

3D Visualization of Building Services in Virtual Environment

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In currently on-going project we develop methods and techniques for visualizing building services in our virtual room. At first we have established a conversion and transmission path from contractors' lighting modeling software to virtual environment software. Secondly we have visualized air flow data in a photo-realistic room in such a way that a non-specialist can easily understand the behavior of air flow. Thirdly we have developed navigation techniques which allow an arbitrary visitor to explore the model without guidance.

Keywords: *virtual environment, building services, flow visualization, interaction techniques*

Background

In this paper we will present the currently on-going project in which we will develop methods and techniques for visualizing building services in our 3D virtual reality environment (Jalkanen, 2000). Special goal is to develop techniques for visualizing indoor climate and visual comfort parameters and integrating these with photo-realistic architectural model. This project is a co-operation of Helsinki University of Technology and some Finnish building design contractors.

Virtual environments (Kalawsky, 1993) are extremely well suited for presenting architectural models and spaces. Studying different construction possibilities in a virtual environment will be both faster and cheaper than building a model room. Most of the existing spatially immersive setups in the building sector are used for architectural models. Visualization of the building services systems in virtual rooms is less usual.

The Experimental Virtual Environment (EVE) is a rear-projection based virtual reality system where users are surrounded by 3 meters wide and high

screens on three walls and floor. The stereoscopic images are reflected into these screens with projectors and users are viewing these images with stereo shutter glasses. In addition to shutter glasses one user is equipped with a six degrees of freedom head tracking device which produces location information needed for computing of correct stereoscopic perspectives. As a result of tracking user can move around the stereoscopic three-dimensional object which he sees through stereoglasses. The user with head tracking device is also equipped with tracked sensors which are used to provide interaction with the virtual environment. The EVE has also 3D audio system capable of producing arbitrary moving positional sound sources into three dimensional space.

The implementation of the visualization part of the project utilizes four software libraries. Visualization Toolkit (VTK) is used to process the flow data and to generate geometrical visualization elements. IRIS Performer is a real-time rendering system and it is utilized to achieve maximum graphical performance. Conversion library called vtkActorToPF, converts the

Go to contents 18

VTK elements in a form that can be used in IRIS Performer. VRJuggler is a virtual reality framework that manages the core of the VR application, including the control of Performer rendering.

Lighting visualization

After a few evaluation steps a working transmission path from lighting program databases to virtual environment was found. At the moment, these photo-realistic visualizations contain lighting distribution on the surfaces of the 3D model (Figure 1). A user (or a group of users) can explore these visualizations by "flying" inside the model. Stereographic images combined with the smooth motion inside the model emphasize the sense of immersion.

Flow visualization (Mantere, 2001)

In the next phase we have defined the conversion and transmission path of computational fluid dynamics data to the virtual room and developing new ways to explore and visualize it. The flow data is produced as a result of CFD calculations by our project participant, engineering office Olof Granlund Oy. The goal in this partial objective is the visualization of air flow data in a photo-realistic room in such a way that a non-specialist can easily understand the behavior of air flow and temperature.

Chosen visualization techniques

When choosing visualization techniques to be used in real 3D environment such as EVE, the criteria differs from the case of ordinary desktop application. Because the third dimension is really there, the visual elements should take advantage of that feature. An illustrative example of this idea is comparison of a simple stream line and a stream tube. Even if the line is in space, it is still just a line without thickness. The observer sees just one pixel wide line no matter how far the line is. In other words the appearance of the line itself does not give any cues about how far it is from the observer. A tube could be described as an extended line having certain thickness. Differently from the line, the tube gives a hint about its distance by



Figure 1. User exploring hotel lobby in EVE.

seeming to be thinner depending how far it is. This effect is also called the 'depth cue' (Kalawsky93).

Before the visualization techniques were chosen they had to be evaluated. During the evaluation it was taken into account that the aim was to create useful visualizations specially based on CFD calculations about office room ventilation and heating systems.

The visualization techniques should not result the elements to lie too close and dense to each other. In 3D space the occlusion could be a problem. Too many visual elements in a small region cause often just a chaotic view. In this case, the primary aim to get better understanding of some phenomena can simply turn against itself. Usually visualizing spatial vector field with too many vectors produces a confusing 'hedgehog'. When discussing about large back-projected displays and stereo images generated with shutter glass technique, it must be noticed that the result is a bit more blurred than on a monitor. That is why the smallest and thinnest details are often almost unclear. In a virtual room it is better to keep visualization as practical as it is rational.

