PLAY WITH PARTS AND JOINTS

Digital Design supported by Rapid Prototyping

LO, CHIEN-JUNG, CHIU, MAO-LIN
Department of Architecture, National Chen Kung University, Taiwan
u7300633@yahoo.com.tw
mc2p@mail.ncku.edu.tw

AND

LIU, MING-NAN
Department of Architecture, National Chen Kung University, Taiwan
norman7079@msn.com

Abstract. Digital architectures are emerging because of the advancement of information and communication technologies. Rapid prototyping becomes important for digital design in the early conception stage because of the complexity of geometrical relations. The paper is aimed to examine the design teaching issues of dynamic structure by rapid prototyping in experimental studies. Our goal is to integrate the process with rapid prototyping in generating variety types of joints adapting different conditions. This study proposes the digital design process by “playing with parts and joints” approach for the educational purposes. By introducing in design studios, the findings and discussion are reported.

1. Introduction

Introducing advanced digital process and technologies is critical to digital design studio teaching and learning. An experimental process is adopted in two different studios for helping us to evaluate different approaches of applying rapid prototyping required for digital design. Chiu and Lou (2006) reported the work in graduate design studio in National Chen Kung University. In this semester, our aim is to teach undergraduate students in Nan-Hua University by re-defining the different module in curriculum. The purpose is to collect the comparison between different teaching methods using the same educational resource.

“Play parts and joints” indicates the tectonic issue that introduces the design method and construction process, while CAD software can help the interactive of design realization as well as developing the detail of different kinds of material and skeleton systems. The goal of our task is re-thinking the process of digital design, i.e. how to make and how to design with digital technologies.

In digital design, students have the same design target by the different tectonic issue and refine their concept for learning the construction
proceeding, such like traditional carpenter caring the detail of different joints and parts. Each stage of the design process can apply different types of rapid prototyping machines. Our purpose is to evaluate learning issues in design process and fabricated process, table 1. It will help better understanding how digital technologies are applied in design education.

<table>
<thead>
<tr>
<th>TOOL / ISSUES</th>
<th>MODEL ACCURACY</th>
<th>FABRICATE SPEED</th>
<th>MODELING DIFFICUTY</th>
<th>LEARNING DIFFICUTY</th>
<th>MATERIAL VARIETY</th>
<th>MATERIAL COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>2D LASER CUTTER</td>
<td>MEDIUM</td>
<td>HIGH SPEED</td>
<td>LOW</td>
<td>LOW</td>
<td>Y</td>
<td>FLEXIBLE</td>
</tr>
<tr>
<td>2 AXIS CNC MILLING</td>
<td>HIGH</td>
<td>LOW</td>
<td>LOW</td>
<td>LOW</td>
<td>Y</td>
<td>FLEXIBLE</td>
</tr>
<tr>
<td>3 AXIS CNC MILLING</td>
<td>HIGH</td>
<td>LOW</td>
<td>HIGH</td>
<td>HIGH</td>
<td>Y</td>
<td>FLEXIBLE</td>
</tr>
<tr>
<td>3D PRINTER</td>
<td>LOW</td>
<td>HIGH</td>
<td>HIGH</td>
<td>LOW</td>
<td>N</td>
<td>EXPENSIVE</td>
</tr>
</tbody>
</table>

2. Methodology for Design Studios

The digital design process should be integrated with knowledge and skills for supporting the design synthesis and design collaboration (Sazlapaj, 2005). This studio emphasizes the tectonic issue and digital design process, and the integration of both. It is important to use precedents for associating some useful ideas in design teaching, particularly connect the concept and forms with design issues (Oxman, 1994).

There are three main issues in this design studio for applying rapid prototyping, Figure 1. Each rapid-prototyping machines such as 2D CNC laser cutter or 3D printer has its strength and constraints, and have to be carefully studied before integrating into the design process. The 16 weeks of design studio is subdivided 3 parts-(1) material panel design, and (2) generic design, figure 2. the steps of each phase include:(1) understanding issues and developing their conceptual model (2) defining their problem and getting the technique (3) refining the solutions and realizing the constrains in verity of constraints.

