Pluripotent Structures: An Exploration into Digital Design & Fabrication by Bio Mimicry

Bio Mimicry & Pattern Making

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ABSTRACT

This project is an exploration into the design & fabrication process of a canopy structure derived from the notion of pluripotency. The term is widely used in the context of stem cells in biological science where pluripotency is referred to the potential of a stem cell to develop into more than one type of mature cell, depending on environment. These can be re-interpreted architecturally as, the quality of design components or elements to be radically transformed into one or more different kinds of components, keeping the general structural integrity of the design unchanged (Kolatan, 2009). Consequently, the pluripotent canopy design is a 3 dimensional double curved surface , having smart pluripotent components populated over its domain, which parametrically has the potential to be transformed to more than one different kinds of elements, keeping the same parameters of construction for each component.

KEYWORDS: Stem Cell Concept; Pluripotency in Nature; Digital Prototyping; Voronoi Geometry;

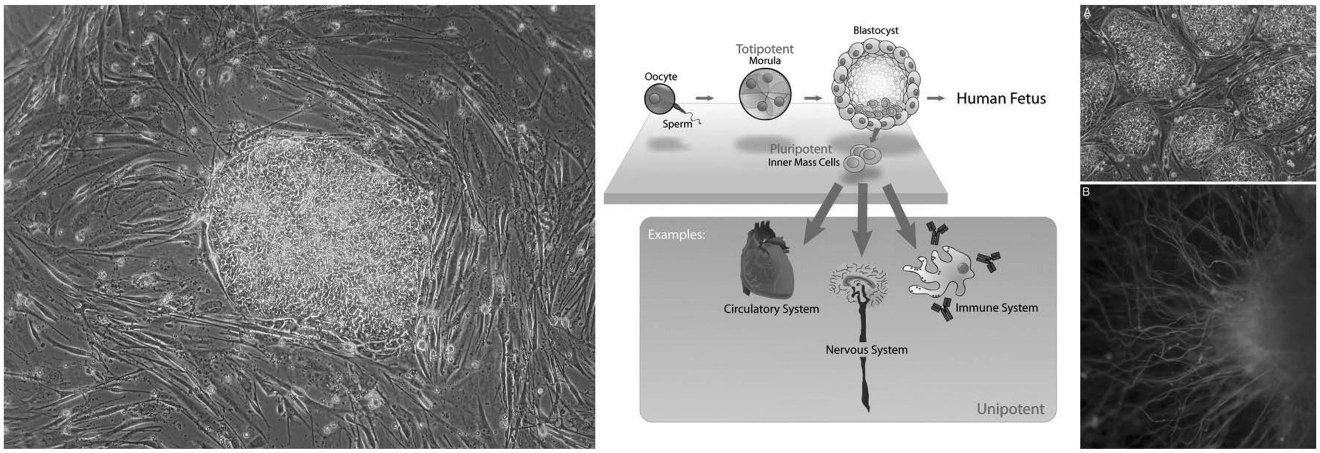

Fig. 1. The figure above shows the Human Embryonic Stem Cell (ES Cell) in Cell culture.

Biological System Research:

Our concept of the canopy design was highly derived from biological cell systems and for the same we studied the principle of pluripotency, which comes from the system of Embryonic stem cells (ES Cells). ES cells are basically derived from the inner cell mass of the blastocyst (which is an early stage embryo). ES cells are observed to possess two distinct properties – pluritpotency & the ability to replicate indefinitely. (Reh, 1998). (Welikson,2007). This means, under defined conditions, embryonic stem cells are capable of propagating themselves indefinitely. Some of the vivid typologies of cell potency (specifies its differentiating potential) studies are:

- Totipotency is the ability of a single cell to divide and produce all the differentiated cells in an organism, including extra embryonic tissues.

- Pluripotency refers to a stem cell that has the potential to differentiate into any of the three germ layers: endoderm , mesoderm, or ectoderm. Pluripotent stem cells can give rise to any fetal or adult cell type. This basically covers more than 220 cell types in the adult body.

- Induced pluripotent stem cells, (iPS cells) are a type of pluripotent stem cell artificially derived from a non-pluripotent cell, typically an adult somatic cell, by inducing a "forced" expression of certain genes.

