ARCHITECTURAL DESIGN THINKING IN VIRTUAL REALITY

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Abstract. Throughout the history of the development of architectural design, from the use of planar representations to three-dimensional media using prespective and physical models, up to the present application of computer drafting, computer modeling, animation and other new design media, drawing has traditionally been used by designers to carry out the most basic design reasoning. Through discussion by Bridges and Charitos (1997, pp. 143), virtual reality (VR) has become a new design medium used by designers. Given that different media lead to different phenomena in design reasoning (Mitchell, 1990), this paper probes into differences in the attributes of design reasoning derived from traditional drawing and those observed when virtual reality is used to perform design tasks.

1. Introduction

Schon (1988) pointed out a multimedia concept similar to the design world. This, which he called virtual world, includes sketches, diagrams, drawings and physical models. Of them, drawings represented the making process in concept development. Through this design world, he points out that pattern of reasoning is shared by different designers and that it has no significant difference from reasoning in everyday life. Furthermore, he cites that design reasoning includes four universal types.

Using their chosen materials and instruments, designers usually create their own design worlds. For instance, when a designer works on a drawing, he constructs a Euclidean design world. When a designer uses physical models, he enters a three-dimensional design world (Mitchell, 1990). They refer to and present certain a state of design world of a state of real world and in so doing can be of great significance in offering solutions to certain design plans but may also lose their meaning when applied to others. In other words, what the designer sees and understands is limited by the design world constructed through the design medium he has chosen to adopt (Rowe, 1986). In a mixed collection of drawings, diagrams and actual models, different design worlds tolerate different types of observations of the real world, thus allowing different reasoning to be made (Mitchell, 1990).

Virtual reality is a subset among the different media used in constructing design worlds. It still faces technical limitations (Bridges and Charitos, 1997) and its special characteristics in relation to design reasoning remain unclear. In contrast with the significant characteristics of drawings, those of virtual reality

include providing a three-dimensional interaction experience to users, and not just an environment for observing images (Walker, 1990). I have therefore designed an episode in a design process. In the protocol analysis of drawings and virtual reality, both of which involve knowledge of architectural design, questions were asked based on the four types proposed by Schon. One of the questions posed is on the difference in terms of the use of rule types in design reasoning between a representation using virtual reality and a traditional mode of presentation dominated by drawings.

In this study, the protocol analysis mode of thinking aloud was adopted to discuss the topic of virtual reality vis-a-vis design reasoning. Discussion later centered on the use of drawings and virtual reality as media for representing design reasoning, in relation to the different phenomena associated with rules commonly applied in design reasoning processes. The topic of virtual reality is discussed under design process and the various design reasoning phenomena covered above are taken as objective references for improving virtual reality's interface.

2. Background Review

2.1. DESIGN WORLD AND REAL WORLD

The theoretical model proposed by Mitchell (1990, pp. 38) for the concept of design world is "a collection of graphic tokens, such as points, lines, and polygons, forming a two-dimensional or three-dimensional arrangement". These points, lines and polygons are primitives in the design world. Graphic tokens included in design worlds are moved, deleted, geometrically transformed or processed in some other ways. Thus, a hypothetical design world may refer to and describe, through a certain process, all possibilities in the real world. In contrast with the real world, when we describe a design, what we discuss is constructions of imagination about design world. This structure may consist of drawings, physical models, computer models and other design media (Mitchell, 1990). This design world concept has been discussed by different analysts and given different names in the past (Rowe, 1986; Schon, 1988; Suwa and Tversky, 1997).

2.2. DESIGN REASONING AND DRAWING

2.2.1. Design Reasoning

The basic task of a designer is to utilize large quantities of rules stored in the knowledge base to look for another design world situation in a given design world situation. Such a design world situation reflects another situation that exists in the

real world. This design processing that changes design world situations is the so-called design reasoning (Mitchell, 1990).

2.2.2. Drawing

Drawing, a design medium traditionally used to build design worlds was viewed by Schon from its cognitive characteristics. Through it, he proposed a universal viewpoint on reasoning behind architectural designs. He believed that designing involves not only information processing or search and that the so-called pattern of reasoning is shared among different designers and does not significantly depart from everyday reasoning. For him, rules for reasoning are largely implicit, overlapping, variously applied and contextually dependent. Furthermore, because of the universality of design knowledge, these rules are derived from the following four 'holding environment' types associated with design knowledge: function building types, references, spatial gestalts and experiential archetypes (Schon, 1988).

