AIA PAVILION SYSTEM INTERACTIONS

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INTRODUCTION

This paper will discuss the assembly and construction process of the AIA pavilion, a 180sf lightweight structure in the French Quarter of the historic city of New Orleans. The paper will demonstrate how parametric software, such as Grasshopper can inform fabrication and material systems. It will explain the fabrication process of a pavilion in detail and make an argument for plastic as a material that not only responds to the malleable characteristic of digital tools but also to environmental issues.

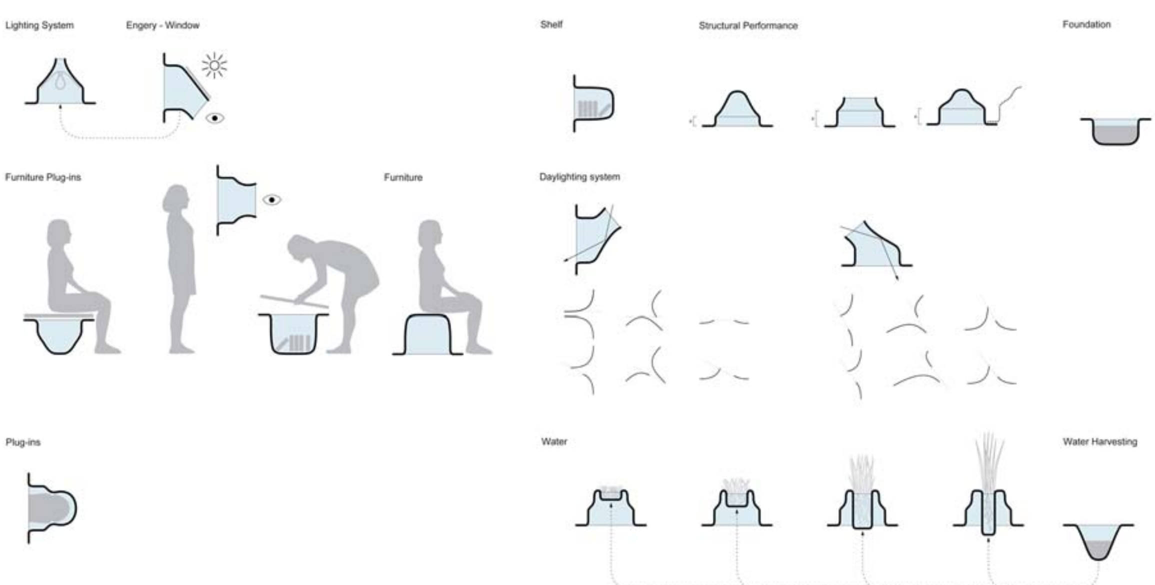
KEYWORDS

design build, Grasshopper, CNC, parametric design, digital fabrication, plastic

INTRODUCTION

The project was selected for realization at an annual AIA call of entries that asked for interventions that bring to life the historic city of New Orleans. The project suggested a series of event spaces sited within usually hidden, often private courtyards to reactivate the city. At night the pavilions would reverse the city's fabric: What was a private space during the day would become a public space for music and other events at night.

FIGURE 1. Possible variations of modules.



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The AIA pavilion connects research in generative design and digital fabrication with research in environmentally friendly construction methods. The pavilion was developed from 320 variations of a single module. Each module is generated from different sets of information that are derived from the module's unique position within the overall form and context, different architectural and structural requirements and unique site conditions. The architectural qualities emerged from the interaction of these different sets of information. The entire project was scripted in Grasshopper, a scripting plug-in for Rhino.

DESIGNING FLEXIBLE SYSTEMS

The pavilion was designed as an efficient lightweight shell structure that allows for easy transportation and rapid assembly and disassembly. The base geometry of a sphere was transformed to adapt to specific site conditions and solar orientation. It was optimized relative to size and location of apertures, floor surface, program, and structure. The geometry was then tessellated into 320 unique triangular proto-cells that were transformed into cells of different attributes.

