(Un) Intended Discoveries
Crafting the Design Process

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Abstract

Computer Numeric Controlled (CNC) fabrication machineries are changing the way we design and build. These technologies have increased productivity through greater efficiencies and have helped to create new forms of practice, including increased specializations and broader collaborative approaches (Kieran Timberlake 2003: 31). However, some argue that these technologies can have a de-humanizing effect, stripping the human touch away from the production of objects and redistributing the associated skills to machines. (Dormer 1997: 103). The (Digital) Craft studio explored the notions of technology and craft to understand how and when designers should exploit the tools employed (both the hand and the machine) during the design and production processes.

Introduction

> *"As educators and students, we should get back to what originally inspired us to become architects ourselves… Ultimately, it is the intimate connection to the process of making."*
>
> *Christiano Ceccato*

As the computer has evolved over the last few decades, critical discourses have begun to question the computer's "controlling" nature. Malcolm McCullough suggested in *Abstracting Craft* (1996), that the design process had become "less a matter of putting oneself in the job and more about getting the most out of the machine." (McCullough 1996: 16).

Today, computer numeric controlled (CNC) fabrication technologies have given architects new and powerful ways to shape the design and construction processes. They have proven their value by providing an expanded range of possibilities because of their ability to perform in ways the hand cannot. In 1948, pointing out the value of machines in the production of objects, Sigfried Giedion stated that "in its very way of performing movement, the hand is ill-fitted to work with mathematical precision and without pause… It cannot continue movement in endless rotation."(Gideon 1948: 47).

Traditionally, CNC technologies and their ability to perform mechanical operations in quick succession have been used to provide us with higher degrees of precision and increased efficiencies. Some argue that these benefits have brought designers closer to a more direct and seamless connection with the final construct. However, these technologies only mimic the actions of the hand and the human touch and lack the intuition and spontaneity which the hand/brain coordination affords. (Dormer 1997: 165). As most commonly used today, CNC technologies ultimately end up disassociating the "hand" from the direct act of making, and marginalizing it to just assisting in the labor of assembly. This goes to the heart of the tension between technology and craft. Consider E.F. Schumacher's comments in *Small is Beautiful: Economics As If People Mattered* (1973):

> *"The type of work which modern technology is most successful in reducing . . . is skillful, productive work of human hands, in touch with real materials . . . A great part of the modern neurosis may be due to this very fact; for a human being, defined by Thomas Aquinas as a being with brains and hands, enjoys nothing more that to be creatively, usefully, and productively engaged with both his hands and brains."*

"To engage both the brains and the hand" is analogous to engaging technology and craft. Technology (from the Greek, tekhno and logia) refers to the "systematic treatment of an art, craft, or technique."(Miriam-Webster). Its output is not an object but an abstraction of information to be processed by a tool. To craft is "to make or produce with care, skill, or ingenuity," a "manual dexterity or artistic skill."(Miriam-Webster). Craft relies on a tacit and haptic knowledge of tools and materials to give it form. In most cases, it is associated with a personal or individually produced artifact. Ultimately, craft depends on a close association between the hand, the brain and the material.

Furthermore, technology and craft, as described by David Pye in *The Nature of Art and Workmanship* (1968), involve two distinct notions of workmanship; the workmanship of certainty and the workmanship of risk. The workmanship of certainty refers to a mass or serial production in which design, prototyping and manufacturing aim to achieve 100 percent certainty through a system of distributed knowledge. The workmanship of risk, on the other hand, involves the ability of individuals, not systems, to determine the appropriate level of success. (Pye 1968: 7). At any moment along the process a single skilled person or each person in a group of skilled individuals holds the key to its success. The workmanship of risk relies on a personal creative knowledge of the tools, materials and techniques. One must understand each type of worksmanship and its role in the process in order to be called upon to use it (or not) when the need arises.

Distinguishing between the two types of workmanship during the course of a project is critical to a designer, and therefore, to a professor and a student of design. Pye goes on to state,

"But there is more in workmanship

than not spoiling the job, just as there is more in music than playing the right notes. There is something about the workmanship of risk, or its results; or something associated with it; which has been long and widely valued. What is it, and how can it be continued?" (Pye 1968: 9).

