Rapid Types: A Coffee Pod and Alternative Digital Processes

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DIGITAL PRODUCTION

Two platforms of industrial production currently shape the practice of architecture: software and hardware. With the advance of digital technologies (and the progress made in both platforms), it is now possible to integrate the design and construction of buildings into one seamless process. Software, particularly Building Information Modelers (BIM), allow designers, consultants, and builders to integrate all of the idiosyncratic complexities that make up the construction process, including building systems, cost, performance and schedule into one, fully-loaded three-dimensional digital model. Design programs are no longer used simply for speed, representation, and visualization, but as an integral part of the design process to the extent that designers use software to test and even generate architectural geometries.

Computer Numerically Controlled (CNC) machines have also been adopted by some of the leading builders and designers today to increase the efficiency, speed, and quality of their work. The use of CNC mills has begun to alleviate some of the problems caused by human error, prompting us to reevaluate our definition of craft and our dependence on trade oriented skills, a knowledge base only acquired through experience and repetition of human-centric activities. Other industries have successfully negotiated the transition from manual labor to machine production, and it's about time that architecture follows suit.

It is through the use of software and hardware in a concerted building design and construction effort that we can change the practice of architecture and offer innovative solutions as our profession moves forward. In fact, a digitally integrated design and construction process is the only sustainable way to move forward, as a depletion of resources will require us "to integrate shaping (morphology) and making (fabrication) into a seamless whole."[1] The energy lost and material wasted by document inaccuracies and the mis-coordination of building systems will not be as acceptable as it is today. Requests for Information could signal design deficiencies and become grounds for a lawsuit on account of negligence. As both parties often bear the brunt of design and construction mistakes, both architecture and construction industries stand to benefit from a more digitally coordinated building process. As Kas Oosterhuis predicts, "designers will need to rethink their contractual position as only consultants and will need to take on financial responsibility for the manufacturing process as well.... The benefits for the building industry will be huge: no more mistakes in the accuracy and transfer of the data, no more delays in the exchange and understanding of the concept, and no more need for remodeling. Production will be clean and precise; assembly will always be correct, and all steps in the design and building process will be just in time and just what is needed."[2] A sustainable design practice is not one that is only concerned with building system performance but design and construction performance as well.

This interest in working through digital design and fabrication technologies, the translation of information between the two, and the opportunities offered by immediate feedback from rapid machine output framed the core investigations of the design/build studio *Rapid Type* offered at CCA in the fall of 2010. The final project, Rapid Type Coffee Pod, explored the limitations and opportunities that one encounters when working seamlessly between a digital model and CNC fabrication.

THE MOBILE COFFEE CART

The Rapid Type studio received a large donation of Alpolic, a unique aluminum composite material manufactured by Mitsubishi Plastics, Inc. The material is typically used for exterior cladding on large office buildings or for signboard backing. Our objective was to explore alternative uses of Alpolic within the limits of currently available CNC fabrication technology. Our challenge was to give volume to a material that is typically used flat and establish a program and building type that would enable us to move forward with material experimentation and test our hypotheses through the full-scale actualization of the design.

To begin, the studio researched and analyzed the socio-economic gap between highly designed prefabricated houses and under-designed, but widely popular and more profitable, food trucks. Since the turn of the century, prefabrication has remained a popular topic, both professionally and publicly. But the history of manufacturing in architecture shows that a peculiar shift happened in the early 1940s. Prior to the 1940s, the manufacturing of prefabricated buildings and the products of other industries had kept pace, even sharing facility resources, distribution models and assembly processes.[3] As World War II erupted, the manufacturing and mass production of products, such as automobiles and airplanes—fueled by military needs that fed stateside consumption—began to outpace the factory production of buildings. Though plenty of architects continued to champion prefabricated buildings—Walter Gropius, for example, worked closely with General Panel Corporation to develop the Packaged house system[4]—the mass manufacturing of architecture had seen falling demand and has ever since been relegated to small prototypical runs or mostly theoretical propositions. In 1943, the first prefabricated trailers that included bedrooms and other domestic comforts were introduced. Though mobile trailers, which later

