

DIGITAL CAD/CAM MEDIA REALIZE CHINESE CALLIGRAPHY AESTHETICS IN ARCHITECTURAL DESIGN

A Case Study 'Calligraphic House'

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Abstract. This paper attempts to explore a design method that incorporates the concept of ancient Chinese Art aesthetics into modern architectural form and space. Through the Case Study, a preliminary framework of freeform design process in using CAD/CAM media is concluded. It reveals the digitalized design process of artistic freeform space and shows Chinese calligraphy aesthetics in contemporary architecture.

Keywords. Chinese Art: aesthetics; calligraphy; CAD/CAM media; digital design process.

1. Introduction

1.1 APPLICATION OF DESIGN MEDIA IN FREEFORM ARCHITECTURE

Ever since the twentieth century, in addition to the two-dimensional drawings, architects have greatly depended on the physical models of various scales in the design process to assist their design thoughts, and have spent more time and efforts than they spend on the traditional designs where the architectural space is two-dimensional, and create the freeform designs which are complex and non-geometrical. Of all, there are Sagrada Familia (1882 - present) and Casa Mila (1905-1907), which are characteristic of Gaudi's sculpture architecture, Rudolf Steiner's Second Goetheanum, Le Corbusier's Notre Dame du Haut (1950-1955), Eero Saarinen's TWA Flight Center at John F. Kennedy International Airport (1956-1962) and John Utzon's Sydney Opera House. These freeform architectural designs employ more flexible material – concrete – to

build with. However, during these building processes, there are still plenty of problems, which take lots of time and efforts to solve.

Not until the digital era did the digital design media emerge (Mitchell and McCullough, 1995). In 1990, in order to build a fish-shaped building, whose structure is complex and non-geometrical and cannot be completed with the traditional design or construction methods, Frank Gehry adopted the Computer-aided Design/ Computer-aided Manufacture (CAD/CAM) which are utilized by the aerospace industry to assist the whole design process. He used the digital CAM control system to precisely manufacture the physical model whose surfaces are freely curved in the CAD drawing system to examine the design. He then utilized the Rapid Prototyping (RP) Output Technology in the CAM to manufacture the structure units, and assembled the units on the site. This process where Gehry adopted the CAD/CAM technology to assist the design, or called the digital fabrication, has become a new digital design medium which assists the complicated freeform architectural design and construction process (Ryder et al., 2002; Kilian, 2003; Kocaturk et al., 2003; Kolarevic, 2003; Sass, 2004).

From then on, Gehry has successfully built several complicated freeform buildings, including the well-known Guggenheim Museum in Bilbao and the recently completed Walt Disney Concert Hall (Lindsey, 2001; Ragheb, 2001). In recent years, few young designers or design teams, such as Greg Lynn, dECOi, NOX, ONL, Bernard Frankert, and UN Studio, have started to conduct the digital fabrication process to proceed with the architectural design and the construction process. Some researchers also attempts to study and understand deeply the features of CAD/CAM media in the aiding of digital design process and digital manufacture process. Gibson et al (2002) describe their own works to investigate potential applications of Rapid Prototyping for architectural modeling, as well as an attempt to explore the limits of this technology. Afify and Elghaffar (2007) analyze the freeform projects to discuss and understand the digital manufacturing techniques and its fabrication, production process.

From the design works and the studies, we can see that with the assistance of the new media CAD/CAM, digitalizing the design process allows the designers' thoughts to be more freely presented. Therefore, the designers' design concepts change, and the new concept of design forms gradually tends to be the free forms which are continuity, liquids, folds, blobs, surfaces, dynamic, immaterial, and bionic breed (Lynn, 1995; Zellner, 1999; Leach, 2001; Schmal, 2001; Mori, 2002; Rosa, 2003; Senosiain, 2003). The form and style of the architectural space present a continual relationship of curvilinear lines and curved surfaces of the forms, and allow the architectural space to be more similar to an artistic space.

2. Problem and objective

Oriental aesthetics, whether it is Chinese traditional architectural elements, Chinese calligraphy, or Chinese painting, showing the aesthetics of curved lines and freeform expression. Especially, Chinese calligraphy not only represents the character but also manifests the basic characteristics of all Chinese arts (Nakata, 1983). Calligraphy is an organic composition of dots and lines, showing the aesthetic art of lines (Harrist & Fong, 1999). The moving lines form a surface; the organic composition of dots, lines and surfaces form a painting. The moving surfaces form the body in the basic composition of sculpture, architecture and some other art forms. Freeform designs, which express a fluid form, represent these Chinese artistic aesthetics in architectural space.