2.3. DESIGN REASONING AND DESIGN MEDIA

Through the design media and instruments of their choice, designers establish their design worlds. For instance, when a designer works on a drawing, he establishes a Euclidean design world. When a designer uses physical models, he enters a three-dimensional design world (Mitchell, 1990). Furthermore, a state of design world that refer to and present a state of real world can be of great significance in offering solutions to certain plans but may lose their meaning when applied to others. In other words, what the designer sees and understands are limited by the design world constructed through the media he uses (Rowe, 1986). While it is necessary for a designer to adopt a large quantity of incomplete and ambiguous drawings in order to discover and grasp all formal possibilities, he does not necessarily have to make a complete and integral depiction of three-dimensional form in a design world falling under two-dimensional intermediate situations. For this reason, it is possible to say that in order to construct design world primitives and theorems, an area where designers can develop formal possibilities is created. Furthermore, in so far as the different design worlds constructed through different media are concerned, different design worlds tolerate different types of observations of the real world, thus allowing different reasoning to be made. This is similar to the fact that a two-dimensional plan cannot generate the same critical language as that of a section (Mitchell, 1990).

2.4. THE SET OF DESIGN MEDIA

The history of architectural design thinking developed from a two-dimensional spatial representation to the application of three-dimensional perspective and use of models. Today, the media used also include images, computer drawings, computer models, animation and other such digital media. Architects have developed these different design materials for constructing design worlds in order to afford a better grasp of ideas in their minds and to formulate their architectural works (Liu, 1996). These design media are of course growing in number. With the invention of new technology or the development of new concepts, additional design media appear and form part of these tools.

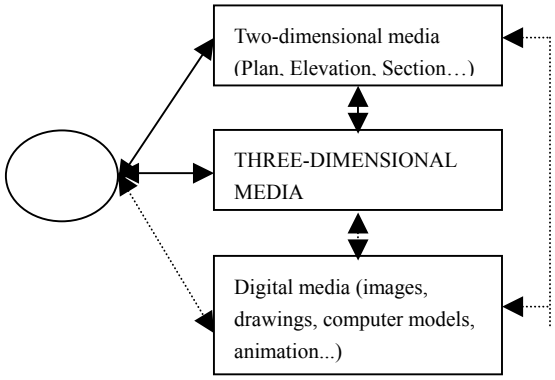

Figure 1. Development Process of Architectural Design Media (After Liu, 1996)

2.5. VIRTUAL REALITY AND ARCHITECTURE

Bridges and Charitos (1997, pp. 143) point out that a two-way relationship exists between architecture and virtual reality (Figure 2). That goes to say that architectural design may use virtual reality for assessment, communication and verification of design motive and that, in turn, virtual reality can build a virtual environment using architectural knowledge. The construction of such a virtual environment is an architectural issue. Contrasting with physical environment, this virtual environment concept is precisely the concept of design world itself. For this reason, virtual reality is also considered a medium for constructing design worlds and can in fact present unique design situations and reflect the process of design reasoning.

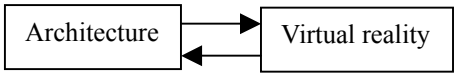

Figure 2. Two-way Relationship between Architectural Design and Virtual Reality (After Bridges and Charitos, 1997)

3. Methodology

3.1. EXPERIMENTAL METHOD

To probe into the thinking process of the designer, the thinking aloud process of protocol analysis was adopted in this study. It is a cognitive psychological method that allows effective analysis of man's inner thinking process (Akin 1979, 1993, 1996; Akin & Lin, 1995; Eastman, 1970; Eckersley, 1988; Lloyd & Scott, 1994; Newell & Simon, 1972).

Two expert subjects are chosen. The thinking aloud process of protocol analysis is employed to study two types of design media. Verbal data on the design media is obtained through voice recording and video-taping. The two contrasting design media were of the same dimensions and design constraints, given the limitations and characteristics of virtual reality in its present stage. The virtual reality medium used is platform Devise software from Silicon Graphics.

Before starting the experiment on the two design media, drawing and virtual reality, separate warm up experiments were designed for two reasons. First, because the subjects have no experience of thinking aloud while designing, it was necessary to test their suitability for the exercise and the experimental method adopted. The experiment is conducted only after completing this warm up exercise. Second, it was necessary to make the subject become familiar with the operation of the virtual reality medium before the actual experiment itself. According to the instructions for the software and the settings I have made, the subjects have to become familiar with such VR operations as walk through, control of the objects, as well as transfer, rotation and combination of the system module furniture.

Experimental verbal data obtained is later encoding classified as functional building types, references, spatial gestalts or experiential archetypes (Schon, 1988). Finally, verbal data that have been encoding classified is analyzed by comparing the differences between the design reasoning of the two design media.

3.2. TOPIC OF THE EXPEROMENT

During warm up, because the purpose of the exercises was to familiarize the subjects on the thinking aloud method, the same topic was adopted for both drawing and virtual reality media. It consisted of a design studio with functional spaces for a design area and a conference room. Using system module furniture, the object was to achieve zoning of functions, circulation and control of flow, as well as the use of windows.