Depending on its position, the edges of each cell were folded differently to provide stiffness within the cell and to make up the overall structure. Each cell adapted further to different functions: windows; seating; foundation; brackets for an electrical lighting system; a daylighting system; containers for plants; and water collectors. The process of informing and transforming each proto-cell based on specific functions was entirely scripted. Each function therefore had to be articulated as rules that informed the cells geometric transformations.

The degree of unpredictability in form increased with the number of sets of information that operated on the same geometry. Scripting became the primary design tool and was not just to automate an existing design. The final overall form and spatial qualities of the pavilion in turn emerged from the cells' variations. By scripting the entire pavilion in this manner, we dramatically increased continuity between digital design and fabrication. Engraved instruc-

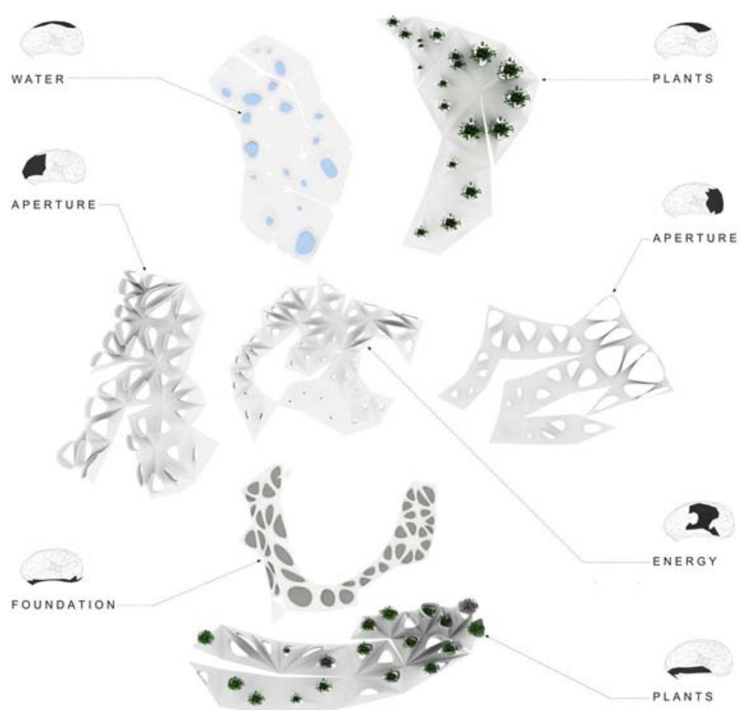


FIGURE 2. Map on different networked modules.

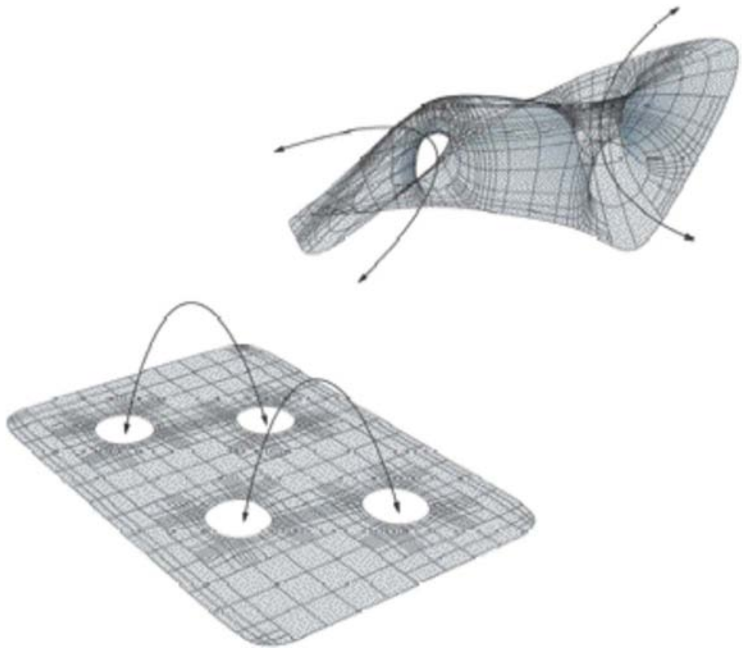


FIGURE 3. The envelope generates wormholes that act brace- and column-like and increase the surface tension.

tions that helped to connect the different cells, plus numbering of all edges and details that changed with each cell, could be added easily to the script as additional information.

