

Digital to Analog

Exploring Digital Processes of Making

Frederick Norman

Auburn University School of Architecture

www.auburn.edu/~normafs

This focus this paper is the translation of a digital information model that defines an object's surface properties and its connection to that which is real or physical. This research, while early in its investigation, seeks to explore architecture and digital design as a material process. The direct connection to output devices such as computer-numerically controlled routers provide a unique opportunity for controlled variation and serial differentiation and seeks to exploit mass customization rather than standardization. Through a series of studies the process from design to machine file to finish product is explored. This connection to digitally driven fabrication equipment creates within the design process an opportunity to realize ones designs both digitally and materially.

Introduction

"Digital technologies have had a profound effect on the world, implementing a radical change to the concepts and working practices of art, science, and industry. Yet in architecture they remain, as yet, largely immaterial."

Cecil Balmon

Computers are changing as well as challenging the practice of architecture in the conventional sense. New practices of architecture are seeking to collaborate outside the traditional team of collaborators, such as engineers and contractors, and are once again returning to an interest in making. Investigations into the new fabrication technologies, mass customization, and digital design tools will lead to a better understanding of the computer's impact on design as a process and what we as architects pro-

vide as deliverables. The implementation of digital technology with a focus on making, instead of digital visualization, will be of paramount importance if we desire to push the computer into new areas of design, practice and construction.

For over a decade the computer has provided designers with an opportunity to explore the built environment. The integration of digital technology has not only brought about changes in the process of design but design education as well. The question still remains, what is the role of digital technology on the practice of architecture a decade or two after its introduction? Concentration areas such as visualization and animation have begun to create a more digitally educated architect, but how will today's digitally educated architects differ from those of a decade or half a decade ago? The impact of digital

media on design education cannot be measured by its physical presence in the classroom but by its fluidity of integration into ones process as a tool for exploration.

Exploring the impact of information technology on new design methods and digital fabrication techniques will lead to a revisiting of traditional design processes. The potential for new avenues of collaboration and renewed interest in materials are challenging the role of the architect once removed from the building process. The translation from digital data to their analog equivalent is allowing one to rethink the use of computer as an instrument focused on the process of making. This research seeks to explore the relationship afforded to today's designers as information technology redefines „visualization“ from solely a digital or virtual environment into an analog or real medium. Output devices such as printers and plotters are now being supplanted by 3D printers, computer-numerically controlled laser-cutters and milling machines. How will these new output devices change the process of design and impact the architectural design/build process? How can the fluid nature of digital data assist us in defining that which is real? How can information technology assist us in understanding the material nature of design and methods of fabrication and construction?

The Digital is Material

This renewed interest in making has been born out of a need to build highly complex surfaces created in today's animation software. For over a decade these virtual environments have produced architecture of the digital age to the mind of its critics thought to be unbuildable and reside only within the realm of pixels. Architects have begun to research allied industries such aerospace, ship building and the automobile industry for new methods of digital fabrication and their connection to digital design. The information age has created a common language based on 0's and 1's, allowing architects

to find inspiration in allied design disciplines. New digital paradigms are focusing on methods of mass customization and infinite variation instead of the modernist machine paradigm of standardization and mass production. (Imperiale) Mass customization is replacing mass production. Mass production was all about the economy of making things in quantity, but mass customization does not depend of quantity to be cost effective. Mass customization is about cultural production as opposed to industrial output of mass production. (Kieran / Timberlake)

The architects return to making, while ironic, stems from the infusion of digital technology into the practice of architecture that has taken place over the past decade. A new language of digitally born forms has brought with it a desire to accurately describe the tectonic nature of this new architecture. These new digital environments once thought to reside only within the virtual realm now have the opportunity to become real in a very material sense. Just as the exploration into animate software and time-based media was outside the traditional toolset of the architect, architects are once again searching outside their own discipline to discover what other design industries have already implemented. The connection between digital design and computer-aided manufacturing has already radically changed other industries such aerospace, automotive, and shipbuilding. It is that common language shared among disciplines that allows the exchange of information, techniques, and product delivery. Digital workflow can now be continuous from conceptual design to final product. That workflow can remain digital created once and shared between designer, fabricator and contractor. Timberlake and Kieran remind us in their book, *Refabricating Architecture*, how much the role of the architect has changed or in their words „diminished“ from its former role as the „master builder“. In fact it has diminished to a point of having an interest in appearance only. (Kieran and Timberlake) The „appearance“ can now be described in materials terms and the digital is now material. Andreas Ruby describes in an article

entitled, „Architecture in the age of digital producibility,“ that the computer has become a tool in building production itself. Ruby goes on to say that the use of the computer goes beyond merely the form but informs the „constructional realization of form.“(Ruby) This is in contrast to conventional or traditional design methods whereby orthographic projections of plan and section are used to represent a particular form. Architecture in a digital age now has the opportunity to use the constructed digital model as the generator of the numeric data to drive the fabrication equipment in the production of building components.