Another issue is the demand for real-time rendering. The elements which are used in the visualizations must not put too much load on the graphics system. Usually that means compromise between the quality of the geometry and the achieved frame rate. With very large models one limitation is

also the memory but that has not been a problem in this project.

Paths of weightless particles

Solution chosen is to generate multiple particle traces from starting points very close to each others. The middle trace is visualized with a colored tube with cones indicating the direction of the flow and the outer traces are shown as simple colored lines (Figure 2a). The coloring is based either on velocity or temperature scalar values depending on the choice of the user. In addition, both tube and lines are slightly transparent allowing the observer to see also the photo-realistic geometry of the room behind the flow visualization. Using this technique, the geometry is kept quite light but it is still able to partly illustrate the behavior of real air mass. The room model will also remain recognizable because of the transparency and usage of minimal amount of massive elements.

Animated particles

Though the tubes and lines can be used to illustrate the velocity of the flow with varying color, it is better to visualize this particular attribute with animated particles moving along those paths (Figure 2b). In virtual environment like EVE a rough comparison of the speeds of two moving particles is often easier and more understandable than comparing two different shades of some color. Besides the convenience, it is always stimulating and makes the virtual experience more immersive when there is something lively in the virtual world. So animated particles were also chosen to the collection of the visualization elements.

Cross sections

Besides the velocities and directions in different regions of the flow, the observer may also be interested in some scalar quantities. A plane colored with the colors mapped to the scalar values is like a cross section of the dataset but the colored plane surface can be set in the scene as a 3D object and viewed in the virtual environment (Figure 2c). The possible scalar values are the absolute values of flow velocity and temperature.

Isosurfaces

Cross section surfaces presented in previous section are good for overall sights of some regions, but if the observer is interested in any particular scalar value there is still a need for another visualization technique. According to its name, isosurface illustrates the surface in the space where a scalar quantity has the same selected value (Figure 2d). In this project where the focus is in visualizing the resulting flow and temperature from ventilation system, observer can easily set the isosurfaces to show the limiting surfaces and thus illustrate the pleasantness range of the office room.

Transparency and the large number of polygons in isosurfaces have easily a degrading effect on the frame rate. Hence both in the generation and usage of isosurfaces some consideration should be used.

Interaction techniques in navigation (Laakso, 2001)

Our aim is to develop interaction techniques (Bowman, 2000) which allow an arbitrary visitor to explore the architectural model by himself. This requires the adaptation and testing of different navigation device and methods.

Input devices

Conventional input devices, such as keyboard or mouse, are not the best possible solution to be used in virtual environment. There is a number of specialized types of hardware devices that have been developed or used in virtual reality applications. We chose to test out three different input devices: wand, data glove and speech recognition.

Wand

A wand is a common device in surround screen virtual environments. It is the major input device used to interact with and control a VR experience in a typical surround-screen virtual reality system. We decided to test what we can do with our existing equipment. The main requirements for a wand are some kind of tracking equipment and some buttons. Both of these were already available in the EVE (Motionstar tracker

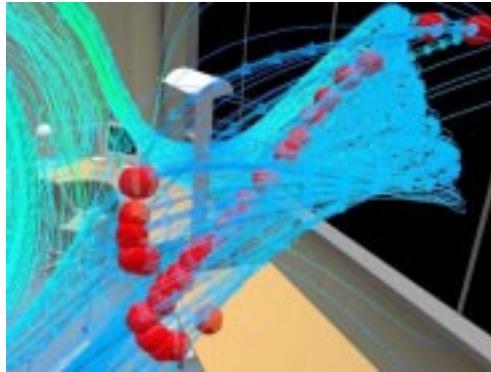
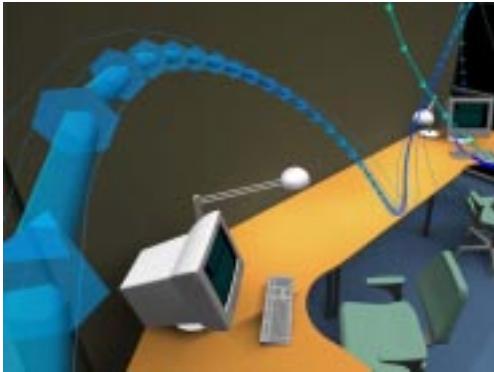