![Figure 1. The framework of design issue](image-url)
In this case, the two parts of curriculum are parallel, one is for design studio, and another is for technological lecture. Therefore, the design studio subdivides two parts: (1) top-down process - top-down thinking require the clearly design issue and design concept is completed, like the final project-“wall” house design; the case study help student to understand the architecture form reasoning; (2) bottom-up process – the process can enhance the knowledge in tectonic realization. Students design and construct the material panel to study the possibility of tectonic design. Through the technological lecture, students practice CAD software to study the modeling and variations, Figure 2.

2.1. TUTORIAL LESSON 1 (CASE STUDY)

The tutorial lesson demonstrates the design possibilities and potentials by computer simulation and using the real cases to analysis design and construction process. Selective cases introduced include Federation Square in Melbourne and National swimming center in Beijing, figure 3. The case study helps student learning design process by the way of top-down thinking and exercise develop the full scale module, its way of bottom-up thinking. Particularly learning of undergraduate student, they need the experience in full scale study both in the way of design imagination; that case will help them to close their design.

Figure 2. Process of Design Studio

Figure 3. Federation Square in Melbourne and National swimming center in Beijing
2.2. TUTORIAL LESSON 2 (VARIATION AND TRANSITION METHOD)

Students are asked to conduct case studies for evaluating their design alternatives, then defining the methodology of design method. The process will help students to enhance their imagination as well as design conception. The first design project in the undergraduate studio is making the material panel, and there are discussions with physical material and virtual material, figure 4. Students apply the 3D modeling software (Form Z and 3D max) to generate the form, and represent different variation in the schematic design.

Figure 4. Game of generating panel form

2.3. FIRST EXERCISE-THE (60X60 CM) MATERIAL PANEL

The exercise provide generating method, and first step is realize material specific both in real and virtual. Technological Lecture provides the generating method for making form, figure 4: (1) Division-2D geometry division, use the basic geometry system to subdivide the panel. (2) Filter-set the conditions and rules to pick up useful geometry point. (3) Replace-replace the point and ignore the original point by setting rules. (4) Overlap-overlap the two different results of geometry system and give connection requirements. (5) Sweep-give a thickness to define line and generate 3D form.

The second task is using the different specific CNC milling machine to produce the parts and joints. They will separate different parts for fabrication. So, usually students like more complex form in virtual world, but when they start to practical work, they realize how to simplify the model is actually important. We can see the photos, Figure 5, the gaps of transition in concept will appear.
3. Project of “wall” house

“Wall” house is the final project in these curriculums. The concept is making a surface irregular structure building. After the developing the concepts of housing, students apply their developing material panel to transit the walls and ceiling by generating method. Each assemble units compose the parts of house, and set the different division mechanism for function in housing design. The process of final stage: motion simulation in design both use the virtual simulation by 3D software and CNC milling to test the structure strength. After that, we have the assemble units prototype, but this just an experiment model, we need the construction logic and combine the tectonic issue that contains the culture specifics, figure 6.

Figure 5. Demonstration the method in different variation

Figure 6. Design process
3.1. DIFFERENT SCALES OF MODELING (TIMING OF USING PROTOTYPING)

There are three scale model of the design project, wall of material panel (full scale), contain the hole, mock-up (1/5 scale), form modeling (1/30 rapid-prototyping machine made). The purpose is closed to reality. By the final task is design “wall” house, they should transit the material panel design to apply in different conditions, like ceiling and doors. Each phrase of our curriculums is step by step to help the student realize the timing and conditions in application of rapid prototyping.

3.2. PARAMETRIC FORM

The parametric design will help us to realize the method of design process. A schema of prototype causes by tectonic experiment, and represents in parametric modeling. It is necessary in generating skill of design and construction process. Steel, wood, acrylic are our materials in the experiment. While various approaches or methods in digital design exist (Kolarevic, 2003), we are developing the “Basic Joint Modeling (BJM)” for fabric components. Taking the process of form making from the computer screen thorough technology to production may assist architecture studies of digital era find another way to create physical model. (Katerina, 2006)

4. Discussion

The above exercises provide the foundation for discussing some design teaching issues.

4.1. KNOW-HOW AND EXCHANGE EXPERIENCE

In the past 5 years, we had instructed design experiment in graduate studio at NCKU for teaching students to apply rapid prototyping machine for developing design scheme. To realize the mock-up and full scale models, students need to hand-on real materials for implementation. For this reason, it requires skills to integrate rapid prototyping technique for developing their project in order to enhance their design ability.

