

A REVOLUTION OF THE DESIGN PROCESS

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Abstract. Along with the development of computer technologies and CAD/CAM, digital tools are increasingly adapted in architectural design. Developed thus far, functions of digital tools are no longer limited to two-dimensional drafting or final presentation; they have become tools that can assist design thinking. Because of the involvement of digital tools, the design process has been greatly affected; or, one may say that digital tools liberated the confines of forms and structuring of architectures. This research aims to explore the procedures in the design process using digital tools. In the conclusion, we found that in an attempt to abridge the gap between design ideas and actual implementation, the designer used the digital reality simulation function very frequently to assist in decision making, and in order to process more complex and freer forms, the designer relied on the 3D design environment to carry out his thinking process and amendments. In addition, the digital design process is mainly conducted through the methods of 1, 3D modeling, 2, Simulation, 3, Generation, and 4, Fabrication. The steps and methods in the digital design process are obviously different from the traditional ones, which focus mainly on mass-production of 2D drawings; therefore, it is certain that the new tools will change the outcome of the designs.

1. Introduction

Since 1990, Computer-aided Design (CAD) has become a widely adapted tool in the field of architectural design. Developed till today, the advancement of computer technology has also brought into the approach of the Computer-aided Manufacturing (CAM). Due to the fast development of CAD/CAM, digital tools are now playing a more and more important role in the design process. Nowadays, uses of digital tools are no longer limited to simple drafting or final presentation; they have become digital design tools

that can assist the designer in his/her thinking process (Chiu and Chiu 2003). Since the emergence of digital tools in the design process, the forms and structuring methods of architectures have been liberated from the traditional geometric confines, which, in result, induced the emergence of a new style architecture – free-form architecture (Mitchell 1998).

Freedom from the confines of forms and liberation from the limitations of spaces have been the ideals desired and pursued by many architects in the past. Take Gaudi for an example; in order to create an illusion of space in his design, Gaudi spent tremendous time in crafting and sculpturing along with numerous numbers of drafting to achieve his ideal. Another project that is representative to the style of free-form at earlier times would be the Sydney Opera House (1957 – 1973) by John Uzon. However, as the technology of digital tools were not yet matured at the time, construction technologies alone were not able to construct a style that is full of energy, elegant, and free, as the architect envisioned. In result, the architect had to settle for a more traditional geometric structure. Until 1992, Frank Gehry utilized the technology of CAD/CAM and created a fish-design sculpture for the Olympic Games in Barcelona. The move started a digital tool revolution in the profession of architectural design. In recent years, many renowned architects, such as Gehry, Greg Lynn, Peter Eisenman, UN Studio, and Asymtote, have all adapted digital tools into their design process to create a world of space/form liberated Free-Form Architecture.

In another aspect, studies of computer aided design have gradually moved the focus to the application and effects of digital tools in respect to the designs. This type of digital design process, which utilizes the aides of digital tools, has touched off wide discussions on various subjects – Mitchell (1998) discusses the formation and creation of free-form structures from the aspect of shape grammar, while Chiu (2003) explores when and how to appropriately utilize various digital tools based on the digital design process. Moreover, since actual execution of construction for free-form structures is more complex and difficult than that of the traditional geometric structures, studies on fabrication became even more important (Kilian 2003; Kocaturk, Veltkamp et al. 2003). Kocaturk attempted to create a set of arithmetic computer system data structure to aid in solving the construction execution problems of complex forms. In addition, many hardware auxiliaries, such as RP technology, CNC and 3D Scanner, have also been developed to satisfy the needs (Shih 2003).

2. Problem and Objective

From the above research literatures, we know that at current time, applications of digital tools in the design process have gradually changed the

traditional design process and also affected the outcome of designs. In a digital design process, the architect has a bigger space to create more liberated and freer forms of design through the aids of computer software; however, such designs also create higher complexity in the free-form geometry (Mitchell 1998). Thus, designing production and fabrication solutions of such forms becomes an important stage in the design process. Although we have become aware that such design process and the forms resulted will be different from that of the tradition methods, what then are the factors that bring about the changes, and what procedures or steps in the design process are actually changed? These micro-factors can be further discussed through the process of an actual design project. This research aims to explore the digital design process from an actual case study and discusses in depth the factors that bring about changes in the design process, as well as how it is changed.

