VIRTUAL REALITY IN EARLY DESIGN: THE DESIGN STUDIO EXPERIENCES

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ABSTRACT
The Design Systems group of the Eindhoven University of Technology started a new kind of design studio teaching. With the use of high-end equipment, students use Virtual Reality from the very start of the design process. Virtual Reality technology up to now was primarily used for giving presentations. We use the same technology in the design process itself by means of reducing the time span in which one gets results in Virtual Reality. The method is based on a very brief cycle of modelling in AutoCAD, assigning materials in 3DStudio Viz, and then making a walkthrough in Virtual Reality in a standard landscape. Due to this cycle, which takes about 15 second, the student gets immediate feedback on design decisions which facilitates evaluation of the design in three dimensions much faster than usual. Usually the learning curve of this kind of software is quite steep, but with the use of templates the number of required steps to achieve results is reduced significantly. In this way, the potential of Virtual Reality is not only explored in research projects, but also in education.

This paper discusses the general set-up of the design studio and shows how, via short workshops, students acquire knowledge of the cycle in a short time. The paper focuses on the added value of using Virtual Reality technology in this manner: improved spatial reasoning, translation from two-dimensional to three-dimensional representations, and VR feedback on design decisions. It discusses the needs for new design representations in this design
environment, and shows how fast feedback in Virtual Reality can improve the spatial design at an early stage of the design process.
Representing floor plans for interactive evolutionary design
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Goals of the design studio
The Design Studio started in its current configuration in 1998. It was founded with the following purposes in mind:

1. To facilitate the research programme VR-DIS of the Design Systems group. VR-DIS stands for Virtual Reality - Design Information System (Achten et al. 1998). The studio was to provide the hard- and software to develop the research projects on, and to provide a testing environment for system prototypes.
2. To facilitate and innovate design education by incorporating this technology in design studio teaching.
3. To mutually influence research and teaching by integrating the products of research in the design studio, and to explore in the design studio the boundaries of new technology.

The primary goal of introducing VR-technology in the design studio is not to use it as a presentation tool at the end of the design process, but to use it from the very start of the design process. Currently, typical design studio work seldom uses the computer in the formative stages of design. It is only slowly making its entrance in the sketch phase in a mixed use with drawings and scale-models.

By providing the hardware, software and the working methods that increase the use of the computer, we hope to explore and push the boundaries of what is possible with the computer in design. The student work and research work in this respect can inform each other and provide feedback.

The design studio consists of six Intergraph machines that run on WindowsNT. The machines are dual-Pentium II 400 MHz machines with 256 MB RAM. They are equipped with Intergraph Realizm GT videocards with 16 MB frame buffer memory, 16 MB texture mapping memory, and geometry acceleration, specifically designed for real-time graphics. The systems are completed with 21" monitors. For projection purposes, there is a projector and a screen. All machines are on a network. Students have individual accounts and space on the network hard-disc. They can work together by sharing directories. The basic software is AutoCAD r14 for modelling, 3DStudio Viz2 for modelling and visualisation, WorldUP for Virtual Reality, Photoshop for graphics, and Internet and Powerpoint for presentation (see Figure 1).
Normal design versus the VR-cycle

In the recent years that CAD has been introduced in the design studio, its typical use is that of a modelling tool, used separately from sketching and scale-modelling, and without much interaction between those activities. VR as a technology has been explored to some extent in various approaches (for example Bridges et al. (1997), Bourdakis (1997), Caneparo (1997), Shih (1997), Wall (1997), Bradford et al. (1997), Terzidis (1998), Wong et al. (1998), Dobson (1998), Klercker (1998)), but is not yet widespread. Given the focus of the Design Systems group on Virtual Reality, we have chosen to introduce this technology as our specific approach to the design studio.

In the spectrum of abilities required in architectural design, three-dimensional reasoning is a key issue. The organisation of space in a design often informs (and is informed by) the materialisation, structural design, HVAC installations, and the implementation of function.

In the majority of CAD software, making and using three-dimensional representations requires many additional actions from the user part. The link between two-dimensional and three-dimensional representations is tenacious and not adequately supported. Also, the interface of the software is inherently two-dimensional, often based on the common desktop-metaphor. These factors inhibit a fluent transition from working in two-dimensional representations such as plan and section to a three-dimensional representation.

Virtual Reality technology has a few interrelated characteristics that improve on the factors stated above:

- Immersion. The perspective projection of the design on a monitor or head-mounted display gives an accurate image of the design as perceived by an observer inside the design.
- Real-time rendering. Fast rendering enables a steady flow of images of 15-25 frames per second, which gives the idea of continuity.
- Position and orientation feedback. The linking of rendering images to position and orientation and in particular to match these images with changes in real-time greatly enhances the effect of immersion.
• Interactive manipulation of the digital environment. Objects and elements in a VR model can be changed and the effects are shown in real-time.

In short, Virtual Reality provides an immersive environment which permits real-time walkthroughs in a design. In Eindhoven University of Technology there is a long-time experience with the use of this technology, in particular through the work of Calibre Institute. Up to now, it required powerful computing systems and a lot of fine-tuning of the model to optimise results. This inhibited regular use of VR in the design studio. With the installation of the Design Studio, however, machines and software have become available that allow quick and (almost) ubiquitous use of VR.

The VR cycle: AutoCAD/3DStudio/WorldUp
The software that is used in the Design Studio (AutoCADr14, 3DStudio Viz2, and WorldUP) normally is seen as quite separate from each other. They all read some standard file-format (DWG, DXF, or 3DS) but they are conceived as single programs.

