VISUALIZING REVISIONS: REPRESENTATION IMPLICATIONS OF DIGITAL FABRICATION

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Abstract

Digital architecture contingent upon a conversation between digital visualization and digital production deploys an iterative and seamless process-oriented design development. Feedback loops are integral to this process/product, and thus require extensive management of complex visual and data related information. While much attention has been paid to fabrication and serial customization of digital architecture, very little discussion has been forwarded about innovations in visualizing and representing the design data integral in this feedback loop. This paper will examine innovative representational devices such as the matrix, sectioning, layering, and bracketing as new forms of organizing and visualizing complex data intent upon communicating multiple levels of operations during the fabrication process.

1. Introduction

Architects using digital technology today can simulate with a digital model an entire building, its elements, its construction, and in turn use this three-dimensional information to construct actual building components using machines driven by CNC (computer numerical control) equipment and other advanced manufacturing techniques. Increasingly, the computer plays a key role in the translation of information for direct fabrication, which ultimately questions the specific role of the designer. Not only has digital technology allowed us to think differently about formal manipulations, the devices used to fabricate are influencing how we build. Both the ways in which we think about architecture and the instruments and techniques we use to produce architecture are changing dramatically. We have perhaps arrived at a new form of “Architecture Machine,” slightly different than the one suggested by Nicholas Negroponte in his seminal book by the same title at the dawn of computing in architecture (Negroponte, 1970). Today, I suggest we must revisit similar ideas to those outlined by Negroponte by examining how we visualize information throughout the process of production as we experiment with the process of making architecture.

Digital architecture contingent upon a conversation between digital visualization and digital production deploys an iterative and seamless process-oriented design development. Feedback loops are integral to this process/product, and thus require extensive management of complex visual and data related information. Innovations in visualizing and representing the design data are essential in this feedback loop. Representational devices such as matrices, sectioning, layering, and bracketing reveal relationships unable to be considered in the original conception of the project, and serve as visual feedback connecting a dynamic design process. Concepts of efficiency, nesting, and tolerance are all important concepts to visualize during design development, yet still these concepts are more a result of a necessity for engineering the cut-out of the 2-d sheet, the warp of the 3-d tool path, or the structural necessity for digital production. This is a process in which Wassim Jabi demonstrates “the emphasis on structure is crucial to this shift [to digital production].” (Jabi 2004)

In terms of visualization, Branko Kolarevic argues: “the need to externalize representations of design, i.e. produce drawings, will lessen as a direct consequence of the new digital possibilities for producing and processing information.” (Kolarevic, 2003) Nonetheless, visualization is still necessary. This paper will examine emerging forms of visualization for fabrication that communicate not on the perceptual/representational, but on the operative. A visual communication intended as much for the machine as for its human counterpart. An important distinction is made by Sharples, Holden, and Pasquerelli when they discuss a division in the
simulation process from the versioning (and fabrication) process: “While simulation remains a useful formal estimate of future organizational strategies, versioning of vector-based information allows immediate results to be transformed and refined as the previous tests feed additional data through the framework of intentionality” (ShoP, 2003). Finally, these new forms of visualization resulting from simulation and digital fabrication are more akin to scientific visualization cultures such as medical imaging. This kind of visualization is more interested in tolerances than in shadows, and in productively feeding back to revise an iterative design strategy.

1.1. Representing today our future buildings

In the late 20th century, prominent “paper architects”—those known primarily for their ideas and proposals, rather than completed buildings—relied heavily upon experimentations in representation. A number of these “paper architects” (such as Daniel Libeskind, Zaha Hadid, Rem Koolhaas, Peter Eisenman, Thom Mayne, and Bernard Tschumi, et al.) are now actively engaged in building, and demonstrating that experimental representation methods they used in the past are directly informing their design processes in their built work. Similarly, digitally-driven architecture today entails many experiments that suggest promising new directions for the future of design. Innovative representational devices are evolving which allow new forms of organizing and visualizing complex data—a necessity for directing machines to follow multiple levels of operations during the fabrication process. These representations inform the design process as feedback for new design iterations before final fabrication. Once the process of this interaction becomes clear to the designers, we can see a shift in scale applying the same principles. Consider today the movement of ShoP in New York City in just a short few years from an installation at PS1, to multiple condo units, to a master plan of the East River in Manhatten (in conjunction with Richard Rogers).

1.2. Changing practices require changing processes

Innovative building fabrication techniques (i.e., the processes of manufacturing the various physical components of buildings) that were once considered at the experimental edge are becoming commonplace and are changing the definition and organization of architectural practice. Increasingly, the design process entails a kind of “conversation” between digital visualization and digital production. Once the design information is ready for translation into physical form, the digital files used to generate the project are prepared so as to drive the fabrication process. The cladding of the Porter House Condominium, a recent project in New York by SHoP Architects, is an innovative example of this in practice. Digital information was fed directly into a laser-cutter to produce the zinc panels that line the building’s façades, creating a smooth transition between the design and the fabrication process, and eliminating the need for typical “shop drawings” (drawings prepared by the fabricator to confirm that a given product will be consistent with the architect’s intentions). Varying degrees of fabrication are deployed in ShoP’s innovative practice. The recently completed Camera Obscura is an example of a 100% digitally fabricated project. Rather than using the traditional plans, elevations, and cross-sections to explain how to assemble the building, SHoP used three-dimensional diagrams directly generated from the computer model to explain where each assemblage was located in order to facilitate construction. At the 2003 ACADIA conference at Ball State University, partner Chris Sharples likened this innovative process of assembly to a “very large model airplane kit, just like when you were a kid.”