3. Free-form Design Project

3.1. ACTUAL DESIGN PROJECT

This research attempts to analyze the digital design process by observe to an actual free-form project. The case is an under construction free-form project—GreatLink Free-form Project. GreatLink Electronics Taiwan LTD is an OEM cable assembly company. The site is located in Shenzhen, China. It is sitting in front of a mountain with a great sky view (figure 1). The site planning includes 2 main factory buildings, restaurant, staff dormitories and landscape design (figure 2). A free-form design in the lobby of the main factory is the focus of the whole design planning.



Figure 1. Site view

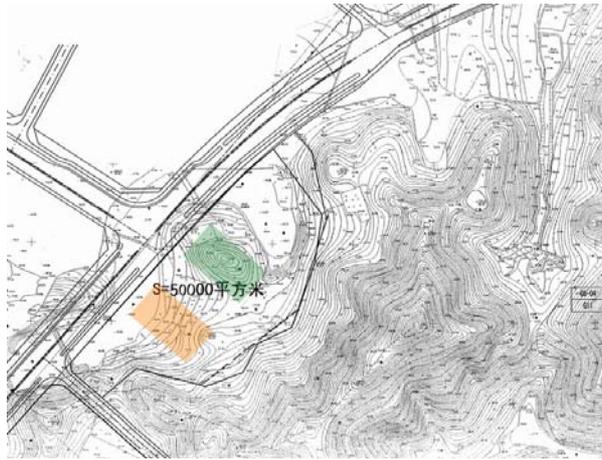


Figure 2. Site-planning area

3.2. THE PLANNING DESIGN CONCEPT

The main concept of this project is “Nature” and “Digital”. In order to innovate the image of cable and to pursue the digital concepts in the site, the two main office/factory combinatory buildings and the restaurant are shaped as a continuous curved line (figure 3), with installation and the construction of laser-cut steel frames/skins, membrane, fiber lights and concrete structure. The free-form design includes the 6 meters high lobby’s partitions and the rain canopy.



Figure 3. Whole design concept

3.3. DIGITAL DESIGN PROCESS

There are 3 main stages in this free-form design process: Conceptual Stage, Development Design Stage, and Detail Design / Construction Stage. Digital tools are the majority design aid in the process. There include hardware such as computer PC, Printer, Laser Cutter, RP, CNC etc; and software like Maya, Autocad, FormZ, 3D MAX, Photoshop, Premeire and etc. The whole digital design process as below:

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TABLE 1. Digital Design Process

Conceptual Stage	Development Design Stage	Detail Design / Construction Stage
<ul style="list-style-type: none"> • 2D Simulation • Sketches 	<ul style="list-style-type: none"> • Digital 3D model (great quantity) • 2D/3D Simulation (great quantity) • Physical model (laser cutter) • Animation • Form Generation by the computer software (Lobby interior design) 	<ul style="list-style-type: none"> A> Detail Design • 2D Sharp drawing (great quantity) • Digital 3D model B> Free-form fabrication • Skin & Structure
Software: Maya, Autocad, FormZ, 3D MAX, Photoshop, Premeire Hardware: PC, Printer, Laser Cutter, RP, CNC		

4. Discussion

As table 1 shown, we realize that application of the digital design tools such as digital 3D model, 2D/3D simulation, physical model, animation, form generation of computer software, digital fabrication are essential in the whole process. Following are the particular discussion on what and how digital tools represent and assist design thinking.

4.1. CONCEPTUAL STAGE

In the conceptual design process, in addition to use traditional sketches, designers also utilize digital tools to aid design exploration. After using some 2D concept images and sketches to represent design ideas (figure 4&5), designers start to create and simulate 2D/3D concept images by computer (figure 6). Computer simulation is performed to explore design concept. Thus, either 2D images or 3D simulation/models are represented in the conceptual stage and act as the crucial role in design exploration.