Utilizing digital tools to present the traditional Chinese Art, especially the studies on the linear aesthetics of calligraphy, has been explored and discussed in the studies of new media. In addition to the exploration into how digital media present the features of the strokes and ink, it is also proposed in these studies that the free lines presented by the calligraphy can also be the inspiration of the design concept of three-dimensional spatial forms (Chang & Chang, 2005; Yeh, 2006). For instance, the Qingdao design concept proposed by *AleppoZONE* design team is one which employs the strokes of cursive scripts to construct and design the forms (Figure 4)

However, how does one realize the space that expresses the Chinese aesthetics form in contemporary architecture? What is the role of the digital CAD/CAM medium in the design and construction process of freeform design? This paper attempts to integrate a framework of digital design and construction processes with Chinese calligraphy aesthetics forms and apply them to architectural design.

3. Methodology and steps

This research conducts Case Study to analyze the digital design process in a design case. The steps are as follows:

STEP 1: CASE SELECTION

In the aspect of case selection, this research mainly selects a freeform architectural design case in Taiwan. The selected case is a “Calligraphic House” project with the Chinese art design, which is one of the cases in “Next-Gen 20: Ao-Di Housing Project in Taiwan” carried out in Taiwan since 2007. This international project is a residence project which will truly be realized. It will

be built in 2010. In the project, each of twenty national and international architects designs a three-story residential building whose area is around 495m². The “Calligraphic House” project is proposed by *AleppoZONE*, a design team led by Professor Yu-Tung Liu of *Graduate Institute of Architecture, NCTU*. The author is also the chief designer of the team. As a result, this case can be analyzed with familiar and large quantities of design data.

STEP 2: ANALYSIS

It is hoped in this study that the design process which realizes the freeform architectural space full of oriental linear art can be explored. Hence, the case is analyzed mainly based on different stages or steps in the design process. As the chosen design case is an on going project and not yet been built, so the analysis structure focuses on four design stages: 1. Architectural program; 2. Conceptual design; 3. Design development; 4. Detailed design

4. Case study

Take the “Calligraphic House” project as the case study, and analyze the design process in four design stages:

1. ARCHITECTURAL PROGRAM STAGE

Digital volume

The site in this case is located on the hill of Ao-Di, Taipei County. At the beginning, a digital site model is built with Maya 3D software. A model of “digital volume” with the specific area is utilized to plan the spatial volume and to analyze the arrangement relationships (Figure 1).

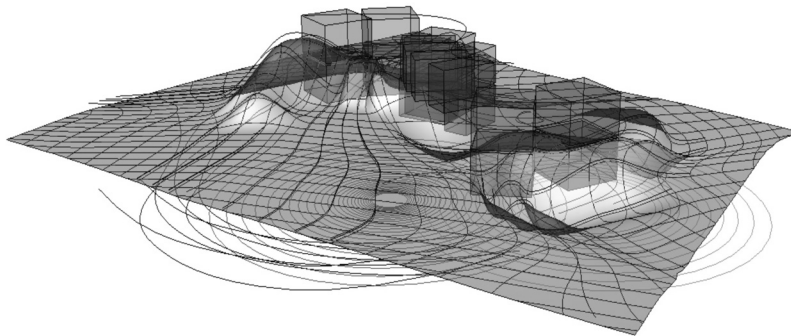


Figure 1. digital volume

2. CONCEPTUAL DESIGN STAGE

Form-finding

The design concepts are adopted from calligraphic ink monochrome paintings. The theme is “Calligraphic House”. It is hoped to create a residence which has the artistic conception expressed with the calligraphic ink, and which contains the momentum and verve expressed with the cursive scripts. In the process of the concept development, the relationship between the written strokes of cursive scripts created by Huaisu in the Tang dynasty and the lines is analyzed first (Figure 2), and then the digital tool is utilized to operate the “form-finding” process.

The method to operate the “form-finding” is to derive the design form by means of three-dimensional dynamic simulation function in MAYA. First, start with two-dimensional strokes done with Chinese calligraphy within the range of the site. Then, transform the tracks made by the calligraphic ink strokes on the paper into three-dimensional strokes by utilizing three-dimensional dynamic simulation software (Figure 3). And then, by using the “edit surface” function of the three-dimensional parameter software, create the spatial strokes with the previous calligraphic strokes and the analysis of the lines, forming the curves which are continual and comprise the calligraphic lines, and then construct the curved surface form with these curves (Figure 4). This operation process is similar to the calligraphic cursive scripts which are written freely on the paper.



