Figure 7. Final installation of the Myco-Scape prototype at CFC Barcelona event © M. Elatab, 2019

MYCO-SCAPE

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Abstract: The research presented in this paper investigates the development of a modular system, which supports the growth of edible oyster mushrooms in the urban environment (i.e. public space, facades, rooftops), by producing both food and construction materials. It consists of modules to locate the mushroom substrate (straw and mycelium) and an external surface, parametrically designed, tailored to control the environmental conditions (e.g. shading and humidity). In order to develop a growing module as sustainable as possible, wood has been selected for realisation of panels and the frame structure. A second main objective of the installation, is to act as a demonstrator: creating a 'culture of caring' for locally sourced and produced food. The paper explores the complex design negotiations between these drivers, focusing particularly on their performance optimization, and finally highlights the system potential as exemplified through a successful implementation of a 1:1 responsive wall prototype.

mycelium / parametric design / food production / responsive design / performance optimization

Figure 1. Making of the natural straw substrate and incubation process © F. Ciccone, 2019

DIGITAL FABRICATION AND NATURE BASED SOLUTIONS

Myco-Scape is a living system designed to promote the integration of nature in cities and to allow the use of Mycelium-based composite materials —panels grown from mycelium supported on a plywood frame—which can provide performance control from micro-climate conditions to the production of oxygen, food or new construction materials. (Hebel, 2017)

The project uses digital technologies, such as computation design and digital manufacturing, to implement and control of site-specific features, so that the prototype is capable of passively controlling the parameters that affect plant growth (e.g. temperature, humidity, solar radiation). By implementing Myco-Scape in buildings, hybrid facades can be built to combine the production of food (fungi) with construction materials (facade panels made of mycelium), while simultaneously improving the microclimate and also contributing to the production of oxygen.

The project opens the possibility to new hybrid and collaborative urban micro-economies: active citizens and associations can contribute to produce food and objects with materials derived from nature-based solution; while start-ups can develop the brand of their products and take care of their commercialisation. Myco-Scape represent a first experiment of digital fabrication and design opti-

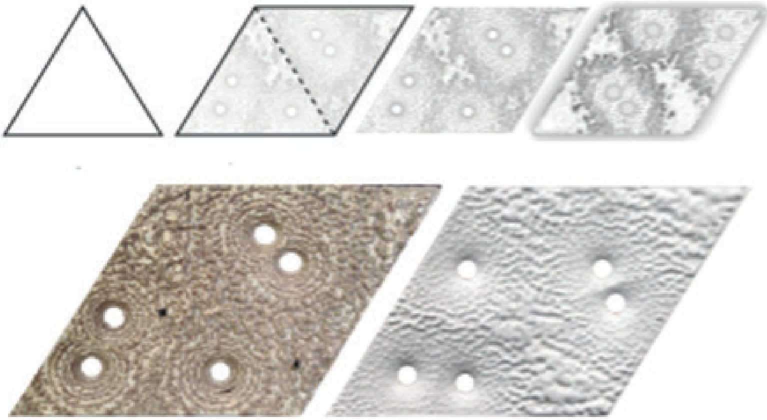

Figure 2. Exploration with 60 degrees triangles & 45 degrees triangles © M. Elatab, 2019

mised prototype able to transform buildings into systems for living, producing, and restoring the environment.

Substrate Setup

The prototype development has been organised in different design-controlled and growing phases. The first is focused on the creation of a natural straw substrate for the cultivation of mycelium. After pasteurising the straw for half an hour in boiling water, it was let to cool down and was spread out evenly in a sterilised table surface to fasten the cooling process. Then the substrate was separated within sterilised bags which consisted of half straw and half mycelium. These bags were then placed into a hydroponics tent, at a stable humidity level and temperature of 24 °C. (Figure 1)

INTEGRATION OF DIGITAL DESIGN EXPLORATIONS

Computational design software —specifically Rhino 3DM and Grasshopper — were implemented for design modelling and optimisation of the panels, as a reference of bionic research pavilion ICD (2011) as well as facilitating the development of a common design platform that allows for adjustments based on defined parametric inputs. This algorithmic script influences the system design on both the indi-

