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THE PEDAGOGICAL MEANINGS OF AN EXPERIMENTAL FULL-SIZE MOCK-UP OF COMPUTATIONAL DESIGN

YASUSHI IKEDA[1], KEISUKE TOYODA[2] and TSUKASA TAKENAKA[3]
[1] *Keio University, Fujisawa, Japan*
yasushi@sfckeio.ac.jp
[2] *NOIZ Architects, Tokyo, Japan*
kt@noizarchitects.com
[3] *AnS Studio, Tokyo, Japan*
takenaka@ans-studio.com

Abstract. Skill in the use of digital media tools is growing more important in architectural education. However parametric objects in computational geometry or digital fabrication as an assist for project-based learning are not in themselves sufficient to extract the potential of computational design. When we consider the performance of a design, or the fundamental purpose of parametric design toolsets in the contemporary context, education must act as a connecter to the ambition of global sustainability. With regards to the advantage of computational methodologies, students benefit by developing a holistic vision of non-standardized assembly technology. This is particularly useful in overcoming problems of mass production, and with the creation of interactive technology that is incrementally adaptable in the process of answering to unpredictable change. In this context, a comprehensive understanding of digital tools as part of a holistic and ecological architectural design mindset is crucial for future designers. Exploring effective ways to guide students in the development of this capability is therefore important. This paper documents a recent effort in this direction through examples of education within a digital design studio. As a conclusion the paper discusses important factors in the encouragement of students as they develop a comprehensive understanding of the use of digital design culture.

Keywords. Digital design studio; full-size mock-up; comprehensive capability; practical performance; project-based learning.

1. Introduction

With the ongoing progress of digital communication media in architecture and urbanism, programmable 3D data has become a comprehensive tool for sharing ideas. Consequently, it has begun to affect the form and function of objects, as well as the construction and utilization of living spaces. 3D data is used in many ways, including the visualization of complex topology and geometry, the simulation of environmental factors, and the materialization of unique shapes and tectonics through digital fabrication. It is used to navigate the vast design space that results from algorithmic processes, in the adaptation to dynamic environments, and in responding to human behavior through digital sensing technology. As these uses become more common, the skilled use of digital media is growing more important in the education of architectural designers.

The use of parametric objects in computational geometry have become common as design tools, while digital fabrication is becoming less expensive and more popular. However computational processes are often viewed as a limited part of the architectural design process. In a more negative light, computational design is criticized for killing creativity by its focus on technical issues and unjustifiable novelty. Without answering those critiques directly, it is possible that a more comprehensive theory of computational design is needed in order for designers to completely take advantage of the tools and to grasp their full potential. The criticism provokes a look beyond the technical advantages and improvements in functionality, towards the more fundamental question about the ultimate purpose of design with regards to the use of these emerging tool-sets.

One answer to that question is the sustainability of human living systems. It is a logical fit as all of the tools when taken together offer the power to engage with complex dynamic systems. In that case the development of a comprehensive understanding of the digital tool-sets is an essential capability for future designers. If this is the case then it is important to explore effective ways to guide students as they build those capabilities through their work.

With this in mind, looking back at the last five years of our design coursework one of our ambitions was to encourage students to develop a comprehensive understanding of computational design as they developed their digital literacy. The organization of courses, and studio courses especially has changed as we learned better how to achieve that aim. This paper documents our efforts in this regard and introduces ongoing efforts to develop teaching methodologies that allow students to develop both technically and philosophically in the process of their education as architectural designers.

2. "Porus Torus" - installation work for research exhibition 2010

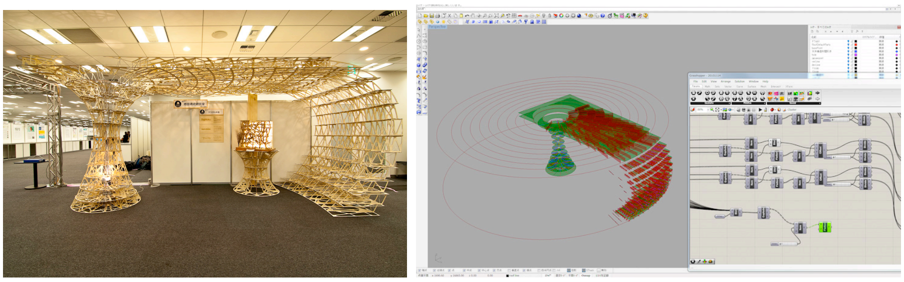


Figure 1. Porus Torus (left) and the generation of geometry and parts (right).