To minimize the amount of material used for the envelope and to create a lightweight structure, the envelope generates wormholes that act brace- and column-like and increase the surface tension. The formation of wormholes within the surface allowed for the lightweight structure to be as light as 123 kg.

FLEXIBLE MATERIAL SYSTEMS

The highly malleable nature of plastic made it suitable to the digitally derived form of the pavilion and its complex geometry and cell variations. The material is light, impact resistant, and easy to fabricate. This contributed to rapid assembly, disassembly, and transportation. The material choice also responded to sustainability and environmental concerns.

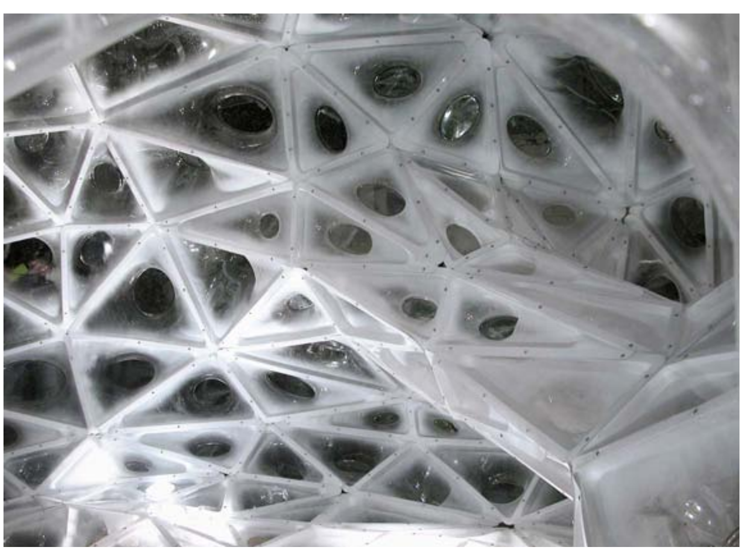


FIGURE 4. Interior view showing the envelope of the pavilion transforming into a column-like configuration.

Research in Bio Plastics led to three different alternatives: Bio-derived Polyethylene (Bio-PETG), Polylactic acid (PLA) plastics, and Plastarch (PLM) starch based plastics.

Bio-PETG is produced from sugarcane, a plant that has been an integral part of the culture and economy of Louisiana for 200 years. The material is manufactured from sugarcane feedstock that is used to produce Ethanol, which after a dehydration process becomes Ethylene. Producing PETG from sugarcane has tremendous environmental benefits. Any plant produces oxygen and extracts carbon dioxide from the atmosphere. Due to its large abundance of sugarcane, Brazil is the leading researcher and manufacturer of Bio-PETG in the world.[1] According to a 2004 study by the Carbon Dioxide Information Analysis Center in Brazil, "Over 1.5 billion pounds of CO_2 will be annually removed from the atmosphere, which is equivalent to the fossil emission of 1,400,000 Brazilian citizens".[1] Brazilian chemicals group Braskem claims that using its route from sugarcane ethanol to produce one tonne of polyethylene captures (removes from the environment) 2.5 tonnes of carbon dioxide while the traditional petrochemical route results in emissions of close to 3.5 tonnes.[2, 3] This product is virtually identical to regular fossil fuel-based PETG, with its exceptional thermal and recyclable characteristics. Although Bio-PETG can be recycled, it is not biodegradable.

Polylactic Acid (PLA) plastic is a transparent plastic made from many different renewable resources, such as corn (United States), tapioca (Asia), or sugarcane (rest of the world).

