A realistic view to virtual reality; new possibilities in construction.

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Introduction

The world of computer aided design has been characterized for many years be a constant flow of new approaches and techniques. It is difficult to recognize the real value of the different items. Some of these techniques are computer aided (stereo)imaging, animation, holography and virtual reality. These systems and these techniques are mainly used for the presentation of a final design. Because of the constantly improving performance of CAD systems and their users, these systems are more and more useful for the evaluation of several design proposals during the design process. However, because of the great impact that artistic images and advanced animations have on a presentation of a design it seems to be more rewarding to use CAD systems for this purpose only. Even new techniques like Virtual Reality systems seem to be valued in relation with their presentation capabilities instead of their possibilities to support design modeling and evaluation during the design process.

This paper describes the main results of research and development work on a Virtual Reality system. One of the results is a Virtual Reality application that will allow different participants in the design process to work together in a virtual building on a scale of 1:1. This system, a multi user design system, will offer modules for modeling and for evaluation. With these modules this system will show that new media are not only useful for the improvement of design presentations but that they can also be used for the improvement of the building performance.

Virtual Reality systems are based on different existing presentation techniques, like photo-realistic images, stereo-images and real time-animation. The added value of this kind of CAD systems is determined by a new kind of interface (a sensored interface) for the control over the animation, displayed through the head-mounted displays or eye phone and for the control over a 3D pointer for the selection of commands and objects in a model. For a better understanding of the proposed multi user design system, this paper will also discuss some of the different existing presentation, modeling and evaluation techniques that are used and it will describe the main characteristics of the Virtual Reality computer system, the peripherals and the applications.

Presentation Techniques

For the presentation of designs different kinds of techniques exist that are useful for different purposes, such as:

Photo-realistic images for design presentations

Photo-realistic images can be generated by more or less sophisticated visualisation programs. The image can be hidden-line, flat or smooth-shaded, rendered or 'rayed',

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showing a design or a product. This product can be represented by e.g. lines, faces, solids, colours, texture maps and bump maps within a certain view.

Stereo images for better depth perception

Stereo images need a clever approach to the definition of the eye points, a focus point and a view-angle. They also need a special medium, such as a stereo viewer, red and green glasses or a full colour dual screen. The perception of depth in an image can be improved further by allowing 'real time' changes of the eye point.

Animations for more information and better 3D evaluation

Animations can be generated by existing visualisation programs and need equipment for recording and playing the sequences of images. The 'message' of an animation should be determined by e.g. a story board. An animation can show a (static) design model in various ways or a transformation of a (dynamic) design model. As an image can be used for (re)presenting a product, an animation can be used for the (re)presentation of a process.

Holograms as a portable interactive presentation medium

Holograms can store several related (stereo)pairs of images on (vertical) strip-shaped parts of this hologram. These images can be related in such a way that the hologram shows movement of the eye point along a straight horizontal line. It is also possible to show a (limited) change of the state of the design model. Computer generated holograms can show objects in different colours by combining a red, a green and a blue hologram into one hologram. The use of colour improves the quality of this kind of hologram by improving the contrast in the (re)projection of the objects.

The use of computer generated holograms can be improved further by also dividing the holograms into horizontal strips (making squares) to allow movement of the eye point in both horizontal and vertical directions. This however would increase the number of images and the total calculation time enormously.

Special programs have been developed for generating the right images and special equipment has been put together to project these images onto the original hologram.

Comparing a hologram with an animation shows that a hologram is portable and interactive. The viewer can look at an object from random chosen eye points, where an animation has a predetermined sequence for showing the images of a design model.

Computer generated holograms are mainly used for an original presentation of a final design or a building.

Conversions for optimal flexibility

Conversions are translations of one file format into another, without changing the content of the files. Conversion tools are useful to allow different participants on the building process to use their own local CAD system as a kind of pre-processors for constructing a design model.