Impact on Design Communication

It has been through drawing that architects have traditionally communicated their design intent to contractors and builders. As the integration of digital design methods become more a part of ones process a paradigmatic shift will occur in the way architects communicate the buildings we design. As we begin to explore the potential of designing within a digital medium a material understanding must begin to emerge.

The representation of materials in an immaterial realm has brought about a fixation on image over that of an object's true physical properties. This fixation on image limits the role of the computer as merely a tool for visualization. Advances in software technology have provided the designer with the ability to accurately represent a material in an immaterial digital world. Material properties in the digital realm are assigned characteristics such as reflectivity, incandescence, transparency, diffuse, specular, shininess, eccentricity, and color, all of which represent a visual component of a physical object. The true properties of a material like strength, stress, and texture can only be experienced in the physical realm. Digital design has also taken on a new vocabulary and method of form making. As Joseph Rosa describes in *Folds, Blobs and Boxes: Architecture in the Digital Era*, the differences in vocabu-

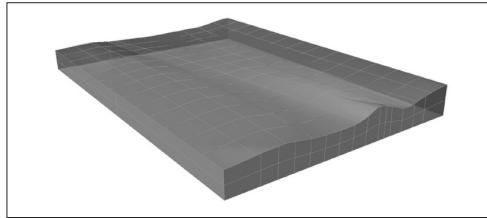


Figure 1
Digital Surface.

lary in contemporary architecture verses that of a predigital era where „beauty, scale and proportion... have given way to adjectives like smooth, supple, and morphed.“ (Rosa) (Figure 1)

Digital representation has brought about blurring between what is real and what is digital. The separation between the digital and the physical has widened with the increase in digital design. Designers are becoming further removed from the material, that which is physical, to explore the intangible, ephemeral accepts of virtual space. The focus of this research is to bring a material understanding to a digital design process and allow a digital craft to emerge. The reconnection of design and fabrication via the computer is providing opportunities for architects to return to a previous era of the „master builder“. Computer-numerically controlled devices allow architects to share in the process with fabricators, to understand more the act of assemblage and fabrication.

“The ability to digitally generate and analyze the design information and then use it to directly manufacture and construct buildings, fundamentally redefines the relationships between conception and production – it provides for a information continuum from design to construction“

Kolarevic

Branko Kolarevic describes an emerging future whereby as the communication between interested parties, i.e. designers, engineers, fabricators, is facilitated through an exchange of digital information the „legacy of the twentieth century drawing sets, shop drawings and specifications, will be inevitably

relegated to dustbin of history“. (Kolarevic) This new paradigm shift in the application of digital technology of one entrenched in representation or image will give way to one that places the digital model as the sole source of information. The information contained in the digital model will provide the needed data for design and production. Lindsey describes in his book, *Digital Gehry*, that the „most elaborate use of digital information is in directing the actual construction of the components of a building. Design process is continuous through the digital model, computer-aided manufacturing allows the continuity to extend from design through construction.“(Lindsey) The file to factory process will only be successful for architects if we understand the material nature of the building process. This will require not only the understanding of traditional notions of materials and construction but the limitations and possibilities the digitally driven fabrication equipment hold. The creation of the digital content has now only to transfer to our collaborators. For over a decade we as architects have been engaging the digital technology as a tool for design

inquiry stopping short of its potential connection to making or production. In our most recent history, architects have been about the business of producing drawings. We now have the opportunities to extend our design process to include the production of architecture. Today’s digitally educated architect has the opportunity to blend both the digital and the real. The ability to digitally realize ones designs will require an understanding of materials, digitally driven fabrication equipment, and the processes of assembly. The understanding that comes with a file to factory process will provide a feedback loop during the design. The value of creating feedback loops can be seen in providing a design understanding during the process design instead of at the end of construction.

