TEACHING PARAMETRIC DESIGN IN ARCHITECTURE

A Case Study

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Abstract. The increasing technological advancements nowadays make the integration of digital tools and techniques in architecture pedagogy a must. A course in the department of architecture at Birzeit University in Palestine was proposed as a summer course in order to introduce students to the possibilities of using digital parametric tools and techniques in architecture design and manufacturing. In reflection of the experiment of the course, in which students were asked to design and construct a temporary pavilion, the paper will examine the potentials and challenges of using parametric digital tools in architecture design, and the way students imagine and conceive the performance of their design ideas virtually and practically. Furthermore, the project proposes that form is not be constrained to the form-making process, but form must be a response to a material system and its properties, and thus material should be engaged in the design process. Initial design ideas are explored by building a parametric 3D digital model using a visual scripting platform. This virtual model allows to evaluate the performance of the design and the assembly method before realization; in addition to experiment with design alternatives and forms. The final full-detailed digital model will be used in the fabrication phase to construct a one-to-one scale physical model in the real world, which gives students the chance to get sense and interact with the implemented environment and to experience their designs in real world.

Keywords: Parametric Design, Material systems, Architecture Education.

1. Introduction

How the technological advancements and tools affect the practice of architecture? We have been witnessing a paradigm shift in the role of architect recently; the technological developments that have afforded digital methods and techniques of fabrication in architecture brought the architect much closer to the making processes.

In other words, architects cannot leave their drawings to someone else to think about the fabrication details (making the joints for example) of the forms they propose (especially the complex ones), but they are also asked to think about how such forms and shapes will be fabricated. This means that architects have to be part of all design stages; they are not just in the conceptual design stage, but they also have to be part of building the project up with proposing ways of fabricating it. (Hassan, 2016)

The increasing need to understand the implications of designs, which include thinking of their construction and fabrication, is key in contemporary practice. Hence, it is crucial to include and embrace this way of thinking in architecture pedagogy and to be part of architecture design studios.

As an attempt to think of digital tools and techniques as part of the architectural education, a course was proposed in the department of architecture at Birzeit University in Palestine for the first time as an initiative to introduce students to the innovative processes using such tools and techniques in architecture design and fabrication processes. Parametric modeling and digital fabrication methodologies have been adopted in this course. Through the course, students have been working on designing a temporary pavilion and investigating the material systems which affect the method of construction and fabrication.

In the first stage of the course, students were challenged to produce a full-detailed virtual 3D model using softwares such as Rhinoceros and Grasshopper as a starting point, to finally build it up in a one-to-one scale physical model. Such working approach enables students to test and explore their design ideas before implementation. Using such innovative tools will bring a new level of thinking when students master them, which help students to create some kind of designs which are unimaginable before and thus enhancing creativity.

2. Literature Review

Two main topics were explored in the course which are: parametric design techniques and digital fabrication methods.

2.1. PARAMETRIC DESIGN TECHNIQUES

'A particular "style" is embedded in the digital code and graphical interface used.' The term 'Parametricism' has coined by Patrick Schumacher, a partner in Zaha Hadid Architects, as the name of a putative new movement in architecture in which architects can create complex forms using computer tools through the description of a design problem using variables.(Weston, 2011)

But what does it mean to think in a parametric way? And how thinking within a 3D environment helps architects in their design process? The basic principle of parametric modeling is to "develop a *generic description* of an object or class of objects, in which the shape is controlled by the values of a set of design variables or parameters" (Ugail, 1999). So, to create a parametric model includes creating a schema which shows the relationship between the geometry of the design and its mathematical logic.

An increasing number of architects are now using parametric tools and techniques that allow them to define the relationships between various parameters in their designs, and change them in an iterative manner. This has produced an architecture of previously unimagined forms.(Weston, 2011)

Many architects such as Zaha Hadid and Norman Foster, among others, use parametric design softwares to convert their forms into a dynamic parametric models to control the detailed building geometry. Consequently, architects and architectural firms find themselves in need to employ persons with a range of skills to master the new techniques as part of their design teams.

