USING IMMERSIVE VIRTUAL REALITY SYSTEMS FOR SPATIAL DESIGN IN ARCHITECTURE

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KEYWORDS

ABSTRACT
In the very young discipline of Virtual Reality Applications only a few reports are available about using this technology for periods longer than in experimental setups. This paper describes experiences made during four years of usage of Virtual Reality (VR) in educational training for architects. About 100 different people were working with our systems during this period. Two programs were developed at Bauhaus University with the aim of teaching students in architecture in three-dimensional sketching. An other program for free and own interfaces and environments is currently under construction and will be presented at the international computer fair „CeBit“ in 1999. The first program called voxDesign is based on the metaphor of voxels. The second program, planeDesign, uses rectangular planes to describe room-like situations. All programs force the users to design in a 1:1 scale, which means that the design and the feedback actions are coupled in an embodied way. A real walking metaphor is used for navigation. The experiences made by the students are explained too.
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1. Position statement
Virtual Reality in Architecture. This paper does not consider the different kinds of digital architecture, many articles were published in the past and only few results were shown. Most of the discussions try to give new impulses using terms like trans- or avatararchitecture (Novak, 1991, 1996) or Peter Eisenmann with his attempt of a virtual house (Eisenmann, 1997). We want to focus on what is possible with computers in a more qualitative than quantitative meaning.

We want to show that at least two things happen in the area of Computer Aided (Architectural) Design (CAD):

a. there are new methods of interaction with digital architecture and
b. digital and solid architecture will change itself by using these new methods.

Our attempt is to provide first approaches towards a Virtual Reality Aided Design (VRAD).

2. Computers in the architectural design process

19 years ago Hoskins (1979) published a work about simple design techniques using computer technology. The users (architects) were given small bricks as a design tool. The surfaces of the bricks were electronically recognizable by a computer. The computer generated a three-dimensional model according to the position of the bricks. This approach is very different to ways of interaction in todays CAD systems: no knowledge of the program was necessary! On the other hand the possibilities of expression were very limited due to the limitations of the bricks itself and were not limited to the simplest interaction techniques of this system! Based on everyday experiences complex digital models could be build by simply aggregating atomic elements. Virtual Reality technology could serve as such an intuitive, almost unrestricted tool for architects among other designers to express their ideas in a very creative way.

Since a few years this VR related techniques are being used for virtual walkthroughs through digital (CAD-) architectures and are well known in the architectural field (figure 1).
The VR principle of threedimensional interaction with the digital environment and the situation, to be an autonomous part of this world could lead to the hope, to create new design support techniques, similar to the researcher about the mentioned digital bricks.

Other work in this direction could be found at the HITLab in Seattle, at the University of North Carolina, at the University of Virginia and at other institutes. Figure 2 shows the elementary parts of a VR system for the threedimensional design work.

Based on this promising approach we have started at the Bauhaus-University Weimar several projects during the last years.

The following goals and desires serve as a basis for our research activities:

- Providing intuitive usability through unspecified design tools
- Generating and experiencing the designed world in a 1:1 scale communication with and within the virtual world; this means the architectural design objects and elements are able to be modified and could interact with each other, for example could change their size and the relation or position.
- Extending the expressibility of solid and virtual architecture, developing new ideas and forms of architecture
- Close implementation-usage loop
- Experimental usage and enjoyment

3. Requirements for the intuitive usage of VR-techniques in the architectural design process

The technical possibilities of VR are not sufficient for a successful design in such an environment. Some research was undertaken about communication and interaction in virtual environments but mainly without paying attention to a specific discipline or task, especially not for architecture. Furthermore a lot of research was done about improvements of technical parameters, especially investigating a high seperation of the users from the real world (immersion) and about the development of highly realistic presentations (resolutions etc.).
On the other hand questions of the psychology of perception are subject to a lot of research, e.g. in the treatment of phobias (fear of height, spider phobia). These developments are of interest because the presence is their fundamental background. Otherwise the patient could not be treated. In our case of architectural design and evaluation the so called "sense of being there" is a substantial psychological state for the successful usage of such a VR system. Some basic contributions to this field were also made at our university (Regenbrecht & Schubert, 1997).

