The Desk-Cave

A Low-Cost Versatile Virtual Reality Design and Research Setup Between Desktop and CAVE

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Virtual Reality has become an almost ubiquitous technology in many applications, but it has seen limited success in design support. Reasons for this seem to lie in lack of easily available tools, high threshold for non-programmers, and high cost of equipment. In this paper we describe a Virtual Reality environment that is developed at Design Systems called the Desk-Cave. The Desk-Cave is a low-cost VR setup that combines principles of a CAVE system with a work desk. Architecture students with no specific training in VR technology use the Desk-Cave in design projects both in the early stage and the final presentation stage. The system allows quick transfer to the Desk-Cave and architectural evaluation of design proposals.

Keywords: Virtual Reality, architectural design, design process, cel shading.

Introduction

There has been a relatively long period of stagnated development between the early use of Virtual Reality in architectural design (see for example Dagit, 1993; Ager and Sinclair, 1995; Donath et al., 1995; and Alvarado and Maver, 1999) and the current stream of innovations in which VR plays again a predominant role (e.g. Petric et al., 2003; Lang and Hovestadt, 2003; and Drosdol et al., 2003). In the intermediate period, Virtual Reality as a set of technologies has been integrated in a wide variety of applications, such as in virtual environments for the Internet (e.g. Caneparo 1997; and Brown et al., 2000), interactive model viewing in most 3D modeling CAD packages, and in many computer games.

Although this indicates the wide success and ap-peal of VR as a technology, the use of VR in design support is almost exclusively developed and applied in academic circles and seldom in practice. It does not seem to be the case however, that the need for VR-like support has disappeared. Throughout our own research and educational work, we have been applying VR in design support tools (e.g. Achten et al., 1999; de Vries et al. 2003) and design projects (Achten and Turksma, 1999) on a regular basis. Additionally we observe a trend that students and architects turn to game-engines for VR-like studies and presentations (e.g. Uddin and Yoon, 2002; Hoon and Kehoe, 2003; and Moloney 2002). They rather take the additional limitations of game engines than using official VR platforms.

Otto et al. (2003) aptly summarize why VR in design support, despite its potential, is still not commonly used: (1) lack of easily available well-founded tools, (2) high threshold for non-programmers; and (3) high cost of equipment (Otto et al. 2003, pp. 233). Consequently, removing these problems would provide a substantial step forward to the use of VR in design support tools. Therefore we should be looking for developments that:

1. Provide generally available robust tools that allow transfer of designs in VR environments.
2. Provide 'one-click' button functionality.
3. Provide low-cost solutions.

In this paper, we present the latest development in our applied VR work for design projects in the form of the Desk-Cave. The Desk-Cave is a low-cost Virtual Reality setup that combines the immersive and non-obtrusive qualities of a traditional CAVE with a desktop-working area. The setup of the Desk-Cave is presented, and then its application in design projects. The paper is concluded with a brief discussion and assessment of the current state of affairs.

Desk-Cave setup

The first version of the Desk-Cave was realized in early 2001, and remodeled at the end of 2003. The Desk-Cave is a work desk surrounded by three screens on left, front, and right. On all screens and on the work desk there is projection by means of four standard issue digital beamers. The work desk is integrated with an A2-format digitizer, so the system can have various kinds of input (mouse, pen strokes, trackball, etc.). Each two beamers are connected to a pc-system with a dual video-output channel. One pc runs the prototype system and directs the viewpoint information to the other pc, which stands by in slave-mode. Between the screens we need to achieve a seamless transition so that the projection of a three-dimensional space is continuous. Furthermore, the projection should be

such that in the position of the user, the perspective projection is correct. Because the user sits at the work desk, and therefore is a-centrically located with respect to the left and right screens, the viewing fustrum of the projections has been modified for these screens (Figure 1).

In this way we establish two major effects: (a) an immersive environment without the use of cumbersome headsets, and (b) a one-to-one scale perception of any projected model in the Desk-Cave. Because the user is sitting rather than standing, and not interfered with additional hardware, the Desk-Cave allows for longer periods of interacting with the system than a CAVE or any other VR setup with headset or glasses for stereo projection. Furthermore, consultation with up to two other people is possible.

Desk-Cave in projects

The Desk-Cave forms a general environment that can be used for various applications next to its use in design projects. In this paper, we focus only on the design projects. As we have stated earlier (Achten and Turksma, 1999), the expected benefits of using VR in the design process are: (1) improved spatial reasoning, (2) easier translation from two-dimensional to three-dimensional representations, (3) and immediate spatial feedback on design decisions. In order to achieve these effects, it is crucial that the switching between design modeling and viewing in the VR environment is as fast and effortless as possible.