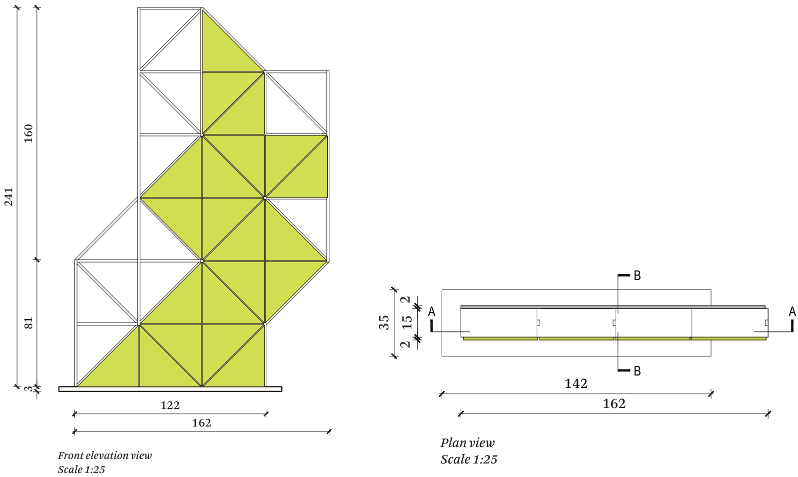

Figure 3. Final panel layout development and implementation © M. Elatab, 2019

vidual panel and the overall global system design, according to site-specific and climate-specific inputs, resulting in an innately digitally fabricated responsive design.

In terms of the pattern design, the surface was divided into points according to the U-direction and V-direction, then circle packing was applied on the surface based on the attractor points (openings) and an attractor curve (highest surface). Different tests were held regarding the pattern logic, according to shading analysis and water collection analysis. Then, the results of these tests have been optimized to implement the final design.

STRUCTURAL DEVELOPMENT

Advanced ways of fabrication require new ways of designing and manufacturing (Figure 2). Myco-Scape was conceived under the paradigm of Co-Design, where new possibilities in fabrication are explored through continuous computational feedback. In this project, the algorithms developed by the project team generate the shape of each element of the installation according to architectural design intent and structural requirements, while all Computer numerical control fabrication aspects are directly embedded and negotiated. Two topologies have been

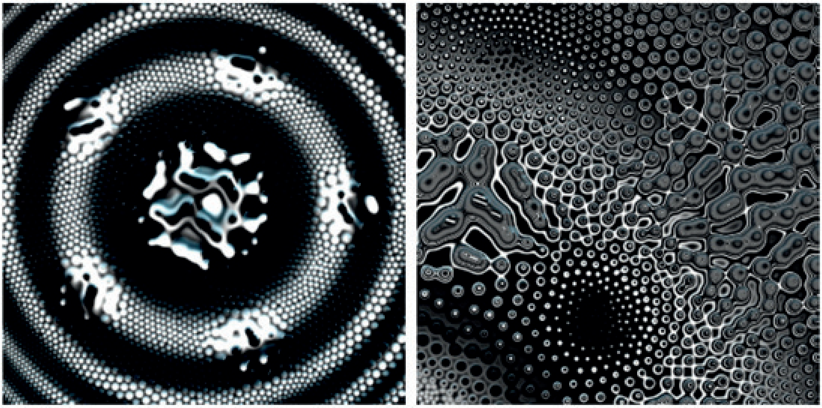

Figure 4. Reaction-Diffusion precedent images in Quantum Decoherence © Robert Hodgin, 2010

experimented: the first, is an equilateral triangle (50x50x50 cm) while the second is a right triangle (50x50x70 cm). The second design solution was chosen, due to the better implementation of the waffle structure and in a dynamic vertical layout. Multiple geometries based on 21 triangulations has been tested to optimize surface-pattern relationship. (Figure 3)

PATTERN RESEARCH

Two of the most important strategies that are required for the growth of fungi, at the fruiting stage, is water and shade. With these two factors into consideration, the design of the pattern aims to recreate microclimate conditions through a varied topography, which regulates the flow of water and the lighting exposure around the holes that allow mushrooms to fruit. For these reasons, the meatball method is used to generate the overall pattern. These new geometric entities permit to precisely details surface pattern through special animation software like WaveFront (Schumacher, 2018). Furthermore, this method was chosen because of its smoothness through the merging of different metaball fields together. (Figure 4)
Figure 4. Reaction-Diffusion precedent images in Quantum Decoherence © Robert Hodgin, 2010