Finally a VRAD system should consider the theory and practice of architectural design as it is seen today. The process of design is very complex and difficult to formalize (Schmitt, 1993, 1996). With our approach we follow theories which focus on the act of design instead of the result. A very promising theory of the design process could be the one provided by Christopher Alexander (Alexander 1977), it can be lined out as follows:

"..to design, it is essential . . .
...to work on the site, where the project is to be built,
...to work with the people, that are actually going to use the place when it is finished,
...to begin as something very loose and amorphous,
...to close your eyes, to have a undisturbed stream of ideas and thinking,
...to do this in a loose and relaxed way,
...to keep this total area in your mind,
...to make the essential points and lines which are needed to fix the design result,
...do not try to design on paper ...
"

A first step towards a VR system which follows these statements was to implement some applications with a basic and simple functionality. Our approach is very humble but it serves as a subject for discussion, evaluation, and critique and does not mean a universal solution.

4. Three VR-Applications used and usability reported
At Bauhaus University Weimar, a strong relation with Virtual Reality Architectural Design (VRAD) systems exists. Since 1994, when the multidisciplinary project atelier virtual was founded, three VRAD systems have been developed, namely voxDesign, planeDesign and VRAM. The voxDesign software environment specifically focuses at sketch oriented creation of spaces with voxels, whereas planeDesign is space oriented making use of planes. VRAM is using both concepts, based on a new software implementation, where all interfaces and the design world itself are able to be described on the same way: with easy modelling and editing functions inside or outside this VR system.

All systems make use of a Virtual Research VR4 Head-Mounted-Display, a stylus, a magnetic tracking device and the at the university developed platform construction. To allow the user to interact with the virtual environment without technical restrictions (like the many cables) and to keep the basic needs of an unconstrained, natural design process within the virtual environment the wooden platform construction enables a movement in a 4x4x2.5 meter in an almost unconstrained working and walking space. All applications described
Dirk Donath, Holger Regenbrecht

here are working in combination with this construction. (Regenbrecht & Donath 1997)

Figure 3: a concept to use gestures\textsuperscript{vi} in a virtual design environment (J. Lehmann, 1995; www.uni-weimar.de/iar).

4.1 voxDesign, 1995
The first application developed is called voxDesign. It uses voxels, cubes with 2.5 centimeters edge length, as the atomic medium of expression. Voxels can be positioned in space just by sketching them using a pen-like device (Polhemus Stylus) and a head-mounted display as an output device. For the users of this simple software there was nothing to learn except pushing a button and getting a three-dimensional menu for activating some additional functions.

Figure 4: one of the first example of a design result with voxDesign: A. Brechtel, D. Donath, Bauhaus University Weimar, 1995.

4.2 planeDesign, 1997
The second application (planeDesign) is as simple as voxDesign and uses rectangular planes to design spatial situations. In addition to that some object-based interaction techniques were tested with planeDesign always taking into account that the software should be usable without any training. Figures 5 to 8 are showing views out of the virtual environment.
Using Immersive Virtual Reality Systems for Spatial Design in Architecture

"To design is not to know what you are doing, but to feel, you are right."

The starting point to develop this kind of space definition is based on one of the main meanings of architecture: to define artificial space in form of setting up "borders" between our natural environment. PlaneDesign is a tool for the conceptual phase in the design process, to get directly from your ideas (and mind) a more clear picture about your raw design solution in a scale of 1:1. While voxDesign respects one of the main techniques in the design process - sketching -, planeDesign reflects the elementary intention of architecture: space. We have no scale, no measurement abilities, no exact positioning tools, only an intuitive way to create planes to define different spaces. Using a real - digital - stylus the architect describes flat walls, ceilings, floorings or whatever in a flexible position. The results showed in figures 5-8 are maybe simple and boring: but please consider, that these are pictures of a directly interpretation of the mind and ideas. These results transform into more accurate CAD or CAAD systems is easily possible. It is also possible to embed CAD models as a starting point or design context in your VR environment. The exchange file format is VRML or DXF.