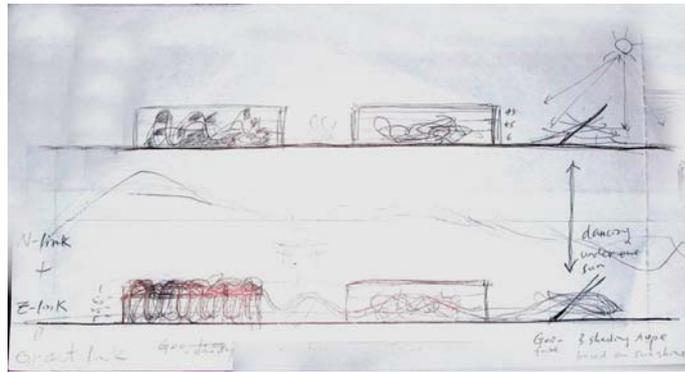


Figure 4. Sketch

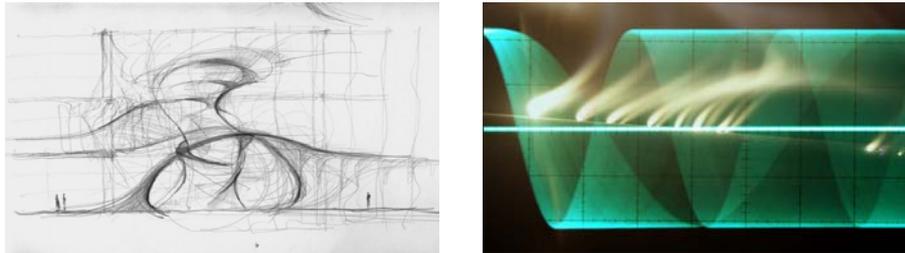


Figure 5. Sketch and concept image

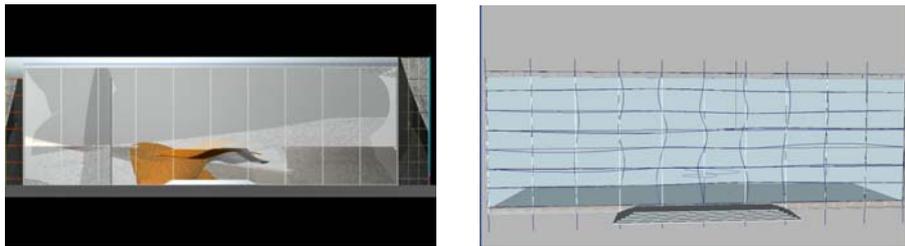


Figure 6. Computer simulation of the design concept

4.2. DEVELOPMENT DESIGN STAGE

Various digital representations are used for design aid in the Development Design process. In particular computer simulation and 3D modeling are considerable approaches to manipulate the digital design. Moreover, animation, physical model, Form Generation by computer software also been used in the design process. The statement of these digital representations in the Development Design process is analyzed through some instances.

4.2.1. 3D digital model

In the Development design process, digital 3D model is a considerable approach to assist the design amendment and design thinking. Since the free-form is more complicated than the geometry form before, designers demand 3D environment to proceed the design process. The dominance of easy modification and time saving prompt the designer using digital 3D model instead of making a physical model. Furthermore, digital 3D model provide unrestricted form modeling, it gives rise to liberate the space design (figure 7).

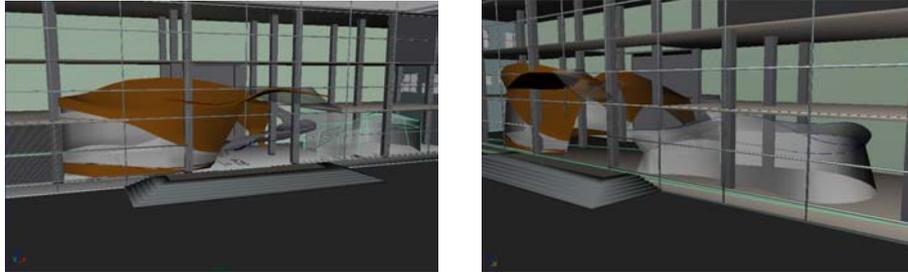


Figure 7.3D digital model

4.2.2. Simulation

Designers always try to bridge the gap between the design ideas and design construction. Traditional 2D drawings such as plan, section, elevation and perspective unable simulate actual scene. However, digital tools possess powerful function of reality simulation. In the design process, designers utilize great amount of digital reality simulations to inspect and determine the form design, material, color scheme, lighting, and others design decision. For instances, designers simulate the effect of the sunshine to the main building design (figure 8). In addition, the simulations of the different form of the back wall design help to make a good design decision (figure 9). Besides, the selection of the different material in free-form skin design (fold/curve skin, glass/metal) also depends on the digital reality simulation (figure 10). Regarding to the study of color scheme and lighting, simulation become even more essential (figure 11&12). Thus it can be realized that the digital reality simulation allows designers know well of the design achievement and make a design decision or judgement in advance.



