Redefining the Parametric Pedagogy

Reflections on a digital design build studio

- Gernot Riether
  College of Architecture and Construction Management, Kennesaw State University, U.S.A
  griether@gmail.com
- Andrew John Wit
  Tyler School of Art, Temple University, U.S.A.
  andrew.wit@temple.edu

Abstract

During the summer of 2014, a unique pedagogical prototype was initiated and tested through a short five-week digital design build workshop lead by Professors Gernot Riether and Andrew John Wit at Ball State University in Muncie, Indiana. Unlike the typical design studio typology where projects are initiated through a series of top down predetermined project frameworks, this studio allowed for projects to emerge through student's navigating an area of research in digital design and fabrication. The studio was supplied by nothing more than an entrepreneurial mindset, initial budget and the requirement that an architectural project would be realized at full-scale by the end of the semester. Over the course of the semester, students tested, stumbled and pressed through a series of follies and prototypes that resulted in the realization of the Underwood Pavilion. This paper explores a novel design pedagogy, through the lens of this Digital Design Build Studio.

Keywords: Studio pedagogy, Computation, Design Build, Digital Fabrication

Introduction

As computational tools, digital fabrication and robotic systems become evermore engrained within the ethos of architectural education, it is important for educators to also reimagine our current teaching methodologies within the realms of architectural design as well as within the design build studio. To respond to rapidly evolving digital tools, we must embrace the idea of creating new and more emergent systems for learning. Rather than focusing on a top-down teaching approach concerned with the direct transferring of knowledge from professor to student, knowledge can also evolve though the students involvement in synergetic, self-organizing and interdisciplinary collaborations orchestrated in collaboration with professors. This open framework can create a diverse studio environment with the ability to quickly adapt in innovative ways to rapid changing of technology, tools and methodologies, while creating an environment of both innovation and entrepreneurship.

The current studio model can limit innovation through predetermining and constraining design parameters that the students are able to work within. Design problems in such studios can manifest themselves such as: Utilize a specific design method, design a specific building type, design for a specific function, design for a specific site, design with a certain material or to a specific scale. Rather then beginning with such predetermined goals the "Digital Design Build Studio" that will be discussed in this paper will question the typical design studio process by deriving a framework defined by two main guidelines: 1) Research: contribute to a current discourse in digital design and fabrication and 2) Application: conclude the investigation and research with the realization of a full-scale architectural installation within a given budget and completed within the studio duration of five weeks.

Rather than focusing on the production of a set of desired artifacts, the goal of the "Digital Design Build Studio" was to maximize the possibility of novel emergent ideas through the fostering of a collaborative and entrepreneurial mindset within the studio. The final built project was created through the application of newly developed design processes rather than a project goal decided upon from the onset.

Figure 1: The Underwood Pavilion.

This paper will examine the "Digital Design Build Studio" course format, the student's self-organizational abilities and follies, emergent interdisciplinary qualities and proposals, as well as research projects, prototypes and methodologies that emerged through the utilization of this pedagogical prototype that ultimately led to the creation of the Underwood Pavilion (Figure 1). In addition to successes, this paper also examines the hardships, failures and mishaps associated with this studio approach.

The Digital Design Build Studio Methodology

Design Build Studios have always challenged pedagogical frameworks for different reasons. Depending on their goals, different models already exist.

One of the first promoters of the "design build" idea in the U.S. is Steve Badane's design build studio Jersey Devil. The firm was founded in 1972 by the bringing together of skilled craftsmen, architects and inventors. Since then his idea of design build has influenced many architecture schools within the U.S. such as the Yestermorrow design build school, founded 1980 by John Connell as well as the University of Alabama's Rural Studio which was founded 1993 by Dennis K. Ruth and Samuel Mockbee. The main objectives of these programs were to impart practical experience to architecture students while also demystify the building processes. Using hands-on experience, students were taught not just how to design, but also the skills of craftsmanship and community engagement.

Currently, the increasing availability of robust digital design and fabrication tools within architecture schools suggests a new kind of design build studio characterized by the emergence of novel digital tools, design instruments and methods. A new studio typology can now focus both on the possibilities inherent within digital design and fabrication processes, as well as on the challenges and opportunities associated with automated production. A design build studio driven by these issues might not only teach architecture students about innovative digitally focused workflows such as: design to material, fabrication, assembly and construction, but can also become an important research tool outside the studio, affecting communities, construction industries and the practice of architecture and the discipline of architecture as a whole.

