

Use of Virtual Environments in the Promotion and Evaluation of Architectural Designs

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Abstract

Virtual environments can create a realistic impression of an architectural space during the architectural design process, providing a powerful tool for evaluation and promotion during a project's early stages. In comparison to pre-rendered animations, such as walkthroughs based on CAD models, virtual environments can offer intuitive interaction and a more life like experience. Advanced virtual environments allow users to change realtime rendering features with a few manipulations, switching between different versions while still maintaining sensory immersion. This paper reports on an experimental project in which architectural models are being integrated into interactive virtual environments, and includes demonstrations of both the possibilities and limitations of such applications in evaluating, presenting and promoting architectural designs.

Keywords: virtual environments, architectural design, interactive walkthrough, design review

1 Introduction

Computer Aided Design (CAD) is an accepted technology for architectural design and has changed the workflow essentially. Rendered still images and video clips of animated walkthrough with high visual quality based on CAD models can be created with widely available tools and are used for presenting and promoting architectural design ideas to customers. They support the communication and become a selling feature. Virtual environments are the next step in the development of the working environment of architects. Interaction becomes possible while maintaining a high visual quality. At the lowest level of interaction, the viewpoint can be chosen freely, allowing free natural navigation through the environment. Programmed interactions like opening a door add another dimension. Important is also the possibility to switch between different design versions (i.e., details) while maintaining visible immersion. The highest level of interaction is achieved when sketching becomes possible within the environment, allowing the architect to respond to customer requests during a design review session. Due to equipment, adapting CAD models, and maintenance virtual environments remain costly. Nevertheless, bene-

fits for the architectural design process justify the investments for certain projects.

The article reports about an experimental, interdisciplinary project for media and architecture at the FH Düsseldorf. A virtual environment based on stereo back-projection with shutterglasses and tracked interaction devices was set up. The interior space of the entrance hall (Figure 1 shows a realtime-rendered image within the virtual environment) was used as a model, having the advantage that the experience in the virtual environment can be compared with the real space. Goal was to achieve high visible quality while allowing a high level of interaction.



Figure 1: Virtual environment of the entrance hall at the FH Düsseldorf, University of Applied Sciences

The architectural design requirements for virtual environment as well as a brief review of similar projects are given in Section 2. How virtual environments can be integrated into the architectural design process and what additional steps are necessary are presented in Section 3. Achieving high visible quality requires specific focus on modeling and texturing which is given in Section 4. Interaction models and working with the system is described in Section 5. The implementation itself and the system design is outlined in Section 6. Finally, we discuss our experiences with the system and give future directions in Section 7.

2 Architectural design requirements

Computer based architectural visualization is used for both evaluation during the design process and for communicating ideas and spatial relationships to the

builder. During the design process it is important for the architect to be able to make quick modifications in the 3D-model: the geometry, the materials and the colors. In the final presentation for the builder the emphasis lies on photorealistic images and animation.

It is one of the goals of architectural visualization to give the customer a realistic impression of the building. There is a great variety of visualization tools – from soft charcoal and colored pencils to CAD – and rendering software and now in the early stages of development, the virtual environment. Commercial software solutions render excellent surfaces, photorealistic textures and lighting effects. Animations which allow the user to navigate in the scene (qtv, vrml [BCM97]) have been important steps in the presentation of virtual buildings.

This progress has been made from the earliest stages of CAD with people power, cpu-power and ingenious programming creativity. But frontiers remain in abundance:

1. Displays with a small viewing angle (e.g., monitor) do not recreate the experience of live human perception. Anyone who has rendered virtual perspectives, particularly in interior spaces, has wished for
 - a wider camera angle without the resulting distortions
 - a way to look up or down without angled verticals lines and/or curved horizontal lines
 - a tool that could simulate human peripheral sight.
2. High-end 3D-perspectives and animations are projected on a 2D-screen or printed on flat paper - allowing limited spatial experience.
3. Interactivity, if at all available, is limited to changing the position of the camera and/or variations in pre-rendered materials.

Virtual environments have the potential to approach solutions for these limitations:

1. Stereoscopic computer graphics (for stereovision) [McA93] creates a spatial experience approaching live perception
2. The position and head direction of the viewer can be tracked, the 3D-model and perspectives are instantly recalculated and adjusted.

3. Input devices enable interactive manipulation of the 3D-Model.

3 Workflow

Virtual Environments (VEs) enrich architectural presentation to an immersive view of 3-dimensional design. For optimal architectural workflow it will be necessary to integrate the processes of design and construction and VE presentation. Two possible approaches: Implementation of construction features (including blueprints, dimensioning) directly into VE or Development of interfaces for exchange between CAD and VE. An example for the first approach is the Virtual Architectural Design Tool[ICCN99].

