Information Exchange in Digitally Driven Architecture

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Abstract *Digital technology has altered modes of architectural production. Software enables architects to create complex digital models with multiple layers of information, and use this information to fabricate physical building components with machines driven by CNC (computer numerical control) and other advanced manufacturing techniques. As a result of this new potential brought on by managing and exchanging information, both the ways in which we think about architecture and the instruments and techniques we use to envision, evaluate, simulate, fabricate, and assemble architecture are forcing a reconsideration of the mechanisms for developing and producing a built work. Technology has historically served as a catalyst for new ideas in architecture. Today, it is digital technology serving as the key agent for innovation in design, fabrication, and construction. Critical to an effective new methodology is the clear, reliable, and consistent digital exchange of information among all parties involved in creating a given project. This paper will articulate shifting skill sets necessary for digitally driven architecture and make the case for encouraging effective means of communication and information exchange through case study illustrations and presentation of a specific project developed at Ball State University's Institute for Digital Fabrication and the Center for Media Design.*

Digital Exchange Exchange of information is central to the building enterprise. Communication and collaboration between architects, manufacturers, fabricators, material suppliers, and contractors is key to the success of digitally driven architecture. As Branko Kolarevic has clearly stated, "the currently separate professional realms of architecture, engineering, and construction can be integrated into a relatively seamless digital collaborative enterprise…" (Kolarevic, 2003). All participants must be willing to collaborate in order to benefit from this exchange, and therefore, architects must engage in new methods of communication at different stages of design through production. The medium of exchange is most frequently through data files (for communication, testing, modeling, and manufacturing). This restructuring of process and communication is literally an entire digital platform for information exchange that traces a project from conception through fabrication and management of assembly. The important question remains, how will we participate in the exchange? The roles of the participants are still in flux, and vary on a per project basis and also vary in levels of complexity and scale. Additionally, contractual arrangements in the building enterprise still need to evolve to facilitate exchange as the digital master model plays a more central role for feedback at all stages of the design and build process. Regardless, a major shift is occurring in modes of architectural production and master model lies at the center of this shift.

Master Model The master model provides a three-dimensional representation of a project and all of its individual components. The importance of the master model is that it is embedded with design decision and production information such as geometry, material properties, performance potential, fabrication information, and assembly knowledge. The model can be used in four primary ways:

First, the master model encourages systems of relationships, associations, and constraints created parametrically which describe the interactions between components, assemblies, and context. In this way, inevitable design changes are easily propagated through the entire model, eliminating repetitive modeling tasks and ensuring greater freedom for variety. Second, the master model allows for the simulation and testing of a project, using digital tools to analyze its performance under gravity, wind, and other simulated data forces. Third, the master model contains all of the geometric information needed to directly fabricate or manufacture a product or component. NC tools and advanced manufacturing techniques use the digital information for precise production of standard and non-standard products. Different prototypes can be created without expensive retooling providing a means to inform the master model according to actual material production through a "physical-to-digital" feedback loop. Fourth, the master model facilitates the assembly of complex products and projects as a database of parts and locations which can support bar-code scanning, direct laser positioning systems, and track material and part inventory. Assembly, construction, and shipping/delivery can be phased, choreographed, and coordinated through to completion.

The master model is the center of digital exchange. Value is added through the evolving model as each agent in design and production weighs-in on the project with knowledge, expertise, and decisions. The digital exchange, using a digital master model is cross-disciplinary, collaborative, and achievable at any scale.

