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Digital Craft

Fabrication-Based Design in the Age of Digital Production

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Abstract A clear distinction generally exists between processes of design generation and processes of design production. The profusion of digital fabrication tools and technologies make evident such distinctions in the context of design production but at the same time carry potential for material and fabrication-based processes promoting generative design methods. Such strategic application and customization of digital fabrication tools, inherent in and inclusive to the process of design generation, require the knowledge and skill-set of production associating material to its fabrication and assembly methods. The paper addresses the area of *material fabrication based design* and the term *Digital Craft* is coined to suggest that certain skills acquired through customization processes may contribute to fabrication-guided design protocols. Through the demonstration of some design projects for responsive skin systems the paper classifies three forms of fabrication-informed production processes in which the notion of *craft* is manifested through material selection, fabrication method and assembly logic corresponding to sewing, lathing and weaving techniques respectively.

Keywords Ubiquitous Computation · Digital Fabrication · Responsive Skin · Digital Craft

1 Introduction

Design by virtue of its very nature is largely dominated by formal exploration. Its physical manifestation however is fundamentally perceived by way of implementation and deemed reductive and/or limited as far as generative design methods are considered [1]. The rapid development of digital -design fabrication methods and ubiquitous computing challenge such convenient truths promoting design that is *informed* by fabrication (as opposed to simply being formed by it).

Ubiquitous computing is defined as a post-desktop model of human-computer interaction in which information processing is integrated into common objects and activities [2]. As opposed to the desktop paradigm, in which a single user consciously engages a single device for a specialized purpose, ubiquitous computing promotes simultaneous engagement of multiple computational devices and systems. For the most part, the user is unaware of the type and class of the technology which is being exercised. Weiser has termed such practice "calm technology" [3]. Calm technologies are typically intuitive in that they are accessible for the novice user as well as the engineer who brought them about. We refer to the range of access and legibility as *user transparencies*, or the ability of the technology to display itself across multiple levels of expertise-guided readings.

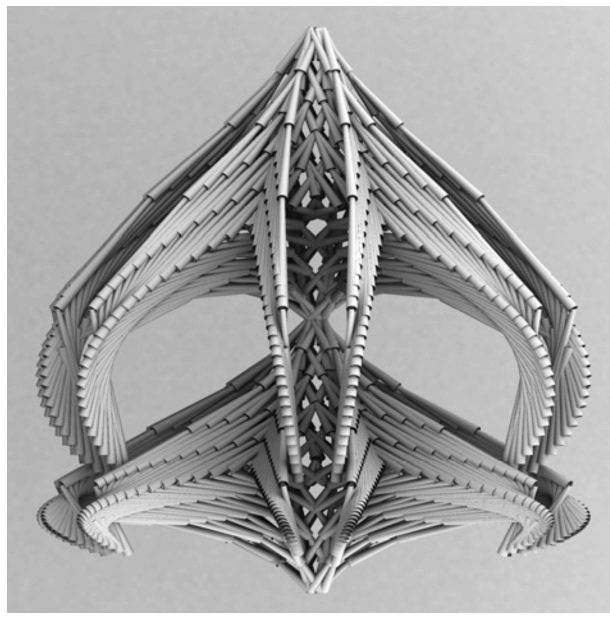

Fig 1 Digital craft: light-responsive spatial system

In the many subfields of design and across the board, from wearable electronics to breathing walls, ubiquitous computing has transformed the way in which we perceive and/or welcome technological immersion [4]. However, beyond the notion of controlled user transparencies with regards to *use and function* ubiquitously redefined by concealed circuits and diminutive sensors, the question of *method* or *way of making* has yet to be

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addressed. Simply restated: what is the relation between the way in which things are made and how they work? And what are the ways in which such relations may be classified and understood in order to promote efficiency of use and effect of application between the design artifact and the tool which gave it birth?

Such questions carry relevance for process (methodology) and function (application) in that they may potentially promote a significant fit or connection between the artifact and its context (whether user or environment). *Fabrication-based design* prioritizes the tools and fabrication methods being assigned to generate material form and behavior over manifestations which are purely formal in nature [5].

Traditional craftsmanship is still considered by many an aphorism in the milieu of making. The notion of techné (Greek for "craft") is defined as the rational method involved in producing an object. It denotes the implication of principle knowledge over matter and the application of a skill that is involved in its production [6]. Given that a craft by itself can not expand to become the first article of production it is required to consider its context of application.