In the past we have developed various design tools using the WorldUP development environment (Sense8, 2004). Although this environment is productive for research purposes, we experienced in the design projects that for regular architecture students it still forms a too high threshold. In order to streamline the transition process, we have switched to the OpenSceneGraph toolkit (OSC, 2004). Models are imported from 3DStudio by means of the OpenSceneGraph Exporter to which we have

added support for the easy exporting of lightmaps in order to view also the results of lighting computations. In OpenSceneGraph we implemented the so-called Design Systems Viewer, which enables walk-throughs with collision detection and ground tracking in the Desk-Cave. These changes had the following effects with respect to the previous system:

1. Substantially larger models can be viewed now in the Desk-Cave.
2. Reduction of number of actions required by the user to export models.
3. Immediate „play" functionality when the model is imported.
4. Reduced need for VR-optimized modeling.

The transition from model to viewing in the Desk-Cave now only takes exporting the model, and saving it to a network location from where it can be accessed by the Desk-Cave. Thus, the transition time has been reduced from the previous 15 seconds to 2-5 seconds, depending on the size of the model. More importantly, this also means that the number of operations to make any given model suitable for viewing in the Desk-Cave has been reduced greatly.

The Desk-Cave in its new setup has been applied in several MSc.-graduation design projects. These projects are by students who graduate in architectural design, and who thus have a keen interest in understanding and developing their design, but not in getting further involved in the 'nuts and bolts' of advanced visualization techniques than is required for getting a good architectural design. Therefore, the ease with which the students can use the system is an important benchmark for us to determine to which extent we are successful in addressing the
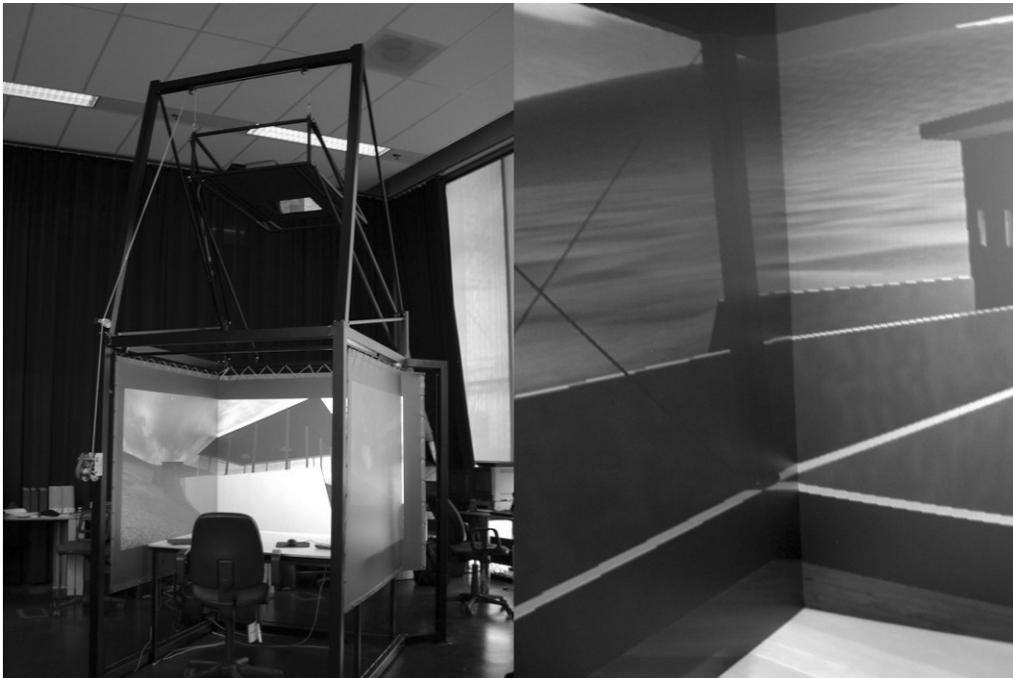

Figure 1
Left: The Desk-Cave setup.
Right: Transition in corners.
Model by Daan Willems.

problems set out in the introduction. In most cases the Desk-Cave was used in the early design stage when the students are in concept formation of their design. Therefore, the models typically represent mass-studies in urban context or spatial-planar first compositions of a design concept. The students created many variations of their ideas and viewed these in the Desk-Cave. In consultation sessions various aspects of the variant models such as location of the design in the site, volumetric appearance, relationship to other buildings, relative scale, movement patterns towards and from proposed exits, and spatial complexity were compared. Due to the one-to-one scale perception the visual impact of
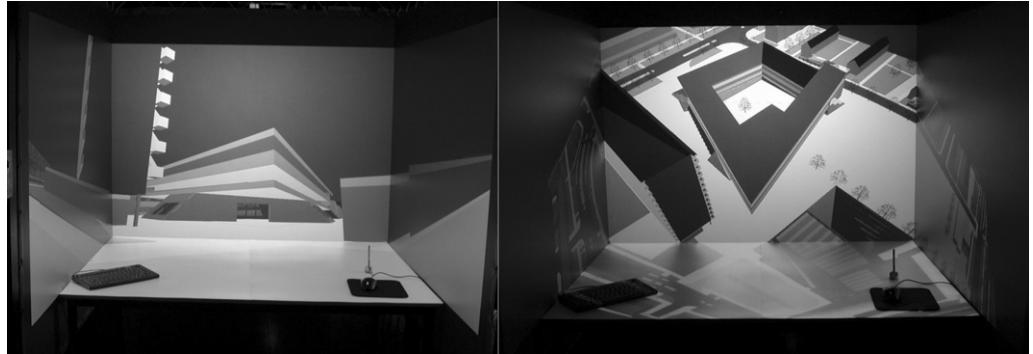