Conversion tools are also useful to allow the use of different presentation techniques and or presentation media for a presentation of one design model.

Research and development work is being done to build special converters for a large number of different model and image file formats. Modelcom takes care of the conversion of different 3D design models into models for different programs that are able to generate images. It converts 2.5 D and 3D data, colours, blocks, layer structures and adds surface normal directions and it guarantees the consistency and completeness of a model.

Imagecom takes care of the conversion of different generated images into image descriptions for different presentation media.

Although these conversions make the use of different CAD systems and presentation techniques easier, it still means extra work with more chance of mistakes. One system with one file format could prevent such mistakes.

Building upon the experience with different presentation techniques and conversion tools research and development work was started to design and construct one multi user design system that can be used for modeling, presenting and evaluating a design proposal.

Virtual Reality as a more natural way of using CAD systems

Virtual Reality systems can be used for modeling, (re)presenting and evaluating a 3D design model. The most important techniques that are used in our VR system are stereo images, real time animation, sensored interface, eye phone and 3D mouse. Other techniques that could be used are 3D sound (around sound) and tactile feedback. More difficult but not to be excluded are smell and air-flow simulation.

The so called sensored interface makes use of a magnetic field to determine the position and attitude of the eye phone and the 3D pointer-controller. This interface is used for the control over the animation, shown by the head-mounted displays or eye phone and for the control over a 3D pointer for the selection of commands and objects in a model. The eye phones use one display per eye and stereo images to provide a proper perception of the 3 rd dimension. The 3D pointer, with the symbol of e.g. a hand or an arrow, can be moved around through the 3D computer model, or virtual building, by a 'data glove' or a 3D mouse. A data glove, with gesture recognition, and a 3D mouse, with different buttons, can be used for the selection of a command (e.g. move, pick and drop) and for the selection of objects.

The performance of Virtual Reality systems depends on quantitative (e.g. size, complexity) and qualitative aspects (e.g. colour, light) of the design model and on the processing power of the design system for the generation of stereo-images in a real-time animation.

Virtual Reality systems can be used by different participants in a design process working together in a virtual building on the scale of 1:1. These participants can make use of the more natural sensored interface for walking around in a design model and for making changes. Telecommunication techniques (glassfibre cables) should be used by the participants to work together in one design model. Conversion techniques are needed for a flexible approach to the physical file format of a design model. This flexibility is needed for a multi disciplinary design team, where every member can have a different CAD system.

Research and development work in this field is being carried out in co-operation with Division Ltd, UK and will deliver a milestone in our explorations of various CAD techniques. One of the main results, in relation to the use of a Virtual Reality system for

presentation purposes, is a VR Presentation program that allows the user to go through or around a wire frame (axonometric and perspective projections) or rendered (shaded and shadowed) design model.

Cardinal Virtual Reality system

To enable research and development work on the subject of Virtual Reality an investment was made in the VR system ProVision from Division Ltd. and in VPL peripherals. One of the main reasons for choosing this system was the invitation to actively participate in the further going developments of this system. Based upon the progress that has been made this system has recently been updated in regard to resolution, colours, speed and flexibility.

The Provision system consists of 8 transputers, that are linked by a network, and 2 Inmos 860 parallel-processors for generating stereo images at animation speed (both 16Mb shared memory) or at least at a high refresh rate.

Images of a design model, consisting of 10.000 polygons in 64.000 different colours, with a resolution of 512*512 (320x200 at the headphones LCD) can be refreshed at approximately 15 images per second.

A Personal Computer with a specific interface card can be a server. This system should be used to store an retrieve design models and it can be used to run specific applications e.g. to build a model outside the VR system. VPL peripherals were chosen because they were operational in combination with the Provision system.

The sensors, Polhemus tracking devices, detect movement in 6 directions (translation along and rotation around 3 axes, x,y and z). These sensors are attached to the eye phone and the 3D mouse to identify the position and attitude of the head and one hand. The eye phone is used for visual feedback and has two small backlit LCD screens with a resolution of 320*200 and 64.000 colours.

