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Research

Design-Through-Production Formulations

Abstract. Ever since the topic of design and digital fabrication in architecture surfaced ten or so years ago (encouraged by organizations of ACADIA, ECAADE, SIGraDi, and CAADRIA), it has thrived as a productive strategy for advancing the discipline. Clearly, new maps have been charted in architectural discourse that will steer us toward a promising future. Beyond just developing skills to serve new methods of design-through-production, we must now question what ends this methodology serves. This writing is an attempt to chart three potential trajectories inherent in a design-through-production methodology 1) outlining an ethic of production at regional levels in light of the ocean of global information access, 2) investigating the formulation of form inherent in digital design methods, and 3) finding humanist aims through a technological lens. Finally, several pedagocical cases are offered as incremental examples to a collective body of work which applies the design-through-production methodology.

Introduction

Over the decade of the aughts, architectural discourse has charted a new course. In the wake of the digital affect on mainstream architectural thinking, we find ourselves in a great age of exploration. Research in digital fabrication has moved from the general to the specific, while simultaneously contributing to emerging discourses in areas such as manufacturing, social impact, sustainable practices, biological structures, etc. Specific work on building component design, coupled with a performance-based pragmatic rigor about durability, strength, performance, and production have provided concrete examples of *design-through-production* investigations, and led to further clarity that the "state of the art" is indeed flourishing within and without architecture.

Open methodology

This moment in the world has engendered a shift in production (physical and cultural) as significant as the Industrial Revolution, and quite possibly even the shift from the late Medieval period to the Renaissance. Although patronage such as that of the Medici during the Renaissance is not clear today, the shift in production is being led by the technological and relational capacity of information; as the work synchronizes to the latest software, it coordinates a massive exchange of information across all cultural and political territories. As such, traditional, highly specialized disciplinary boundaries and methodologies are proving inadequate to engage the complex and interconnected questions of a global society affected by information technology.

Given global connectivity, digital communication has become central in a design-through-production process. Critical team-based machine, computation, and *most* specifically, human interface strategies are essential to solve today's complex problems, which span unsystematically over and under our established methods of problem solving. William Mitchell summed up the necessity for a new methodology in how we take on contemporary design questions quite clearly:

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> One of the huge problems with design has been the way that the lines get broken up into these traditionally defined disciplines… The big important design issues just don't fall in these categories anymore. They sprawl in messy ways across them. We [at MIT] have architects, urban designers, economists, mechanical engineers, electrical geeks, and we put them together into an intense multidisciplinary design environment… it's everyone's responsibility to contribute to everything and educate the rest of the group as necessary on the issues that you know the most about [Makovsky 2010: 52].

Connect globally / Make locally: an ethic for design-through-production

Design-through-production projects may find unique solutions in any region by customizing open and globally shared methodologies to particular local conditions; researchers connect to the global stream of information about digital design techniques, and engage local industry partnerships invited to add specific value to the feedback loop. Bringing industry partners into the collaborative early adds tangible and practical value to the design process from the outset, and provides a demonstrable service to the region by affecting industry, both in methodology and in production. No matter the region, there are established material, cultural, and industrial processes that may inform and be informed by the digital information exchange in a design-through-production process.

Form is informed by performance

To be certain, each new design-through-production project explores unique territory and contributes to the knowledge map by adding to a matrix of possible applications. In most cases, *Form* is in*form*ed by per*form*ance!—this is the great customizable mantra for this new era in design. Yet, the principles that govern the human decision-making, in light of this new kind of digitally generated work, have yet to be clearly articulated. Nonetheless, techniques and methods have expanded to create new opportunities for making architecture and related design projects. In fact, research has tended to be less about framing new principles for making digital architecture and more about adding specific cases to the knowledge base, as each new project helps to define a collective body. Alongside slowly emerging theoretical rudders (steered towards advancing emerging processes of digital design and fabrication) are the essential pragmatic applications of *production* knowledge that truly keeps this discourse afloat—locally crafted material must perform according to the laws of physics, the demands of budget, the tolerances of equipment, time constraints, local restrictions, etc. Additionally, today's digital *design collaborative* needs to be simultaneously well-versed in the interrelationships between geometry, digital modeling, parametric organization, performance simulation, and the like.

Technology and humanism

Are we experiencing a Neo-Renaissance? Indeed, there is a re-birth of sorts underway brought on by flows of information, leading to a collapse of old and constricted paradigms. Yet, the term "re-birth" is less prescient than the term "re-scripting," which suggests an undoing or reworking of traditional methods; perhaps, then, we are in the first years of a DE-naissance—an un-birth of tired methodologies, practices, and disciplines!!!