Figure 8. Simulation of the day and night effect



Figure 9. Simulation of the back wall form designs

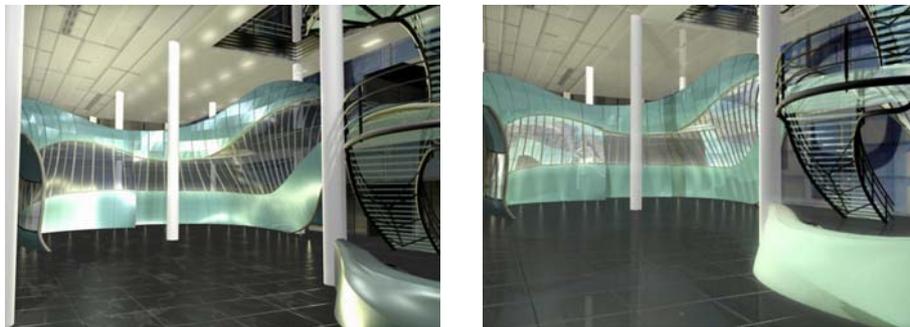


Figure 10. 3D Simulation of the materials: left-fold skin; right-curve skin



Figure 11. Simulation of the color schemes



Figure 12. Simulation of the lighting

4.2.3. Physical model

Furthermore, the manipulation of the physical model also different from the traditional approach. It operated by the digital output data of the free-form's skin and structure segmentation and to proceed by the laser cutter to fabricate the accurate physical model (figure 13). Designers explore and test the proper way of the construction by this process even though the process of manipulation is quite complicated. Moreover, physical model helps designers to comprehend and grasp the relation of the complexity 3D free-form design further.

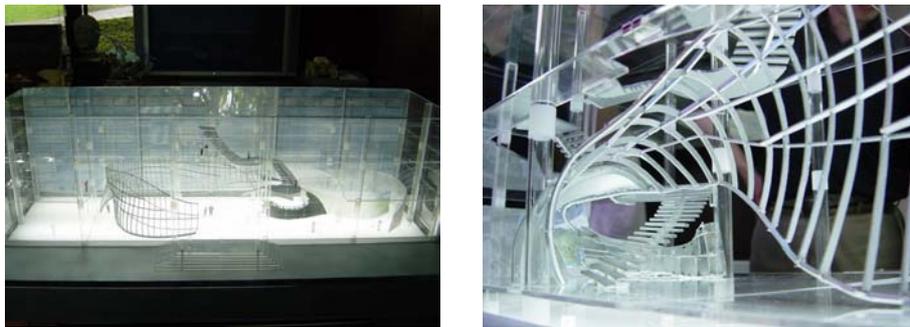


Figure 13. Physical model (by digital fabrication)

4.2.4. Animation

Formerly, representation of the digital tools especially animation always regards as final representation of the completed design, however animation no longer limit in such role in this Free-form digital design process. A study animation is proceeded to inspect the design and assist the design development. Designers find out the effect of sunshine towards the building design during a day by the aid of the motion simulation. After realize the situation, designers start to modify the façade design of the building (figure 14). This shows that the animations which show out the 3D motion

simulation express the relation of the “space” and “time”. It would be the useful approach to help designers know better about their design in the real world situation.



Figure 14. Study animation

4.2.5. Form Generation of computer software

Digital tools also used as an innovative design device other than the changes of the design steps and processes. The interior design of the main lobby in the free-form design utilized the simulation of dynamics theorem in MAYA software to generate the creative form of the ceiling decoration (figure 15&16).

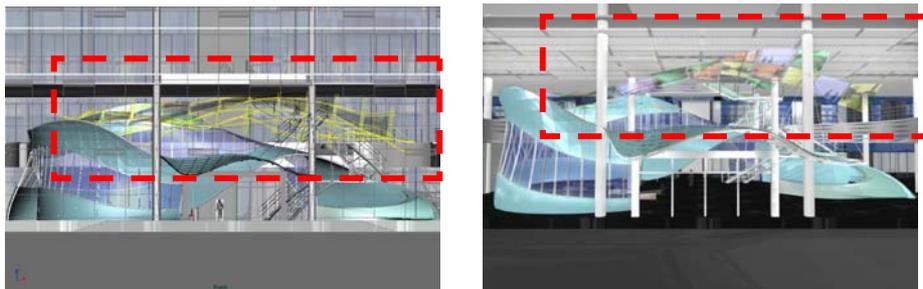


Figure 15. Form generation (by MAYA)

