Immersive 3D architectural worlds: How to get in and out again

SCHNABEL Marc Aurel, KVAN Thomas

Department of Architecture; The University of Hong Kong; Hong Kong, China
http://arch.hku.hk marcaurel@hku.hk tkvan@hku.hk

In this paper, we examine the perception and understanding of spatial volumes within immersive, non-immersive virtual environments and physical models and their translation to a tangible representation in a series of design-representation experiments. Students experienced, assessed, and analysed spatial relationships of volumes and spaces and subsequently constructed models of these spaces. The goal of our study is to identify how designers perceive space in Virtual Environments (VE). We explore issues of quality, accuracy and understanding of rebuilding architectural experienced. By comparison of the same task within a screen-based or real 2D realm, we are able to draw some conclusions about aspects particular to immersive VE activity.

***Keywords**: Virtual reality; design translation; design understanding; design interpretation; design outcome*

Introduction

Virtual Environments (VE) may be used in the process of architectural design. Designers recognize VE as a tool of form-finding and communication and presentation of their ideas (Bertol 1997). VE-equipment and presentations are used not only in professional settings but also gaming and other consumer activities (Leach, 2002). Virtual design practices are developed from lessons learned in academic contexts (Wojtowicz and Butelski, 1999). However, Stuart (1996) points out that research on the outcome of results and the opportunities for applying VE in of architectural design is still in progress. In the past decade, many architectural design exercises and professional projects have used Virtual Design Studios (VDS) as a medium for collaboration. As stated by Kvan (2000) the qualities of design and their outcomes are directly linked to the communication and collaboration. Immersive-VE (IVE) have not yet been used widely for design interactions, although immersive Virtual Environment Design Studios (VeDS) offer new opportunities and solutions to architectural design problems (Schnabel and Kvan 2001A). The first VeDS (VeDS, 2001) resulted in conceptual manipulations of space; the results suggested further work needed to be carried out to clarify just how well 3D forms are understood in IVE. The experiments described in this paper engaged students in describing forms they examined in IVE, thus investigated the relationship of 3D space perceived within IVE as compared to descriptions made in the physical realm.

The Cube

For the purposes of an experimental task, we interpreted an abstract architectural arrangement that can be studied in 2D or 3D environments. We modified a tool, MAZE that we had used for related experiments (Schnabel and Kvan, 2001B) to enable students to experienced enclosed volumes within a spatial assembly. This cubic structure simulates a simplified architectural spatial configuration that can be analysed, interpreted and transcribed by using immersive and non-immersive media.

Experiment

The experiment was designed to investigate a student's understanding of space as described in a variety of means: within a conventional representation of 3D space in conventional 2D floorplans; and using digital 3D models, using Desktop-VE (DVE), a VRML model displayed on a PC-Monitor, and immersive VE (IVE) using an 3D model viewed with a head mounted display (HMD) and its tracking devices.

Twenty-four architectural students were asked to explore and study the given 3D cube, which was built on a 4*4*4 grid framework (Figure 1). This cube was constructed of eight coloured and distinguish-different volumes (Figure 2). The spatial volumes were designed such that they were not intelligible from reading the surface descriptions only. Students were assigned to inspect one of the three representations (paper, DVE, IVE), and asked to reconstruct the cube using wooden blocks. A time limit of 25 minutes was given to study the cube as well as 20 minutes to rebuild the shapes using 168 wooden cubes, with 21 cubes available for each colour (Figure 3).

In the 2D design environment participants were given five 2D floor plans (Figure 4), represented the five levels of the cube structure. Participant of the DVE-condition used a web-browser with a VRML plug-in (Cosmoplayer) to view interactively the 3D cube-model, while IVE-participants used the MAZE-application, which allowed them to navigate and explore the given cube freely and in real time within the IVE.