In the experiment itself, the topic was to design a working space. To prevent the subjects from totally remembering the design reasoning they have made for each medium while describing the design process, the topic has been divided into Plans A & B which differ slightly in the position of the deck and in terms of vertical circulation. Overall, the same design constraints were maintained to

assure that the subjects work on similar types of design topics during the experiment.

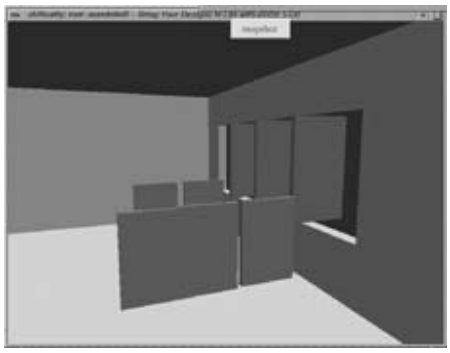

Figure 3. Topic of Warm Up Experiment.

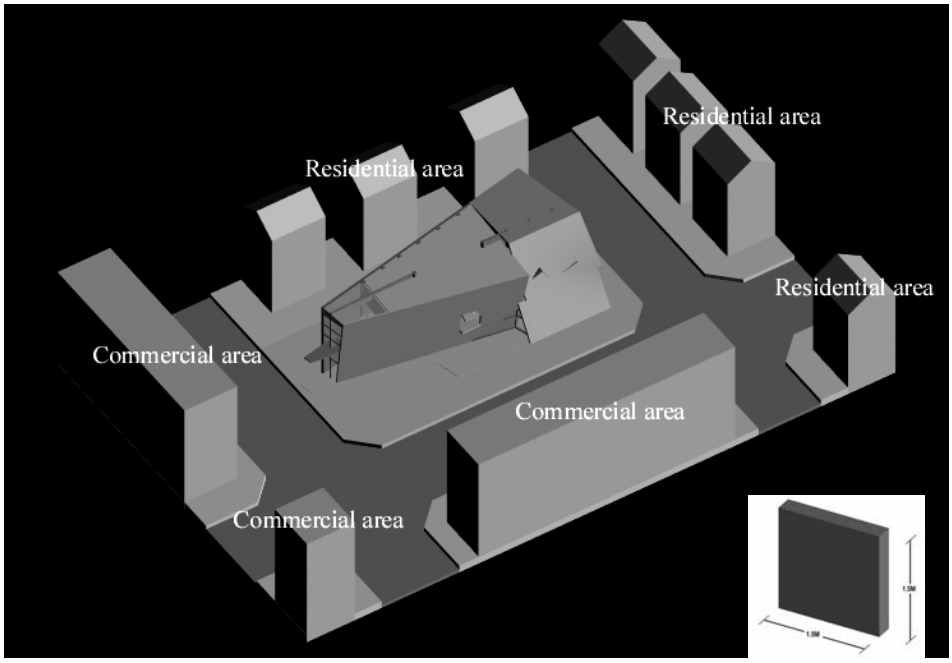

Figure 4. Site Allocation and System Modules.

Several architects jointly designed a working space. After development by one designer of the basic concept based on the rules and on the conditions of the site, other designers were consulted on details of the interior spatial designs. The designers consulted were given 1.5 m. by 1.5 m. system module partitioning to attain the following spatial functions while facing several given design constraints.

The necessary special functions include: (1) Primary and secondary entrance (two out of three possible choices), (2) Entrance lobby, (3) Administration and reception, (4) Major designing area (for six designers and must be in close proximity with the model room in the deck), (5) Chief designer's area (for one person), and (6) Conference area (with a capacity for all employees to confer and listen to briefings).

The following design constraints have been imposed (Akin 1988): (1) Zoning of functions, (2) Efficiency of use, (3) Privacy of use, (4) Circulation and control of flow, and (5) Use of windows.

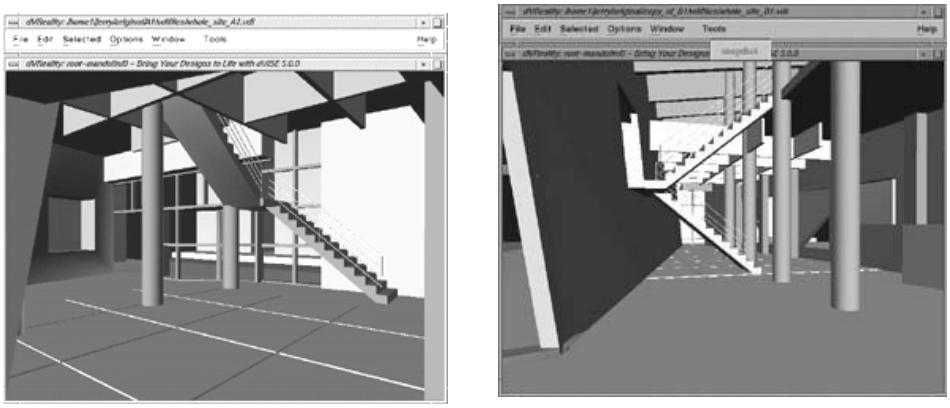

Figure 5. Plans A & B for Design Working Space.

