CONTESTED BOUNDARIES: Digital Fabrication + Hand Craft

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ABSTRACT

This research investigates the relationship between efficiency, precision and tactile variation within architectural design and fabrication. A digitally driven design may be seamlessly precise and consistent but also feel sterile and distant from the human body. A materially driven design may be intimate and tactile but lack the accuracy needed to connect elements. Digital fabrication techniques are combined with hand craft material manipulations in search of a unique hybrid tectonic that merges connection accuracies with subtle but sensual divergences between repeating modules. Prototypes have been constructed at the object and inhabitable scale.

KEYWORDS: instrumentality, tacit knowledge, digital fabrication, hand craft, design and computation.

This research utilizes a hypothetical scenario as a means to express a theoretical inquiry rather than revert to the scientific (restricted) procedures of "theory through experiment" (Glanville, 1999). A design investigation associated with texture was carried out in order to explore the extent constraints influence design. Texture is translated and transformed over two mediums: digital parametric software and physical material fabrications. A hybrid fabrication method evolves through this process, combining digital fabrication techniques with hand craft material manipulations. Current fabrication trends, automation and optimization, are challenged with this alternative approach. Within the broader theoretical discourse of "theory from theory," this research identifies and challenges constraints often taken for granted within the theories of tools and design (Glanville, 1999). The purpose of this paper is to construct an alternative ideology to the rhetorical and sometimes fashionable pedagogical routines within the discourse.

Constraints and Instrumentality

> *"We are about to begin a design exercise. The instructions will be short and explicit, and after they are given you cannot ask any questions. There will be five exercises, each lasting five minutes in length." The students waited, looked at each other and then back at the Professor.*
> *"Using pen and paper, draw a chair." The students began to draw instantly and finished early.*
> *"Using pen and paper, design a chair." The students all stopped, paused and thought. Eventually, they each began to draw.*
> *"Using pen and paper, design a surface which one can sit on." The students again began to draw, this time more ambiguously. Each student drew only a single iteration.*
> *"Using only paper, design a surface which one can sit on." Finally the students stopped drawing and began to fold the piece of paper, manipulating its material properties. In the previous two instructions the students were not told to draw, yet they still reverted to the common preconceptions that one must draw when given pen and paper. Again, only one design iteration resulted from each student. After another five minutes the last instructions were given.*
> *"Using only paper, design a surface which one can sit on, and make five iterations in five minutes." The students instantly began to manipulate the material as quickly as possible, resulting in less predictable, more curious consequences (Choma, 2010).*

In order to design, one must have constraints. Often times, designers begin to work within a particular medium without explicitly acknowledging how such embedded constraints will influence their design process. For instance, a digitally driven design will yield different results than those emerging out of physical material manipulations. Within each medium lie layers of embedded constraints. This design experiment begins in the digital realm, within parametric design software, utilizing points, lines and polysurfaces.

Within each medium lie numerous potential tools. A tool can be used purely as a recording device of preconceived visions (instrumentation) or it can be embodied as a mechanism to generate unpredictable, new ideas (instrumentality) (Krueger, 1998). Donald Schön describes a tacit knowledge interaction called "reflection-in-action"; where an individual is in an intuitive, responsive dialogue with the tool (Schön, 1987, 40). By embracing instrumentality and reflection-in-action, constraints become design opportunities.

A surface can be smooth or textured, but at some point a texture can have such a depth that it is no longer perceived as two dimensional, but rather it extends, contests the boundaries and becomes spatial. Through the gross exaggeration of depth, hand crafted variations can be more obviously perceived as spatial features as opposed to subtle texture. Thus, this research instrumentalizes surface texture as a device to test the digital-hand crafted construction technique.

Digital Embedding

George Stiny challenged ideas of symbolic calculation for design with visual calculation. Instead of being forced to calculate all possible outcomes in the beginning, the designer can embed anything they see (Stiny, 2006). This design process began by embedding. First, a buckyball was created, with circles packed around the boundary of a sphere. Then, diagonal lines were drawn from the center points of each circle to triangulate the geometry. After triangulation, the intersections of the newly drawn curves were connected to the center point of the sphere. A volume packing structure emerged, as triangular cones shared a common centroid.