Today, most of the discussions surrounding CNC technologies revolve around its ability to produce a consistent quality with exact results from that which was digitally modeled; in other words, in the workmanship of certainty.(Kolarevic 2003: 78). The workmanship of risk rarely enters these discussions. It is assumed that the precision of the tool eliminates any risk associated with making. Risk and the critical creative role of the craftsman/artisan, are taken out of the equation.

The (Digital) Craft studio, a graduate level studio at The Catholic University of America School of Architecture and Planning, considered the notions of the workmanships of "certainty" and "risk" and the changing nature of craft that results from CNC fabrication technologies. How can digital design and fabrication technologies be used to re-connect the hand with making? How can we use CNC technologies to learn about materiality and methods of construction and assembly? How can a design/fabrication/assembly process be crafted to consider "certainty" and "risk" as an integrated whole? What can be learned from this design process and what are the implications to the creative act of making? And finally, what are the pedagogical implications resulting from these investigations?

Pedagody, Process & Project

Arguably, the fascination with digital visualizations and fabrication technologies has been driving recent contemporary architectural research. However, while the obvious ability to create new forms of representations and formal languages is tempting to a design student, the knowledge gained (i.e. proficiency in software platforms and a skillfully keen eye toward form making) may be built on foundations of limited duration. (Lewis 2002: 20).

Rather than emphasizing the formal potentials of the technology, the studio was intentionally process-intensive. The approach would require students to work within the established abilities and limitations of the tools utilized, developing strategies to rethink the everyday conventions. This process-heavy approach would create a repetitive feedback loop in which continuous critique and inquiry helped the student identify possible opportunities during the design, fabrication or assembly (construction) processes. Once determined, the students would arm themselves with valuable criteria necessary to inform subsequent design decisions, fostering spontaneous and innovative solutions which may have been overlooked if left undetected.

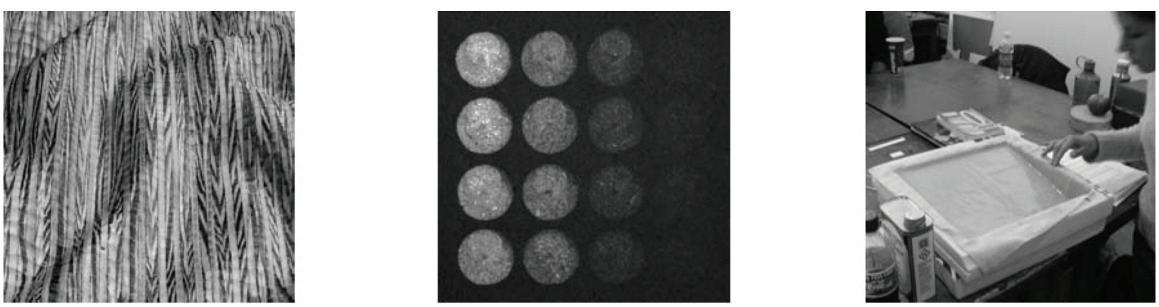
These issues were explored through the design, fabrication and assembly of a large, space-making device that serves as both office and lounge space for the student body and organizations in the school of architecture.

Sixteen students worked collaboratively to develop a design proposal and a fabrication/assembly process that required similar and consistent involvement from all students. This ensured that the process and aesthetic outcome would be influenced by the development of a systemized approach, as well as each student's intuitive responses.

The course began with a rigorous examination of materials and techniques. Students conducted research through an iterative process of testing hypothesis, learning from mistakes and identifying opportunities. Neither the hand nor the computer was the dominant tool in the process; rather, they were considered as one tool. Students were asked to produce a series of sample panels that exploited both CNC fabrication and traditional hand-working techniques (i.e., sanding, etching, and carving) with the hopes of creating new material expressions in terms of workability, tactility and form. (Figures 1-3).

Students evaluated the material samples by comparing the various techniques of production (e.g., casting, bending, perforating) and their associated methods of workmanship. Through this repetitive feedback loop, they were informed by a series of "discoveries," whether they were intended or not.