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evolved into mobile homes, experienced exponential growth and commercial success after the 1940s, the last decade has marked a dramatic plunge in mobile home revenues, which have dropped by almost 74%.[5]

In recent times, the only financially viable prefabricated buildings have been mobile restaurants, also known as food trucks. Over the last five years, food truck revenue has risen 15% while house prices have fallen 28%.[6] Prefabricated homes have fared even worse due to the over-abundance of new (and empty) homes and dropping prices. To gain exposure for the material experimentation at the core of the studio's directive, whatever project that was to emerge from the Rapid Type studio had to be commercially relevant and socially current. Thus, it became clear that the mobile food truck offered the studio the best and most financially sustainable platform on which to develop the project design.

RAPIDTYPE: AN ATYPICAL PROTOTYPE

One reason for the decreased production of prefabricated buildings was the time architects invested in the prototype—a preliminary representation of an idea—rather than the product itself. The ubiquitous access to CNC machines has made traditional prototypical testing obsolete, an advantage of manufacturing that other industries have long enjoyed. Prototypes are no longer models of what we expect a design to become but what they already are. Furthermore, it is now possible to rapidly produce multiple permutations of a design while testing each as a fully functional, real-scale fabrication from which we can glean immediate feedback to improve the next design iteration. For this reason, we named the studio *Rapid Type*, implying a faster, non-linear process better tuned to the final manufacture of the design than traditional prototyping.

Figure 1: Matrix of Prefabricated Structures Comparing Cost, Transportation, Material and Size

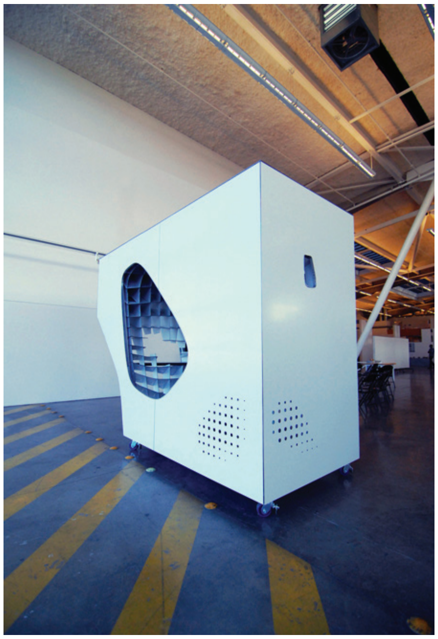

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Figure 2: Exterior, Rapid Type Coffee Pod

Although the goal was to design one mobile food cart, our use of Alpolic during the schematic phase and the early adoption of the CNC technologies we would employ for construction allowed us to more accurately test (and therefore predict) issues of performance, assembly, and material behavior. Multiple *rapidtypes* were tested at different stages of the design process, providing valuable insights into how the material might be used in other applications. Even though not every design or material experiment contributed directly to the final project, every test was documented and added to a body of knowledge available to others interested in using Alpolic.

By working with the actual material and details that could be directly transferred between the design software and CNC mill, we hoped to minimize the disconnect between the digital model and its physical manifestation. The completeness of the digital model, including material thickness, detailing and even the inclusion of fasteners, allowed for the virtual rehearsal of the entire assembly and construction process. Any issues that might compromise the project were identified prior to fabrication, saving time and money. Because of the accuracy of each *rapidtype*, the fabrication and assembly of the Pod took only two weeks to complete.

VOLUME DRAWING

It is becoming clear that with the inclusion of digital technologies in the design process the persistence of 2d drawings in the practice of architecture, and worse, the construction of buildings, has become outdated, wasteful, and not a best practice. The transfer of information from a 3d digital model to a set of 2d drawings, then back to a 3d physical construct, as is the current norm, subjects the information that is being transferred to interference, noise, deletion, and other mutational effects that change the designer's original intent. Various levels of simplification occur in the process of transcribing a three-dimensional object as a two-dimensional orthographic projection. For the Rapid Type studio, our interest was to maintain the integrity of the digital model in the final physical construct by developing geometries through various methods of digital design that would produce models amenable to CNC fabrication.