Ranulph Glanville once said, "Something happens before you make a mark on a page, something happens while you make a mark on the page and something happens after you make a mark on a page" (Glanville, 2009).

A buckyball had been transformed into a volume packing structure. A buckyball structurally relies on its global synclastic curvature, while a volume packing structure relies on an internal logic. The outer boundary no longer has to be derived in order to be structural and can take on any form. This sparked the next iteration. A cube was placed off-center within the sphere. From the outer boundaries, extruding triangular cones intersected the cube to define a gradient triangulated pattern. The curves on this new boundary condition were then re-extended to the same centroid as before. A gravitational force was then applied to the boundary polygon curves with the centroid acting as an attractor, deforming the curves on the outer perimeter. Through the applied force, the curves

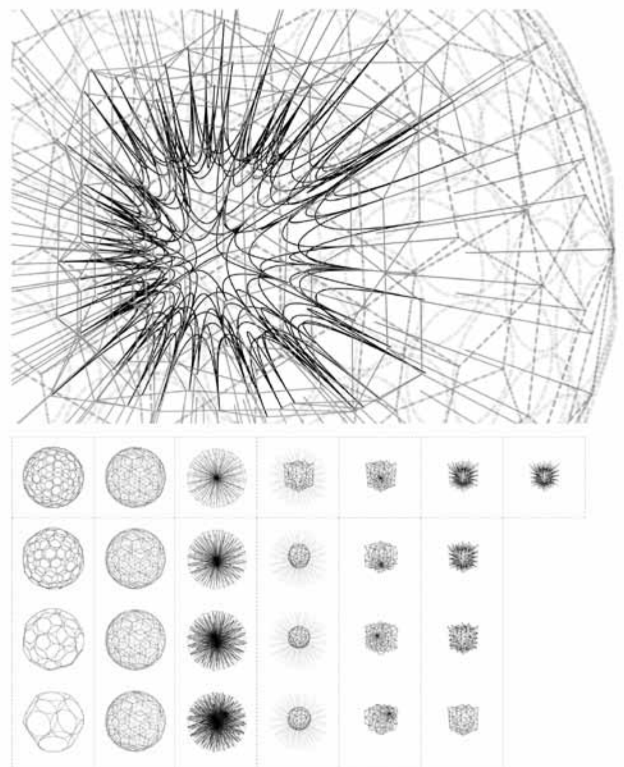

Figure 1. Embedding vaults into a geodesic order defined by a cube

collapse inward to form catenaries. It appears as though fan vaults had been packed and embedded into a volume packing organization (Fig. 1).

Typically, the orientation of a vault or catenary curve is critical to its structural performance. Artist, Marcel Duchamp once labeled a urinal as a fountain, as he changed its context from a bathroom to a museum (Duchamp, 1917). As the fan vault changed its role from a global geometric logic to a module for a volume packing structure, its initial purpose and specificity became obsolete. Its geometry no longer performed structurally, and instead began to function perceptually in an unprecedented manner. As the vaults rotate around the common centroid, the outer boundary of the cube becomes redefined with what appears to be quills or spikes, while the inner boundary becomes defined by pillow-like curvatures (Fig. 2).

It is important to note the embedded constraint associated with the process of transforming curves into polysurfaces. The order in which curve cells were transformed into surfaces is important for complex patterns, especially when each surface has an inherent algorithmic grain and needs to maintain matching edge conditions with its neighbors.

The definition of boundaries, conventionally a constraint, is a design opportunity in this case. Both the inner and outer boundaries defined by vaults could extend to frame more than one global geometry. The outer boundary no longer has to be an offset of the inner. In this example the inner boundary is defined by a sphere while the outer boundary is defined by a cube. The