As methods for design and production are re-scripted, what DO we value? Technology is certainly the key driver of a new paradigm, and certainly, the technologist is critical to the conversation today. Along these lines (and sixty years ago), Mies Van der Rohe argued for the total interconnection between technology and architecture:

> Architecture depends upon its time. It is the crystallization of its inner structure, the slow unfolding of its form. That is the reason why technology and architecture are so closely related. Our real hope is that they will grow together, that some day the one will be the expression of the other. Only then will we have an architecture worthy of its name: architecture as a true symbol of our time [Van der Rohe 1950].

Lewis Mumford countered Mies van der Rohe's position by positing that,

> progress, in an organic sense, should be cumulative, and though a certain amount of rubbish-clearing is always necessary we lose a part of the gain offered by a new invention if we automatically discard all the still valuable inventions that preceded it [Mumford 1964].

The tension between van der Rohe's and Mumford's arguments presented here, is exactly the debate that we must engage today between technological and humanist approaches.

Now, technology is discussed most frequently as "informational technology," and we are seeing its influences across the broad spectrum of society. However, projects that advance only technology for the sake of technology seem to fall flat. In light of the influence of information technology on society, can we develop a humanist position to help ground solutions to contemporary problems? As we restructure how we design for complex contemporary conditions, regardless of technology, the human is always in the middle of the equation. Scientific formulations only establish the fields and conditions of operation, but a dataset without practical human application will ring hollow.

> Even though scientists have the most to do with technological imagination as invention, they generally feel very little responsibility to participate in the technological imagination as part of a larger social imagination [White 2003: 121].

Steve Jobs of Apple Computers underscored this necessity for the human relevance of technology in his Apple Keynote on March 2, 2011: "It is technology married with liberal arts, married with the humanities, that yields us the result that makes our hearts sing" [Jobs 2011]. To this end, the real potential of design-through-production lies not in the *design* (input), nor the *production* (output), but rather in the human decision-making influencing a collective human impact (*through*put).

The Institute for Digital Fabrication

At Ball State University, we have a commitment to two pedagogical strategies: *immersive learning* and *emerging media*—in other words: engaging industry directly, and cultivating skills with information technology. *Immersive learning* aims to intersect classroom activity with real world partnerships. *Emerging media*, explores the latest technology in order to prepare students for our information-driven world. The Institute for Digital Fabrication (IDF) at Ball Sate University believes that these two areas add a strategy to the pedagogical formula that is critical for making a regional impact while still adding valuable knowledge within the global exchange of ideas. The Institute for Digital Fabrication encourages a digital design-through-production methodology and curriculum through the lens of multiple course-based projects. These courses are a central component of our *immersive learning* pedagogy, simultaneously preparing students to develop a skill set with digital information, while directly collaborating and sharing skills with industry partners. More importantly, this pedagogical method always promotes team-based design groups over sole authorship as a more realistic preparation for

students. Information exchange is central to the realization of team objectives. As such, communication and information sharing skills keep the collaborative productive as projects evolve by effectively managing feedback and the global exchange of ideas between local production and design. Each design-through-production problem is seen as contributing a case to the emerging discourse, whether it be about different materials, performance properties, and mostly practices of industry in regards to the material. In this way, solutions for each parameter that constitute the design problem are useful as a reference to a collective catalogue for emerging design-through-production-based practices. This particular case-based scholarship, by dealing with unique input variables, makes relevant each operative strategy of folding, carving, bending, and the like. The key is the open sharing of information, in order to affect innovation for those who are chasing similar problems. Each project carries with it a wealth of design and production formations informed by material limitations, formulating details, full-scale production considerations, fabrication devices, different form generation techniques, etc.

Collectively these projects interrogate technology, and the real hope—human considerations, that will make significant additions to the map for the future of architecture in this great new age.

Cases for the Institute for Digital Fabrication

The following projects are to be seen as case contributions to the discourse on digital fabrication using design-through-production methodologies at Ball State University in the Department of Architecture.

Case in design-through-production : Center for Media Design Institute for Digital Fabrication

Fig.1. Digital office customized interior

This commission used design-through-production strategies for the Center for Media Design unit at Ball State University and was overseen by Joshua Vermillion, the Operations Manager of the Institute for Digital Fabrication (fig. 1). Each station was designed primarily in Rhino and Grasshopper, by cutting small undulating strips from full plywood sheets and, by deploying a zero-waste strategy, maximizing the yield of each panel. The components were custom-machined plywood and aluminum work pods derived strategically from clients' organizational and digital workflow.