Figure 2. Calligraphy Figure 3. 2D to 3D simulation Figure 4. Form-finding process

Final-form

The physical model of the “final-form” constructed with the design concept is output with RP to examine the design form. It presents the momentum and the verve of Chinese calligraphy no matter it is in the two-dimensional, elevation or perspective spaces (Figure 5).

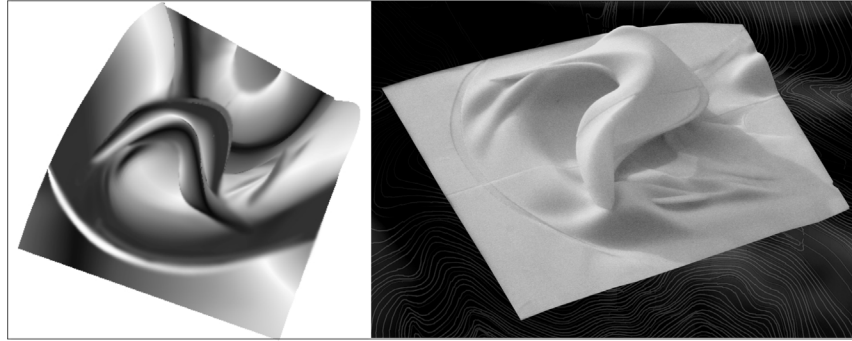


Figure 5. Final-form RP model

For the “final-form” at this stage, in addition to the design form whose main concept is based on the calligraphic lines, we hope to use the conception of calligraphic ink monochrome paintings as the major presentation in the design concept to express the spatial feel of the residence. The whole architectural design simply uses black, white and gray levels as the main color scheme. The designer takes advantage of the digital media simulation and creates a spatial conception in which there are beautiful and serene mountains and waters which are prominent features of calligraphic ink monochrome paintings (Figure 6).

In addition to the architectural design form which uses the calligraphy and the ink as the design concepts, the interior furniture design also derives from these two design concepts. Based on the construction of ink strokes, the digital three-dimensional software is utilized to create from the free lines the three-dimensional and streamlined interior furniture designs such as the tables, chairs, book shelves, and beds (Figure 7).



Figure 6. Simulation image



Figure 7. Calligraphic furniture

3. DESIGN DEVELOPMENT STAGE

As the design form is composed of curvilinear lines and curved surfaces, the designers have to comprehend the relationships of the streamlined spaces by means of three-dimensional models. However, the spatial model of such a complicated spatial form is hard to be handmade in the traditional way.

Therefore, digital CAD/CAM design media is needed during the process in order to manufacture the “3D master model” and “CAM physical model” operated with the CAD in both virtual and physical settings. We use the virtual and physical models to examine and revise the design, which is described as follows.

3D master model

Once the master form is finalized, smooth the curved surface form and divide the frame and the skin. In order to accommodate the free curves of the design form, the structure system adopts the cylindrical tube framework system. The data of divided framework design is submitted to the structure technicians to proceed with the drawing analysis and to calculate both the FEA structural analysis of the framework and the structural analysis of the curve floor load (Figure 8). In the meantime, the roof surface is also analyzed with the Gaussian curvature, and then the form is adjusted to a reasonable degree according to the structure and curved surface analyzed with the drawings. Besides, as for the division of the curved glass in the design form, during the process, cooperate with the technicians of Bentley Microstation to do the research on the automation division of the curved glass. The main purpose is to hope that the glass can be divided in a standardized and rationalized way in order to reduce the manufacturing cost of the curved glass. After the frame and the skin are rationalized with the drawing analysis, revise them to be the “3D master model” (Figure 9). This model is the master model of the finalized design. It is the reference for the acquisition of the drawing data in the next stage of construction plan.