Although digital fabrication tools have become the norm within architecture schools, there are a few schools that have clearly defined themselves with digital fabrication as one of their main research agendas such as the Architectural Association (AA) in London, the ETH in Zürich or the Institute for Computational Design (ICD) and the Institute of Building Structures and Structural Design (ITKE) at the University of Stuttgart. In many of these cases, design build projects are realized over more substantial periods of time, spanning multiple semesters while also harnessing high-level researchers seeking post-professional or doctoral degrees.

Most of the projects developed by these institutions re-explore material, tectonics and structure through a novel digital lens. The DRL10 Pavilion for example, a pavilion designed by AA's Design Research Laboratory, was used to test a glass fiber-reinforced concrete paneling material. AA's Driftwood Pavilion experimented with timber construction techniques. ICD/ITKE Research Pavilions by the University of Stuttgart experimented with plywood sheets in their 2010 and 2011 pavilions while utilizing composites in their 2012-2015 pavilions.

All of theses projects allowed architecture students to not only experiment with materials but also test new digital design and fabrication techniques at full scale. Also the projects have a similar intention they differentiate in how they were developed and integrated into the architecture schools' curriculum.

The DRL10 Pavilion was the result from a competition, held in 2007 by AA's Design Research Laboratory (DRL). The Drift pavilion resulted from the summer studio "AA Summer Pavilion program" that ran between 2005 and 2009 by AA's Unit 2 led by Charles Walker and Martin Self. ICD/ITKE Research Pavilions by the University of Stuttgart resulted from PhD programs from two of the universities institutes; the Institute for Computational Design (ICD) led by Prof. Achim Menges and the Institute of Building Structures and Structural Design (ITKE) led by Prof. Jan Knippers.

All the projects benefitted from close relationships to industry and used sites in close proximity to the architecture schools. The AA pavilions are temporary installations at Bedford Square in front of the Architectural Association, School of Architecture. ICD/ITKE Research Pavilions were built at the university's campus in Stuttgart.

The parameters of our studio were distinctive from other studios completed at the previously mentioned institutions.

The Digital Design Build Studio by Riether and Wit

This studio differentiated in four ways form previously mentioned digital design build projects: 1) the studio was taught as a core studio in the master of architecture program and not as a post professional program such as at the AA program or PhD program at the University of Stuttgart, 2) the studio used a very different model for funding; it was primarily financed by small internal grants, 3) the project was completed with community partners and built outside the universities facilities and 4) The "Digital Design Build Studio" was run as an intense summer studio that only lasted five weeks. These differences forced the instructors to reinvent the framework for the studio entirely.

Different than in post professional degree or PhD programs, master students are not exposed to the same levels of research. Therefore the studio was initiated by the exposing of students to research questions situated within the current discourse of digital design and fabrication. Asking students to formulate a research question within that context was seen as a means of preparing them for their up-coming thesis research. The question would also allow students to further develop their research agenda that they identified throughout the summer studio further in during their thesis project.

The studio was structured around weekly deadlines, defined by the students at the beginning of every week (Figure 2). Deadlines were accomplished in specific, research-oriented teams also defined by the students. The open course structure allowed for the creation of dynamic teams with the ability to shift individual group members, subdivide into smaller think tanks or entirely reconfigure all teams. This fluidity generated an organizational structure that could also swiftly adapt to varying parameters and problems that emerged throughout the fast-paced design process of the studio's final project. In addition, the system allowed for the gauging of individual and team effectiveness as the groups rapidly evolved and reconfigured through necessity.

Figure 2: One of daily round table discussions.

Throughout the course of the semester, not only were students immersed deeply within the ethos of computation and digital fabrication, but the format also allowed students to formulate their own course direction, and framework for their final project. Through software testing in computational environments such as but not limited to Daniel Pikers Kangaroo Physics plug-in in conjunction with full-scale prototyping, students quickly tested and eliminated design and research directions.

In addition to the typical expectations within a design studio, students were pushed to autonomously create an overall formal structure composed of smaller think tanks which not only created designed artifacts, but also identified research agendas within a specific discourse as well as the discipline of architecture in order to contribute to current research in digital design and fabrication.

Starting the studio this way also exposed students to an area of research not only through books and architectural projects but also papers published in conferences such as ACADIA, SIGraDi, eCAADe or CAARDIA and online forums such as the Grasshopper Group http://v5.rhino3d.com/group/grasshopper allowing students to position themselves as experts in this field.