The form integrates function with dynamic gradient effects of thinness/thickness and porous/solid effects. Light becomes a secondary "material" participant by engaging the user as it appears and then disappears through changes in vantage point, and temporal shifts.

Case in design-through-production: Transformer
Institute for Digital Fabrication

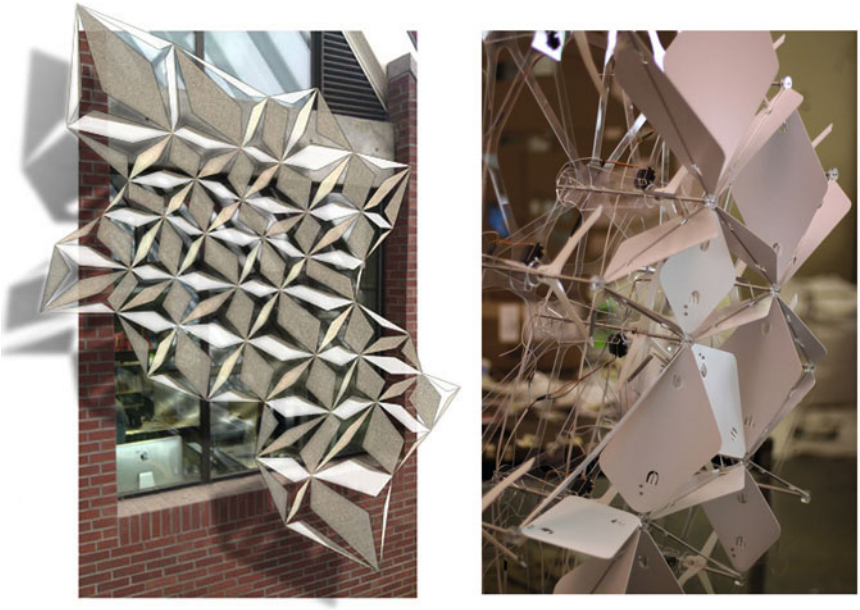

Fig.2. Sensor reactive light screen

Transformer is a layered, light-responsive shading lattice, designed and fabricated by an interdisciplinary team of students and faculty (fig. 2). The system acts as an active shading device, potentially for use within a building envelope. The prototyped system is comprised of quad-shaped, polystyrene petals arrayed in overlapping, radial clusters. The petals are situated within a lightweight but rigid and patterned support armature formed from planar polycarbonate and acrylic components while housing matrices of sensors and motors. Local variations in petal movements and aperture size are controlled by simple microcontroller arrays and varying script configurations that interpret light data from photoelectric sensors to drive small servo motors. The axial rotations from the servo motors are converted into opening and closing motions for the petals via custom gears and axles.

Case in design-through-production: tetraMIN
Institute for Digital Fabrication

The hanging screen aggregate named tetraMIN consists of componentry generated from tetrahedron geometry via Rhino's Grasshopper parametric modeling plug-in (fig. 3). Comprised of laser cut polytetrafluoroethylene (PTFE) scraps, each component forms a periodic minimal surface, and is propagated into a regular pattern by a series of reflecting/mirroring operations. The PTFE is the former roof material from the RCA Dome, a large pneumatic roof stadium prior to demolition in 2008, and was donated to the studio by People for Urban Progress, located in Indianapolis, Indiana. System prototyping and fabrication was accomplished in one week by a nine-member team of Ball State University architecture students. Working with the Institute for Digital Fabrication's faculty and equipment (primarily laser cutters), the team fabricated each component with a tab-and-slot connector system to enable the assembly of the screen. Inexpensive zip ties are also strategically deployed throughout the screen assembly for structural stiffening.

