COMPUTATION WITHOUT COMPUTERS

Operating Digitally with Manual Techniques in Design Education

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Abstract. This work documents the implications of using physical media to teach digital design concepts, techniques, values and approaches. With the pedagogy and work of a seminar and studio across two Universities as test cases, this research seeks to prove that a parametric and algorithmic approach to architecture is most fruitfully understood as the connection between logic, mathematics and aesthetics. Students trace the indirect relationships between process and product so as to enable the application of these connections in a non-linear, exploratory and goal-flexible design process. The first phase of student work involves the creation of an image, constructed with ink or graphite on paper that embodies a parametric aesthetic. Students are tasked articulating and performing operations, such as dividing a curve, packing shapes, and conditional transformations. The hypothesis of this research is tested in more comprehensive projects that follow as environmental forces are resolved through dynamic and ambiguous visual and spatial conditions.

1. Introduction

This work is manifest in and relevant toward design education. The creative research documented here was conducted in the classroom and the implications are pedagogical. This paper follows a set of experiments in two different types of courses at two different institutions. The contrast between the curricular mandates for each of these courses offers an opportunity to test the hypotheses that will be outlined in this paper on multiple levels. One of the two courses is an introductory design seminar, “Computer Applications in Architecture,” (University of Maryland School of
Architecture Planning and Preservation) obligated to enable an understanding of the theory, historic context, and application of digital media. This course balances a need to contextualize and frame the role of technology in design with the need to apply technology in the most nimble, effective and rigorous ways. In a discipline—architecture—that is itself defined by innovation and transition this goal of teaching "fundamentals" can easily become self-defeating. Students in this course are simultaneously enrolled in one of the first few semesters of design studio.

The second environment in which this experimental pedagogy is applied is an advanced graduate architectural design studio, “Graduate Digital Media Concentration Studio.” (Catholic University of America) Here, the curricular agenda is the application of and experimentation with the most advanced digital media techniques. During this semester of focus the theme is articulated as, “parametric modeling and animate aesthetics.” The primary challenge of this course is the need to prepare students to direct their own research while conveying what is often considered to be the most oblique aspects of the computational spectrum: the low-level manipulation of data structures and algorithms.

To satisfy the goals of both courses computation is introduced—or reintroduced in the case of the advanced studio—without computers, and as an exercise in generative drawing. Effects of the drawing are translated into physical models, digital models, and finally, the amalgamation of architectural systems. The lessons learned from these activities translate into an approach to environmental sustainability as a design issue. This paper describes the initial foray, the drawing, and its direct implications on later outcomes.

2. The Student-as-computer Project

In the introductory seminar, the notion that design computation is most accurately and most legitimately considered “abstraced craft” (McCullough 1996) is paramount. McCullough's influence in this course is direct—much much of his writing is required reading—and serves as the theoretical genesis for these experiments. These manual exercises are intended to transverse from the direct to the abstract, highlighting the similarities (as articulated by McCullough) throughout the process. Students, all of whom are “computer literate,” are rarely computationally aware. In order to appreciate the implications of digital craft students experience computation directly. Given one of three algorithms written by the instructor (all are published at http://0095b6.com/lostritto/?page_id=1257) and selected by the student, he or she is instructed to perform the operations outlined, as much as possible, like a computer. These algorithms are purposefully written with
some ambiguity despite the fact that the language used is explicit and exact. Interpretation is not forbidden but must be approached consistently and precisely. For example, randomness is required in some of the algorithms. This requires that the student develop his or her own random number generation subroutine. Other required processes are more geometric such as the division of a line into equal segments or constructing a circle through three points.

2.1. RANDOMNESS

As a concept, randomness, although abstract, is easy to comprehend and therefore provides a convenient foray into the nature of design computation. Without the heuristics of improvisation and pseudo-randomness by variation, legitimately effective randomness becomes difficult to perform. As is often the case with functions buried in software, students develop an associational connection between cause and effect. The math in-between remains elusive and dormant in students’ minds despite that it is paramount to the function of all design software. Articulating the manual processes designed by the students becomes an important pedagogical act.

2.2 REQUIREMENTS AND RESTRICTIONS

Students each produce one large (30" x 30") drawing with graphite on paper. The algorithms provided all achieve direct aesthetic effects such as Moiré patterns, natural material characteristics (fur, in particular) and biology-inspired phenomena. These exercises are not without creativity (another lesson taken from McCullough: that restrictions reinforce the creativity, not stifle it.) (McCullough, 2006). In clarifying the interpretation of the algorithms and emphasis is placed on an authorship of the “how” rather than the “what.” An explicit requirement of this assignment is that all process artifacts of any kind including calculations, construction liens, and errors remain as compositional participants. The most related content to the work produced by the students are the generated drawings by C.E.B. Reas (2006). The success of Reas’ work as art is evidence of the evocative, and therefore effective, capacity of an algorithmic aesthetic. It also serves as support for the idea that the product of this exercise, the computation in its most raw form, is of value as an artifact, and the translation of its effects is a legitimate exercise.

2.2.1. Packing Algorithm

This algorithm introduces students to a problem that requires explicit documentation of reciprocal processes, conditionals and optimization.
2.2.2. Moiré Circles Algorithm
Here, rhythm, part-whole relationships and randomness are explored.