- Multipotent progenitor cells have the potential to give rise to cells from multiple, but a limited number of lineages. An example of a multipotent stem cell is a hematopoietic cell — a blood stem cell that can develop into several types of blood cells, but cannot develop into brain cells or other types of cells.

- Oligopotency is the ability of progenitor cells to differentiate into a few cell types. It is a degree of potency.

- Unipotent cell is the concept that one stem cell has the capacity to differentiate into only one cell type. It is currently unclear if true unipotent stem cells exist.

Based on the above biological system research, we base our canopy design on the concept of pluripotency, by which one base architectural component can transform itself into three or more different kinds and thus we obtain a series of self-organized canopy system components integrated from the same basic cell composition.

Introduction:

At the beginning, we needed a base surface or a grid network system over which the pluripotent components are to be populated. We intended to form a complex organic geometry to create ambiguity & interest in the final composition after the components are aggregated. The exhaustive study of the pattern revealed interesting geometrical construction, which is reasonably attainable by voronoi pattern, 3 dimensional grid networks over the surface. These grid networks generated individual panels over which the components could be aggregated. This part of the project was framed & modeled in Bentleys Generative Component Software Suite. The program proved to be extremely efficient in radically constructing mathematically derived curves & surfaces, which is appreciably convenient to adjust & adapt at future phases of the project. We encoded the entire system of surface & component design in Bentleys Generative component software suite. Generative component provided us with the platform to parametrically construct and adjust digital design throughout the process by changing the fundamental constitution of each component. Next phase of the project after populating the pluripotent components on to the base grid network/ surface was to explore different models of technological procedures that existed to fabricate the prototype of the canopy. Various small-scale physical models were tested to analyze the pros and cons of each methods & assembly system, which rendered us to pick the most efficient & precise rapid prototyping technique for this project.

Pluripotent Component Design:

The component design had an irregular hexagonal shape, with a perforated central core, which would act as the skylight opening for the canopy. This can also aid in dual materiality in the design, creating plausibility of extensive design variation in the canopy. The perforation can be varied to add vivid density of light & shadow in the space. Consequently, to add pluripotent qualities to our smart component, the attributes, which we variegated, are depth, height & the proportions of the petal sizes. In addition, some of these components, extended its profile from the core, protracted itself to the ground acting as a structural system supporting the surface. These structural components were instantiated at regular intervals making the design viable & structurally efficient.

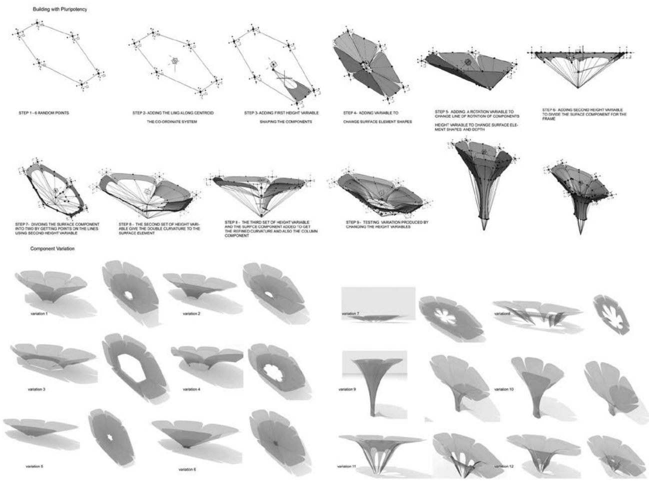

Fig. 2. The design of the pluripotent components, which is aggregated over the base surface. The above fig shows the various kinds of profile and form the base pluripotent module can take simulating the concept of pluripotency.

Fabrication Tests:

Fabrication phase of the project involved substantial tests with trial and error procedures to understand and learn effective possibilities by which the design can be constructed precisely. These tests were not an endeavor to devise any novelty in design from the available fabrication technology, but were more like an exploration to understand which prototyping system works best for our design.

Metal Sheet Fabrication:

Metal sheets were tested first to model the canopy precisely. However, in this process, the model turned out to be extensively laminar & 2 dimensional. It completely lacked the 3 dimensional surface qualities of the components in the digital model. At the same time metal sheet, fabrications showed construction joints, which was undesirable. Subsequently, the output was not a seamless surface fabrication; this form of construction was discarded.