Although PLA plastic is very similar in appearance to both PETG and Bio-PETG, it is biodegradable and recyclable through a "Cradle-2-Cradle" certified process of Thermal Depolymerization.[4] Through this process, "a highly purified lactic acid is extracted and can be considered as raw material for the manufacturing of virgin PLA with no loss of original properties." This is the only material of the three that can be truly recycled and reproduced without losing any of its original characteristics. One disadvantage to PLA is that the cost is presently very high. This can be attributed to the fact that PLA is a fairly young product. PLA plastic's connection to corn ethanol research in the automotive industry might be promising. If biofuel derived from cornstarch becomes a standard in the future, one could see PLA plastics being in very high demand. A disadvantage still is the uncontrolled biodegradability of the material. Currently, one could imagine PLA as a temporary building product.

Plastarch (PSM) is a starch-based plastic. PSM plastic is generated from thermoplastic starch from the likes of potatoes and corn, combined with other biodegradable materials, such as sorbitol, glycerin, polyester, cellulose, and polyvinyl alcohols. A plastic blend therefore consists of two phases—the continuous and hydrophobic polymer phase and the dispersed and hydrophile starch phase. In the hot, anhydrous smelt in the extruder, the water-soluble, dispersed starch phase is mixed with the water-insoluble, continuous plastic phase to form a water-resistant starch plastic.[4] By having different composites and "starch-blends" of PSM plastic, one can adjust different additives to tailor the material for a given application.[4] The customizability of this material is a major advantage. For example, if one would like to increase the overall strength of the PSM material, one would increase the ratio of cellulose to the existing mix in order to add strength, or add different polymers to decrease its water absorption, making it more waterproof.[4]

FLEXIBLE FABRICATION SYSTEMS

The research in complex geometry and material was aligned with a research in different digital fabrication techniques. Geometric principles were related to material characteristics. The main criteria were function, structural performance, weight, weather resistance, sustainability, and cost.

Flexibility in manufacturing usually means the ability for one machine to produce different products or parts, vary an assembly process and sequence, and the ability to adapt to changes in the design. In industrial design the term "machine flexibility" is used for a machine that can manufacture a variety of products. The term "Flexible Manufacturing Systems" or "FMS" is used when several machine tools are linked in a flexible dynamic way.

The studio speculated with manufacturing and assembly processes to create the similar but unique modules the pavilion required for a flexible manufacturing system. Developing such a system required adjusting the boundary condition of the pavilion's system of cells to the boundary conditions of flexible fabrication methods.

The 300 modules of the pavilion were all different but part of a same family. Each was a different size and proportion, but shared the same base geometry of triangles. The section of each module was different but each could be developed by extruding the base geometry. Since each module was fabricated from thermoformed plastic sheets, it allowed for different forming techniques due to the programmatic and contextual requirements. Three thermoforming techniques were investigated; draping, drape-forming, and vacuum forming, and programmatic advantages associated with each option. The fabrication method responded to the parametric digital model with its flexibility of fabricating the cells. Since the model was entirely scripted, the model could update to fabrication constraints at any time. A continuous feedback loop was created between digital modeling and fabrication. A flexible mold was developed that could adapt to different triangular geometries with three molds tested:

Spring mold: Is a mold that consists of different tube segments that are held together by a system of springs. The tubes are cut at 2″ intervals. All triangles could be produced with 36 interchangeable tube segments. Advantages were that very little material was consumed for the formwork, and the spring itself produced interesting surface effects on the material. The disadvantage was that it was time consuming and created round corners that weakened the structural performance of the module.

Block mold: Is a mold that is assembled from woodblocks of different shapes. The advantage is an easy way to assemble the different forms; the disadvantage was a large amount of parts to generate a satisfying precision of the individual triangles.

FIGURE 5. View of the pavilion in the courtyard.