Results

Volumes and enclosures are differently perceived and expressed in 3D volumetric structures, such

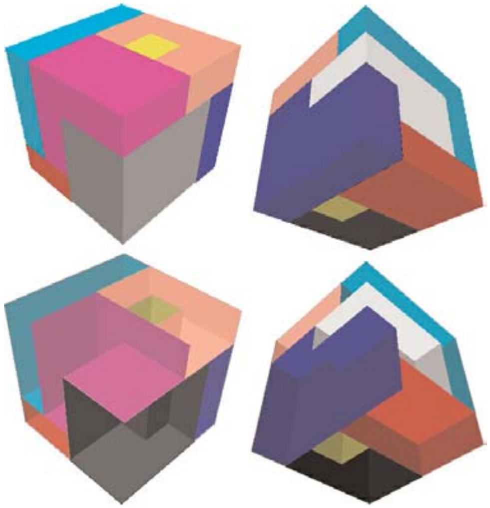

Figure 1. Outside- and inside view of the cube

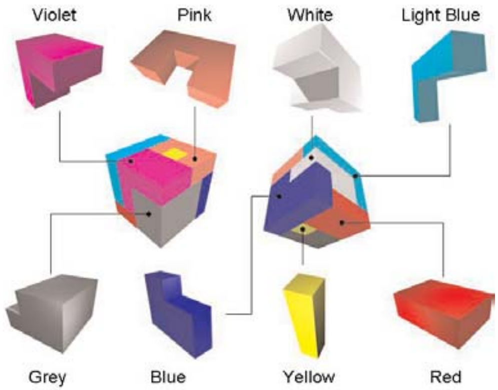

Figure 2. The 8 volumes of the cubic structure

Figure 3. Wooden blocks in eight colours

Figure 4. 2D plans for the 2D condition

as our 3D cube. This resulted that students working within the two VE-settings explored and investigated the spatial form and relationships of the volumes more fluid and had therefore a better understanding of the three-dimensionality. The participants studied and rebuilt each shape and their relationship to each other within the cube. In total contrast of that, students using the 2D medium analysed the cube as a stack of 2D 'floors' not relating to the spatial expression of the eight volumes. They simply memorized the floor plans and rebuilt them in the same manner. The evaluation of questionnaires, completed by the participants after the experiment, supported these findings. VE therefore offer designers a greater overall 3D understanding of space and volumes.

Yet in the majority of resulting cases only participants of the 2D media were able to rebuild the cube nearly without any error (Figure 5). In some cases participant of the VE conditions placed shapes at a wrong location of the cube (such as upside down or back to front), however the volume was recognized correctly and placed in context (Figure 6 and 7). Desktop interactions with mouse and keyboard are very common and students are well trained in the use of DVE. Nevertheless, the overall outcome was much lower than expected. Students named technical problems of interface and navigation as a major obstacle in their analysis of the cube. They were able to rebuilt distinct shapes, which were easy read- and accessible. While participants were able to use the IVE system, the results do show that their performance was substantially worse than the other systems. When de-briefed, the students noted that technical problems of hardware and software were significant inhibitors. Further they reported that settings for ease of use outside the virtual model were not adequate for actions taken when inside the model; for example, when they approached the model, the speed of approach was correct, yet when inside the volumes, the speed was too high.