The 3D mouse with command buttons was preferred in stead of the more expensive, less suitable (calibration per user), more difficult (learn gestures) and less robust data glove. With this mouse different commands can be chosen and executed by using the buttons or by pointing at them as symbols in the virtual environment. The position and the attitude of the mouse, as detected by the sensor, give the necessary input for these commands.

Modeling Techniques

A design model, constructed with certain modeling techniques, is of great importance for the preparation of a presentation or for the evaluation of a design. Different techniques can be used for modeling a design and for communicating the results.

CAD modellers

CAD models are the result of a modelling process with a CAD system. Different CAD systems and different users will deliver different results. During the modeling process attention should be paid to quantitative aspects (e.g. size and complexity) and qualitative aspects of the model (e.g. colours, light).

A design model has to be designed, constructed and managed just like a building. During the design phase of a model attention should be paid to the completeness and consistency of the model. During the construction phase attention should be paid to the efficiency and

effectiveness of model. And during the management phase attention should be paid to administrative (as little as possible input) and procedural aspects of a design model (input as late as possible).

During the model design phase decisions have to be taken about the level of detail of components, the geometry (shape, size and topology) and attributes (aesthetic, structural, physical) and about the settings, sub models (layers) and other characteristics (kind, appearance, behaviour) of the components.

Decisions about quantitative and qualitative aspects will have to involve trade-of between the capabilities of the system and the user and the purpose of the model. Other aspects, like completeness and consistency or geometry and attributes, need the full attention of the user, undistracted by unnecessary features.

Research and development work in this field is being carried out with the co-operation of students and will deliver a dedicated VR CAD system.

This work has resulted in a first VR Modeling system, a comprehensive and simple 3D modeller to construct (and reconstruct) design models. The most important functions within this system are 'Insert', to insert existing models of (reference) objects, 'Move', to move objects around, 'Change', to change attributes or other characteristics, and 'Size', to change the dimensions of an object.

Tele-communication

Different participants on the design process should be able to work with the same Virtual Reality CAD system and model at different locations. Therefore there is a need for telecommunication between a host CAD system, with the design model and the programs for modeling, presenting and evaluating this model, and several guest CAD systems, with the necessary peripherals, that can use the model and the programs locally or remotely.

Research and development work is being carried out together with a number participants in the internationally well known projects The House of the Future and The Office of the Future. For the Office of the Future a special VR application is under development for the evaluation of aesthetic, ergonomic and lighting aspects of office interiors. Between the Office and the House of the Future there is a glass fiber cable available for experiments in relation to the multi user design system.

These experiments will also pay attention to the way in which different participants can really work together. They should at least be able to see and hear one another and they should be able to see what someone else is doing (with his 3D pointer).

VR systems can deal with their user in different ways. The user can have the 'camera's' in his eyes and be invisible or the user can be visible through a 'camera' in a certain position. In the case of a multi user design system, each user should have 'camera' in his eyes and should also be seen, as a simple symbol showing his position and if possible his attitude to the other users.

Evaluation techniques

To improve the performance of buildings in the future, design proposals should be evaluated in an objective way during the design process. Different aspects can be evaluated such as functional or technical aspects and organisational, aesthetic, ergonomic, structural or physical aspects. Virtual Reality systems will be able to play an important

role in the evaluation of all these aspects. In this case, however, the Virtual Reality system is and will be used first for the evaluation of lighting and acoustical aspects. The presentation capabilities of the VR system can be used for the evaluation of aesthetic and some ergonomic aspects of a design. The modeling capabilities can be used to (re)construct the design models that should be evaluated.

Our experience of our environment depends largely on the way in which our senses (seeing, hearing and feeling) receive and interpret its visual, acoustic and thermal characteristics and quality.