The Underwood Pavilion: Process

The Digital Design Build studio was initiated as a student lead, intense, five-week Digital Design Build Studio consisting of eight graduate students and two faculty members who functioned as collaborators or "Intellectual Venture Capitalists" (Senagala 2009) rather then top-down leaders.

To meet the complexities of the students proposed project, extremely tight schedules were initially created by the class. Although students created a rigid course organization to maximize time, this framework still allowed for a high level of flexibility in design opportunities as no initial formal constraints were given. Throughout the first week, the students self-organized into a series of four collaborative research based think tanks. Based on research interests and the distribution of unique skills, each research group created a general proposal that identified novel aspects of computational design and fabrication in relation to envelope, structure and material that they wished to take further. Formal presentations insured that initial research directions were completely unique from each other and allowed for groups to clarify their ideas with others before investing in research over the rest of the week.

Following the first week's completion, the think tanks presented their outcomes as finalized proposals. As an overall research body, the class decided that they were interested in further investigating and creating a novel tensile fabric clad, tensegrity structure. Rather then relying on the traditional design model for tensegrity structures based heavily on physical form finding, students took the initiative in investigating and creating novel design processes through the formulation of innovative digital methodologies for structural simulation through tools such as Rhino 3d, Grasshopper, Karamba and Kangaroo Physics.

During the second week groups were reconfigured, forming four new unique think tanks: Team A investigated novel methods for the computational programming and calculation of tensegrity based systems. Team B investigated materials, performed cost analysis (based on numbers calculated by Team A) as well as tested full-scale structural mock-ups for structural and fabrication feasibility. Team C specialized in fabrics for the skinning of the pavilion (typologies, material properties and modeling). And finally, Team D investigated techniques for the creation of both digital and physical representations of tensegrity structures (Figure 3). Over the course of the week, a body of research was compiled which would allow for the design, materials purchase, fabrication and construction of a novel tensegrity system as soon as a design was chosen.

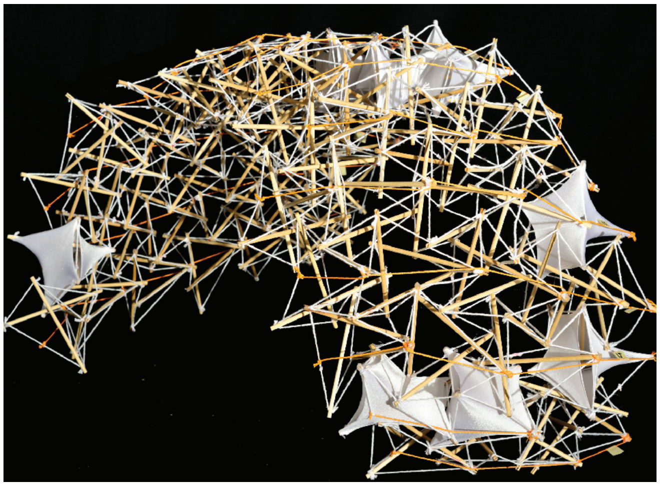

Figure 3: 1/4" = 1'-0" scale process model.

The design process began at the beginning of the third week, when students reconfigured again into design based think tanks. Through a series of intense design charrettes, in-class workshops, critiques with outside experts in the field and structural engineer consultations helped finalize the project's formal and materials pallet. As the third week progressed and projects and individual design ideas were either taken further or left behind, students continued to reevaluate and reconfigure their groups. Groups of discontinued projects dispersed filling the knowledge gaps within the remaining groups until only a single project remained.

Simultaneously, this design process also made it necessary for the students to develop responsibilities such as coordinating with community partners, searching for a site for the pavilion, gaining additional funding opportunities for materials, fabrication and transportation as well as creating press releases for the projects opening and potential gallery exhibits of the design process.

During week four, students acquired funding, materials and prepared for fabrication of the full structure. A fabrication process was designed, tested and planned for the final week of the studio. Small and large-scale prototypes were tested from standardized materials allowing for the rapid prototyping of various module typologies. Environmentally friendly materials, long-term durability and material efficiency all became major criteria during the final selection of the construction materials. For example: after studying a wide range of materials one could build a tensegrity structure from materials such as fiberglass, aluminum, wood, steel or ready made systems such as tent poles; after testing different options at half scale and full scale prototypes students selected aluminum pipes for the compression struts, galvanized steel cables for the tension members and elastane, an elastic membrane for the envelope.

Figure 4: Module fabrication in the school's wood shop.