Digital Exchange Case Study 1: the MIT Stata Center A case study at the highest level of complexity and scale, the MIT Stata Center in Cambridge, Massachusetts, designed by Gehry Partners illustrates digital exchange occurring at a significant number of levels throughout the design development and final construction. Started as a basic model of the design idea, the master model evolved into a completely detailed document of every part of the building as the architects, engineers, and other consultants continually added information. The model allowed this large design team to coordinate their efforts and manage the complexities of a large project. Every piece of the building was modeled, including the structural, cladding, and mechanical systems; by the end, the completed master model held all of the information needed to manufacture and assemble the building. Digital fabrication information from the master model was exchanged with fabricators and manufacturers for making many of the components. The players integrated in this innovative digital exchange included Gehry Partners working with CATIA software (Gehry Technologies/Digital Project) for computer modeling. Skanska International was responsible for the construction. A. Zahner Architectural Metals were employed for the fabrication of the metal skins, CAPCO for the structural steel, and John A. Martin for the structural engineering, and others. A digital master model was the central source of information exchange with all of the participants examining and contributing at various stages in the process, thus transforming the entire design and building process. For instance, using data developed collaboratively with the architect via the master model, the stainless steel exterior panels were digitally fabricated in Zahner Metals' indoor shop facility, allowing for incredible precision. The 20' x 40' panels were bar-coded and shipped to the job site ready to be bolted in exact position to the building structure. Assembly knowledge was gleaned from previous experience with Bilbao: "Each structural component was bar coded and marked with the nodes of intersection with adjacent layers of structure. On site bar codes were swiped to reveal the coordinates of each piece in the CATIA model. Laser surveying equipment linked to CATIA enabled each piece to be precisely placed in its position as defined by the computer model" (LeCuyer, 1997).

Digital Exchange | Digital Fabrication Case Study 2: Camera Obscura
A smaller scale case study serves as a proof of concept for the digital exchange of information at the small building scale. In fact many of the examples of digital fabrication exist as small-scale interventions and building skin applications. Digital fabrication techniques, once considered experiments in abstract form generation, are today fundamental to redefining methodologies of architectural practice relying heavily on feedback between digital modeling and digital production. The Camera Obscura by SHoP Architects remains a good case study of an entirely digitally fabricated project. Rather than using the traditional plans, elevations, and cross-sections to explain how to assemble the building, SHoP used three-dimensional assemblage diagrams directly generated from the computer model to explain where each component was located in

order to facilitate construction. Additionally, every part of the construct was preconceived in the model that exported its information to fabricate the final building component pieces.

Digitally Driven Architecture…

We can no longer think about CAD-related software in the simple terms we have known; rather, we must critically deploy multiple software platforms and garner agility with its use in the service of a digital master model. Much of the energy of digitally driven architecture is process-based and about effective management of the tools in order to better inform initial design thinking. It is important to note that the question about design decision-making is still left open. Many of the new digital design languages "borrow terms and reflect qualities specific to the jargon of the digital tools we use. However, a clear and critical definition of new principles has yet to materialize..." (Klinger, 2003). Although, Joseph Rosa pointed out in the early years of digital fabrication that "terms such as beauty, scale, and proportion that were once used to describe the massing, articulation, and texture of pre-digital architecture have given way to adjectives like smooth, supple, and morphed, derived from digital-age vernacular" (Rosa, 2001). Nonetheless, it seems that process oriented pragmatic problem solving strategies are what gets all of the attention. The question of design principles is still a rich territory for scholarly attention.

Today, effective management of a raft of digital skills and devices is paramount to well-developed digitally driven architecture. This fact has broad implications on how we train architects for a future that relies upon digital exchange. Some of the digital skills necessary to operate digitally driven architecture include: vector graphics, image manipulation, three-dimensional modeling: surface modeling/ solid modeling/ parametric modeling, video editing, motion graphics, scripting, three-dimensional printing, stereo lithography, database development, GIS (geographic information systems), web interface, fabrication/ CAM, performance analysis, lighting simulation, and many more. A greater diversity of digital expertise is necessary in the design through production process.

Innovative representational devices illustrate the need for shifting skill sets and devices for communicating digitally driven projects. "The ability to move directly from three-dimensional modeling to real three-dimensional output challenges the need for traditional means of representation such as plan, section, etc. This subjugation of traditional forms of representation and fabrication has serious implications for architectural design process and production." (Klinger, 2001) Plans and sections have given way to devices such as nesting diagrams, unfolding, surface optimization, and material tolerance simulations, and more. These new devices emerge from the need to direct machines to cut, bend, and fold precise physical shapes. However, these devices also allow us to envision possibilities by informing the design process and revealing relationships previously unseen in more traditional methods. By final fabrication form has been effectively informed. As we cycle through modeling, simulation, analysis, and fabrication, and assembly information is gained that enriches the design before the project is even built, and perhaps even altering the original design direction. Multiple iterations are necessary to evolve design, and many more players are weighing in at earlier stages in the modeling phase.