Branko Kolarevic asserts, “Digital technologies are enabling a direct correlation between what can be designed and what can be built, thus bringing to the forefront the issue of the significance of information, i.e. the issues of production, communication, application, and control of information in the building industry. By integrating design, analysis, manufacture, and the assembly of buildings around digital technologies,
architects, engineers, and builders have an opportunity to fundamentally redefine the relationships between conception and production. The currently separate professional realms of architecture, engineering, and construction can be integrated into a relatively seamless digital collaborative enterprise…” (Kolarevic, 2003)

Technologically driven change has always been a catalyst for new ideas in architecture, and today, digital technology is a key agent for innovation in design and construction. The central requirement is the clear, reliable, and consistent exchange of information among all parties involved in creating a given project.

1.3. Various techniques

Parametric relational structures, such as those generated in CATIA and Pro Engineer, provide an important way for designers to move beyond visual representations to the issues and relationships underlying the operational and geometrical make-up of architecture. The relationship tree is a mapping of the rules, constraints, parent/child relationships, and parameters of a project, continually adjusted as the project evolves by way of a feedback loop between designers and makers. This mapping allows the design team to manage complexity as projects usually exist as a multiplicity of files that elude the typical notions of identity. Ingeborg Rocker discussed this when she stated, “...‘identity’ evolves and dissolves solely through the differential in-forming process, the repetition of difference throughout time. The object’s formerly presumed unity dissolves as its versions, and the versions’ relations, evolve. Subsequently, identity never becomes entirely comprehensible as it solely becomes a temporal, relational and hence incomplete remaining construct. Identity evolves and dissolves like a diffuse network that continuously transforms, and therefore becomes rather than exists, through the
profund play of difference and repetition.” (Rocker, 2003) The parametric relational structure is a way of mapping the feedback loop-based digital process, a way in which one perceives the richness of careful decision making by seeing beyond the temporality of the design’s graphic identity.

The growing role of simulation in digital design has led to architectural representations which look more akin to structural, aerospace, automotive, and even medical diagnostics. Finite Element Analysis can simulate and display stresses, heat transfer, and fluid dynamics by color-coding the digital model. Similarly, Gaussian Curvature Analysis can be used to check the manufacturability of a surface by analyzing the surface quality and curvature magnitude. Such factors as surface continuity and developable surfaces refer to the operational unfolding and machining of surfaces rather than any spatial or tactile qualities. While typically occurring behind-the-scenes, all of these representational tools allow the design team to make more informed design decisions in less time and are necessary for communication between architect, engineer, and fabricator.
Sectioning, unfolding, and nesting representations are all extracted from the digital master model as a means to directly generate the tooling and manufacturing of building components, taking the place of conventional fabrication shop drawings. While this commonly takes place at the end of design work, intended for direct communication with CAM software and computer-driven machines, the quick automation of these forms of representation by special algorithms allows a design team to create unfolding and nesting diagrams throughout the design process. This feedback loop provides analysis of efficient use of materials and machining time. Fabricated mock-ups and prototypes can be manufactured in this way to test tolerances. Just as photographers perform bracketing tests to adjust the parameters required for the perfect image, the design team can quickly generate details to achieve perfect fitting tolerances for building components.

As digital tools provide the opportunity for serial differentiation, countless design variants are generated during the design process. Matrixes allow the designer to manage and examine this repetitive complexity. The matrix is a graphic way to convey past decisions in the context of the resulting variants, as well as, to direct the next set of decisions and chart new trajectories of inquiry and exploration. Zahner Metals employed the use of a matrix to keep track of the flow of digital information for the fabrication of Herzog and De Meuron’s copper skin cladding of the deYoung Museum in San Francisco. Digital model files were charted according to the operations performed (such as slicing, unfolding, stamping, and punching) and the timetable of the fabrication and assembly process. Matrixes are also useful in arranging variants created in surface/form-based searches and animations sequences, generated by key-framing or inverse kinematics. In any case,
matrixes are a way to graphically document process and technique—a process/product—rather than any single, final design solution.

2. Conclusion

A new taxonomy of representational devices in architecture is useful to assist the designer in visualizing information that will inform their digital design processes. While useful mostly behind-the-scenes in the case of digital fabrication, representations of the design, simulation, and fabrication processes are still powerful tools for the design team to organize and manage complexity, streamline the design and fabrication process, and to test and simulate qualities of production such as manufacturing efficiency. It should be said that, while these representation tools seem cutting-edge to the profession of architecture, most of them are borrowed and adapted from other disciplines and industries. No doubt, these tools are extremely useful for architects in the development of a process/product and will continue to evolve. All of this begs the question of what takes precedence, the process or the product? The end product is what the public sees, feels, and experiences in the physical environment. But, the design process and feedback loop requires the ability to convey information through innovative graphic representations. These new types of representational strategies are a truly powerful tool in the creating not just one final product, but also a multitude of variants for digital fabrication.

References


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