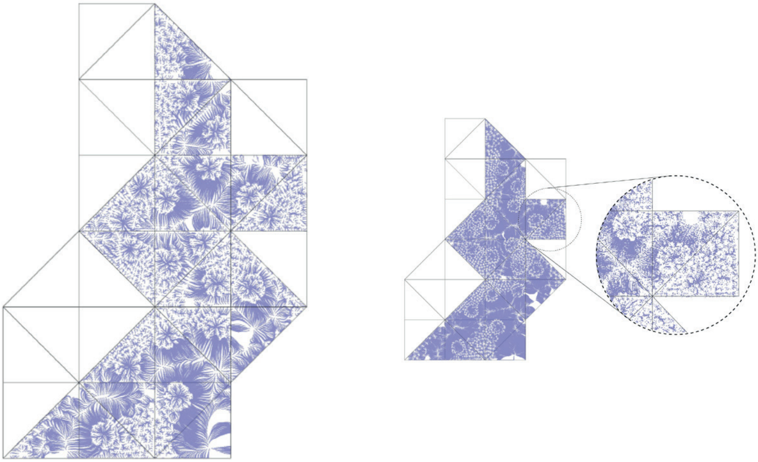

Figure 5. Water strategy - sparse pattern simulation © M. Elatab, 2019

DESIGN EXPERIMENTATION STRATEGIES THROUGH ENVIRONMENTAL CONDITIONS

Water strategy

Specific water flow algorithm (Park, 2018) has been simulated on the designed surface pattern, allowing water to drain towards the lowest area of the structure. Since the substrate needs to be hydrated, a water collecting pattern has been overlapped on the design of the waffle panels. Design-wise, the pattern forms metaball bumps around the holes that can maintain water and keep the surface moist which in its turn, helps the growth of mushrooms. (Figure 5)

Shading strategy

A crucial element for the fruition of oyster mushrooms is also the placement in a shaded spot with exposure to some indirect light. The specific layer for the pattern design serves this purpose, by creating a shading system which is formed around the holes. The homogenous red area that describe high light exposure has been

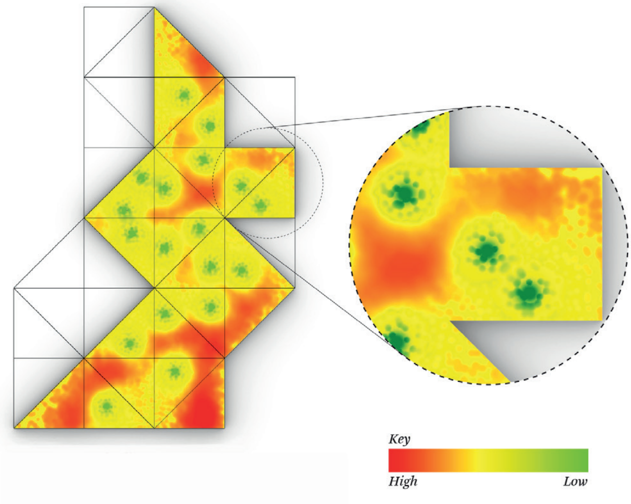

Figure 6. Shading strategy – high/low exposure simulation © M. Elatab, 2019

avoided for the localization of holes, while dark-green areas prompt the suitable positions.

A simulation of the shading method (Lopez, 2016) was performed to demonstrate where to avoids structural joints, connectivity and holes positioning conflicts. The method reflects this presence where red colour translates to higher points than that of green (lower points) in the overall height of 5 cm. (Figure 6)

Fabrication process

Plywood is a semi-natural product, stronger than steel in static bending strength, made from a renewable resource, which allows the cultivation and wide application to gardening. On the other hand, it serves the design purposes for revealing wooden layers and to control the waffle modules (plywood board of 30mm) fabrication though CNC milling machine . To improve the pattern simulation, different milling tools in various depths have been used for smoothing the surfaces and holes. Moreover, this strategy has been adopted in order to reveal wood's natural colours and to create a topographical effect on the final surface. At the end of the milling process, the overall surface has been cut into triangular panels. Smaller connectors have been cut in two plywood boards of 15mm and then assembled all together.

The final prototype consists of a plywood waffle structure and 21 specifically designed plywood panels. The substrate, which was ready for fruition, was perforated with different openings and attached behind each panel. In the presence of regular water spraying the mushrooms fruited in few days and perfectly blended within the design of the prototype. (Figure 7)

FINAL REMARKS AND FUTURE RESEARCH PERSPECTIVES

Climate change and the need for adaptation, forces us to rethink our way of life and to reconnect agriculture back into the urban realm, considering that 80% of all food is expected to be consumed in cities by 2050. Nature-based solution represent a significant field of inquiry in this development scheme, considering food overconsumption and waste management two connected challenges for the transition to a real circular economy model (MacArthur, 2019). Myco-Scape represents a provocative vision of how nature-based solution can contribute to research and development debate on new sustainable materials in the light of reducing our environmental footprint in the construction sector. Building with mycelium will investigate the innovation and alternative strategies behind the potential uses of food-waste as new material for design, that can be consolidated into customized devices for architecture.
Open research perspectives, in this direction, would include the embedding of AI systems and further ICT technologies in architecture and nature-based prototypes like Myco-Scape. Further interaction with autonomous robotic machines which are able to detect the stages of mushroom growth through software algorithms and harvest them would be very interesting to be explored. In this way, cultivation, substrate replacement and mushroom collection could be fully controlled. (MAEID, 2019) Moreover, applications for controlling the environment (water/humidity/ventilation) and/or applications for people's interaction with the installation could raise awareness regarding the maintenance of the prototype.

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