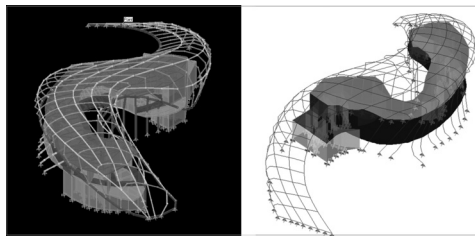


Figure 8. Structural analysis

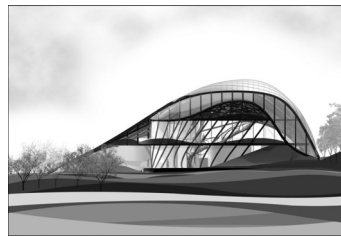


Figure 9. 3D master model

CAM physical model

In addition to rationalizing the frame division model, the divided frame is cut in a one-meter unit to manufacture 2D unit drawing. The CAM equipment laser cutter is then utilized to cut the unit, and finally the physical model of the frame is assembled to discuss the structured form and its rationality (Figure 10). In

addition, the skin model of the form is also manufactured by using the RP equipment to discuss the curved surfaces of the design in the early stage of design development (Figures 22). After the design revision and adjustment, the data of the finalized “3D master model” are delivered to the professional factory to manufacture the design form of which the curved terrain is made of CNC wood material and of which the materials are resin and RP output. The finalized CAM physical model is in the complete proportion 1:100 (Figure 26).

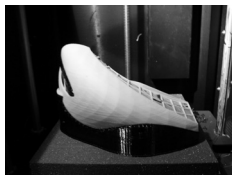
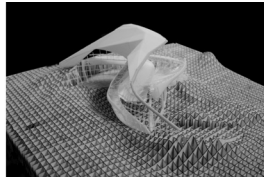


Figure 10. Laser cut frame model Figure 11. RP skin model Figure 12. CAM final model

4. DETAILED DESIGN STAGE

The detailed design and the shop-drawing of the design form of “Calligraphic House” must be based on the “3D master model” in order to get the 2D drawing data of the design unit. In addition to drawing the 2D drawings, this freeform design must also be presented with the multi-angle 3D perspective presentation. This is different from the collection of traditional 2D shop-drawings. The main reason is that even though plenty of floor plans, elevations or sections have been drawn to express various spaces in the 2D drawings, it is still insufficient in the design presentation of forms. Therefore, 3D models must be utilized as assistance so that the spatial relationship of any elevation of the form can be obtained at any time.

5. Conclusion

A preliminary framework of freeform design process in using the CAD/CAM media concludes this research (Figure 13). It reveals the digitalized design process of artistic freeform space and shows Chinese calligraphy aesthetics in contemporary architecture.

From the analysis and discussion in the design process of “Calligraphic House”, the auxiliary role the digital CAD/CAM design media play in each different design stage is understood, and the freeform design featuring Calligraphy linear art is accordingly carried out. In the process, it can be seen that the designs from the architectural form to the interior furniture, and even to the detailed design of local architectural elements all adopt the free lines of

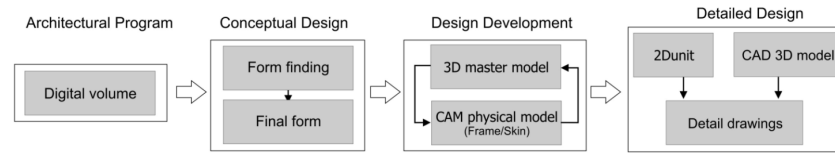


Figure 13. A preliminary framework of freeform design process in using CAD/CAM media

cursive scripts and the conception of calligraphic ink monochrome paintings as the major design concepts.

The way to operate the design is also to construct from the free lines and then form a free form of curved surface. The operational mode of “constructing the surface from the lines” in the 3D parameter software in the CAD/CAM digital media is an advantage to the construction of the free form, and it is easier to edit. On the other hand, it is easy to manufacture the precise physical model of the spatial design, which is complicated and formed with the curved surfaces, by means of digital control with the CAM equipment.

Hence, with the assistance of CAD/CAM digital media, the design concept of “Calligraphic House”, which is full of the lines of free and unrestrained cursive scripts, is digitally controlled in each stage, from the initial stage of architectural plan, the stage of concept development, the stage of design development, to the current stage of detailed design and construction plan. The connections among the 3D master model and the CAM physical model and the design drawings are very smooth. And it is easy to proceed with the design revision. In the end, the curved surface of freeform design is very close to the original design concept, formed with the free lines of cursive scripts.

6. Limitation and Future Study

The significance of this research is to explore a design method that incorporates the ancient aesthetic concepts of Chinese art into modern architectural form and space. The lack of relevant case studies and the validation of the framework is a definite drawback to this study but, it is hoped, a future study will present a more complete framework including the construction process and extend the research to the tectonics of freeform architecture.

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