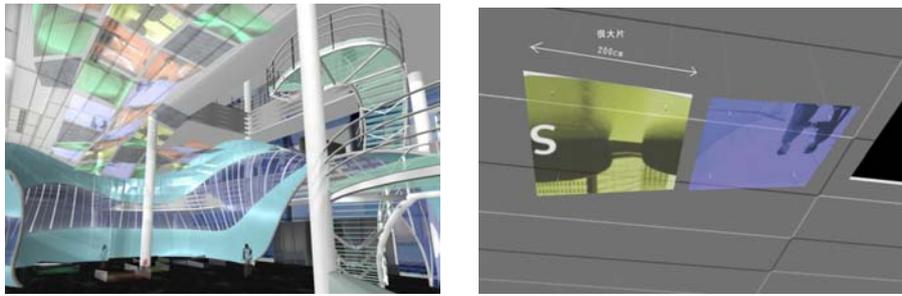


Figure 16. Form generation (by MAYA)

4.3. DETAIL DESIGN/ CONSTRUCTION STAGE

In the detail design stage, designers draw the 2D sharp drawings as the traditional design process. As well as these 2D drawings, designers attempt to use 3D model to express the complexity detail design.

In addition, the fabrication is the essential step in this free-form construction stage. Division of the skin and structure of the free-form geometry process enable the complicated form to feasibility be constructed. Designer then associated with construction factories following the digital output data is done. The main procedures are as below:

1. Decompose and segment – Designers decompose the free-form to structure and skin elements separately. Then convert the 3D element to 2D drawing data which able to be export (figure 17).
2. Export and manufacture– Associate with construction factories for the output data and manufacturing (figure 18).
3. Testing fabricates– A testing fabrication process is needed to solve the construction problems which are not known in advance by the drawings (figure 19).
4. Site Construction – After complete the testing process and solve the probable facing problems, next will be constructing in the real site.

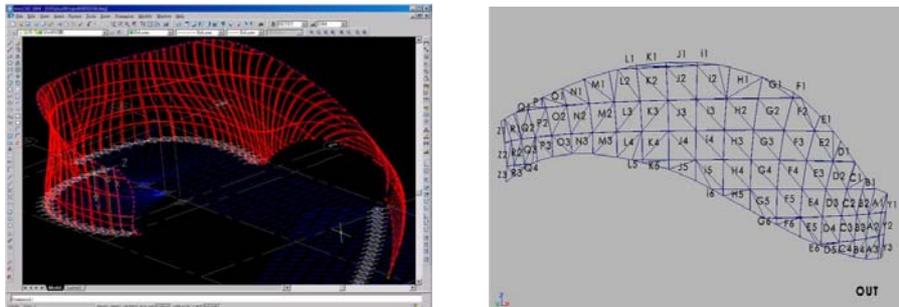


Figure 17. Convert 3D element to 2D drawing data



Figure 18. Manufation and testing fabrication



Figure 19. Testing fabrication of the free-form structure

5. Conclusion

As the design process shown, the applications of digital design tools have a majority in development design stage and detail design/construction stage. The whole digital design process mostly relies on simulation and 3D modeling. Due to the complexity of the free-form spaces, 3D modeling and computer simulation get advantage to contribute to designers to realize and modify it easily. Hence, designers change from 2D drawings to 3D modeling to assist their design thinking by using the digital tools.

Consequently, the design process is bound to change after the use and the aid of the digital design tools. Through the digital design process of GreatLink free-form project, we observed some changes in the design process and steps compare to the traditional approach. They can be concluded as below:

1. 3D modeling---3D environment to assist design thinking.
2. Simulation--- 2D/3D Real simulation to assist the decision of design form, color scheme, texture, lighting and etc.

3. Form Generation---Digital design tools as an innovative design device.
4. Fabrication---Precise construction process.

6. Significant and Future Studies

This research is significant to the digital design education. This is a growing trend to introduce the digital design process to the architecture students in digital era. Although the research concludes some different design processes, it is still a preliminary analysis. Future studies hope can base on this pilot study and develop a whole digital design process which can be practiced in design education. Moreover, attempts to broaden the scope of the free-form fabrication and study the digital design process of a large-scale, complex, free-form buildings.

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