Figure 2: a) Tube and lines, b) Animated particles, c) Cross section, and d) Isosurfaces

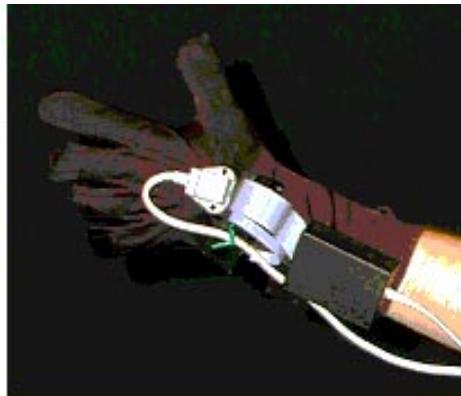
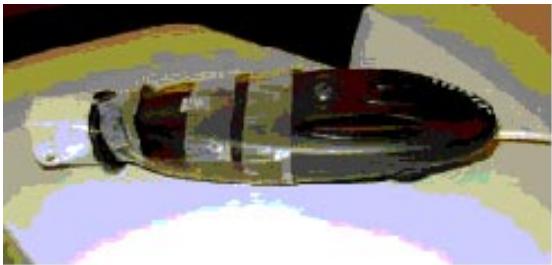
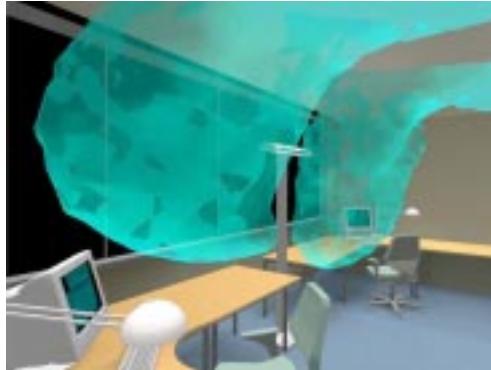


Figure 3: a) Prototype of custom wand, b) 5DT data glove with tracker

and wireless Logitech Mouse), so we were able to construct our own wand variant just by combining these into one unit (Figure 3a).

Data Glove

The second input device studied was a data glove. Hand movement tracking combined with gesture recognition offers a natural and intuitive way for users to input information, for example navigational commands. Constructing our own data glove was obviously out of the question, this time we had to buy the device (Figure 3b).

Speech recognition

The ability to issue verbal commands to a computer and have the computer to understand and respond has long been a desired goal of the human-computer interface community. Verbal commands are often much easier for a human to remember than a contrived keyboard combination or button combination on an input device.

ViaVoice is a user-dependent system, it requires a formal training session to be performed prior to running the recognition system. For this application, our grammar consisted of very simple and short navigational commands, such as “move forward” or “turn left”.

Movement modes

For the navigation in virtual architectural environments we have defined four different movement modes. Some of them restrict the user movement or rotation directions.

WALK - movement only in the horizontal plane, no limits in rotation so one can freely “walk and look around”.

DRIVE - movement only forward/backward, rotation only left/right, just like driving a car.

FLY - movement only forward/backward, no limits in rotation, just like steering an airplane.

HOVER - no limits in movement or rotation so one can float around freely.

The idea is that for example the WALK-mode may be the most natural choice for exploring the interior of a

building, but outside one may need some kind of free-floating mode to get the general overview of the environment. It is of course possible to change the mode freely during the session.

Conclusions and future work

The new techniques developed in this project offer new possibilities for the building contractors in marketing, product development and design. The preliminary examination of lighting models in virtual environments has been successful, and the project partners have been satisfied with the quality of experiment. In the future they are interested in to include real-time control of lighting conditions. Additional future research area is addition of sound generated by air condition, computers and other equipment normally available in office environment.

This work indicated that combining a realistic room model and an air flow visualization results an understandable solution. When the whole visualization is presented in a spatially immersive virtual environment, the sense of the space and the spatial relations in the model are experienced stronger. The project encouraged us to keep the development work going and strengthened the confidence of the project participants to VR technology.

The navigation methods developed in this project are clearly better than those we had before. In the preliminary tests even novice users could quite easily navigate around the models even if they had never been in a virtual environment before.

Acknowledgments

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[Go to contents 18](#)

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