Examined in a digital model, a veil-like, undulating screen was derived from an analysis of the sectional relationships of the site. (Figure 4). The resulting form was a complexly curved surface that required the geometry to be simplified into a series of developable surfaces that could be fabricated from a planar material. Given the previous material investigations, we decided to use layered sheets of plywood because, as both a natural and engineered product, plywood embodies the humanity of the craftsperson and the technology of production. A gradient perforation pattern was created from the surface's curvature analysis. (Figure 5). In order to increase the pliability of the material, the perforation pattern was subtracted



Figures 1-3. Material Explorations

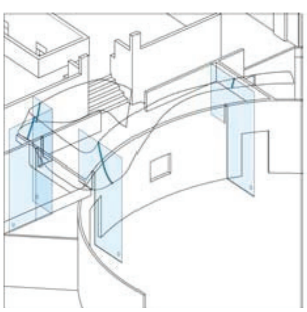


Figure 4. Sectional Relationships

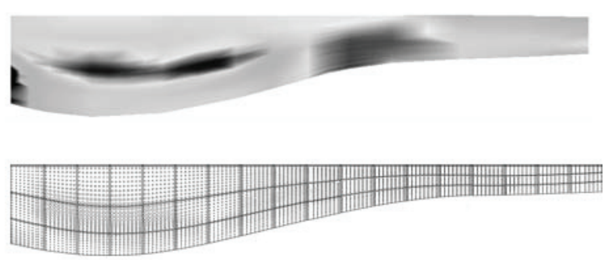
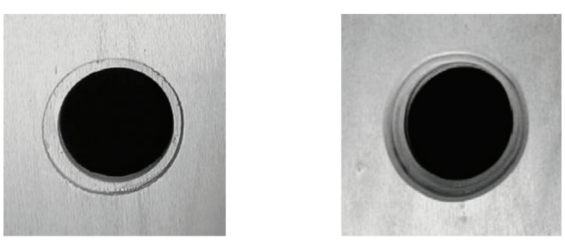


Figure 5. Curvature Analysis and Perforations

Figures 6-8. Fabrication of Panels

from the twisting surface in the computer model. Each layer was digitally unrolled producing two-dimensional cut templates. Exploiting the repetitive and precise capabilities of the CNC milling machine, each uniquely dimensioned layer was cut. The four layers were then laminated to one another and secured onto a fabricated buck (formwork) to attain their required curvature. (Figure 6-8).

Once removed from the buck, each panel was inspected. Inaccuracies and flaws, including misalignments in the layers, incorrect orientations of the grain and panels formed in reverse, were identified. Each student determined the appropriate level of response given the initial flaw. Misalignments of the layers were erased by sanding the panel edges. (Figure 9, 10). Incorrect grain orientations were accepted and eventually exaggerated prior to milling, as these "imperfections" were seen as an opportunity to reinforce the quilt-like nature of the surface. In some cases, it was necessary to remake inversely formed panels, since they would not conform to the intended surface form.



Figures 9-10. Unintended Discovery and Response

During this process, it was noted that the use of digital tools did not always lead to accurate results, nor did the use of the hand insure a well "crafted" object. What was originally virtually modeled and visible on the computer screen was only a perception of the "ideal": perfectly smooth edges, joinery that met with exactly specified tolerances and bends in the exact areas desired. The actual outcomes revealed the inherent properties of the material and the varying qualities inherent in each of the student's work. As a result, the design/fabrication/assembly process expanded and exploited the findings from the intended and unintended discoveries.

Conclusion

Unlike other professionals who are bound to strict external rules, the architect must question the norms and/or conventions of both the predetermined rules (i.e. codes, zoning, costs, labor force, ecology, gravity, etc.) and those rules which he or she may develop to guide the design process (i.e. material limitation, means and methods of construction, client desires, etc.).

The instructor intended for the students to develop a set of rules from the materials chosen, the tools utilized, and their associative workmanships of certainty and risk. In some cases, students came to the process with preconceived notions about materials and tools. Through a direct engagement with the two, more often than not, students "unintentionally" discovered the parameters and limitations of the materials (plywood) and the tools; whether hand tools, power tools, or CNC tools. Slowly, an understanding of the notions of certainty and risk informed subsequent design and fabrication decisions. Through this inquiry, the design process was to unfold, culminating in the full scale construction of the program given.