In architectural design there has been a long-standing and understandable pre-occupation with the visual environment. Over the last decade there has been an upsurge of interest, occasioned by the escalation in the cost of fossil fuels, in the thermal environment. To date there has been little or no interest in the acoustic environment except at the extremes of noise pollution.

The aesthetic and economic interest in the visual and thermal environment has stimulated research and development into models and programs to simulate these phenomena. One of the results was the joint development of DIM, a first principals inter reflective, multi chromatic model of natural and artificial lighting which generates images of high fidelity. Another result was the external development of ESP, a first principals dynamic model of the conductive, convective and radiative exchanges of thermal energy which accurately predicts the quality of thermal comfort.

DIM (Digital Illumination Model)

Dim is a suite of programmes for the formal and functional evaluation of the lighting, natural and artificial, of building interiors.

The basis of DIM, originating from ABACUS at the University of Strathclyde, is an extended radiosity model which tracks a representative number of lightrays, generated by the light sources (windows and luminaires) as they inter-reflect within the space. These inter-reflections are affected by the diffuse and specular characteristics of the properties of the surfaces of the space and the objects within it.

Output from the program consists of values for illuminance, luminance and spectral distribution of these values for a variable number of points within the 3D data set. The output can be displayed in tables or graphs or of course at visual simulations. The images generated are of high fidelity and Philips Lighting is already using the model (Visulux) for the design of a wide variety of lighting schemes. The extended radiosity approach has the major advantage that the lighting within a 3D space is completely simulated, irrespective of the viewing parameters. It is then very efficient to rapidly change the viewing parameters as in a Virtual Reality system, offering real-time experience of realistically rendered environments.

SAX (Sound Advice Expert)

Although operating in different sections of the waveband spectrum DIM and ESP are both concerned with the propagation of energy around complex spatial volumes bounded by surfaces with complex properties of energy absorption and reflectivity. Theoretically, then, they could share common program code. Practically, in fact, they do.

Research is proposed for the development of a system to predict acoustical characteristics. This research will draw upon the relationship between DIM, ESP and SAX, in particular concerning the commonality of geometry and physical properties.

It is further proposed that the output of SAX should be 'experiential' rather than abstract. The acoustic quality of a concert hall cannot be evaluated by reading numerical values of sound pressure level over the acoustic waveband spectrum.

Virtual Reality systems are offering an innovatory interface with models of the visual environment. Here we propose an Acoustic Virtual Reality system, based on an early idea in which the user is experiencing, quadraphonically, the acoustic quality of any seat in any proposed design.

Conclusions

There are many situations where it is more convenient, less costly, or indeed necessary to simulate three dimensional space rather than to experience, directly, its physical reality. The inaccessibility of the real world may be a result of its remoteness, its hazardous character or because it no longer exists, does not yet exist or indeed, never will exist.

Remote environments, such as lunar homesteads, polar outstations, orbiting space stations and off shore oil drilling platforms are examples of spatial environments which are significantly remote; it is certain that convenience and economy can be served by providing an accessible simulation of the environment.

Hazardous environments contaminated by radioactivity, threatened by fire, structurally unstable or biologically inhospitable are either dangerous or expensive to make save; economy and safety are promoted by appropriate simulation.

Non existing environments fall into three categories:

1. environments which will never exist, e.g. the science fiction movies;
2. environments of architectural or historical interest, which once existed, but no longer exist;
3. hypothesised environments of architects and planners which it is intended, ultimately, to bring into existence.

The development of Virtual Reality systems offers a major step forward in our ability to experience simulated environments. In most current VR systems there is, however, a disappointing level of realism resulting from the inadequacy of the applications.

The technical ingredients for a multi user Virtual Reality system exist, but the level of realism is conditional for its acceptance. To reach this level, experiments will have to be performed dealing with the theoretical background in relation to the practical use in stead of the technical features. The technical features for a multi user design system are now available and operational within our laboratory.