Grasshopper -a plugin for Rhinoceros software- was used in the course as a parametric modelling tool to create virtual simulations of students' concepts. The plugin is mainly an algorithmic modelling tool for Rhinoceros which provides a visual scripting interface, allowing users to build their 3D models without a prior knowledge of complex programming languages or scripting experience. It is worth mentioning that Grasshopper should be treated as a tool in the design process; it can be an extension of the process which enables architects to create innovative new possibilities and to test a variety of new ideas in a quick and easy way.

2.2. DIGITAL FABRICATION

With the increasing cost of crafting and the decrease number of skilled people who have the ability to craft, Digital technologies and fabrication methods allow for a re-invention of craft through a new 'digital lens' (Sheil and sixteen makers, 2011). Digital fabrication allows for the creation of complex crafted objects that were no longer possible.

Furthermore, digital technologies allow architects to explore new architectural possibilities with current materials through engaging with material systems. There are many ongoing initiatives which promote and facilitate the use of digital fabrication techniques for design communities and the public as well. This in turn makes the interest in these methods quickly becoming widespread and networked.

For this course, students used a laser-cutting machine as one of the digital fabrication tools to cut the pieces and components in order to be assembled later. Students can use the laser cutter not just for cutting, but also to etch onto a material which will be useful for labelling.

3. Problem and Methodology

The adoption of digital design methods in the realm of architecture is often interrogated superficially; merely used as tools for form finding with the lack of any depth or inherent meaning.

The main goal of the proposed course is to challenge the current paradigms of digital methodologies by looking at architectural design through a new ‘digital lens’. This digital lens can engender a new design process by bridging the gap between the virtual and the physical environments. A process that looks critically at material engagement within the digital processes. The Nordpark Cable Railway project, by Zaha Hadid Architects, is considered as an example that represents a disconnection between form finding and material construction which is clear in the adopted approach of cladding.

In this course, the project was conceived to test how parametric modelling tools could be employed, not for form generation, but also as a way to think of engineering and constructional detailing. Material engagement can be facilitated by following this methodology:

1. Encoding a computational geometrical and functional representation of the design virtually, Grasshopper can be used to create an associative parametric definition to build a virtual prototype.
2. Thinking of the fabrication method as part of the design. For physical prototyping, students were asked to explore and test a range of digital fabrication techniques for model making. This can help them to understand the correlation between the virtual and physical environments.

4. The Investigation

Students have been challenged by the course's assignment to design a temporary pavilion and then fabricating it. This pavilion is seen as a test bed of form generation that works hand in hand with material practices which allows for experimentation of concepts, methods, forms, materials... etc.

Site selection and thinking of the pavilion design in relation to its surrounding context was part of the assignment. Students were asked to select a site within the boundaries of the university campus in order to involve students in the current master planning process in which the department of architecture is part of it. So, they need to think of the notion of public and design gathering spaces that can function as seating areas or platform for lectures.

To do so, four groups have been assigned to work on their pavilion prototypes. Students were asked to keep the following framework in mind in their designing process and to keep it integrated together; this is to make sure that the development of their projects goes through a rigorous approach to material properties and digital fabrication methods:

-The understanding of the selected material systems and the interrelation with the parametric design process to create new possibilities.

- An understanding of the methods of digital fabrication associated with the selected material and how these methods affect the assembly of the chosen design.

The following phases characterize the experiment undertaken:

4.1. **PHASE A.** PARAMETRIC DESIGN

In the first phase, students were assigned into four groups, four students in each group, in order to produce 4 concept models at the end of this part through using the digital parametric design techniques.

First, they were asked to choose a material system to work with and explore. The reason behind choosing a material is to explore how the material properties can determine design. Then, students have to explore the selected material system in more detail through engaging with its properties. This was in help for students to apply an appropriate geometry and fabrication method in a parametric form which corresponds to the selected material.

Structurally speaking, and since the pavilion is temporary, students need to think carefully about the methods of construction that they choose which best suited the selected materials. The way the pavilion touches the ground also needs to be considered.

Figures (1-2) show two concept models that proposed at the end of this phase (of scale 1:10). The proposed systems create an integrated form of geometry and structure. Each group worked on a method of fabrication which is appropriate for the chosen material. The digital fabrication methods that students worked on include: sectioning, contouring, triangulation and waffle structuring.