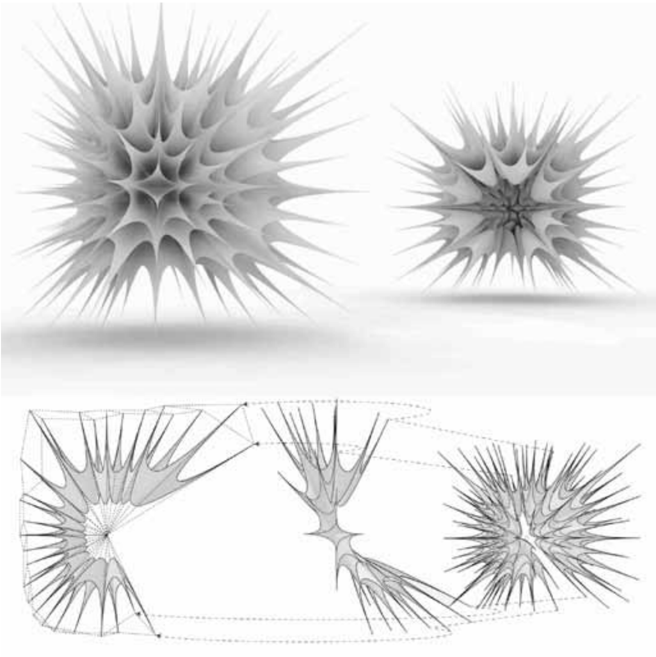

Figure 2. Exposing boundaries defined by quills and pillows

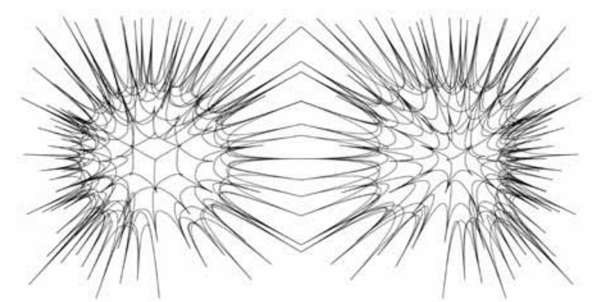

Figure 3. Challenging the global geometry of the inner and outer boundaries

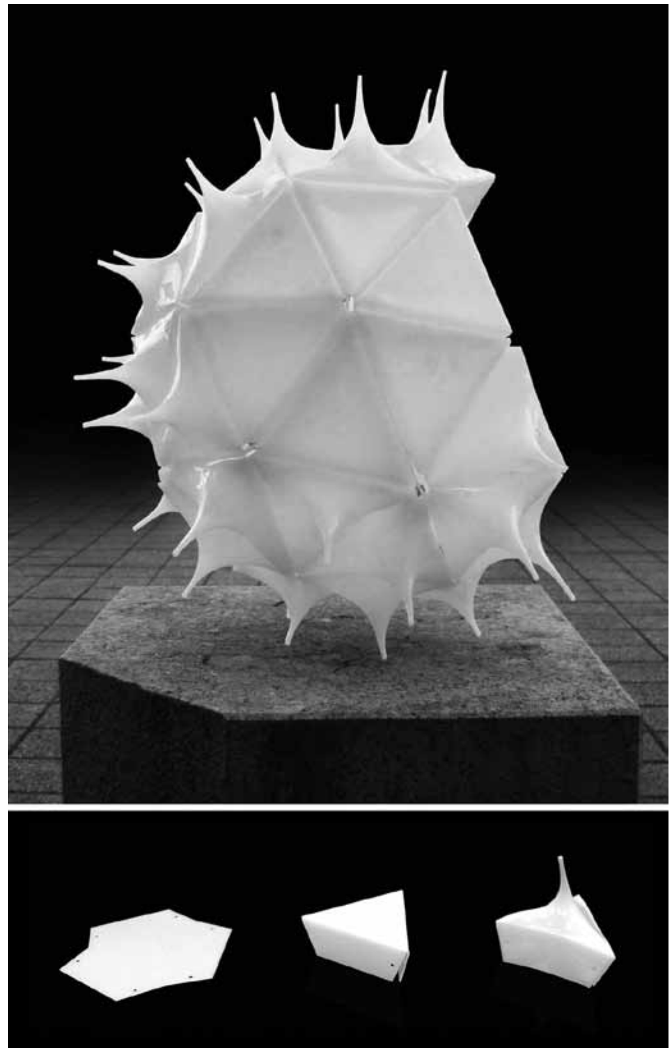

Figure 4. Photograph of the physical prototype and fabrication process

geometry begins to have the illusion of material thickness as it mediates between two boundary conditions, creating a spatial depth within the geometry's boundaries (Fig. 3).