This pavilion-like installation work was our first attempt to ask student teams to combine multiple features of computational design. Since it was a public demonstration about the potential of computational tools in architectural design, we tried to include and visualize especially unique aspects from the point of view of novices to the field. For example, we chose the radial geometry of a torus as a starting point for design because it naturally produces unique forms that are obviously distinct from shapes that might be derived from the use of standardized parts. Non-standard fabrication is a unique feature of laser cutting. Algorithmic tessellation can be used to generate a series of no standard parts that are nonetheless similar enough to be manageable in terms of complexity and buildability. We called this approach non-standard homogeneity as it enabled the construction of an irregular form with relatively simple parts.With regards to project-based learning with full size mock ups, when we made this project we already had several years of experience with research-led pavilions and had developed a systematic methodology around the topic of portable architecture. In this case the size and uniqueness of the project had a significant effect on student motivation and helped them to also develop management skills in a collaborative team setting. In the process of developing the project we noticed that even though it was a small pavilion the structure required the solution of many technical issues to make it buildable, including the development of joints, assembly methods, ways to move it and to lift up parts. From a pedagogical viewpoint it is ideal because these are most basic topics of architectural technology, all useful in projects of much larger scales.

Simultaneous to the physical design of the pavilion we also started research on how to apply computational methods to the tasks of plan optimization and the generation of different forms through mathematical algorithms. However, this latter aspect seemed to be an unapproachable topic for most of the students who did not have mathematical sensibility or an interest in computer science. When we attempt to extend these topics to all students taking a design studio at school some means must be put in place to encourage students to take on the challenge. In part that was the original motivation for the scope, size, and approach of this project, however we found some unexpected effects. In our observation students are conscious of the use of these digital tools in order to improve the practical performance of their design. For example, for technical reasons related to the location of the exhibition of the pavilion we needed to punch out holes in each panel part in order to reduce the total amount of combustible materials. Eventually one of the students proposed an algorithm that would generate the pattern of holes covering more than 70 percent of the surface, while avoiding any impact on the connections. In the practice of design pragmatic intentions overcame reluctance to use mathematical solutions. We took this as a key lesson of the project.

3. "Emergency Light Wooden Structure" – 4-day international workshop, 2011

While we were planning the next step in our program of computational design studios Japan was suddenly struck by a terrible earthquake in 2011, leaving more than 25,000 people dead or missing.

Although damage in Tokyo was light, our school was forced to postpone the start of the school semester, and most events were likewise cancelled. This event gave us both time and a need to rethink the ethics and social meaning of design and architecture. Initially we felt our computational methodologies had almost no power against unpredictable natural disasters, but this was turned around and we looked for ways to use the technology I closer alignment with the goals of resiliency and the sustainability of our society. We organized a workshop to build "the fish arch" with children from an elementary school in the disaster-struck area during the O-Bon festival (a mid-summer Buddhist festival to honor the spirits of one's ancestors) 6 months after the Tsunami hit the area. We wished to ease and encourage the local children's mental state. Having survived the disaster they were living amidst the wreckage of their homes and so we felt it could help them to better imagine a future if they had the chance to build something new with their own hands and in a symbolic way begin the reconstruction together. After some struggle we developed a small and simple application of the technology that showed the potential to include a noble attitude in the design mindset.

Figure 2. The Fish Arch (left) and the Emergency Light Wooden Structure (right).

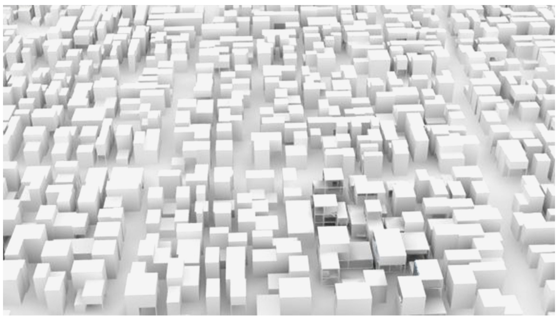
It is an unforgettable lesson, and as a result we decided to restart a workshop that had been suspended because of the disaster, this time focusing on the creation of works that learned from the unexpected experience.