2 Theoretical Foundations

2.1. Factory to File

In the words of Pye, technology is "the study and extension of technique" [6]. Technique denotes a specific approach for accomplishing a given task or function by way of perceiving and putting into use material integrity and processing methods. A hierarchical approach tends to prevail where fabrication methods and material considerations are only brought into the design process as final design solutions in preference to promoting explorations which are generative in nature.

However, the material and technique in which a natural artifact has been formed is directly linked to its behavior [7]. So ways of making things are inextricably linked to what and how they serve as final artifacts. The work of the craftsman involves the knowledge and skill-set of particular practical arts. A craft of any kind which embodies the skill set and techniques of selecting and processing material is inherently apparent in the final artifact [6].

Today, rapid prototyping technologies offer this knowledge to the people. But there's obviously more to the notion of *digital craft* than simply hitting the power switch. Machining is by convention a form of execution, a final phase. "File to Factory" protocols have indeed pushed ahead our vision as designers with regards to efficient CAD/CAM/CAE processes [8] and yet the other way around, "factory to file", has never been considered. In other words, machine execution should not merely be regarded simply as a service tool for materializing design but rather an *opportunity* to inform the design process as one which integrates machine-logic across all scales of production. Material choice and fabrication methods are not innocent decisions, but are rather pre-determined factors which guide the design both with respect to artifact and process from start to end.

2.2. Ubiquitous Sensing

An intelligent wall or a responsive skin is, at its simplest, an environmental manifestation of technology that is already being appropriated [9]. However, in much of the work generated recently which falls under the umbrella of "responsive environments" there still exists a separation, both in process and authorship, between "what" a building senses and "how" it does so.

Electronics is mostly embedded in the artifact *post* its production rather than considering an appropriation between the sensors and the sensing elements of the building. In most of the work shown here, the *digital presence* (or any proof of CAD) is in most cases absent: complex geometrical form is fabricated in physical matter, and sensors are embedded within it as potentially seamless and ubiquitous elements enhancing material response to local stimuli. One of the crucial ideas that this work seeks to portray is that of *integrated electronics*. Simply put, this means that instead of "adding-on" sensors to the artifact, material choice and processing is targeted towards, and guided by, an understanding of the mechanical properties which initiate dynamic behavior.

2.3. Digital, Ubiquitous Craft

In his essay, "The gadget lover, Narcissus as Narcosis", Marshall McLuhan defined the relation between media and self as an amalgam of tools and bodily extensions seamlessly at work [10]. The "servomechanism" is an adaptation of the self to its technological extensions such that a closed system is created whereby the detection of such extensions as individual entities is unattainable. In this light, the designed artifact may be perceived as an entity weighted with commensurate "extensions". The tool, technique or technology applied for production has as much value and meaning as the artifact itself, inherently promoting explicit effects which are the result of a non-innocent affinity between machine and material.

Craft, in general, represents such an affinity between the maker and its immediate context, the environment, which is to contain the object of desire. As such, beyond its traditional description or meaning, craftsmanship may be reinterpreted as a set of instructions combining knowledge and application, matter and tools. An operational framework for processing and re-organizing material constructs. Thus a craft of any kind may potentially serve as a guiding instruction-set, a formalism, which merges knowledge of application with an instrumentality of material organization.

3 Aims

Material and fabrication based design denotes design processes that are informed by material and/or fabrication constraints in the generative phases of design. The aim is to develop a preliminary taxonomy which attempts to redefine the use and application of digital fabrication tools and technologies through the notion of craft. In this context the term *digital ubiquitous craft* delineates the ability or potential to control material form and behavior through a particular fabrication method inherent in the nature of the exploration.

4 Methodology

This paper considers several design projects for responsive skin systems, from the perspective of *digital ubiquitous craft*, its significance and implications for a design paradigm engaged with, and brought about by material production.

Three classes or types of "craft" are demonstrated by each of the three projects presented. Such distinctions are bound to transform in the context of the workshop by perusing one or more of the design explorations presented here as a comparative study exemplifying the three approaches.

Each class defines a relationship between the type of structure or morphology developed and the tools applied and/or customized to support materialization. In addition, each class assumes its initial point of departure with regards to a given *phase of production*. Such phases include for example material selection, material fabrication and material assembly and are directly assigned to a given form of *digital* ubiquitous *craft*.

