RAPID CRAFT

MACHINE IMMANENCE AND NAÏVE MATERIALIZATION

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Summary

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 *rapid craft* is proposed to suggest that certain skills acquired through fabrication-customization processes may contribute to fabrication-guided design protocols. Through the demonstration of some design experiments for responsive structural skin systems the paper classifies three forms of fabrication-informed production processes in which the notion of *Rapid Craft* is manifested through material selection, fabrication-method and assembly logic corresponding to sewing, lathing and weaving techniques respectively. The conception, development and application of such classification express a shift in contemporary design discourse promoting the notion of *fab-finding* in the context of generative processes of design.

Keywords: Digital fabrication · rapid craft · fab-finding · material fabrication· responsive skin structures

1. Introduction

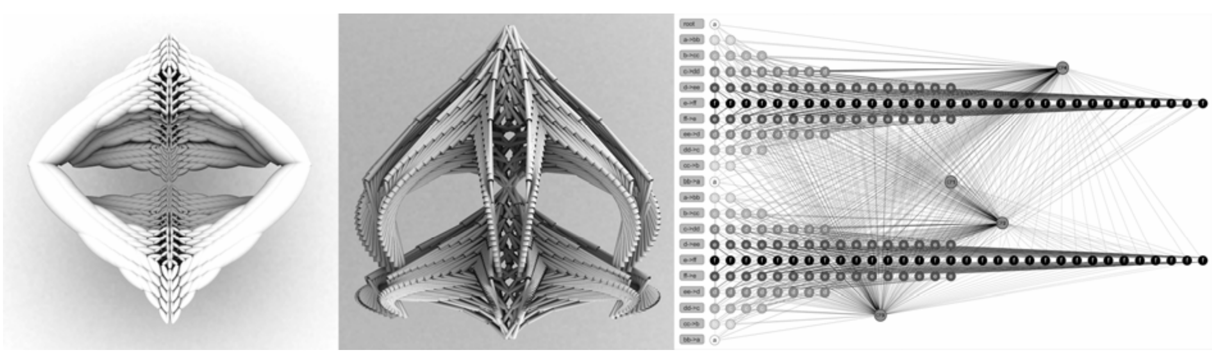

Fig. 1 Rapid Craft: light-responsive structural systems and logic dependency graph illustrating parametric association between physical features and environmental conditions.

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 challenge such processes of production promoting design that is *informed* by fabrication, as opposed to simply being (free-) formed by it.

The question still remains: what is the relation between the ways in which things are made and how they work (beyond their formal uniqueness)? Furthermore, 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 artefact and the tool which assisted its fabrication? Such questions carry relevance for process (methodology) and function (application) of digital design in that they may potentially promote a significant fit or connection between the artefact and its context (whether user and/or environment). *Fabrication-based design* prioritizes the tools and fabrication methods being assigned to generate material form and behaviour over manifestations which are purely formal in nature [2].

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 [3]. Given that a craft by itself can not expand to become the first article of production it is necessary to consider its context of application.

2. Theoretical Foundations

2.1 Factory to File

In the words of David Pye, technology is "the study and extension of technique" [3]. 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 artefact has been formed is directly linked to its behaviour [4]. So ways of making things are inextricably linked to what and how they serve as final artefacts. 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 inherent to and apparent in the final artefact [3].

Today, rapid prototyping technologies offer this knowledge to the people. But there's obviously more to the notion of *rapid 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 [5] and yet the other way around, "factory to file", has never been considered. In other words, machine execution should not 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. This notion extends from Simondon's view of the craftsman engaging both his knowledge and creativity in the process of making, beyond acting as machine servant or assembler [6]. Material choice and fabrication methods are not innocent decisions but rather pre-determined factors which could potentially guide the design with respect to both artefact and process.

2.2 Machine Immanence and Naïve Materialisation

An intelligent wall or a responsive skin is, at its simplest, an environmental manifestation of technology that is already being appropriated [7]. However, in much of the work generated recently which falls under the umbrella of "responsive skins" 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 artefact *post* its production rather than considering the association 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 sensing*. Simply put, this means that instead of "adding-on" sensors to the artefact, material choice and processing is targeted towards, and guided by, an understanding of the mechanical and structural properties which initiate dynamic behaviour.

2.3 Rapid 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 [8]. 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 artefact 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 artefact itself, inherently promoting explicit effects which are the result of an intentional 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 a naive instrumentality of material organization.

3. Aims

Material and fabrication based design denotes design processes that are informed by material and/or fabrication constraints as part of 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 *rapid craft* delineates the ability or potential to control material form and behaviour through a particular fabrication method inherent in the nature of the exploration.

4. Methodology

This paper considers several design projects for responsive structural skin systems, from the perspective of *rapid 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. 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 *rapid craft.*

5. Classes of Rapid 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 here as the first class of *Rapid 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 [1]. 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).

Fig. 2 Resin - impregnated latex membrane model demonstrating curvature induced by pre-stretching, shown in two scales.

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. 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.