The ideal VE for the architect would allow:

1. direct transfer of the 3D-Model from any CAD-Software into the VE¹
2. realistic renderings
3. interactivity - including:
 - (a) drawing and sketching directly within the VE
 - (b) constructing 3D components including definition of surface and texture
 - (c) inserting, deleting and modifying parametrical objects
4. long distance collaboration via internet (see [SKKD01] for experimental results)

With this vision in mind our project focused on the following strategic steps:

1. For the construction of the 3D-Model we chose ArchiCAD [Gra02] because it supports many of the desired features. ArchiCAD is based on GDL (Geometric Description Language [GDL02]) which offers a parametrical object format. Because GDL-objects can be used in multiple CAD-formats more and more building product manufacturers are offering GDL-objects of their

¹Interfaces that allow exchange of 3D-models including full functionality from any CAD software into the VE have yet to be developed. The exchange format IFC which has been developed by the International Alliance for Interoperability (IAI - [IAI02]) supports the exchange of data among several leading CAD solutions including ArchiCAD, AutoCAD, Nemetek, ideCAD and others.

products. GDL-object-libraries are available free of charge through the internet and are maintained by the manufacturers. ArchiCAD allows an intuitive construction in both the 2D- and the 3D-environment. The transfer of the 3D-model from ArchiCAD into the VR was realized with standard interfaces.

2. The 3D-model was imported (see Figure 2) into Maya where UV-coordinates and textures were added. Then textures were prerendered, including the lighting² in Maya. The final 3D-model was exported via VRML for usage in a VE based on Open Inventor [Wer94].
3. Tracking and input devices for interactivity were implemented in the VE

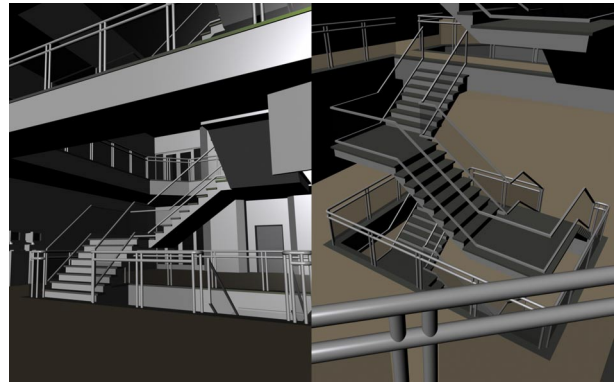


Figure 2: Imported model in Maya

4 Modeling and texturing

The CAD data cannot be directly imported into the virtual environment. The number of polygons has to be reduced for better runtime performance. In our model we deleted several floors which were irrelevant for the walkthrough. The goal for the interior design was to review the installation of display and communication systems on the first floor. While transferring geometric data between different systems, artifacts e.g. wrongly oriented vertex normals can occur. Such artifacts can be corrected as shown in Figure 3.

Current graphic hardware supports only a limited number of light sources (i.e., 8 for OpenGL). Smooth light distribution of many light sources, important for the final impression of the space can be preprocessed

²the lighting effects are “baked” into the texture

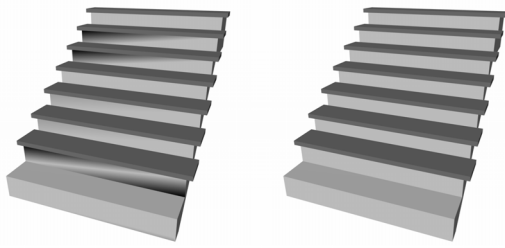


Figure 3: Left: wrongly oriented vertex normals, right: corrected object

in case no interaction between light and viewer takes place, i.e. assumption of static light conditions. This process is called texture baking and is demonstrated on a simple cube in Figure 4. More complex lighting simulation like raytracing or radiosity can be applied which are not suitable for realtime processing.

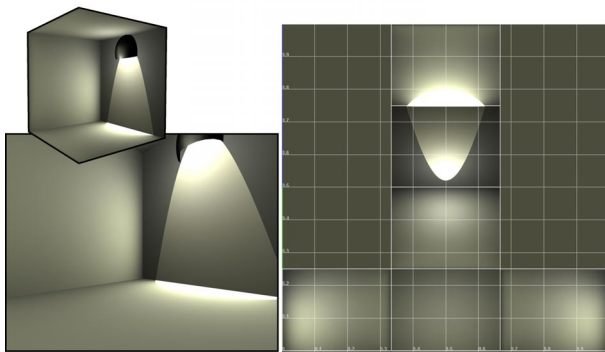


Figure 4: Cube lighted from inside (left: normal rendering, right: baked texture)

As a preparation for light baking all surfaces have to be textured, including assigning UV coordinates as shown in Figure 5. This can be a time consuming process if special tools are not available³. By partitioning the UV-map for several objects, the required texture space can be optimized for best runtime performance and quality. Also light sources have to be placed and parametrized.

Figure 6 shows the lighting of the floor with preview and rendering within the modelling (i.e. Maya) envi-

³The product MapSet from ORAD supports such activity in the application domain of virtual studio. Such a tool was not used in this project.