Figure 2
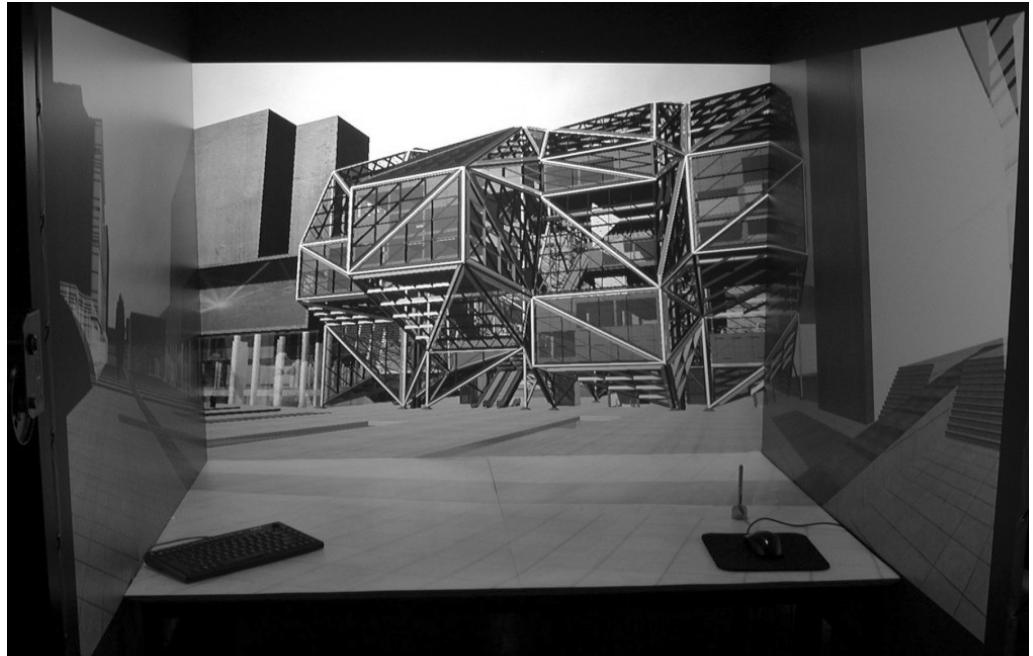*Variant study in early design phase. Model by Dennis van Herel.*

Figure 3
Final presentation MSc.-student project. Model by Alex Kunnen.

several proposals can be quickly assessed (Figure 2). In one case the Desk-Cave was also used for the final presentation of a large model of a design project (Figure 3).

Cel-shading in the Desk-Cave

Especially in the early stages of design much attention is given to the volumetric appearance of design variants. Direct visualization of a 3D model in VR usually leads to rather bland and 'flat' effects due to even lighting and the typical lack of geometric detail. Often students tackle this by applying textures to the model. This is problematic because (1) wrongly applied textures in terms of relative size are distractive; (2) stock textures seldom provide the correct impression of the design that the student wants to convey; and (3) applying textures is a time consuming and distracting activity.

To avoid this, we have looked at cel-shading. In cel-shading, the model is rendered in two passes: first the solid surfaces, and second the edges of the model. The solid surfaces are rendered in four tone shading, so combined with the edges this gives the model the appearance of a line-drawing, or cartoon-style rendering (Figure 4). The lack of textural detail, the four tone shading, and the edge-drawing of the model are more consistent with the design intentions when students are in the early stage of design. We are currently experimenting with the right settings for this technique to get a more satisfactory impression.

Discussion

The improvements made in the Desk-Cave were clearly appreciated by the students who also indicated they gained a better insight in their own design proposals during the early design stage. The reduction of actions to get a model in the Desk-Cave is not yet 'one-click' button, but does no long require any more sophisticated actions than saving a model in a particular location. Further incorporation of the Desk-Cave in design projects will lead to a better understanding how to frame design problems and analyze the design variants. In future work, we also hope to expand the visualization modes to better tuned cel-shading techniques for sketchy architectural designs.

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