4.3 VRAM, 1999

With VRAM we are able to overcome the twodimensional interface barrier afforded by desktop screen and mouse to interact with typically threedimensional virtual reality models. The program VRAM is designed for viewing, browsing, editing, and modelling three dimensional models based on the Virtual Reality Modelling Language (VRML). The focus is set on experiencing and interacting with large scale architectural models. VRAM serves as a testbed for threedimensional user interface (3DUI) techniques to allow better navigation, orientation, and modelling within virtual environments. VRAM is both a research and education project at Bauhaus University Weimar, and an immersive virtual reality software environment running on
different platforms (Windows and UNIX) using certain I/O-devices (magnetic tracking, head-mounted display, stereo projection screen). Phase I of IV implements an immersive VRML browser, basic editing functionality, and some selected modelling approaches. Different interfaces can be chosen and generated by the user of the system. The following phases of this project will upgrade the system to a flexible and comprehensive virtual reality aided design (VRAD) system.

Figure 9: Examples of using the VRAM software: real design environment, Bauhaus University Weimar, 1999.

Figure 10: Examples of using the VRAM software: user specific shape of the stylus tool, VRAM, Bauhaus University Weimar, 1999.
Using Immersive Virtual Reality Systems for Spatial Design in Architecture

In figures 9 to 12 you are able to see the whole environment: the user with HMD and stylus, situated on the platform and working in front of the projection wall, where you are able to see the current view of the designer. Each user can create their own interfaces in form of command related 3D icons. In a initial text file has to be set up the relation to the commands of VRAM. We will present this software and environment at first at the International Computer Fair CeBIT in Hannover in march 1999.

5. Digital Space: How should be the architecture for the virtual world?
Virtual environments differ significantly from the real world. While this is true, there are many things for the real world that can and should be applied to virtual space. Because virtual environments are at least and in a sense, spatial interfaces, conscious and unconscious design issues like symbolic meaning and metaphors perceptual, and cognitive factors must be considered.

In fact, a human is a life on the earth, with a fixed behaviour. A human is a member of a society with a certain form of communication behaviour and certain regulations and relations there. A human is a psychological phenomena with traditions, subjective and objective kinds of thinking which leads to specific activities. Therefore, independent if it is a real or virtual environment, we have to consider the well known roles, regulations and consequences of the environment to be a human.

It is not successful to follow all of the possibilities and freedoms of digital arrangements! For this moment it seems to be interesting, impressive and „possible“ to play with the definitions of space, size, order and architectural functions, ... to play with architecture. But the results will come back soon: disagreement, disorientation, unpleasant, boring, bothering, leading to illnesses and sicknesses.

In the last three years we are looking for rules and new or existing knowledge about the form and laws in a threedimensional digital space.
We believe, that

We need a space, following our human background and experiences.
We need a space, following our social regulations.
We need a well known space with well known metaphors and symbols. The author has worked in a research project at the HITLab, where we integrated a design theory of Alexander (Alexander 1979) to develop a method based on case use pattern language, that exposed usability issues early in the process and allowed us to better define requirements for the being and the content of a digital world. (Tanney et al. 1998)

This theory, the Pattern languages have been recognised in many disciplines as a way to address the whole and the parts, the big picture and various levels of detail. Christopher Alexander's, A Pattern Language, is an architectural design method that sequentially walks planners and designers through various patterns from a global scale to a local and more intimate scale.

In combination, these patterns can be used to realise human environment relationships that translate into design requirements and offer greater meaning and significance for the new kind of architecture and it’s sense.