3D Printing:

Direct 3d printing and rapid prototyping was always one of the viable options. However, this technique was also discarded for economic reasons considering the enormous scale of the canopy with respect to 3D printing costs. At current level of expertise and technology costs for 3d printing of such a large structure, it was not at all deemed fit for an economically sustainable & feasible solution. (Fig. 3, Fig. 4)

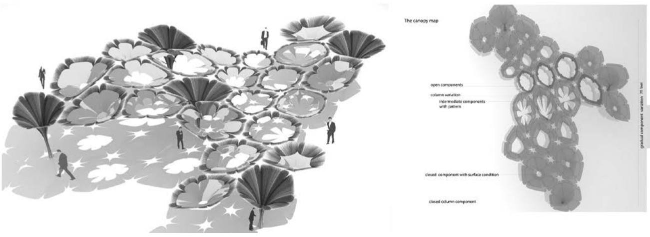

Fig. 3. Site plan & site elevation of the canopy model, clearly showing the complex double curve profile of the base surface

CNC Milling:

At the next phase we tested CNC milling technique by which each of the individual components were fabricated by wood in the machine. For large-scale construction, the components and structural members of the canopy were subdivided into smaller manageable parts. Thereby, all the relevant joints for the same were tested and designed to augment a seamless fabricated canopy.

In contemporary CNC milling machines, end-to-end component design is fully automated expending computer-aided design (CAD) and computer-aided manufacturing (CAM) programs. A computer file is produced by the programs, which are inferred to excerpt the commands needed to operate a particular machine via a postprocessor, and then loaded into the CNC machines for production. Modern machines often combine multiple tools into a single "cell", unlike conventional methods of production where discrete number of different tools-drills, saws, etc. are needed. In other cases, a number of different machines are used with an external controller and human or robotic operators that move the component from machine to machine. In either case, the complex series of steps needed to produce any part of the design, is highly automated and produces a part that closely matches with the original CAD design (Guzik, 2009). This process of CNC milling precisely crafts the double curved surface of each component parts and yet maintains the distinct surface texture that we aimed to reproduce, contrary to the construction of surfaces though smaller individual component logic that fails to impart the unified surface quality. As we already explained through fabrication drawings that we divided the structure into smaller manageable parts in real-time construction process, we were successful to create seamless joints though the milling process. Due to all of these added advantages, we select CNC milling to be a viable technology for our canopy design fabrication.

CNC Milling & Vacuum Foaming Technology:

CNC Milling rendered the large-scale fabrication of the canopy plausible. However, it was not feasible to fabricate translucent or transparent synthetic material by CNC Milling considering it only can mill wood or high-density fiberboard (HDF). Looking towards other plausible potential technologies of fabrication, we found, vacuum foaming was a viable direction. We intended to use it coupled with the satisfactory results from CNC milling technology. Vacuum foaming was used to make plastic or synthetic material prototypes by using