5 Classes of Ubiquitous Craft

5.1. Material Properties: Digital Sewing: Membranes

The ability to support controlled variation of formal expression and structural behaviour through direct manipulation of material properties and organisation is considered the first class of digital ubiquitous craft. Like the craft of sewing or knitting, where geometrical reorganization, also known as "form-finding", of the fabric affects its behaviour, the aim was to relate material operations (such as stretching and shrinking) to behaviour.

This project unfolds the association between geometry and material behaviour, specifically the elastic properties of resin impregnated latex membranes, by means of homogenizing protocols which translate physical properties into geometrical functions. Resin-impregnation patterns are applied to 2D pre-stretched form-active tension systems to induce 3D curvature upon release. This method enables form-finding based on material properties, organization and behaviour (Fig 2). A digital tool developed in the *Processing* environment demonstrates the simulation of material behaviour and its prediction under specific environmental conditions (Fig 3). As the research seeks to unfold the relationship between "curviness" and "stretchiness", strategic decisions were made with regards to material selection. The experiment demonstrates the behaviour of an elastic membrane when upon pre-stretching, local resin impregnation is introduced to promote non-homogenous material distribution within the membrane (once released). The impregnated resin is equivalent to "lines of constraint or hardness" which force the membrane to remain at its initial (pre-stretched) length when released, and as a result induce curvature upon release (Fig 2). Establishing such relations between the impregnation pattern, the direction of stretch, and the resulting geometry would assist in predicting the induced three-dimensional form based on the two-dimensional pattern.

Fig 2 Resin impregnated latex membrane demonstrating curvature induced by pre-stretching.

Fig 3 Real-time digital simulation (in the *Processing* environment) of resin impregnation as applied perpendicular (top) and parallel (bottom) to the stretch resulting in sewed-like cresses and directional folds respectively.

5.2. Material Fabrication: Digital Lathing: Cellular Structures

Computer numerically controlled (CNC) fabrication technologies such as laser cutting (LC), are machine tools powered by mechanical devices typically used to fabricate components by selective removal of material. The operating parameters of such tools may be altered by the software being used to operate them.

The Rotary Station is an add-on tool which may be placed on the laser-cutter bed to allow for rotary-cutting. The gear-driven CNC Rotary Axis permits cutting profiles or tubes in different diameters. Instead of an X and a Y axis, the laser beam is calibrated to the circumference of the tube as its Y axis. The Rotary Station is plugged into the LC bed with a serial connection, converting all geometrical information from planar to tubular format.

In this project for a light-sensing inflatable skin system, components of varied sizes and thickness were placed across the height of a tubular construction. The cutting pattern for the tubular structure was unfolded in digital form to allow for the cutting process to occur. The cylindrical structure was designed to support scale-like elements and allow for sufficient room for the inflatable bladder to be installed inside it (Fig 4).

In order to cut the structure (fabricated from acrylic), a mandrill structure was constructed to support the acrylic tube to be cut. The diamond-like engravings of the surface indicate the laser registration of the tool-path as it rotates the tube in constant motion (Fig 5).

Such cutting processes mimic the wood-turning capacities of the ancient lathe (first introduced by the Egyptians in 1300BC). In this example, the “craft” is assigned to the fabrication process itself regardless of the material being cut (whether wood, steel, glass of ceramics).

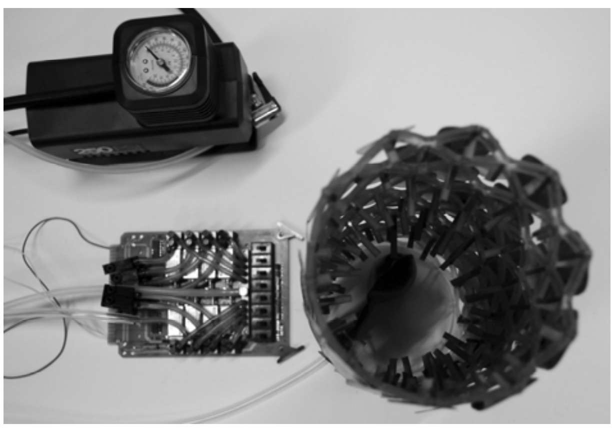

Fig 4 Light responsive inflatable skin system components: cylindrically laser cut structure, scales, light sensors, PCB.

Fig 5 Rotary laser-cutting as a form of “digital lathing”: mandrill designed to support acrylic structure.