Digital to Analog Translations

As we move beyond the image as the principal communicator of design intent and into a file to factory process, the ability for the digital model to provide tangible information for design and fabrica-

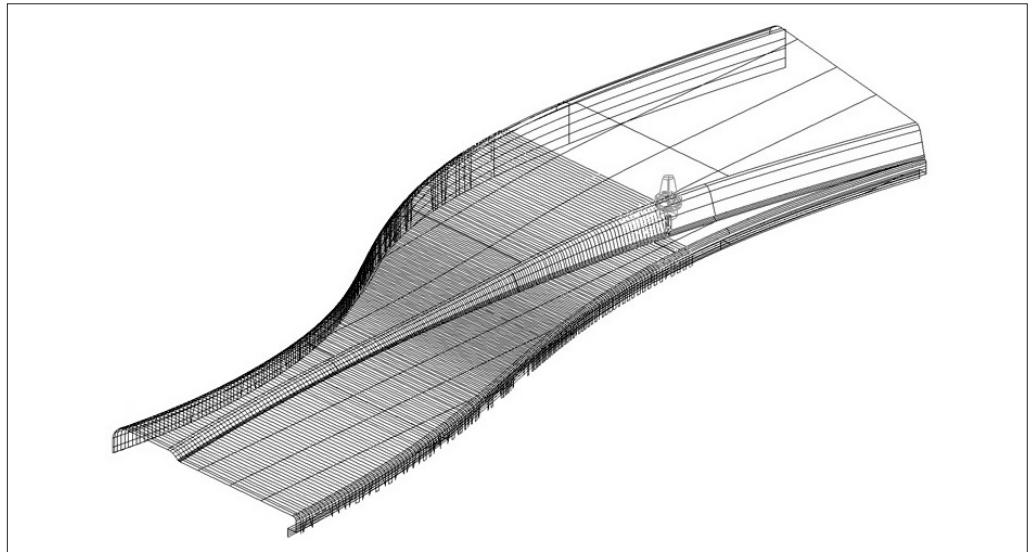


Figure 2
Toolpaths that define a
Surface.

tion will become common place. Typically we use 3-D modeling applications to create surfaces that would have colors, textures and transparency layers associated with them. This process provides a pixel based understanding that resides within the visual field of communication. Using the digital data file, the CAM software can then in turn identify the surfaces to be machined. The tool-paths for machining now defined that surface to be machined out of plastic, foam, or wood. (Figure 2). Using a traditional design method of analog representations, the surface would need to be defined through a series of constructed drawings and in some cases a rendered view to communicate design intent. The digital file needed to drive the fabrication equipment would need to be created by the fabricator working from the drawing set sent by the architect. Working within this digital continuum the ability to translate design to production is simplified and control of the final component can be determined by the designer. To explore the notion of a digital craft in design education, one must shift from its previous focus on visualization and image toward one of an integrated design and fabrication process. To understand the translation from digital design to physical constructions, students must first become familiar with software for design and then the opportunities that computer-aided manufacturing can afford. The studies described outline the ability to move from digital to analog, from the digital design model to a

material object. Inherent within this process is the understanding of the actual material to be machined and an understanding of the machining process. Each of the studies began with a conceptual idea related to the surface, i.e., ripples, skins, pleats and object. These conceptual notions of „surface“ guided the design of each study to produce a digital model.

Equipment and Fabrication Processes

While designing each of the digital models one needed to be cognizant of the process of machining. For each of the studies, a 3-Axis CNC router would be used with the following maximum dimensions 52"x102"x 4" (X, Y, and Z). In addition to being aware of the size limitation on the router, final material, end mills and finish needed to be considered. Having an understanding of the fabrication equipment machining process as well as how the CAM software writes the tool-paths to define the surface characteristics creates the potential for controlled variation in the machining process. Once a surface has been brought into the CAM software a variety of tooling options are available from the end mill type and size to the step over that controls the distance the end mill moves per pass. The controlled variation in the machining process allows for the same surface to be machined in a variety of different ways

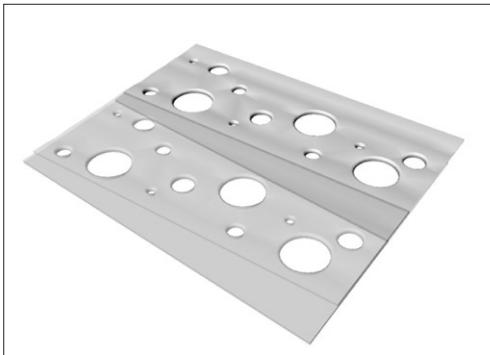


Figure 3
Digital Panel.

Figure 4
Material Panel.

each resulting in a different end product as seen in Figure 6. This variation can be seen in the final machined surface. The original digital modeling file for the panel seen in Figure 3 did not contain the striations seen in the final product. The ribbing on the panel was created by the step over entered into the CAM software to control the final finish of the panel. (Figure 4) This again places the control and the responsibility in the hands of the designer. The final product may not be a machined component but a by product gained through casting or thermoforming. The concrete panel seen in Figure 5 is an example of the casting method where by the machined component, a 2" block of blue foam, was used as a custom form for the final component. During these studies the primary tools under investigation were Rhinoceros for the principal modeling and SurfCAM for assigning tool-paths for machining. The focus of these exercises was to engage the making aspect of digital design and to construct material and assemblage techniques within a digital medium. The surface as created in Rhino provides certain properties relative to its surface normals and flow. In each of the surface studies the digital data stored within the digital surface can now be made manifest within the machining process. These characteristics can be used within the CAM software to produce the desired surface effect. Each study used the digital model as the single source of information for the creation its analog equivalent.