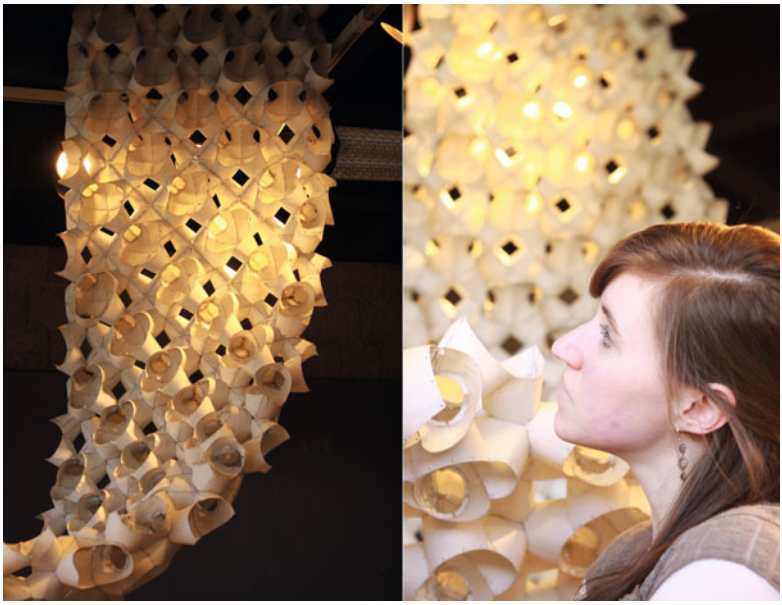

Fig. 3. "tetraMIN", PTFE woven fabric installation

Case in design-through-production: Titanium Bridge
Institute for Digital Fabrication

A digital design and fabrication seminar took on the challenge to develop entries for the Titanium Pedestrian Bridge Competition entitled "Design the Future" (fig. 4) Our interest in this program was two-fold: it was a real project located in the American Midwest (Akron, Ohio), and it was sponsored by the Defense Metals Technology Center, whose agenda was to find more civilian uses for titanium technology. The competition brief states: "Where better to find skilled competitors than from Civil Engineering, Architecture, and Industrial Design departments and schools of qualified universities in the Metals Heartland of America…" This kind of informed client, certainly contributes to making the case for building bridges towards a midwestern regional identity.

Fig. 4. Titanium Bridge: Ball State Scheme using 100% titanium

Case in design-through-production: Indianapolis 500 Hall of Fame Museum Institute for Digital Fabrication

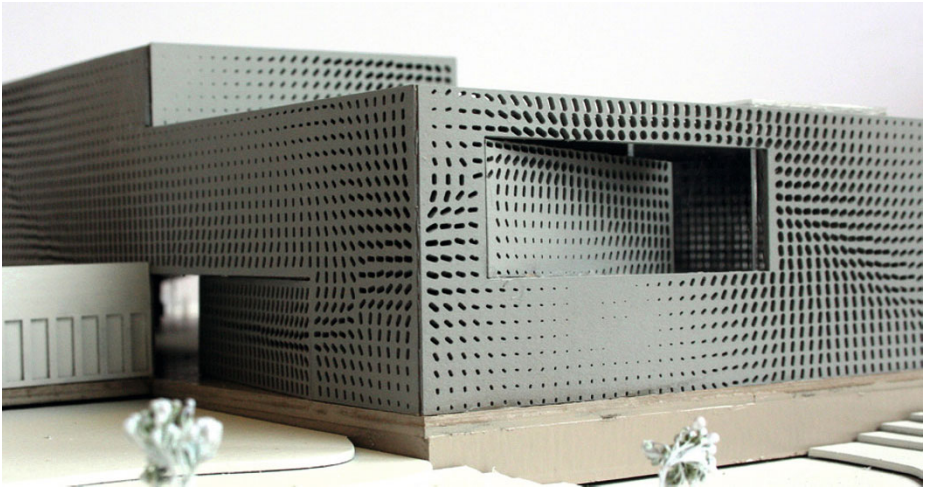

Fig. 5. Indianapolis 500 proposal, content, and team: speed + performance

Students aligned in the first half of the semester into "innovation garages," (led by Professor Mahesh Daas), which involved collaborative teams aimed at brainstorming innovation. The second half of the semester they organized in partnership with the Indianapolis Motor Speedway and proposed an addition to the outdated Indianapolis 500 Hall of Fame Museum (fig. 5). The project goal was to deploy innovative design methodologies and fabrication techniques for a cultural institution that resonates so deeply with the Midwest's culture for production: Indiana is the home of innovation in

the automotive industry. In 1852 in Kokomo, Indiana, Elwood Haynes invented one of the first successful gasoline-powered automobiles. For a hundred years, the "Indy 500" has been the international proving ground for innovations in automobile technology since the invention of the motor-car.

Case in design-through-production: ReBarn Institute for Digital Fabrication

A digital design and fabrication seminar partnered with regional metal fabrication experts at Zahner Architectural Metals in Kansas City, and developed a strategy to repurpose barn siding (275 unique pieces for a total of 300,000 board feet) from a one-hundred year old "Pennsylvania style" barn located near Muncie, Indiana (fig. 6). The project, developed in partnership with the mayor and local parks commission, enhances a public park along the White River. Students and Zahner discussed this project very early in the design-through-production process in order to effectively design, engineer and fabricate reBarn. This collaboration included exchanging information online, and a meeting at Zahner's office in Kansas City, and led to five water-jet cut aluminum surface panels and over 350 variable aluminum joints. Each reclaimed wood component was custom milled using a 3-axis CNC router. The digital design and fabrication technologies along with industry partnerships were instrumental in realizing the project.