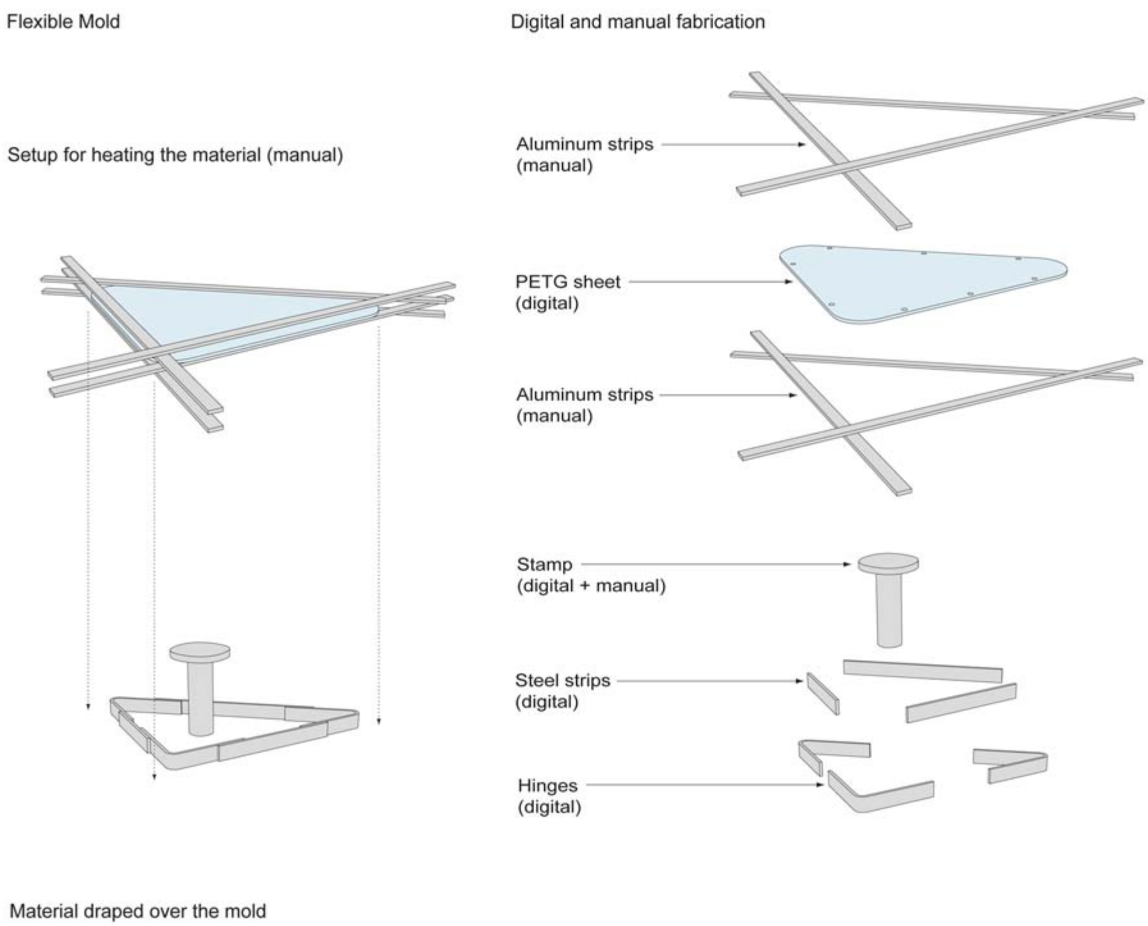
Steel Frame Mold: Is a mold that consists of Steel Strips in increments of 2″ and flexible hinges that can be adjusted to make up for that 2″ tolerance. The Steel Frame Mold was selected as a final mold since it was the most precise and the mold that used the least amount of material. The disadvantage of this mold is that it's a time consuming process to assemble, which ideally would be automated.

CONCLUSION

Using scripting to design the pavilion and using a flexible mold to thermoform each cell allowed us to customize each cell according to different functions and context in a highly cost effective way.

The project responds to the chemical industry that is currently changing its production of plastic from fossil-fuel based products to bio-plastic, which might make plastic the building material for the 21st century.

FIGURE 6. Diagrams explaining the Flexible Mold.



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