4. Analysis

The collection of verbal data from each design episode started from the choice of entrance and lasted until decisions were made on all required functions. All rules used by the designers fall under the four types proposed by Schon. Function type, references and experiential archetypes in the verbal data all were in keeping with original instructions. It must be stated here that in this experiment's verbal data, designers usually decided on or evaluated the design plan based on the actual dimensions of objects. For instance, Subject No. 2, in his description of the drawing he made said that: "A . . . that measures 1.5 meters [and] a staircase that measures more than a meter. Then I added another one meter or so. The entrance to the working area will be found here . . ." Subject No. 1, while describing his design using virtual reality said that: "3 meters . . . 3 meters . . . 3 meters . . . .9 meters . . .for a total of 12 meters . . . This conference area I am designing doesn't have to be this big." This type of special reasoning falling under perceptual geometry was not discussed by Schon and this may be explained by differences in the design tasks. For this reason, I have classified them under spatial gestalts.

4.1. RULE TYPES

In the four sets of verbal data obtained from the designers who used drawing and virtual reality, it can be seen that four rule types were employed in design reasoning. Similar with Schon's conclusion (1988), reference and experiential archetypes were the most common (Please see Tables 1 and 2). These two types were markedly dominant in the design reasoning processes of the subjects in this experiment. Compared with designers who used drawing, those who adopted virtual reality showed a higher incidence of the use of experiential archetypes in making decisions or in evaluating the design decisions they have made (See Table 1).

TABLE 1. Rules types.

	Subject 1		Subject 2	
Ratio (%)	drawing (task B)	VR (task A)	drawing (task A)	VR (task B)
Function types	5.56	0.00	6.25	13.33
References	37.5	16.67	18.75	20.00
Spatial gestalts	43.75	33.33	62.5	20.00
Experiential archetypes	13.19	50.00	12.5	46.67

4.2. DESIGN REASONING

The fundamental task of a designer is to utilize large quantities of rules stored in the knowledge bank to look for another design world situation in a given design world situation. Such a design world situation reflects another situation that exists in the real world. This design processing that changes design world situations is the so-called design reasoning (Mitchell, 1990).

A design situation is a design task involving declarative knowledge. The latter is a description of how something is made to consist of (Anderson, 1981), as for example an office, lighting, building, entrance, and other design knowledge. These reasoning rules employed by designers are themselves the attribute relationships that exist among declarative knowledge (Akin, 1986 pp. 34-35). Furthermore, these design tasks stored in long-term memory serve as a bridge of communication between the design media adopted by the designer and the designer himself.

In this study, analysis is mainly done on the verbal data obtained. Details on design reasoning were classified into three categories: The first is the one-on-one application of a design rule from a design situation to another design situation. The second is the application of different reasoning rules from a

design situation to multiple design situations. The third is the multiple-to-one application of different rules from different design situations to a certain design situation.

TABLE 2. Three cases about design reasoning.

Experiential archetypes ratio(%)	Subject 1		Subject 2	
	drawing (task B)	VR (task A)	drawing (task A)	VR (task B)
one-on-one	14.29	40.00	11.11	14.29
one-to-multiple	3 .33	ıone	2 .00	5.00
multiple-to-one	n ıne	7.14	n ıne	Jone

5. Conclusions. Limitation and Further Research

After consideration of the various analyses made, it was concluded that the designers who used virtual reality employed experiential archetypes at a higher incidence and is characterized by design reasoning that is one-to-multiple and multiple-to-one. Furthermore, they also are dependent on new design solutions or assessment of existing design plans.

Owing to limitations on design in existing technologies (Bridges and Charitos, 1997), it is generally not possible to make a wider definition of design action. Furthermore, experimental conclusions obtained do not fully cover the whole range of design reasoning characteristics of design worlds obtained through currently existing applications of virtual reality.

The application of virtual reality in architecture has been well-documented in the past, especially in terms of design evaluation, communication and confirmation (Kiffman, 1995; Campbell and Wells, 1996; Pinet, 1997). In this paper, in view of the fact that using different design media in constructing design worlds leads to variations in design reasoning, discussion covered some phenomena on design reasoning rules applicable to virtual reality design worlds, as contrasted from those using traditional drawing. In the future, further research can be done on the different design reasoning that can be generated or presented by various media types. Since virtual reality is potentially useful for improving results of this experiment or the advantages of other design worlds, this study has been made to serve as a reference in introducing virtual reality to design thinking for the ultimate goal of contributing to its application in design work.

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