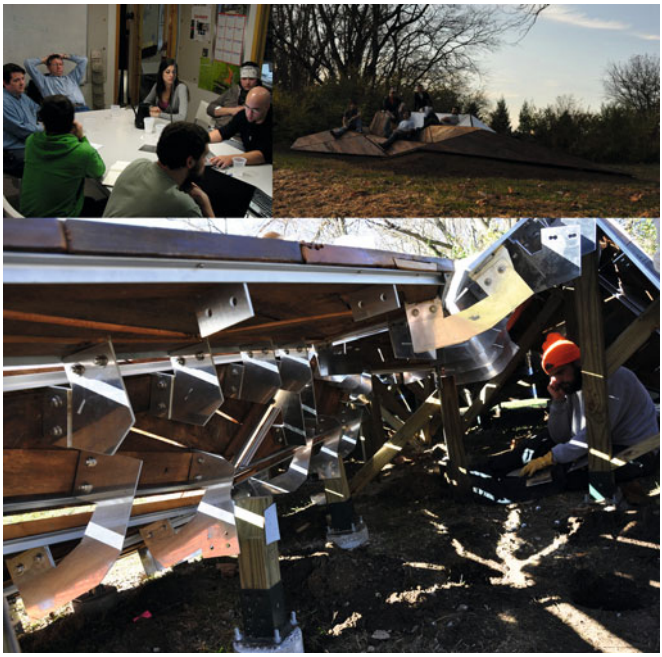

Fig. 6. ReBarn: collaboration, assembly, and occupation (Zahner Metals tooled aluminum and barn siding)

Conclusions

While no clear "Medici" is directly behind the evolution of the present condition, certainly the academy plays a significant role by encouraging new skill sets and training in preparation for a globally-connected/locally-affected world. Nonetheless, many of our

present models for training and engagement are outdated. Particular to the Midwest region of the United States,

> Longworth advocates the development of a regional identity and midwestern think-tanks that will generate new ideas and a focus on issues common to the region. He also calls for a wholesale renovation of education and training… [Carr 2009: 14].

The design-through-production approach to projects can be applied to any region working with particular local conditions and sharing knowledge globally. The above *immersive learning* projects rely heavily on interdisciplinary, applied design and fabrication research, and the evolution of expertise with state-of-the-art software and devices using simulation, analysis, fabrication, and a rigorous examination of the craft inherent in digital design and production. Students connect to the global stream of information about digital design techniques, and work with consultants invited to add specific value to the feedback loop. Industry partners from the local manufacturing sector are integral participants around the virtual table as students formulate their strategies. In the design-through-production methodology, information about final production constraints is essential to initial design approaches. As such, bringing industry partners into the collaborative early adds tangible and practical value to the design process from the outset, and makes a demonstrable contribution to affecting regional industry and labor, both in methodology and in production strategies.

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About the author

Kevin R. Klinger is Director of the Institute for Digital Fabrication at Ball State University, Associate Professor of Architecture, and Director of the Post-Professional Master of Architecture program in the College of Architecture and Planning. Kevin was responsible for developing a Certificate for Digital Design and Fabrication for Ball State University. He has also served as a two-term President (03-05) of the Association of Computer Aided Design in Architecture (ACADIA), an international organization devoted to studying the advances in architecture resulting from influences of digital technology. He was an author and co-editor of the book by Routledge entitled *Manufacturing Material Effects: Rethinking Design and Making in Architecture*, developed in collaboration with Branko Kolarevic. The book assembles leading thinkers, designers, and makers from around the world to discuss experimental processes of material exploration through examining various levels of engagement and new forms of architectural production that bring designers deeper into the complexities of making, assembly, and material formulation. In coursework and through partnerships with the institute, Professor Klinger encourages explorations

in digitally-driven design, deploying techniques of digital fabrication. The Institute for Digital Fabrication operates with an ethic to "connect globally, and make locally," as it strives to both contribute to the discourse on the impact of the digital technological shift, and play a role in identifying opportunities to engage local industry and community partners. The digital exchange of information is central to this innovative process of architectural production, and demands new forms of collaboration with industry for the future of the discipline, where designers and makers are much more engaged in the total design-through-production process. As such, the Institute for Digital Fabrication is devoted to project-based collaborations that result from the intersection of emerging technology with students, industry, community, and research partners. For more information, see http://www.i-m-a-d-e.org.