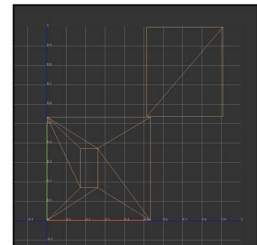
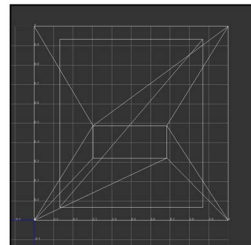
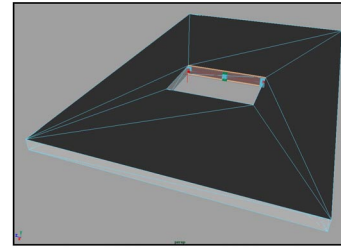


Figure 5: Overlapping UV coordinates, partitioning using layout UV

ronment. Visible in the preview is also the array light setup on the ceiling. Procedural textures with noise distortion of the red tile color and bump maps were applied.

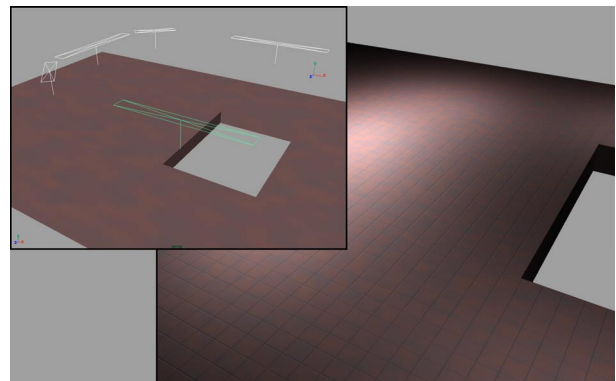


Figure 6: Lighting of the floor with preview and rendering

The quality of a virtual environment is not only judged by its visual resolution, framerate and interaction, but also how it copes with antialiasing. Figure 7 shows hardware antialiasing using a consumer graphics card. With camera movements the flickering along the edges becomes annoying, usually not a factor for still images. For rendering the translucent surfaces (i.e., the glass plates) correctly, while keeping a high framerate, the chosen runtime options are a compromise.



Figure 7: Hardware antialiasing: 4-times GeForce3

5 Interaction and navigation

Navigation is one form of interaction within a virtual environment and is one of the main basic user tasks, allowing to review the architectural design. Support has to be given to facilitate this operation and avoid situations where certain views cannot be reached or even worse where the user gets lost in space. Constraining the freedom of movement helps the user to focus on his main tasks [HWH97].

The movement in our system followed the walk metaphor, constraining the user to the floor as well as using collision detection. The wand – a tracked input device with 6 DOF in space – has a joystick, which is used for moving in space. The orientation of the wand is for changing the viewing direction. For comparison, with head mounted systems the head orientation would have been chosen for controlling the moving direction [FSG98].

A good taxonomy for possible movement control is given by [BKH97], distinguishing between explicit selections and automatic mode changes. Using buttons on the wand, the user of our system can scroll through predefined (camera) positions. This mode is especially useful for demonstrations, where specific perspectives should be shown.

6 Implementation and system design

The implemented virtual environment is part of a unique multipurpose space, which uses the InterSense IS-900 tracking system also for camera tracking as part

of virtual studio applications with a bluebox. The IS-900 is a hybrid tracking system, using ultrasonic range measurements as well as inertial sensors for position and orientation measurements. The hybrid approach allows a high framerate while keeping the absolute errors small. Ultrasonic transmitters 3*3*4 are placed on a grid in 2.2 m height, covering a space slightly more than 4,6 m x 5,3 m. A BarcoReality 909 is used for rear-projection on a 2 m x 1,5 m screen, featuring high resolution and fast phosphors for double refresh rates in active stereographic applications. Shutterglasses (CrystalEyes) are synchronized via infrared and allow free movement in front of the projection screen. The runtime environment was developed in Visual C++ and Open Inventor. The data from the tracking system were polled with constant framerate, using the InterSense SDK. The system layout in Figure 8 shows all main components, including the different tracked interaction devices (i.e., shutterglass, stylus, and wand).

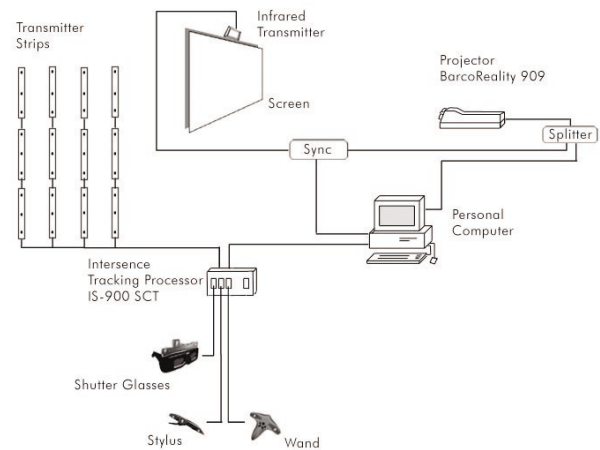


Figure 8: System layout

7 Conclusion and future work

A basic environment for architectural walkthrough with high visual quality has been developed. Our experience with the prototype has shown that a virtual environment can be used for promotion and evaluation of architectural designs.

Interaction with objects in the scene and a simple sketching function, enhancing discussions in the environment, as well as an auditory extension of the display are scheduled for the next project milestone.

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