated Membranes through the application of fibers over the cork (fig. 2), the Voronois logics (fig. 2), Metaballs (fig. 3) and the simplicity of the Pixel (fig. 3). In order to provide the basis of programming and open source resources, the third day of the design studio was fully dedicated to Arduino (C/C++). After this creative design process and after providing the open source knowledge the design studio 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.

Phase 2: LS_01 Prototyping

After the virtual test of all the four solutions, the last day of the module LS_01 of the design studio 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. Four different parametric structures were cut by the CNC milling machine 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. After the electronics

Figure 2. Left: Group A fingers; Right: Group B – Voronoi, in Lisboa (photos by Alexandra Paio).

Figure 3. Left: Group C - Metaballs. Curves; Right: Group D: Pixel, in Lisboa (photos by Alexandra Paio).

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.

Phase 3: LS_02 Design Studio

Between LS_01 and LS_0 was voted online the best prototype. The winner was the group B, with the Voronoi solution and wave movement (fig. 4). After the competition, at the end of the second week, was time to 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 design studio module.

The design studio 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 and physical. 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.

Phase 4: 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 surface. After the two days period of assembling the different components, in the third day all participants had to set-pt the wall in the coffee-shop (fig. 5). 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. The next question to be answered was to

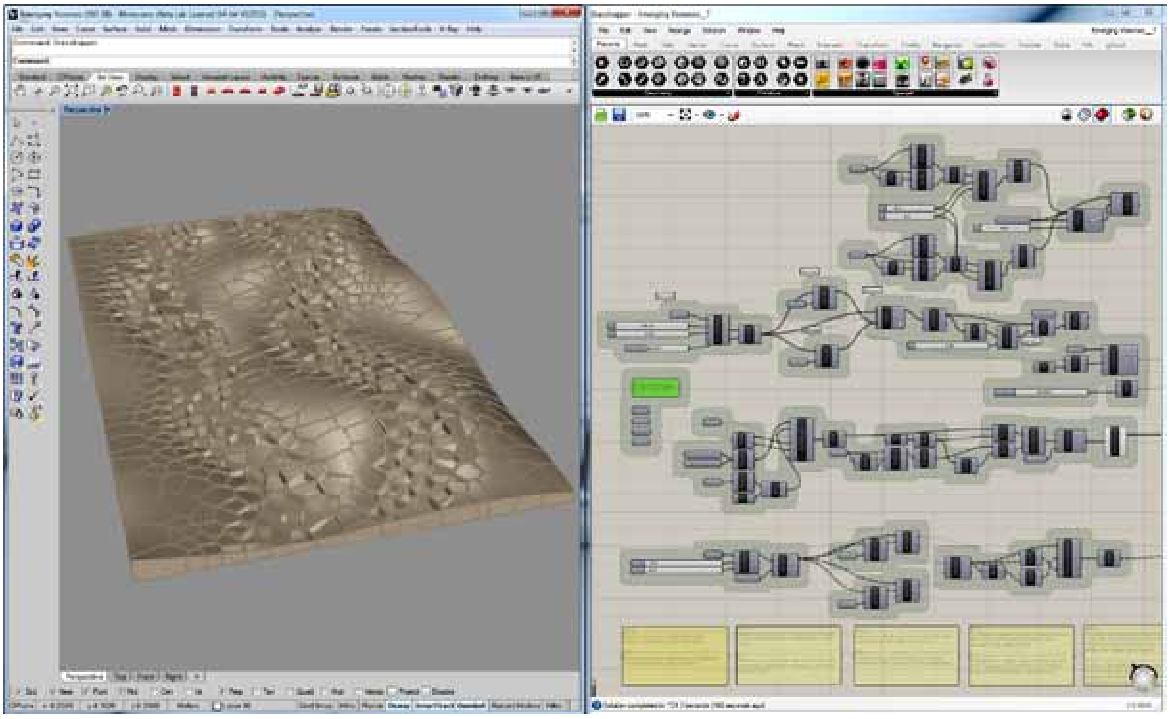

Figure 4. Geometric modeling and parametric control-relation definition in grasshopper.

determine the most strategic location of the movement sensors. The obvious chosen locations were frequently used spots. 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 5. Discursive Wall in coffee bar at ISCTE-IUL, in Lisboa (photos by Alexandra Paio).

4. Conclusion and future work

This paper has presented only a brief outline of the design studio. The challenge of translating complex geometries based in living systems into a physical artifact was allowed by the application of advanced parametric 3D modeling techniques that directly were linked to CNC fabrication technology. The parameterization allowed: (1) a quick adaptability to the several elements of the structure, and (2) the manipulation of the assembly parts only with simple assembly logic. The greatest difficulty was to improve the motors performance within 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.

The future work will explore and create new wall systems. The adopted framework will be developed to seek new achievements by display more intelligent inputs. The new wall will respond and solve different issues related to solar radiation creating an autonomous input/output organism.

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