

## THE ROLE OF PHYSICAL MODELS IN DIGITAL DESIGN PROCESSES

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**Abstract.** In recent years, designers have used digital media at various points of the design process, which helps expand architectural possibilities. Digital media has changed not only the architectural style, but also the design process (Lynn, 1999). In earlier times, some researchers of design thinking have looked at how the role of physical models played in traditional design processes (Millon, 1994). However, the design process has been changed when media designers used to adjust from traditional to digital. Therefore, visual thinking and cognitive behavior of designers also change while using physical models in design processes. From the synthesis of the two aforementioned disciplines, we can find that there exists a point of deficiency. That is the cognitive research about designers who use physical models in digital design processes is absent. This is discussed in the current paper.

### 1. Introduction

Gero (2003) has proposed that mankind construct experience with tools and adapts to these tools based on this experience. The media used during design is not only considered as direct influence towards development of design task, recognition of space, and method of design communication, it also implies possible method of design execution (Hebert, 1994). Therefore, the characteristics and application of different design media have in fact become another potential factor that influences design process. In recent years, digital technology starts to be involved with design; many designers have used digital media at various points of the design process, which helps expanding the architectural possibilities. Digital media has changed not only the architectural style, but also the design process (Lynn, 1999). During the traditional design process, the 3D physical model is another accessory often used other than drawings. Similar to the drawings however, there are also numerous types of operations and expression for such models; for example, the conceptual model for the initial stage of design development, the solid model that reviews the relation of base environment, the sectional model of building interior and even the structural model that expresses the structure (Liu, 1995), all the above models are required for the operation of traditional design.

Nowadays, the rapid development of digital technology, especially the technology of 3D modeling and auto-generating model made by computer, has provided another aspect of design thought for designers (Lynn, 1999). Such trend has persuaded many designers in recent years combining digital tools with the design process. For example, Frank Gehry, Greg Lynn and Peter Eisenman have all used characteristics of digital tools and successfully created the architectural style different from the past. Most importantly, they have also changed the design process at the same time (Liu and Eisenman, 2001); this also indicates that the role played by the physical model during the digital design process has changed along the way.

The greatest difference between digital design process and traditional design process is the level of dependence on the physical model (Liu, 1996). Taking the design process of Greg Lynn for example, the study on the physical model is hardly required and the reason of such change is that traditionally, 3D physical models are absolutely necessary for designers since they cannot convey their spatial imagination in 2-dimensional drawings (Millon, 1994). With the advent of digital media, however, designers have a new medium to test and express their spatial imagination (Becker et al., 2005). Does this mean that physical models are obsolete? If so, then how can the sense of touch and sense of real scale brought from physical models be solved in the digital design process? (Liu, 1996; Mitchell, 1997). If not obsolete, then what kinds of physical models are needed in the digital design process?

The objective of this research is to study the use of the physical model in a digital media era. It examined how physical models can assist designers and under what situation should they should be used in digital design processes. The research also seeks to identify the optimal use digital modeling and the standard operating procedure for using the physical model in digital design processes.

## **2. Methodology and Steps**

The methodology used in this study has three parts: 1. Case studies. 2. Observations and interviews with designers.

### **2.1. Case Studies**

This study takes the role of a physical model in the design process to analyze the design process of Frank Gehry and Greg Lynn for initial understanding.

### **2.2. Observation and Interview with Designers**

Even though the case study analyses have provided an understanding on the role of physical models in digital design processes, such understanding is only superficial. Therefore, it is necessary to obtain further understanding by practical observation and interviews with designers from the entire design process. During the observation stage, two digital design projects are chosen in this study with simultaneous recording of observation. After designer's completion of the design project, the author interviews for better understanding of the designer's reflection on process and procedure they used either in general, or with reference to particular works of design.

Further to influence in the industry, the change of design process induced by digital technology is also reflected in architectural education. Therefore, this study will take design projects made by students in the architectural studio of NCTU as targets of observation and interview. The duration of the studio is one semester, i.e. three months; during this semester, students will complete their own projects and the key points of observation will be based on the process of transferring design concepts to spatial relation and the process of final spatial editing. The observation is divided into two methods: the first method is the irregular observation during student's normal operation and design with the priority of no interference to the designer; the second method is the overall participation in discussion during lectures in the studio and overall video recording as data for later analysis. Although the key points of observation focus on the role of physical models during the digital design process, thorough understanding of the design process is still required during the experiment process. In the later steps, the portion of operating physical models will be extracted for further analysis and discussion.