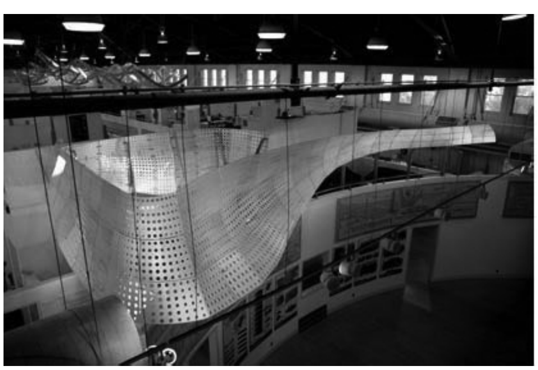
Due to the coupling of a systematically defined process of design/fabrication that utilized CNC technologies (the workmanship of certainty) with an intuitively responsive process informed by the hand's physical contact with the material (the workmanship of risk), the final construct ultimately revealed a condition which was only evident once the full-scale construction was complete; the surface communicated its integrated processes and methods of fabrication at multiple scales, fluctuating somewhere between a digitally produced object and a finely crafted piece of furniture. (Figure 11-12).

David Lewis eloquently states,

> *The task of the architectural education is to create a balance between a passionate inquiry into the contemporary rules of the discipline and the pleasures of architectural play as a creative act of making in and of the world . . . The task of a school of architecture is to establish conditions in which architectural play can begin, develop and ultimately be pursued at the highest level.*

Although, in the professional world, an "unintended discovery" may well have a disastrous outcome, the notion of the unintended discovery actually proves to be extremely effective as a method for teaching technology and the act of making. For the students, the result of this process is threefold.

First, students stated that each unexpected result not only created a condition of wonder, but ultimately helped them to engage themselves directly in the search for an answer, response and/or resolution. Ideally, these discoveries would occur during the planning phases of the project, but inevitably they also occurred during the fabrication and assembly phases, just as this also occurs at times on a "real-world" construction site.



Figures 11-12. View of Final Installation

Therefore, and secondly, being able to differentiate between the notions of certainty and risk, enabled students to make educated, appropriate and often innovative responses in a time critical manner. When this occurred during the fabrication process, students used their knowledge of the computer software, the CNC tools, and their personal abilities with hand or power tools to determine the appropriate level of response given its potential design implications. When this occurred during the installation process, similar considerations were made, but then they were more heavily influenced by schedule and budget, once again not unlike when an architect makes a quick decision in the field.

Thirdly, and arguably most importantly, the process taught students the value of research as a method of gaining design knowledge. Students commented that their views on the scope of research were expanding. Not unlike the traditional craftperson, they noted that the "hands-on" research developed a more refined knowledge of material manipulation and tool usage. Craft is a result of knowledge, invention, uniqueness and risk. Craft also relies on a predefined, yet intuitive process. Through their research, students began to view technology as a potential catalyst for humanizing opportunities to occur, rather than as an end to the means.

Although The Catholic University of America's School of Architecture and Planning has always emphasized notions of craft in its curriculum, examining it through the lens of CNC technologies has brought about a renewed interest in making, and has enlightened students and faculty as to the role and value of these technologies in architectural education. No longer are these technologies seen as useful strictly in form making, production efficiency and speed; they are considered extremely valuable tools in almost all aspects of the architectural curriculum, including design, building technologies, structural systems, material analysis, and architectural theory.

References

Ceccato, C. (2004) Evolving Tools: Digital Fabrication in Architectural Education, in *Proceedings from the 2004 AIA/ACADIA Conference*.

Dormer, P. (1997). *The Culture of Craft*. Manchester, UK: Manchester University Press.

Giedion, S. (1948). *Mechanization Takes Command*. Oxford UK: Oxford University Press, Inc.

Kieran, S. and Timberlake, J. (2003). *Refabricating Architecture*. New York: McGraw-Hill.

Kolarevic, B. (2003). *Architecture in the Digital Age: Design and Manufacturing*. New York: Spon Press.

Lewis, D. (2002) "Position 1: Newness, Play and Invention," *Scapes*, Department of Architecture, Parsons School of Design.

McCullough, M. (1996). *Abstracting Craft: The Practiced Digital Hand.* Cambridge, MA: MIT Press.

Miriam-Webster Dictionary viewed April 10, 2006. http://www.m-w.com/dictionary

Pye, D. (1968). *The Nature of Art and Workmanship*. Cambridge, UK: Cambridge University Press.

Schumacher, E. F. (1973). *Small Is Beautiful: Economics As If People Mattered*. New York: Harper and Row.