The workshop theme asked participants to consider feasible environmental designs that respected both modern lifestyles and traditional values, using computational geometry with wood as the main material. Digital fabrication tools enable designers to use this material in innovative and sustainable ways. Participants were required to realize a form of "*rapid architecture*" that could be compacted and then quickly deployed into emergency areas to cope with a variety of needs: housing, shelter, aggregation points, camp hospitals, privacy in shared public spaces etc. After 3 weeks of online software training we held a 7 day workshop in Tokyo to make a full-scale mock-up. The workshop was brought successfully to completion on September 10th with 4 international teams and 24 participants. The whole process of the workshop and symposia proved to be surprisingly sustainable, as the resulting models have been reused 3 times in 3 different occasions and therefore fulfilled the requirement of compactness, transportability, ease of assembling/dismantling and reusability that were set at the beginning. Through this process we have gained some important insight into the validity of computational design in the face of challenging social issues. The use of these tools in the education of young designers wishing to take on the serious challenge of sustainability also began to take shape.

4. "Digital Eco-City Landscape" - advanced design studio course work, 2012

Following on this project we set the next studio class for senior students in a new direction. Setting aside the construction of full-scale mock-ups we looked instead to the topic of dynamic sustainable system design as enabled by information technologies, including computational modeling of complexity. We asked students to proceed according to the following steps:

1. Chose a typical area recognizing the working systems of human activity, with environmental elements such as food, energy, transportation, economy, culture etc.
2. Consider a model of the system to explain existing mechanisms in order to create its characteristic appearance, including environmental elements, and transfer it to a computational simulation.
3. Find controllable parameters in the simulation in order to understand a range of design space and to get idea for the potential to maintain its structure in the face of contemporary change issues.
4. Propose an urban system to work continuously for at least the next 30 years based on the simulation study.



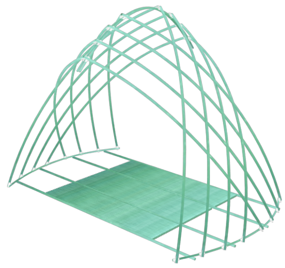


Figure 3. Digital Eco-City Landscape (left) and Computational Bamboo Structure (right).

It was too difficult for a single student to solve all 4 steps. The work itself was used to analyze and predict the changing townscape in one of the most expensive residential areas of Tokyo. Reviewing the currently typical mechanism for property lot subdivision in the city the model indicated that green space in the city would entirely disappear in the next 50 years. In response to this future scenario a system to create micro-scaled semi-public spaces between houses was proposed as a kind of system protocol amongst neighbors. A simulation showed both space diversity and improvement of green coverage effects would result from the applied system. Though we tried to motivate students to learn system oriented algorithmic modelling in order to adapt to a changing environment, the domain was still relatively unapproachable even though they possessed a strong motivation to respond to social issues and especially issues around sustainability. Modelling of environmental mechanisms are very difficult to imagine without an insight in the workings of natural systems.

5. "Computational Bamboo Structure in a remote island" - summer workshop project, 2014

This project was unfortunately suspended because of a volcanic eruption in the middle of its construction in 2014. We were in the final process of building a full size structural bamboo hut for use as a sustainable solar shower in our summer camp at a remote volcanic island in southern Japan. The bountiful self-supporting island community has only 120 residents and no shops or manufacturing. Our challenge was to build for our own needs with as few imported materials as possible, and using in-situ material and energy by application of computational methods. After long discussion and research, we decided to use a combination of local bamboo and 3D-printed joints. To build the structure required adapting to uncertain conditions of the natural materials, and so a flexible geometry was prepared and the final joint confirmed after measuring the bending strength or diameter of bamboo on the site. The approach meant that even if we dismantled the structure after 2 week use, the system could be used every year and rebuilt using renewable natural materials. In the end this idea became a good example for how to create a fresh solution for contemporary issues of local sustainability in a global community. The life of a remote island was in part viewed as an inconvenient location for our study because of the remoteness and shortage of industrial products, however when viewed from a different perspective it was more properly a location with abundant natural resources waiting for innovation. Mass production is arguably wasteful and places low value on local character in our contemporary lifestyle.