In response to new potentials of digitally driven architecture, countless architecture degree programs are retooling their offerings by exploring potentials of digital fabrication within the architecture curriculum. We are just beginning to scratch the surface. As we think about the complexities of a an entire design through production process, the digital exchange of information throughout the entire process, and the issues that allows us to digitally envision, evaluate, simulate, fabricate, and assemble architecture will be important considerations.

Immersive Education for Digitally Driven Architecture…

The Institute for Digital Fabrication at Ball State University aims to leverage its unique design expertise, digitally driven architectural research, and industry engagement. By providing students with an opportunity for an immersive education experience (involving students in applying digital research on real-world projects with regional industry partners) and address the skills necessary for engaging the digital exchange. Students and industry through experimentation are able to retool their methodologies and apply the digital exchange model at various scales--from furniture to building components. The hope is to help broaden Indiana's advanced manufacturing initiatives to serve the state's design and building industry, and expand Indiana's capacity for creative production in existing areas such as architecture and interior design. Indiana has had a long and important tradition of manufacturing and material processing. Our recent efforts have reached out to the Limestone Industry, Hardwood Industry, Steel Industry, Prefab Industry, and Furniture + Cabinet Industry. Full examples of our research and immersive learning offerings are posted on our website: www.bsu.edu/imade.

Ball State University Immersion Case Study: Smartscrap The Institute for Digital Fabrication at Ball State University is presently working on a research project with the limestone industry to test design strategies using a digital database of component pieces from available scrap material. We do this by digitally cataloging waste products from the Indiana limestone industry and developing computational means to apply the catalog information to parametric design models in order to effectively reuse the waste. This system, entitled "SmartScrap", is unique by improving the flow of information from the fabrication process back to inform the initial design decision-making. Completing this digital information feedback loop seamlessly informs design and fabrication decision-making based on available sizes, shapes, and quantities of leftover/waste stone inventories. The Smart Scrap System is funded in part by the Graham foundation for the Fine Arts.

SmartMosaic is one application of the Smartscrap system. Members of the Institute for Digital Fabrication attended the Smart Geometry Workshop in 2007 in New York City to develop the process with the parametric software and scripting capabilities of Generative Components. Other software such as Rhino and Excel are fundamental to the development of this prototype.

The concept of the SmartMosaic system is to select a typical dimension scrap with standard x and y coordinates (resulting from standard slicing techniques in the limestone industry) and scan/record the variable z heights along with color/texture information into a scrap catalogue. These pieces will be labeled with a bar-code for storage. The database catalogue will be available to the parametric modeling system.

The next step is to go into a parametric model to begin design visualization, where we can control the finish of the final façade surface. In the Smartgeometry case we were working with a b-spline surface. In other cases, we are actually importing image data and translating the height of pixel information into a surface condition. Since we have a catalogue of scanned limestone scraps, we use a script to query the database for available pieces to find out what's available to plug into the matrix. Once we have established the field conditions with these pieces we are able to go straight to the physical catalogue with bar-coded pieces and assemble each unique panel system.

Smartscrap illustrates a direct link between design students and the limestone industry. The digital exchange of information is central to the development of this and other similar projects at the Institute for Digital Fabrication. It is our belief that these kinds of unique collaborations will enable students to embark on a more collaborative future in architecture that deploys digital skills to envision, evaluate, simulate, fabricate, and assemble buildings in the future. As conditions shift for architectural practice, collaboration, direct industry engagement, and digital acumen will be fundamental skills for future architects in an evolving world and which relies heavily on information exchange to evolve digitally driven architecture.

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