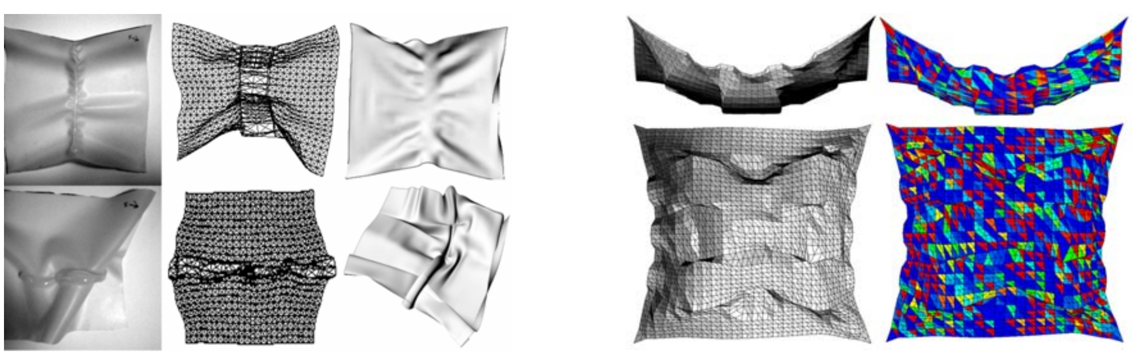

Fig. 3 Real-time digital simulation (in the Processing JAVA based environment) of resin impregnation as applied perpendicular (top) and parallel (bottom) to the stretch resulting in sewed-like cresses and directional folds respectively.

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. 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 4).

Fig. 4 Rotary laser-cutting as a form of "digital lathing". Left: mandrill designed to support cylindrical acrylic structure; Middle and right: acrylic structure with water-jet cut scale-like elements attached in additive (middle) and subtractive (right) methods.

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).

5.3 Material Assembly: Digital Weaving: Deployable Paper Structures and Digital Joinery

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 behaviours 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 behaviour and its geometrical characteristics.

The following experiments demonstrate such notions by introducing a specific logic of cuts and scores to paper and stainless steel sheet models, the geometry of which allows for a unique local and global structural behaviour to emerge (Fig 5, 6).

For instance, 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 the 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 5).

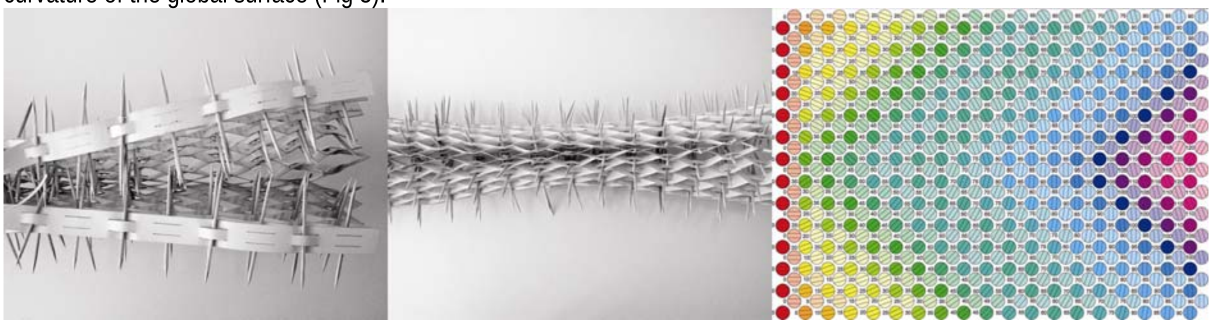

Fig. 5 Inherent tectonics: physical model and assembly diagram illustrating assembly slot orientation as a means to inform curvature

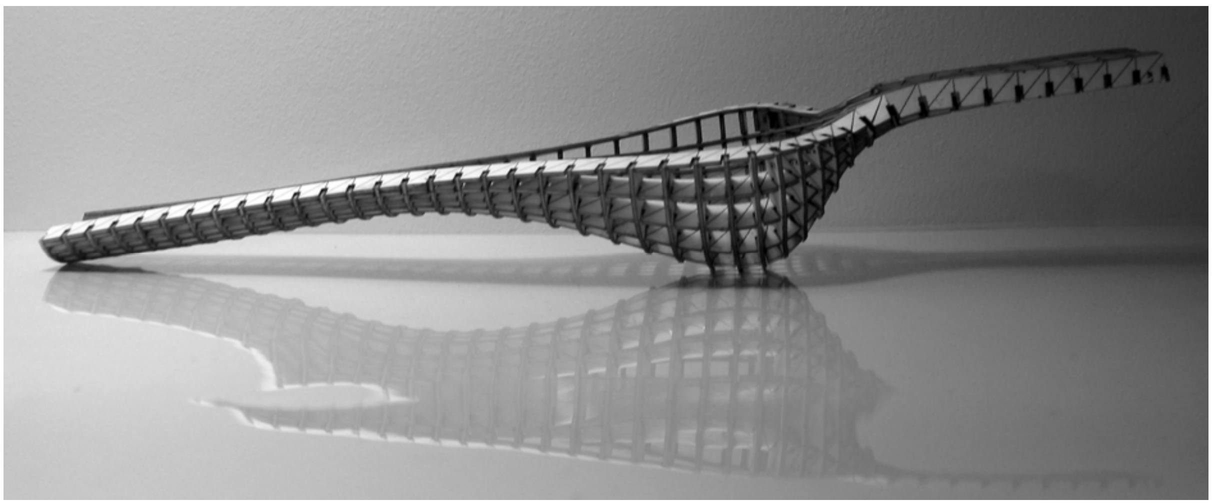

Fig. 6 Inherent tectonics: physical model laser cut and scored to allow for isoperimetric curvature in the assembly process.

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 [9]. 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.

Rapid Craft is a designation for the incorporation of craft materialization knowledge within the framework of CNC and RP processes of fabrication. Technologies for incorporation of naïve materialization within fabrication and assembly processes may be said to be cases of fabrication-driven form generation according to the various craft principles as defined in this paper. The ability to recreate and apply tools and techniques of and for materialization, not only as motorized versions of their ancient ancestor-tools but rather as customized versions of a generic universal technology, points towards a conceptual shift 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 *rapid 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 *rapid 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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