Physical Translation

The next phase of this research investigates the translation between digital and physical formal intentions. With the advancements of rapid prototyping machines and three-dimensional printers, fabrication processes are becoming increasingly automated. Designers are attempting to construct digital descriptions as accurately as possible into physical material, instead of asking the material what it wants to be.

Architect Louis Kahn once said:

> *If you think of Brick, for instance, and you consult the orders, you consider the nature of brick. This is a natural thing. You say to brick, "What do you want, brick?" And brick says to you, "I like an arch." And you say to brick, "Look, I want one too, but arches are expensive and I can use a concrete lintel over you, over an opening." And then you say, "What do you think of that, brick?" Brick says, "I like an arch" (Kahn, 2003, 271).*

The increasing trend of automated and optimized design is transforming the act of making, once a design mechanism, into instrumentation, a recording device of preconceived descriptions. Instead of merely recording as accurately as possible what had already been created in the digital medium, the fabrication process can be further exposed as another design opportunity. Rodney A. Brooks challenged the notion of artificial intelligence needing memory and instead argued that the fundamentals of intelligence lie in the recursive function of perception and action (Brooks, 1999). By ignoring the digital media and the memory it entails, the physical material was no longer forced to create a form. Instead, the unique physical properties of the material derive the form. In this case, the thermoforming properties of plastic were introduced to extend the act of design within the fabrication process.

Within the parametric design software, it does not matter how many unique modules a design has or how complex its edge conditions are. However, constructing a hundred unique vaults each with matching catenary edges is not a simple task. It becomes imperative to simplify the module type by shifting the module's edge conditions, thereby transforming vaults into spikes. Instead of directly using catenary edges, a triangle could define the edges of the module with a spike originating from the surface of the triangle. As a result, only one module was needed to construct the first prototype as it defined a geodesic sphere. Through further exploration into the material's unique properties, a refined hybrid fabrication process emerged to combine hand craft with digital fabrication.

The final fabrication process included three basic steps. First, modules and formworks were laser cut according to the digital parametric model. Second, the flat, laser-cut acrylic modules were placed over a triangular formwork to form the edges using a hand-held heat gun. Last, the centers of the modules were heated with the heat gun and a dowel was then used to stretch the inner material to form spikes (Fig. 4).

The heat gun allowed one to localize a specific zone to heat and form while other zones remain static. The movement of the heat gun, its distance to the surface, the amount of time the surface was heated and the speed at which the wooden dowel stretched the material were all computational weights that factored into the final state of the spike's form. If an initial module was larger than ten inches in length it became too difficult to evenly heat a large enough area and if a module was smaller than three inches in length the material's edge conditions would over heat and deform. The act of knowing how long to heat each surface and the speed and distance needed to push the dowel against the surface becomes "tacit actions" of the fabrication process (Polanyi, 1966).

Conclusions

The challenges associated with translating a digital intention to a physical intention present a difficult dilemma. By instrumentalizing a physical medium and ignoring the memory associated with the biases of the digital visualization, there is the potential for a large gap to develop between the two design intentions. How far of a gap is too far? By challenging the trends of automation and optimization there is a greater possibility of generating new ideas in the subsequent design phases. However, in order to gain the hand crafted tactile variations, much of the initial specificity from the digital intention may be forced to become simplified based on the embedded constraints. Heinz von Foerster once said, "Act always so as to increase the number of choices" (von Foerster, 2003, 227). But more choices are not always necessary. When is enough, enough? A painter needs to know when to stop before painting the extra stroke that ruins the masterpiece. Similarly, a designer needs to realize when to stop instrumentalizing tools in order to save something that might become lost in translation. To negotiate this dilemma, a designer must be conscience of the changing medium's constraints and their consequences.

This investigation does not claim to have developed a "better" fabrication process, but rather asks the question, how do we qualify fabrication processes in our current discourse? A hybrid fabrication process which combines digital fabrication with hand craft techniques suggests an alternative approach to the current fabrication trends of automation and optimization. Perhaps, a slightly slower process which yields a sensibility to intimacy is something to be considered.

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