Material Assembly: Digital Weaving: Deployable Paper Structures

The notion of an *inherent tectonic* implies that certain construction attributes of the system at hand may be brought into consideration in the assembly process itself. Once assembled, the system presents a range of behaviors which have been accounted for in the fabrication and assembly processes.

Such notion is particularly relevant when designing adaptive systems which introduce a high degree of complexity into the design. Establishing the range, increments, and limits of adaptability may be accounted for by coupling the fabrication technique with material behavior and its geometrical characteristics.

The following experiments demonstrate such notions by introducing a specific logic of cuts to paper and stainless steel sheet models, the geometry of which allows for a unique local and global structural behavior to emerge.

For example, the following images demonstrate how a 180 degree rotation of cut lines which connect adjacent strips, allows for the generation of curvature in the surface upon introduction of stretch. Thus, purely by controlling the slot-angle and distribution which assemble the strips together, using different configuration each time, one could control the curvature of the global surface (Fig 6).

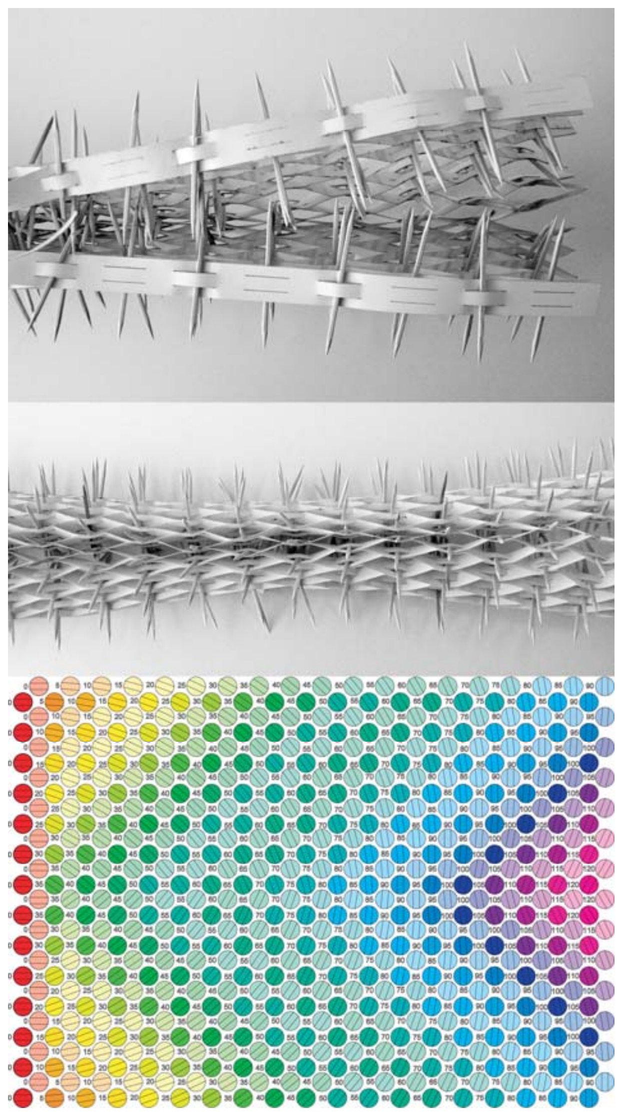

Fig 6 Inherent tectonics: physical model and assembly diagram illustrating assembly slot orientation.

6 Conclusions

In his seminal work "The Work of Art in the Age of Mechanical Reproduction" Walter Benjamin poses the assumption that the very nature of art is defined by (among other things) the way in which it has been produced and materialized [11]. Such supposition may indeed release us into the comfort of revisiting the notion of "art" and "production" in the context of design and digital technologies respectively.

The ability to recreate and apply tools of and for materialization and techniques not only as motorized versions of their ancient ancestor-tools but rather as customized versions of a generic universal technology, points towards considerable potential for custom-fabrication from a design perspective.

The depiction of *design through fabrication* may sustain such material sensibility in design. This work attempts to establish *digital craft* protocols for responsive structural skin systems. Each exploratory phase aims at establishing a conceptual framework which may promote such novel interpretations of digital design tools, techniques and technologies. Finally, the notion of a *Digital Craft* is manifested in this work as a *design method* which promotes the creation of novel structural systems through processes of digital fabrication and assembly.

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