Additionally, as abstractions of a three dimensional space, 2d orthographic projections—plans, sections, elevations—limit any volumetric variation that would differ from the extrusion of the projection. Any 2d drawings describe a flat space that does not account for curvature, thereby limiting the range of feasible architectural forms. As Kas Oosterhuis notes, "to start a design process with the plan and the section is an exclusive approach, which is why it is poor. It excludes thousands of possibilities, and so the designer will never be able to consider these possibilities.... The paradigm shift towards nonstandard 3d is inclusive, as nonstandard 3d includes all possible plans and sections and all possible volumes."[7]

The desire to work three dimensionally was driven by our interest in encouraging formal experimentation, but also by the small size of food trucks. Every angle, nook, and corner had to be considered in the design of the space. Also, given the special requirements for food and beverage service, it became apparent that all space that was not tuned to human movement, equipment, the service of coffee, or the establishment of a brand and identity was wasted. Though orthogonal space is typically cheaper due to the use of standard material sizes and universal construction processes, the benefits of 90-degree angles and geometric simplicity were offset by other considerations of use and performance given the opportunities provided by digital software and fabrication processes.

DIGITAL PROCESSES

To fully invest in digital design processes, the studio considered different digital design techniques. The first was a bottom-up approach, in which architects code genetic algorithms that generate form. The process often begins by establishing a simple set of rules that through repetition, variation, and the addition of other rule-sets, produces a complex form that exhibits unpredictable emergent qualities. Examples include the work of Karl Chu (genetic space) and John Frazer (evolutionary paradigm), both of which "let the computer guide the process."[8] In this approach, the architect is concerned with the initial inputs that define the project's base structure from which the form will evolve. Associations develop parametrically as the model emerges.

The promise of the parametric model is in the user's ability to control the overall form through minor changes to the initial code, expanding one's ability to test alternative design proposals with minimal effort. The tendency is for each variant to retain some formative structure, while the influx of new data begins to shape its particularities. As Roland Snooks puts it: "It is this persistence of formal character and its emergence from behavior that perhaps offers the greatest potential in algorithmic design models."[9] Working through an algorithmic model, designers can incrementally introduce new data and design parameters to the code, thereby isolating the effect of each parameter on the final design. Code that is deemed beneficial to the project is kept or varied again to further refine its effect on the final design. In "Notes on the Synthesis of Form," Christopher Alexander proposed "a model of cybernetic automation: an 'architect-free' self-generating technique that displaced the architect or planner in favor of a self-sustaining feedback loop: environmental data input into a system according to the principle of 'good fit' produce patterns of output."[10] Though admirable in its scope and potential for generating better urban plans using accepted design guidelines, the loss of authorship in the design process is too severe, and the uniformity arising from such a model would be overwhelming.

If we consider the designer as a critical and necessary part of the design process, then the other, top-down approach to digital design offers an alternative method of working. As an example, Frank Gehry's office only enters the digital realm once a physical model has been built. Digital scans are taken of the physical model, which are then reconstructed as 3d models, providing a foundation from which to make new digital models. Like other BIM-based practices, the work of consultants is fed into the primary model and checked for conflicts before final construction documentation is produced. Like all fully integrated digital design processes, the loss of