In this way, this project became a significant case-study for understanding how computational design and digital fabrication could be used to not only create a value in the personalization of things but also in the localization of technologies, in the process overcoming current issues of sustainability in a society built on industrial mass production. Through this experience we established a common concept of sustainable technology as part of an adaptable system that should work over a long time. Design is always the discovery and development of solutions that bridge human activity and technology. Therefore, every student of design should be sensitive to the potential and limiting factors in materials and construction, including the physical, chemical, and visual, etc. These would ideally be considered in light of human activities corresponding to the demands of space quality. One essential vision we would like to teach students is that design is shifting from the discovery of form towards the creation of systems through the use of information technology.

6. "Portable Personal Popup House" - advanced design studio, 2015

Looking at all the observations and feedback from students, we have come to see the production of an experimental full-size mock-up as a very effective means to cultivate designers who possess a comprehensive understanding of digital media and technologies. This is mainly because the process forces students to make use of several fundamental tools of computational design.

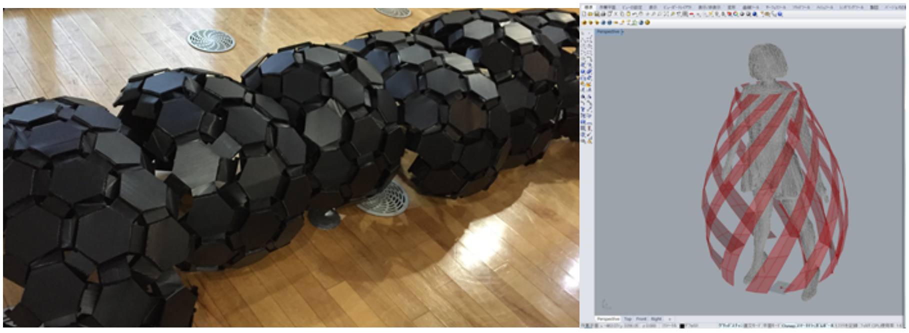


Figure 4. PPP House by H. Okawa (left) and PPP House by S. Ohta (right).

As a result we have set the structure of the new design studio according to feedbacks from students and our observations of results in previous studio works. The objective of the studio is firstly to realize the practical potential of computational design. Secondly it is to build a concrete skill set through a hands-on working method. Returning to our original ambition, our aim is to allow students to learn to use parametric geometry or digital fabrication through the development of a full sized experimental mockup of their architectural design. However, we asked student to undertake intensive research about a specific topic related to the subject of their expected works with a focus on natural phenomenon and the natural forms that can be found in nature. From these we hope they will find a solid basis for design inspiration. The quick hands-on iterative design process gives students substantial feedback from both tools and materials. Though digital Fabrication tools can be a perfect assist for project-based learning, the skill set used to perform quick and precise manufacturing is not sufficient to extract the real potential of computational design. It is important to recognize the ability to develop and use non-standardized assembly technology or incremental processed to answer unpredictable and continuous changes in the systems we work with. Intuitively, natural systems will always offer the best reference when pursuing this idea in practice.

7. Conclusion

As a result we gradually became to aim at education of a designer who is capable of using computational techniques in a creative and robust way. Then looking back previous attempt we have found 5 categories of subjects.

These ideas are considered with regards to the projects described in the Table 1. The latest project purposefully brings them all together with the aim of producing better designers who are not only capable of using the tools at their disposal but also understand their role in the broader context of society. Because our hope is to create an educational program that produces students who will be able to adapt to the most difficult challenges that we will face in the next decades, from sustainable design to social and demographic crisis.

FABRICABLE GEOMETRY: To understand the possibility of the combination of complex geometry and digital fabrication.

ALGORITHMIC ADAPTABILITY: To understand the idea of a dynamically adaptable model that exists according to a massively repeating algorithmic process.

PRACTICAL PERFORMANCE: To look for critical performance of proposed digital systems and their evaluation according to real practical conditions.

SYSTEM CONTINUITY: To create continuous working system that operates in response to human interaction.

BIOLOGICAL INSPIRATION: To investigate and refer to a simulation of natural forms, such as biological systems.

TABLE 1. 5 factors in capability model of comprehensive designer and its application.

Educational Factor / Theme of program	Fabricable Geometry	Algorithmic Adaptability	Practical Performance	System Continuity	Biological Inspiration
Porus Torus	○	○	○		
Emergency light wooden structure	○		○		
Digital Eco-city Landscape		○		○	
Bamboo structure in a remote island	○		○	○	
Portable Personal Popup House	○	○	○	○	○

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