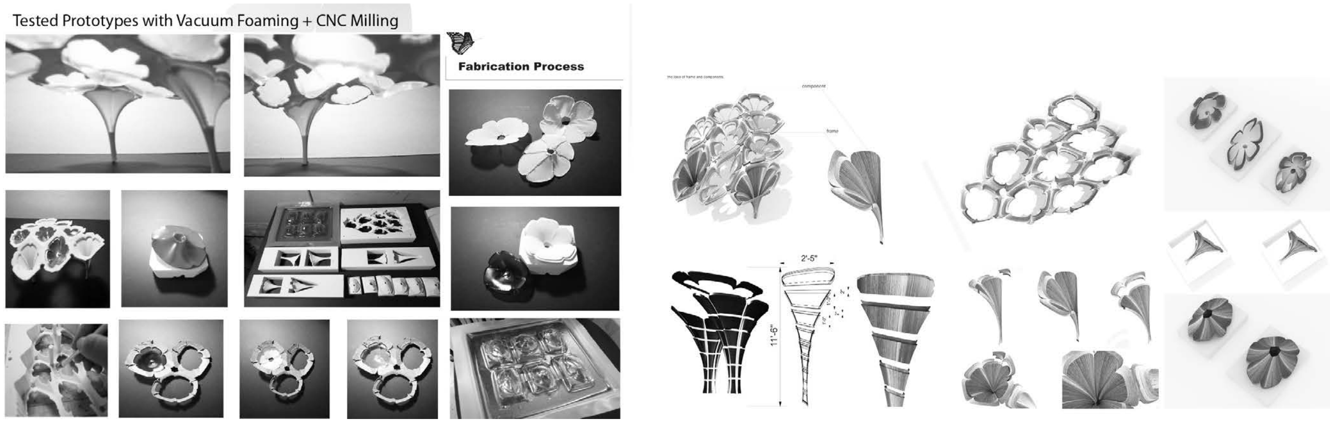

Fig. 4. The left collage shows the different assembly prototypes tested in the process and studied to highlight their pros and cons. The image on the right shows the detail assembly models done in Rhino 3d modeling environment.

the CNC Milled output as the mold. Vacuum foaming enabled the desired dual materiality into the design to create translucent or transparent sky lighting possible in the canopy. Vacuum forming, is a streamlined version of thermoforming. In this process, a sheet of plastic is heated to a forming temperature, stretched onto or into a single-surface mold & held against the mold by applying vacuum between the mold surface and the sheet (Afify, 2007 ; Carper 2010). It is frequently, (but not always), limited to form shallow plastic parts. Moderately deep parts can be formed if the form-able sheet is mechanically or pneumatically stretched before it is exposed to the mold surface and vacuum is applied.

Suitable materials for use in vacuum forming are conventionally thermoplastics. The most common and easiest to use thermoplastic is High Impact Polystyrene Sheeting (HIPS). This is vacuum formed around a wood, structural foam or cast/machined aluminum mold and can be molded to almost any shape. Vacuum forming is highly suitable for transparent materials such as acrylic, widely used in aerospace industry.

In the fabrication process, moisture gets absorbed which expands to form bubbles within the plastic's inner layers. Solution could be suggested by drying the plastic for an extended period at high but sub-melting temperature. Webs form around the mold, which is due to overheating the plastic and so must be carefully monitored. It also occurs when the mold is overtly large or parts of the mold are extremely close together. Objects that are formed often stick to the mold, so it should be made sure there is an angle of 3 degrees or more.

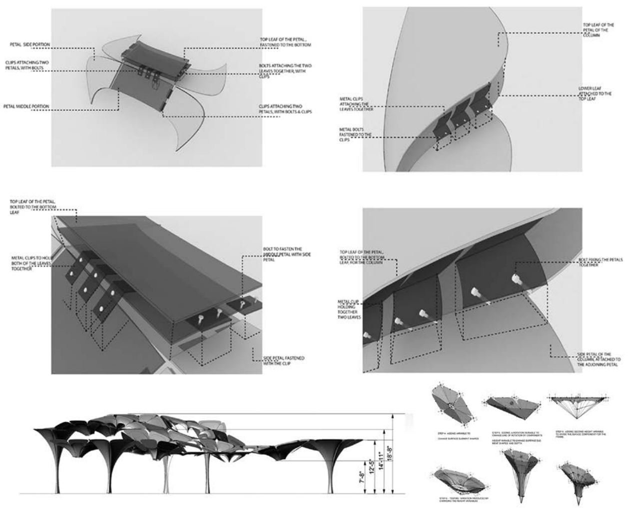

Fig. 5. The image shows the metal sheet fabrication drawings and model enabling assembly joinery detail and drawings.

Conclusions:

Henceforth we were successful to endow the possibility to construct such a big scale canopy at bearable costs, with current technological and fabrication articulations and skills. This research paper further depicts the entire digital design & rapid prototyping process practiced to synthesize a live prototype of the canopy. The design computing and digital modeling of the base surface & the pluripotent component was practiced in Bentley's GC, for its powerful parametric infrastructure. At the later stages, Rhino 3d modeling & Grasshopper tool was employed for quick analysis & fabrication drawing production. At every stage of the project, we worked with fabricators to understand the repercussions and implications of any specific material & fabrication methodology.

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