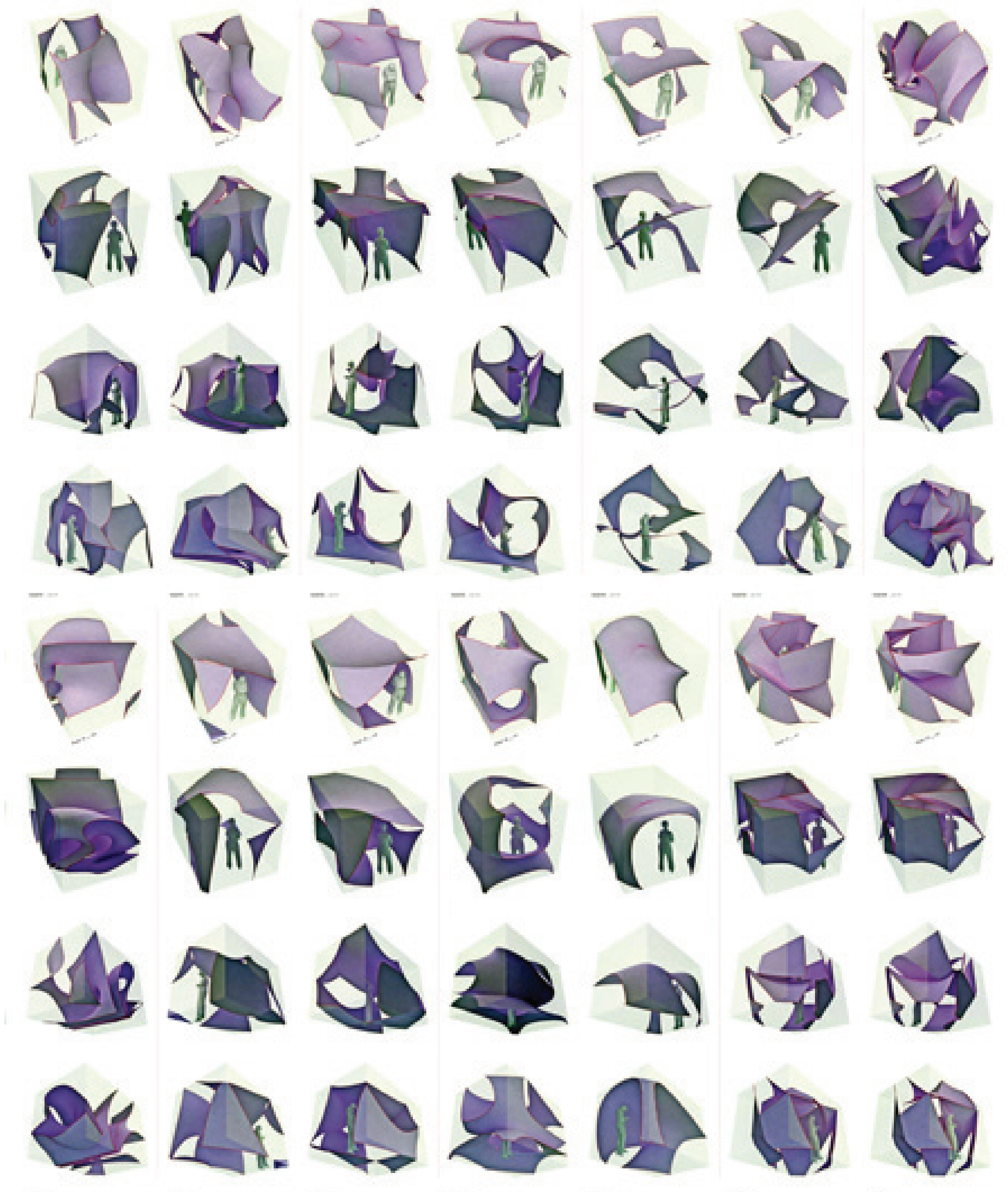

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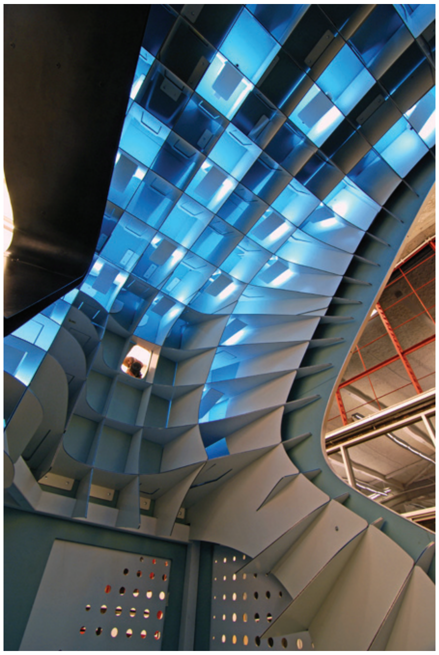
Figure 3: Boolean Catalog