2.2.3. Fur Algorithm
In creating a textured effect that balances order and randomness, this algorithm introduces students to the idea of forces represented as geometry (in this case, two attractor points that control the radius and angle of arcs.)
2.3. FOCUS ON EFFECTS

Besides the discussion of randomness and the other student-developed subroutines, this work has enabled an analysis of the aesthetic implications of various media. The physical effects inherent to graphite used to draw by hand can be classified as noise, inconsistency, accent and simultaneity of texture and line. Many of these are in contrast to what is associated with a "digital aesthetic" (often associated with smoothness, repetition and high contrast, for example). When translated as part of a library of effects—which includes the higher-level effects created by the geometry in the drawings—they yield a unique degree of productive complexity and scalar ambiguity. These qualities are on one hand illustrative of the architectural implications of computation in a discrete sense, but more importantly, are expandable as computational approaches to a range of external forces, including those relating to sustainability. In this way computation, in the minds of successful students and future architects, can shift from being a set of skills into a set of values—a design ethic.
3. Challenges of teaching parametric modeling

The most common method for teaching parametric modeling is with tutorials. Without discounting validity of this approach, especially its appeal to advanced students or those already practicing who wish to share practical knowledge, this work presents another approach. This option may be valuable if these techniques are considered as part of a body of knowledge and relevant to students as they form an understanding of contemporary design issues. A goal of this academic rather than vocational approach is that it can be immediately extendable. A challenge of this value system, which is addressed by this pedagogy, is that new technical and conceptual skills are required simultaneously. When these drawings are complete students have a computational repertoire of techniques and processes. More importantly, students associate these algorithms with aesthetic effects. That they remain as algorithms, albeit in a graphic rather than verbal language, is important because they are neutral in terms of scale and context. Aranda/Lasch exude support the active potential of algorithms in stating, “Algorithms also offer a non-technological implication in architecture. They break down the elusive and sometimes problematic phenomena of shape...deep within them is a struggle between the predilections of the architect and the inherent properties of the geometries encountered. The algorithm mediates these two, acting as a kind of solvent to liquefy them and create the potential for crystallization.” (Aranda and Lasch, 2006)

This identification of aesthetics as the constant throughout translations from drawing to model to architecture is also important. In both courses and for similar reasons, a non-prescriptive ethic is required. In the introductory course these techniques are only considered valuable to students if they can influence design at the level of conception. At the advanced level the challenge is not to provide students with the ability to construct, modify, and edit a parametric model. Rather, the goal is to enable students to independently construct a parametric approach including the identification of parameters in typical situations. In sum, students are taught to design rather than execute a process.

4. Architecture as amalgamation of systems: computation toward sustainability

Numerous authors have described the vast extent to which computation has been prevalent in human history long before computers. Besides the Difference Engine, which is considered the first computer conceived, algorithms have roots in eighth century Persian math (Terzidis 2006) and
Palladian logic (Mitchell 1998). These exercises embrace this history and take a broad view of the implications of computation beyond form generation and representation.

Successful applications of parametric techniques taught subsequent to this exercise require that students become facile at problem development (as opposed to but not in lieu of problem-solving). Just as the explicit interpretation of the provided algorithms required that heuristics, types, and patterns be deconstructed into geometric relationships, successful students will be able to reach beyond the discipline of architecture and synthesize a simultaneous response to environmental, programmatic, and perceptual forces and challenges. This idea of using computation to reinforce a design ethic means that students can frame issues of energy optimization, ecological impact and environmental performance broadly and in a manner that integrates stewardship and perceptual aesthetics. Furthermore, as students develop a capacity to explore and create with and through computation, tangible and quantitative parameters become fruitful.

5. Reinforcing cyclical curricula

This pedagogy allows the beginning student to understand the inchoate potential of digital media as well as its direct physical implications. The “Inchoate Education” as defined and explored by Marc Angelil theorizes that a design education can operate as the threading together of incomplete or transitory ideas, artifacts and processes, and that the act of translation is as valuable as the content itself. (Angelil, 2003) Furthermore, it frames digital media more broadly than just in terms of digital modeling. In this process the parametric model is more akin to drawing than a virtual model. For the advanced student, this drawing exercise exhibits desirable ability to disturb associations, comfort, and reliance on software. Their focus, like a beginning student, on low-level geometric operations can actually lead to an advanced connection between holistic intention and the refinement of aggregate parts and systems. These students have demonstrated a capacity to develop a thesis that includes a method, hypothesis, and conclusion. The result is architecture that performs in response to environmental and aesthetic conditions. As the studio progresses and students are provided with an urban site they develop a program all in terms of forces and parameters. These parameters address sustainability to multiple degrees and at multiple levels. Broadly, the interconnectedness of a parametric process inherently tends toward optimization. More specifically, students are prepared to develop an architectural response toward mediating environmental impact. Implicitly this project proposes a deviation from thinking of sustainability as a sub-discipline and instead as a set of values. Figures 6-11 demonstrate
early parametric drawing exercises and an excerpt from the corresponding student’s building design.

*Figure 6.* Scanned drawing by Rouzbeh Mokhtari, M.Arch ’10.

*Figure 7.* Skin design using parametric process in response to environmental conditions by Rouzbeh Mokhtari, M.Arch ’10.

*Figure 8.* Scanned drawing by Sandra Nakawatase, M.Arch ’11.

*Figure 9.* Skin design using parametric process in response to environmental conditions by Sandra Nakawatase, M.Arch ’11.
6. Conclusion

The incorporation of advanced digital techniques into design pedagogy is an ongoing challenge. This is a fruitful challenge though, because it forces the framing of these techniques in a theoretical manner. The work presented here succeeded in that it fueled student work beyond its defined scope and provoked meaningful critical analysis of the value, meaning and purpose of design computation relative to broad disciplinary issues.

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References