### 3. Analysis

#### 3.1. Case Studies

There are many types of operation for the digital design process, but in general, they can be divided into categories of applying the physical model into the design process, and applying the digital model of VE into the design process. Frank Gehry and Greg Lynn are the suitable designers that can represent these two types of design processes. Therefore, this study has chosen the design process of these two designers as targets of case study.

##### 3.1.1. Frank Gehry's digital design process

In Frank Gehry's design process, physical model is applied to the design process, when best solution of the designer's ideal concept is achieved during the operation process of the physical model (Figure 1A), such solution forms the digital model via input of 3D scanner. The model trimming is then executed under Virtual Environment (VE) and various spatial trends are simulated (Figure 1B), which brings the designer the visual feedback. During the process, the Computer-Aided manufacturing (CAM) is used on a countless basis, which outputs the digital model into physical model for further study, as well as repetitive modification between VE and reality (Figure 1C&D). °

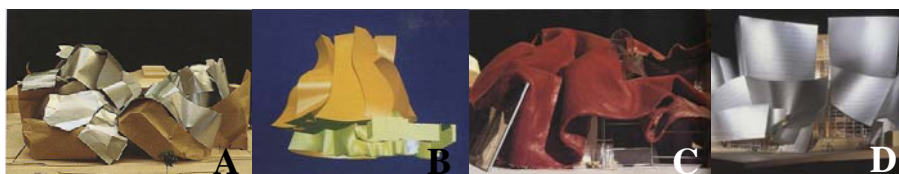


Figure 1. Models used in Gehry's digital design process

### 3.1.2. Greg Lynn digital design process

During the initial stage of his design, Greg Lynn hardly depends on operation of a physical model. He starts from digital model of VE and enters into design operation, which is almost dependent on the 3D model from the computer (Figure 2A B&C). As for the physical model, operation is only executed during the design process after confirmation on type and structure of basic space. In addition, the relationship between the digital model and physical model in the design process is unidirectional, which means that the physical model purely materializes the digital model and delivers the designer's concept via selection of model material. This does not induce a significant meaning for design of space (Figure 2D).

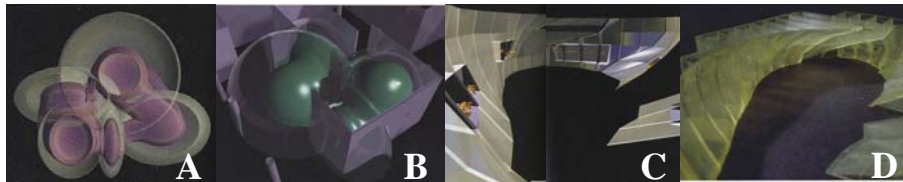


Figure 2. Models used in Lynn's digital design process

## 3.2. Observation and Interviews with Designers

With analysis on students' entire design process from the perspectives of the two digital design processes mentioned above, as well as taking these two design processes as structure of analysis, we select two projects from the students' design that are most similar to the above mentioned design process as targets of analysis. It is expected to achieve further understanding on the role played by the physical model in these two types of digital design process.

### 3.2.1. Project started from physical model

For Student A (SA) at the stage of concept generation, the designer refers to the 2D image and transforms it into 3D image via his own spatial imagination, and then makes physical model by hand (Figure 3A). The designer believes that true feeling of space from physical models at this stage offers great help to the design; if such operation is performed by 3D model in computer, the designer may still think in a 2D environment. As for material applied, the designer initially uses clay to form the abstracted shape converted from 2D image, and then uses card board to make more specific physical model of the spatial imagination (Figure 3B). When there is certain thoroughness in operation of physical model and shape of basic space is ensured, the spatial trimming converts into digital environment immediately for building a digital model with reference to a physical model (Figure 3C&D). The designer believes that curvature operation of digital model is far easier than the physical model, hence the digital model is closer to the designer's spatial imagination comparing to physical model. After trimming of digital model, CAM is not used to output the physical model anymore, because the designer believes that study on space has been completed during operation of physical model at previous stage, and feeling toward the real dimension of space has been understood.

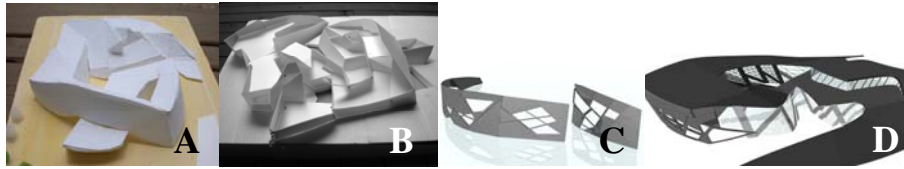


Figure 3. Models used in Student A's digital design process

### 3.2.2. Project started from digital model

For Student B (SB) at the stage of concept generation, random shape formed with lines derived from analysis on site condition is used as core shape of design (Figure 4A); such shape is then used directly in a computer environment for construction of the 3D model (Figure 4B). During process of computer trimming, cardboards would be used directly to make partial physical models for space study; the CAM technology is not used. From trimming under VE to confirmation of basic solid space, the Rapid Prototyping (RP) is used to output physical models (Figure 4C). In this way, the designer can experience the real feeling of space, which helps the designer during the next stage of space study. During stage of spatial trimming, the model is still trimmed under VE, but the designer still needs partial physical models to help with thoughts on space (Figure 4D). Finally, the physical model is generated with application of CAM after confirmation of the final format of space (Figure 4E). The assistance of design presentation for the designer is the greatest function of such model.