information between the digital model and the final physical product is kept to a minimum. A top-down approach shares many of the advantages offered by bottom-up processes, including the potential for establishing parametric relationships, but it too has problems. A top-down approach relies on an idea, or vision, of what the final architectural proposal will be and seeks to rectify all differences into an idealized model that best matches the original intent. The eradication of irregularities leaves little room for emergence, an advantage proffered by digital design, supported by a bottom-up approach, like scripting.

For the Rapid Type Coffee Pod, we opted for a design process that took advantage of the emergent opportunities generated via bottom-up design techniques and the formally subjective, unrestrained aspects of a top-down approach. Most importantly, we sought to establish a design process that was non-linear, in which specific criteria could guide overall decisions on form, scale, and use. A looseness in the design parameters allowed for formal experimentation that was not purely driven by function, opening new avenues of material research. As Malcolm McCullough mentions, "there are few sets of design rules that can be set up to be interesting enough to run on their own. Once the design world has been set up, it still needs to be explored, played and mastered with finesse."[11] Only after a wide range of geometries were produced could we re-invest our conclusions in scripting. By developing new scripts that targeted a loose expression of the base form, we could control overall geometric tendencies while providing a means for new qualities to emerge.



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RAPID TYPE COFFEE POD: THE BOOLEAN

Based on initial programming research and analysis, the studio was able to establish criteria on which to base early iterations of the design. Knowing that the project would have to be mobile, moving from one site to another, and meet size requirements to fit on universal and readily available tow trucks, the maximum exterior dimensions of the cart were constrained to 11'-0" W x 8'-0" L x 8'-0" H. Though not as specific as the outer envelope requirements, issues of program, equipment size, and human occupation contributed to the formal parameters of the interior.

Given these parameters, the studio used digital Boolean operations to explore the difference between orthogonal and curved geometries. Booleans provided a means of quickly producing multiple design studies and a common platform around which to position the work of each student toward a collective end. Each model was built parametrically, and each parameter of the initial operands could be adjusted, allowing real-time changes to update the Boolean. It was essential that the process be repeatable so the studio could add new input and criteria to the model and prompt additional formal permutations that might better solve the design problem. The studio's interest in the difference between curved and orthogonal geometry was not to establish hierarchical dichotomies but to understand the potential for creating a mutually beneficial relationship between formally disparate elements. As Mark Rakatansky suggests, "no thing means anything unless it's in relation to something else. As Bateson said, it doesn't take one to know one, it takes two to know one."[12]

Boolean operations also provided a platform for combining the work done by multiple students. The resultant form is only revealed once the operation is complete, providing multiple stages during which to input new parameters, design criteria, and interests into the modeling process. By mixing, shuffling, and forging new combinations of student input prior to the final Boolean operation, we could identify which inputs provided the best output. Often individual input, though superior alone, was not as constructive for the overall project as the hybridization of many. As film editor Walter Murch

Figure 4: Interior, Rapid Type Coffee Pod

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Figure 5: Condiment Counter, Rapid Type Coffee Pod

notes, "there is a higher level that comes through *recognition*: you may not be able to articulate what you want, but you can recognize it when you see it."[13] By filtering the components of each student's original model into a new collaborative model, in which no single author could be easily identified, the project succeeded in truly being the product of a group-based enterprise.