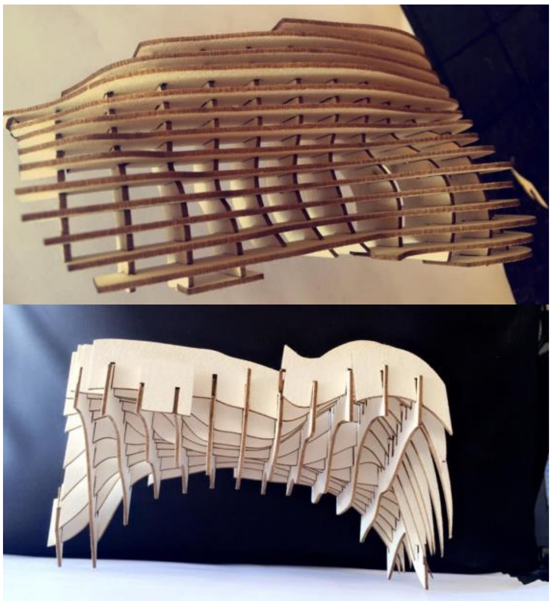

Figure 1. 1st group prototype using the system of waffle structuring

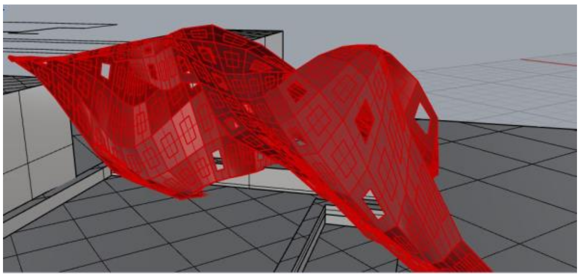

Figure 2. 2nd group prototype using panelizing system for fabrication

An evaluation session was held in order to select one concept pavilion to be developed and implemented by all the students in the next phase. The methodology mentioned above was the main criteria for the selection in addition to the practicality and stability of the proposed pavilion. Figure.1 shows the selected prototype that intended to be fabricated by the end of the summer course through applying the waffle structure system.

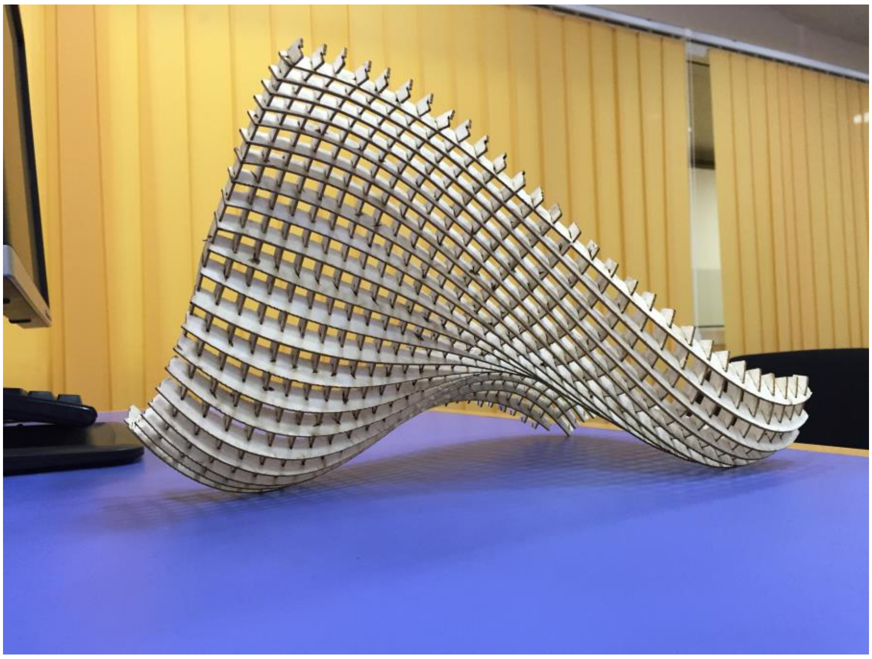

Figure 3. A refined concept model of the selected pavilion.