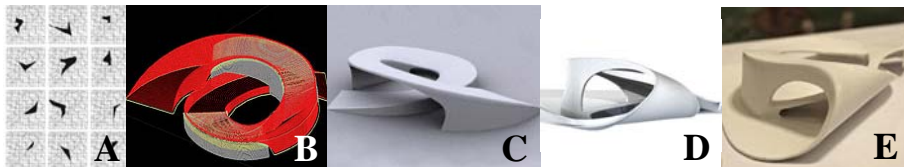


Figure 4. Models used in Student B's digital design process

## 4. Conclusion

Research results show that when a designer uses digital media for designing, the role of the physical model is more important, and more complex than it was in the traditional designing process (Figure 5). Under cross comparison between analytical results from the projects of the two students and case studies, the following few conclusions can be derived.

1. The physical models are necessary in the digital design process.
2. In the early design stage, if digital media was to be used only in a supporting role, then the physical model used needs to be more obscure and easily revised. If digital media was mainly used, then a very accurate physical model is needed.
3. During the spatial study stage, both types of design process need partial models, which allow the designer to think and modify spatial design. Most of the precise models generated from CAM are the entire models of design and not partial, thus it provides the designer with overall visual feedback on real space and helps design operation.
4. Regarding the project from school studio where physical model is applied into digital design process at initial stage, the designer spends more time

on trimming the physical model; therefore, the designer is more capable of controlling the overall feeling of space, so during process under computer environment at a later stage, output and operation of physical model is less needed. On the other hand, the design process with application of digital model during the initial design stage is operated under VE, hence the designer is unable to control the real feeling of space clearly. Due to this, more output and operation on physical models are required during the later stage of the design process.

- There is the difference of CAM skill and maturity of design operation between the industry and school. Although the two sets of cases in this study apply the same methods into design, such relationship has derived different results.

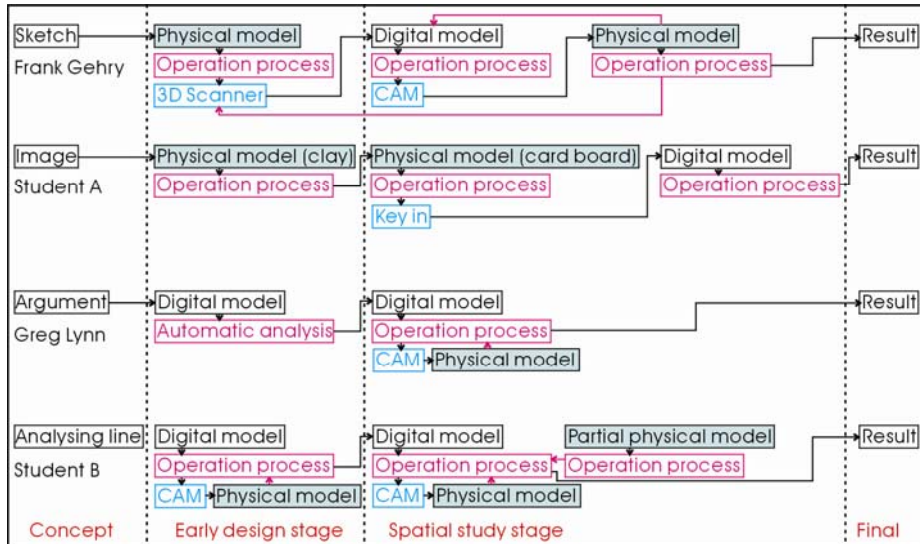


Figure 5. The standard operating procedure for using the physical model in digital design processes of four cases

## 6. Significant and future studies

The study has identified the appropriate applications and supplementary usage of various physical models within the digital design process. These procedures and insights offer a blueprint for the development of digital design program within the architecture design curriculum. Furthermore, the digital technology develops continuously and new technologies keep upgrading themselves. Since these technologies continuously affect the design process and these influences will induce another modification of the design process, these can all be issues of further discussion for consequent researchers.

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