To consider affordances of virtual space and the user's expectation from real world constructs, architectural could help to define a new meaning for space, form, and order. Patterns regarding proportion in the virtual world are able to describe similar relationships or add a layer of interface issues which alter the real world reference to scale.

Patterns like transition spaces, entrances, public and private space are necessary and helpful to make the first step for defining a new and familiar world too: through careful analysis of the scientists from different fields of experts it could be possible to lead Alexander’s “human needs” in the digital space. The interdisciplinary nature of the design of virtual environments makes it necessary to consider issues from multiple perspectives.

5.1 Student design project: architectural pattern for a digital environment
Since 1998 students are working on a reflection of the Alexander’s pattern for a digital world. You are able to see all results and discussions at the homepage of this project under the instruction of the authors. The results are impressive and creative for a new stage of defining the virtual world: in fact, it is necessary to respect the role and meaning of architecture in this world too! Some examples are showed in figure 13. (see http://www.uni-weimar.de/iar, link: [digital space] )

Figure 13: pattern for a digital environment: semester design project, 1998.

6. Summary
It was not the main goal of these projects to serve as a testbed for VR usability in general. The main focus was on some tools and ideas for the very early phases of the architectural design process. But nevertheless some statements about usability can be made, of course without any serious empirical background. The results were gained by frequently applied questionnaires asking for the general convenience with the system and by verbal reports given by the users of the applications to the staff. Each student used our VR systems a couple of hours in practice to realise the design task, each session lasting an average of about one hour (between 30 minutes and 3 hours).

Some results of a more general interest are presented here in brief:

• using the system continuously longer than 1 hour led to simulator sickness in about one third of the students.
• the pen metaphor (Stylus) exhibited very good usability for the given task; the students associated it with sketching
• sometimes there were problems with the stability of the tracking system, this very decreased task performance
• it is not necessary to provide as much colours as possible, 16 colours (in voxDesign) are sufficient for the design task
• during long sessions the students tended to lay down on the floor during the design process
• the most spectacular effect was to "experience" a virtual structure by just going around it
• a stereoscopic head-mounted display is not that necessary, other depth cues are much more important
• the selectable value for the field of view is very dependent on the individual (between 30 and 100 degrees)
• the estimated duration time by the student was shorter every time than the real time
• most of the students were immersed (or at least involved) in the virtual space during their design sessions
• for longer periods of usage the head-mounted display is not very comfortable

7. Discussion
The main advantage is a report based on real task driven usage of a system. Our current projects will combine educational training in a wider range of tasks with usability testing based on evaluation methods with statistically significant results. We started last two years with such statistical verified questionnaires about fields of research like Immersion, Field of View, Sense of presence. The work is done especially by Regenbrecht for his current doctoral qualification.

The whole discussion is in progress. We are able to try, to test and to evaluate our opinion about the sense of and the being in the virtual world. Not more. That's why we should work together and hear to the voice of the new generation.

8. References


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i Besides wellknown and used techniques like early sketch work, a working model and textural/pictural description.

ii especially between 1994-1996 were developed many projects like GreenSpace I/II and Blocksmith at the Human Interface Technology Lab in Seattle, http://www.hitl.washington.edu/projects/


iv atelier virtual: interdiscipline research team with architects, designers, specialists of information sciences, psychologists (see www.uni-weimar.de/architektur/InfAR/forschung/vradmin.html) in the field of VR at the Bauhaus University Weimar.

v see the social discussions about the Virtual Architecture, a kind of architecture only in digital form (Virilio 1994).

vi research about gesture recognition and their using in VR-systems is based on different motivations too: see http://www.peipa.essex.ac.uk/gesture/tools/ or http://www.percep.demon.co.uk/pfol3rd.htm

vii a more funny interpretation, explored in a discussion with G. Schmitt, ETH Zurich at the IKM conference 1997 in Weimar.

viii http://www.uni-weimar.de/iar