The so-called VR-cycle in the Design Studio enables the integration of the software that will allow quick switching between various representations. There are two versions of the cycle:

1. AutoCAD/3DStudio/WorldUP: The design in any stage of the design process is made in AutoCAD. The model is loaded in 3DStudio Viz (which runs parallel to AutoCAD) by means of the DWG link manager. Materials are assigned to elements of the model, after which the model is loaded in the WorldUP Player. The model is inserted in a standard landscape and the designer can walk through it in real-time. Normally, creating a model for a VR walkthrough is a complicated process, but the use of template technology for transferring models and creating the standard set-up greatly facilitates this process. Evaluation of the model in VR can lead to changes in the AutoCAD model, which are immediately sent to 3DStudio because of the DWG link manager. The first time the cycle is set up, it takes about five minutes. The second time, many actions can be left out, and a change in the AutoCAD model can be seen in VR within 15 seconds time.

2. AutoCAD/WorldUP: In this cycle, the step 3DStudio is left out, and WorldUP directly reads the 3DS file exported by AutoCAD. This is even faster than the previous cycle, but the model will lack material renderings that use texture maps, and display colours as they are defined in the layers of AutoCAD. This method is well suited for studies of mass and proportions.

In principle there is also the cycle 3DStudio/WorldUP, but this is at the moment not used since AutoCAD is the predominant modelling tool.

Although students need to have knowledge of modelling in AutoCAD and limited knowledge of 3DStudio Viz, the VR addition does not require additional knowledge. AutoCAD and 3DStudio are part of the regular curriculum of the IT course in the Department of Architecture. The information about the VR-cycle is available on the network for the students. To make the students comfortable with this particular use of the computer, however, we have set up brief workshops that introduce the matter in three hours. In this way, it is also
possible to discuss some additional architectural and computational issues (Achten 1996) of VR in design.

The computational issues concern efficient modelling to increase machine performance, principles of VR, and the use of network facilities. The architectural issues concern incorporation of VR in the design process, and making and evaluating models. Some of these will return in the discussion section of the paper.

Examples of student work
The examples here from student work cover three different uses of VR in the Design Studio:

1. **VR in the early design stage.** This project by Frank Janssen is a running graduation project. From the very start, the VR-cycle has been used to explore and check the architectural consequences of the design. The design task concerns a new design for the station area of Heerlen which needs to locate a complex programme of train station, secondary school, offices, bus station, stores, cinemas, and small police station. VR has served in particular to develop and test the complex spatial relationships between the various parts of the programme (Figures 2, Figure 3).

2. **VR as a presentation medium.** This project by Max Bruner is a graduation project that was completed in 1998. It concerned an urban infill-project of housing in Eindhoven. VR technology and CAD have been used during the whole design process to develop new housing types that are spatially more woven into the local fabric and each other. VR has served in particular to convey the general design, and the individual houses as they are grouped in the conglomerate of the complex. For the final presentation (Figure 4, Figure 5), the VR-model was enhanced by using radiosity rendering as textures for the model, providing realistic lighting information. In this manner, the model could be used twice in different ways.

3. **VR as a conceptual prototype.** This project by Dirk-Jan Bax was a fourth-year project made from the building construction point of view. It aimed to show how a VR model can present the construction order of a building, show placement tolerances, and provide data on elements, suppliers, and time schedule. Based on the design of the student the prototype was programmed in a few hours by Joran Jessurun of the Design Systems group. This project showed how the concept of VR can be expanded to incorporate disciplines that are not yet involved very much in this area (Figure 6, Figure 7).
New and running student projects concern the implementation of design knowledge of structural engineers in the early design phase, the use of genetic algorithms in a VR environment as a form-generating tool, the theme of the "skin" as a design concept, the integration of VR in the design process, and the use of VR to study large scale urban environments.

**Discussion**
The template technology provides synergy between the software programs that up to now are used separately. Students are able to switch fast between the
general modelling tool of AutoCAD to a VR environment to check the design changes in three dimensions.

Students are able to break some mental blocks that traditional two-dimensional representations have such as: stacking and repetition for high-rise, rigid geometric organisations for plans, and limited vertical development of the design.

The computer still evokes a strong focus on the technological aspects, and distracts from architectural issues in the design process. This requires constant attention in the tutoring to teach the student a critical attitude towards the generated image.

Traditionally educated architects find it hard to “read” the VR-models and require two-dimensional representations for judging the quality of the design. In particular in the graduation projects there is a strong call for traditional representations.

Complex and large models noticeably slow down the frames/second capacity of the machines. In our experience, the designing student can handle 5 frames/second and still interpret the consequences of design changes in the VR-model fairly well, but for new observers this frame-rate is obtrusive and distracts from the model.

VR models require a richer visual language to convey the same information as a plan. In urban design for example, a plan can have some geometric shapes indicating building masses, and lines for infrastructure, and those can be quite adequate for judging the urban plan. The same urban plan in VR however, lacks a sense of scale as the buildings typically are extruded from the urban plan. Here, other representations are required to add this information.

We found that both in the presentation phase, and the sketch phase, the strengths of VR lie in conveying the spatial consequences of design decisions, and tackling complex spatial programmes and forms. In this sense, VR can facilitate breaking through mental blocks that “older” representations inherently cause, and thus create new forms of architecture.

VR is not the sole direction to take for future developments of CAD in architectural design, but it is very good in conveying spatial solutions and to study design in the early phase using the VR-cycle. Future work will, among others, consider co-operative design as a number of re-use projects are initiated in which students of various disciplines will participate. Also, design prototypes from running research will be incorporated in the Design Studio (Coomans 1999, Vries et al. 1998, Leeuwen et al 1998).

References