For comparison, in this undergraduate studio, each student develops their own tectonic method and even process for representation and communication. Therefore, each student’s design becomes their own tutorial lesson to help them realize different method of tectonic skill and different method of design in the design project, Table 2.

For example, student 1 was capable of form-making and she proposed a complex virtual schema in conceptual design, but she chose the steel stick and plywood because these materials are easily cutting and practice. Student 1 made joints by easy skills such as using the industrial bearing and metallic joints to deal with complex connection in different axis. Furthermore, student 2 made the simple form and chose the wood (log) to transform his concept with low complexity joints, but its fabricating skill require higher technical levels in every wedge by CNC milling.
TABLE 2. Work of Material Panel

<table>
<thead>
<tr>
<th>no</th>
<th>concept</th>
<th>material type</th>
<th>connection</th>
<th>parts(cm)</th>
<th>thickness(cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>motion adaptive</td>
<td>plywood, steel stick</td>
<td>bearing</td>
<td>2</td>
<td>4 x 5</td>
</tr>
<tr>
<td>2</td>
<td>natural texture*heavy</td>
<td>log (wood)</td>
<td>inset</td>
<td>1</td>
<td>12 x 12</td>
</tr>
<tr>
<td>3</td>
<td>transparency</td>
<td>steel net, angle steel</td>
<td>lock and stitch</td>
<td>2</td>
<td>30 x 30</td>
</tr>
<tr>
<td>4</td>
<td>generic parts</td>
<td>plastic stick, acrylic stick, LED</td>
<td>inset</td>
<td>3</td>
<td>1 x 20</td>
</tr>
<tr>
<td>5</td>
<td>concrete brick *heavy</td>
<td>concrete, glass ball</td>
<td>stack</td>
<td>2</td>
<td>10 x 10</td>
</tr>
<tr>
<td>6</td>
<td>transparency</td>
<td>plastic sheet, metal stick</td>
<td>tie</td>
<td>2</td>
<td>10 x 10</td>
</tr>
<tr>
<td>7</td>
<td>smooth skin</td>
<td>flexible fiber, water pipe</td>
<td>inset</td>
<td>2</td>
<td>60 x 60</td>
</tr>
<tr>
<td>8</td>
<td>transparency</td>
<td>polystyrene, acrylic stick</td>
<td>inset</td>
<td>2</td>
<td>60 x 60</td>
</tr>
</tbody>
</table>

4.2. EVALUATION OF STUDENT PERFORMANCE

As illustrated in figure 7, students prefer the easily material and not pay a long time to deal different material connection, when they choose the complex form created in virtual space. The capability of developing level of details is the most challenge task for teaching. Students typically adopt the simple connection to solve their problems. Alternatively, students will pay more time to think the joints and material issues if they generate the simple form in 3D period. And follow these results; we can see two types of student works. Therefore, we evaluate student performance both in form and joints to understand students’ self-learning and self-developing capability. Eventually, students can better define their interest and what they will implement the digital design process.

![Figure 7. Form and joints complexity levels of design](image)

5. Conclusion

Digital design relies more on rapid prototyping because of the efficiency of physical modeling. The differences of teaching in graduate and undergraduate design studio are revealed in this study and previous study
Through the exercises of playing with parts and joints, we discovered the effectiveness of teaching method in both studios. First, undergraduate teaching follows the basic teaching scheme because of student background, while there are more flexible options in the graduate studio. Secondly, the curriculum in undergraduate studio is modularized and knowledge driven, while graduate studio is situated and problem driven. Thirdly, we taught student to follow the idea and technologies from the bottom-up process in the undergraduate studio, while adopt the top-down process in the graduate studio. In general, teaching tectonic design studio with a digital process allows dynamic operations in the design process to transform the idea to an implemented outcome. Additional supports in rapid prototyping machine in the studio could also enhance the problem solving skill as well as details of observation.

Furthermore, we had started to build a framework for evaluating student performance in the digital process. Comparing two design studios in our study, there are pros and cons of the teaching approach. Students preferred their favorable tools for communicating their design and also evaluated different facility and technology for leverage learning time in the design process. We are continuing to use the lessons learned and materials for setting new studio platform and refining design concepts. Students’ work will become new tutorial lessons in design studios. Their feedbacks also help instructors generating new design pedagogy for providing the different resources of digital design education.

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