4.2. **PHASE B.** PAVILION FABRICATION

The second phase of the course is concerned with the further development of the selected pavilion that is designed in the first one. This was achieved through the engagement with architectural detailing of the pavilion and the method of digital fabrication.

In addition, students investigated the designed pavilion in terms of its joints and connection details, material dimensions and thickness and how its structural stability can be achieved through the careful development of the cross-sectional ribs in order to afford easy assembly and rigidity.

For the adopted pavilion, students worked initially in the development of the pavilion design digitally in relation to the maximum size of plywood sheets able to fit on the laser cutting bed with dimensions of 70*100 cm. Material thickness and its relation to joint and slots details (including the ribs intersection) were further investigated.

At the end of this course, students were able to make a physical interaction with the implemented pavilion. They enjoyed seeing the things they proposed in the first prototype are constructed in a one-to-one scale physical model; the combination of working with the digital model and the possibility of cutting it and assembling its parts together.

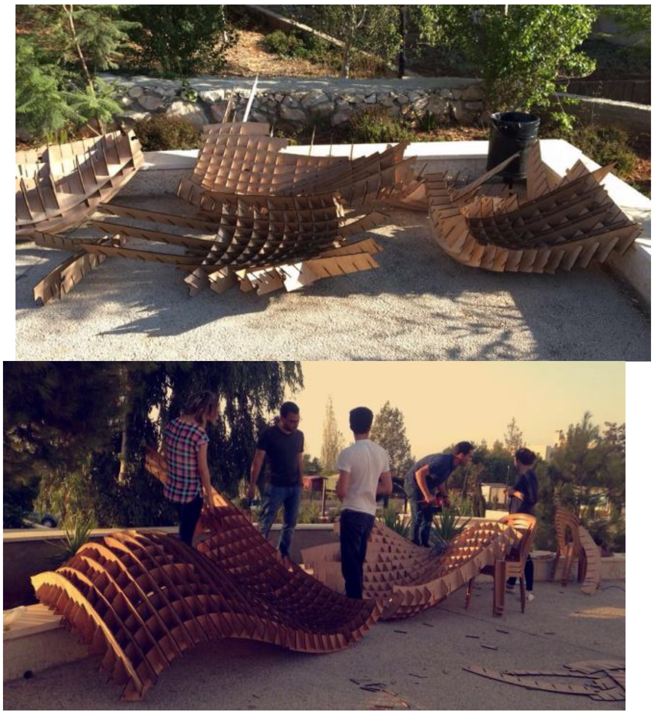

Figure 5. Assembly phase.

Figure 6. Final constructed pavilion

5. Discussion

Thinking parametrically has been very helpful in this course as expressed by students; they found this way of thinking is so compatible with the nature of architecture design process; a process which is very iterative or cyclic with constant modification in design.

It was a unique experience to work with students throughout the course using the approach of parametric design, this approach helped to develop the level of their analytical thinking which informs the use of parametric design tools; the engagement with the material systems and properties.

While students were working in their designs digitally, many constrains have emerged including material dimensions and their characteristics. Many of the materials used in the production of architecture are from a sheet format; this means that students had to think of their proposed forms and shapes out of planar elements. Identifying such constrains can inform the construction techniques.

6. Conclusion

Technology can change the design approach entirely. Creating a fully detailed virtual model allow the designers to experiment with various options from a single model. Through the working in this course, it was clear that parametric design tools can drastically reduce the required time to explore the variability in design that they create and the associations between different facets of the design. This variability is not only offered in the form-finding stage, but it also can be achieved in how the project is constructed.

Technological tools and techniques can open up new possibilities for architects and designers. Thus, it has to be taken seriously in the architectural pedagogy. I firmly believe that such courses and initiatives can reduce the gap between architecture education and its practice.

This project also taught students about the constraints, potentials and difficulties of processes, materials and techniques. One advantage of the approach introduced here is that it doesn't rely on specific knowledge and skills to be able to produce the design; using computer-aided design and manufacturing techniques bring flexibility and ensure feasible production.

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