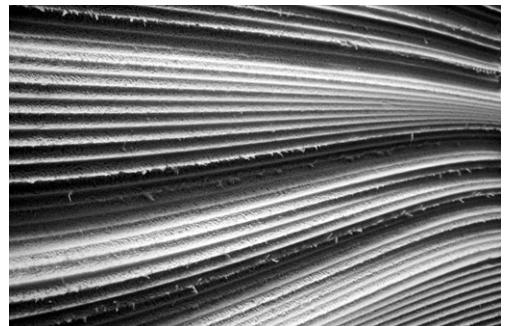
Figure 5
Concrete Panel from a CNC
machined foam mold.

Figure 6

Digital Material

During the modeling process each of the surface studies had to consider the machining process it would later undergo. The consideration of the material, its size, thickness and density, was taken into consideration as each design developed. The digital surface creation completed in Rhino required modeling each of the panels at full scale to its true thickness. Understanding of the cutting process would require that no portion of the surface could overlap another and that the machining would be one sided. While the studies were experiments in surface modification and variation, the outcome of each of the pieces provided a glimpse into the factory process and how one moves from a digital to a material realm.

Another example of using the digital model as the sole source of information for design and fabrication can be seen an installation project entitled „thirty pieces of plywood“. This installation was part of a third-year undergraduate design studio aimed at exploring the connection between the digital and the material. The goal was to physically realize a digital surface, a single membrane that serviced as the only design representation of the project. The installation project required the modeling of all material components and their connections. The students had to engage in a material process within the digital realm. The material selected for the project, plywood, would require an understanding of





its material limits, size, and connection opportunities. (Figure 7) Again in this exercise the digital had to represent the material. Digitally exploring the project at a material level assisted in understanding of potential problems commonly associated with construction at any scale.

Conclusion

Digital tools have brought about a new vocabulary and with it a desire for a more curvaceous and complex geometry. This new geometry brings with it the added responsibility of communicating those designs into a material culture and the built environment. The impact of digital media on design studios across the country can easily be seen in the content produced by our students today that have been generated using digital tools. It is at this point that the role of digital technology needs to re-define itself, returning to a notion of craft and a material understanding within a medium that is inherently not material. Computers have evolved from production devices to conceptual modelers to exploratory tools and now a tool for fabrication. This early investigation has allowed students to understand the translation from digital to physical and the limitations of materials and fabrication processes. Students are exposed to a process by which an understanding of design concept, development, materials, and fabrication can be experienced.

Implementing a file to factory process does not come without obstacles. Beyond the industry

hurdles that would have to be overcome, curricula within schools of architecture will need to address opportunities that a digital continuum from design to production can afford in a digital culture. Currently practice today, as well as education, has integrated the use of the computer as a tool for design drawing, creating representations for a client, contractor, builder or faculty member. These drawings remain part of a process that must be revisited. Digital modeling can now provide more than an image but the instructional data for collaborative design and fabrication. It is this area that academia must begin to address as we push the digital technology into the twenty-first century and begin to train a digitally facile architect who understands the material aspect of design.

References

- Balmon, Cecil. (2000) „The Digital and the Material“. Michael Weinstock with Cecil Balmond AD Magazine: Contemporary Techniques in Architecture: Vol. 72 No. 1 January 2002.
- Imperiale, Alicia. (2000) New flatness : Surface Tension in Digital Architecture. (IT Revolution in Architecture). Basel ; Boston : Birkhäuser,.
- Kieran, Stephen and Timberlake, James. (2004) Refabricating Architecture: How Manufacturing Methodologies are Poised to Transform the Building Construction. McGraw-Hill. New York.
- Kolarevic, Branko Ed.(2003) Information Master Builders. Architecture in the Digital Age: Design and Manufacturing. Spon Press, New York.
- Lindsey, Bruce. (2001) Digital Gehry: Material Resistance Digital Construction. (IT Revolution in Architecture). Basel ; Boston : Birkhäuser.
- Rosa , Joseph. (2001) Folds, Bolds, and Boxes: Architecture in the Digital Era. Heinz Architectural Center Books. Carneige Museum of Art. .
- Ruby, Andreas. (2001). „Architecture in the Age of Producibility“. <http://www.a-matter.de/digital-real/eng/main.asp?es=5> (accessed 15 April 2004).

Figure 7
Digital Fabrication Installation.