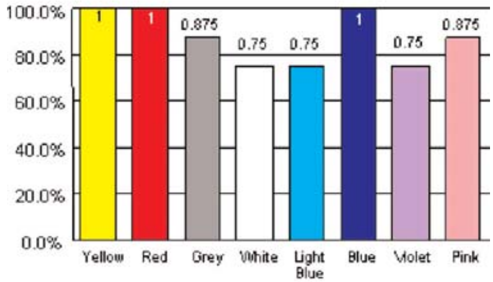

Figure 5: Percentage of Correct Volumes in 2D

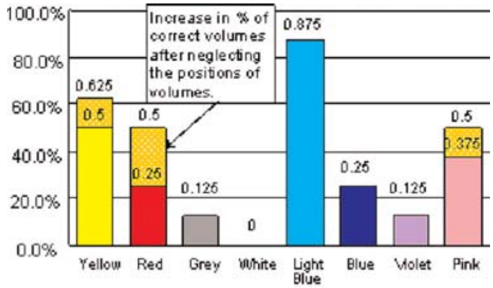

Figure 6: Percentage of Correct Volumes in DVE

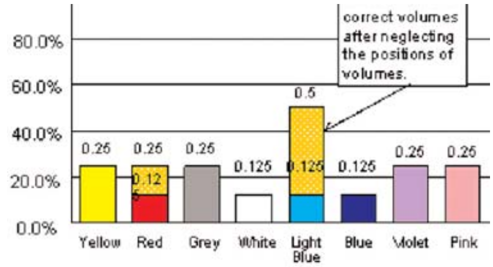

Figure 7: Percentage of Correct Volumes in IVE

Discussion

The students who looked at the printed plan representations did reconstruct the cube most accurately. Observing their processes of reconstruction, however, they engaged in replication of each 'floor' plan one at a time, stacked one above the other. Thus, they exhibited not spatial understanding of the cube. The IVE reconstructions were the least complete, but these results showed that users of IVE do indeed 'read' the volumes better than when working in 2D representations. The results also showed, unfortunately, that IVE tools are still so crude that the characteristics of the systems inhibit their effective use in design tasks.

The exploration of space, volume and location was enhanced. On one side users of VE can change their viewpoints and escape gravity, but on the other they remain all the time 'inside' the models. Digital 3D models are generated with immediacy similar to physical models, constructed to improve the perception of designs developed by drawings. Thus VE provide through its involvement an immediate feedback to its users, which is not possible within CAD or traditional design media. Designers can therefore work more three-dimensionally since every object within VE are experienced through movement and interaction. This possibility offers a different 'conversation' with the design that otherwise is not obvious or possible. Spatial issues are addressed in a manner akin to the real world. The process of design becomes more immediate in some aspects, with the tools enhancing the translation of the designers' and users' mental intention, experiences that were encountered perhaps in spite of the technology used and the abstractness of VE.

These works build upon prior experiments in communication between designers in VE compared to their actions in paper environments and how they collaborate with partners to solve 3D tasks. We carried out an architectural VDS that took issues of VE to a more realistic architectural design scenario (Schnabel et all, 2001), then we reduced the question of volumetric understanding to an abstract problem solving task in order to test issues that arose from the VeDS. In both scenarios our findings are similar. We find that it is important for architects to use in the early design stages a tool that reflects the three-dimensionality of their design such as VE. Using a 2D medium to translate spatial ideas apparently reduces the exploration and communication of volume and space. We demonstrated this with our abstract description of the 3D cube. Assessments of questionnaires and observations during the experiment have proved that students memorized the individual 'floor plans' regardless of their spatial connection in space. This results in a very particular and 'layered' description of a building. To understand and communicate 3D space architects are trained to think and read two-dimensionally. Interestingly the conditions of VE show, despite their relatively low 'success-rate', a constant understanding of the different 3D volumes and their spatial relationships. Distinct shapes of the structure we understood and rebuild. Understanding a 3D space, VE offers new opportunities of languages to designers. Consequently, the field is too rich to cover all aspects in these researches.

Conclusion

An experiment was conducted, in which students studied a 3D cube either conventionally using 2D plans, or screen based VE or IVE and rebuild the same using a physical model. The process was observed to identify the achieved spatial-understanding and the degree of communication. This study has demonstrated despite the fact that 2D representation of 3D space is the pre-dominant medium to understand and communicate spatial arrangements, that designers' understanding of complex volumes is enhanced within a VE setting.

Since IVE play increasingly a role in the design and form finding of architectural creation, virtuality becomes, in that sense, reality. Working in VE architects can explore alternative solutions to those achieved in conventional design methods, despite those issues of visual perception, mental images/workload, errors, comprehension of design and its communication, frequency of creation/feedback/modification-loops as well as impact on the design-creation. Our experiment demonstrated that, the problems of VE are not terminal. Because technical solutions are constantly evolving, difficulties resolved and equipment is becoming more sophisticated and easy to use.

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