The fifth week was utilized for in-house fabrication, structural testing and initial assembly. Completed by the students in three days, three individual teams first prepared all of the module's components: Team One fabricated all aluminum compression members (Figure 4). Team Two oversaw the preparation of all tension members and Team Three fabricated all tensile fabric components. Students set up fabrication and assembly spaces throughout the Architecture Department that allowed for them to collectively and rapidly assemble the modules while simultaneously testing the structure of all the modules and elements in teams of three.

On site assembly was accomplished in only two days (Figure 5). Bundling of the module's cables and struts before transporting allowed for quick and easy re-assembly of the modules on the site. Finally, at the end of week five, the modules were assembled, joined and skinned.

Figure 5: Pavilion construction.

The Underwood Pavilion: Final Project

The Underwood Pavilion became a new destination in the post-industrial landscape of Muncie, Indiana. It also became a part of the city's local art walk. The parametric tensegrity structure, made from 56 lightweight, self-shading modules of elastane fabric, provides visitors with refuge from the sun and framed views of the surrounding landscape.

The Underwood pavilion's modules were developed from different variations of a 3strut tensegrity module. Varying the distance between the upper face and the lower face or varying the scale between the upper face and the lower face of the module informed the curvature of the envelope. These variations also generated different levels of rotation within each module causing the envelope to twist in different directions. The structural simulation engines Rhino Membrane and Kangaroo were essential tools in the form finding process of the pavilion's individual module's as well as its overall structure.

The final tensegrity state of each module could only be reached with all cables in tension and all bars in compression. The entire system remained loose with all members being connected with the exception of a single cable connected by a turnbuckle. This allowed for the modules to be stacked and transported efficiently as a loose low–volume bundle of bars and cables (3" x 3" x 6'). At the site of construction only one cable per module had to be joined. Using a turnbuckle to connect the final node allowed regulating the stress in the module until it snapped into the predicted tensegrity geometry. Each of the 56 modules describes a volume of 3' x 3' x 3' to 4' x 4' x 4'.

To respond to a specific context, the modules were arranged in a tensegrity pattern. Skipping every second module in every second row created smaller and larger openings that were placed to frame the surrounding environment. Elastan, an eco-friendly polymer originally used for sportswear was adapted to create the pavilion's self-shading envelope. Elastan is created from filaments that are more durable than non-synthetic materials such as rubber. It can be produced from 100% renewably sourced raw material such as recycled polyester. Once all modules were connected each module was dressed with an elastic fabric to form a minimal volume that was defined by the location of the struts and the elastic quality of the fabric.

Tensegrity structures have large advantages compared to other structural systems. Using predominantly tension members they are lighter and stronger than conventional systems. As temporary lightweight structure the Underwood Pavilion additionally takes advantage of the self-erecting behavior of tensegrity systems. Using physics engines as a design tool shows how tensegrity systems can be parameterized to adapt to site and program.

Discussion

The paper shows how a digital design build studio can be integrated in a master of architecture program through the integration of a novel and self-organizing based studio approach. In doing that, it allows one to compare the studio to other post-professional or PhD level programs that have already cultivated the idea of digital design build. Through this, the studio discussed challenges, such as budget constraints but also new opportunities, such as collaborations with community partners.

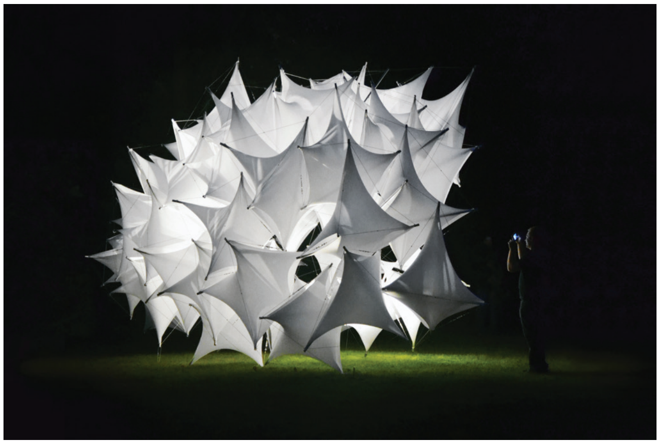

Figure 6: Underwood pavilion.

The paper then discussed the pedagogical framework of the digital design build studio taught by Prof. Gernot Riether and Prof. Andrew John Wit at the Department of Architecture at Ball State University that was driven by research topics rather then fixed building typologies or given site parameters. Setting such conventional architectural problems typically presented to students at the beginning of the semester aside allowed for a project to emerge through the revisiting of architectural topics through a novel digital lens.

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