After the digital model was reshaped to match the form of the final selected Boolean object, the studio rebuilt the digital model as a parametrically driven, scripted geometry. Scripting the digital model through Grasshopper, was a significant step in the transformation of the Boolean object into a fabrication-ready geometry. Each form, surface, curve and point, and the associations linking one to the other, were remodeled as parametric associations. The translation from a loose (yet criteria driven) model of formal relationships to a highly precise organizational model of parts, allowed us to explore the design of a new scale. With the new model, we could consider modifications to the form in relationship to local, small-scale conditions, including the movement of the barista's hands, small item storage, coffee making, the integration of lights and more. These highly specific design conditions reverberate to the overall form. As Manuel de Landa points out, the efficacious feedback of local specializations on the final design is what Deleuze refers to as "the concept of 'Machinic Phylum,' … in which a group of previously disconnected elements suddenly reaches a critical point at which they begin to 'cooperate' to form a higher level entity."[14] Only through non-linear feedback between the top-down design of the overall Boolean form and the bottom-up re-calibration of the geometry could we achieve a design that successfully managed the cross-scalar design criteria imposed on the project while testing new configurations and uses of Alpolic.

Through scripting, we were also able to introduce additional design opportunities. The poché space—the space between the interior and exterior surface—is often relegated to structural and building system requirements. In the final Pod design, the poché space contains the structural steel frame, carrying, primary loads, and the electrical, mechanical and plumbing systems; but, by using a waffle/rib system, we also provided additional space for program, use, and visual effect. In the depth of each rib, we introduced a series of tabs that could fold up to be light baffles or down to form baskets for storing small items, like coffee, cups, or merchandise. Additionally, the profile of each unique rib was calibrated to integrate openings or provide mechanisms for attachment and the distribution of loads from the waffle to the steel frame or exterior shear panels.

Every detail was driven by the requirements of the CNC process. The bit size, tool path, and material properties are all accounted for in the translation of the scripted digital model to the CNC mill. The script automatically unfolds the model and distributes each part to a sheet, where it is then labeled with a notation that corresponds to the digital model. Each part is sent from the computer to the CNC mill, limiting the chance of error and reducing waste caused by the needless printing of 2d drawings or the construction of jigs often needed for building complex geometries. During construction, the notational system guides part-location and the assembly sequence. The entire assembly process is coordinated between the digital model and the physical construct. Similar to the Porter House project by SHoP Architects (though at a much smaller scale), the lack of 2d drawings was a benefit rather than a burden. Speaking about their project, SHoP Architects conclude that, "the most significant aspect of the entire design and construction process was the absence of traditional shop drawings. Instead of transferring the design to dimensional drawings which describe each piece to be fabricated—an impossible task given the number and variation of parts—the design was instead transferred directly to the cutting machine though various software programs."[15] The use of digital software and the integration of CNC fabrication made possible the complexity we realized in the digital model and allowed us to test the material in ways that could not have been tested using conventional fabrication processes.

CONCLUSION

Given the urgent need to integrate sustainable issues in both the design and construction of buildings and the need to limit material waste by supporting technological advancements, it becomes clear that our profession must embrace the transition from analog to digital. As Negroponte contends, "as one industry after another looks at itself in the mirror and asks about its future in a digital world, that future is driven almost 100 percent by the ability of that company's product or services to be rendered in digital form."[16] Using BIM, architects are capable of organizing a complex set of elements into a manageable single model, but the platform needs to progress. BIM models remain representational. Three-dimensional information is still output as two-dimensional drawings, and though coordination has been improved between disciplines, there is still room for error. More importantly, the design process remains dependent on a two-dimensional understanding of space. Though BIM programs are used to construct 3d digital models, they are often still built from a set of orthographic drawings. Plans, sections, and elevations are embedded with three-dimensional information, but the building form is often just an extrusion of the orthographic plan.

Part of our responsibility as architects must be to re-conceptualize our design process to better suit working in three-dimensional, digital space. By working directly with a digital model early in the design process for the Rapid Type Coffee Pod, the studio was able to control every architectural feature, form, building threshold, and detail rather than rely on architectural conventions assigned by predefined blocks within the computer program. The conversion of the digital model to CNC fabrication enriched our design process while simultaneously reducing material and temporal waste. The limitations of design endeavors were not *determined* by the tools we used, but were *enhanced* by them. ◆

ENDNOTES

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