Design Modelling and Design Presentation
From a computer-generated image towards a multi-user design system

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Introduction

CAD systems regularly offer new techniques for the presentation of design proposals like computer-generated (stereo)images, animations, holography and virtual reality. These techniques are mainly used for the presentation of a final design or for the presentation of buildings that have already been constructed. As in the course of time the quality of the CAD systems and their users have improved enormously, it is also possible to use these systems for the evaluation of several temporary design proposals during the design process. Since 'beautiful pictures' and 'wonderful animations' have already shown their great value when presenting a design, it is sometimes as if CAD systems are considered suitable for this purpose only. Even new techniques like virtual reality systems seem to be valued only through the 'tinted glasses' of the presentation capabilities. Hardly any attention is paid to the possibilities that these new techniques offer as an instrument to support modelling and evaluation during the design process. This article will outline the results of research and development in the field of virtual reality.

Virtual reality systems are based on the combination of a number of already existing presentation techniques like photo-realistic images, stereo images and real time animations. The added value of this type of CAD system is determined by the use of a new type of user interface. In effect this interface consists of sensors (hat register how its user moves and looks around. Through this, and by using a so-called 'eye phone' (comparable to stereo headphones for sound) the user, with some imaginative powers, thinks he is standing in the environment that he modelled, or in front of his building design.

After this we will first sketch the outlines of some presentation techniques, that can also be found in a virtual reality system. Special attention will he paid to some specific characteristics of these techniques themselves. Next, a more detailed description will be given of virtual reality systems, focusing on the system that is being developed at Calibre itself.

1.Presentation techniques

For the presentation of a design we can use a number of techniques, each more or less suitable for a certain purpose.

1. 1 Photo-realistic images for design presentations

Photo-realistic images can be generated by several advanced visualization programs. The techniques include: hidden line removal, flat shading, smooth shading, rendering or ray tracing. The final image can be represented by a combination of lines, planes and volumes, each with a different colour. This image may be recognized more easily by using so-called texture maps (for drawings of materials) and bump maps (for structure of materials). (Figure 1)

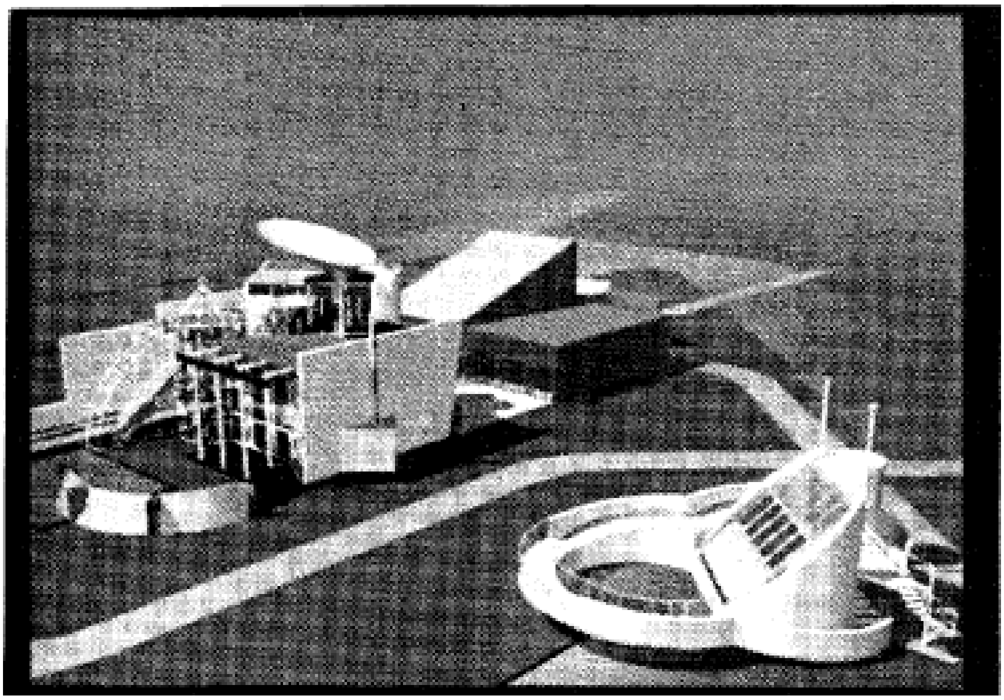

Figure 1 Photo realistic image

1.2 Stereo images for better depth perception

In order to produce good stereo images, eye point, focus point and viewing angle should be defined so 'cleverly' that the representation 'does the trick'. To perceive depth you need a number of aids, like a stereo viewer, red/green glasses or a full colour dual screen (Figure 2). The perception of depth in an image can be improved additionally by allowing 'real time' changes of the eye point (movement) as well.

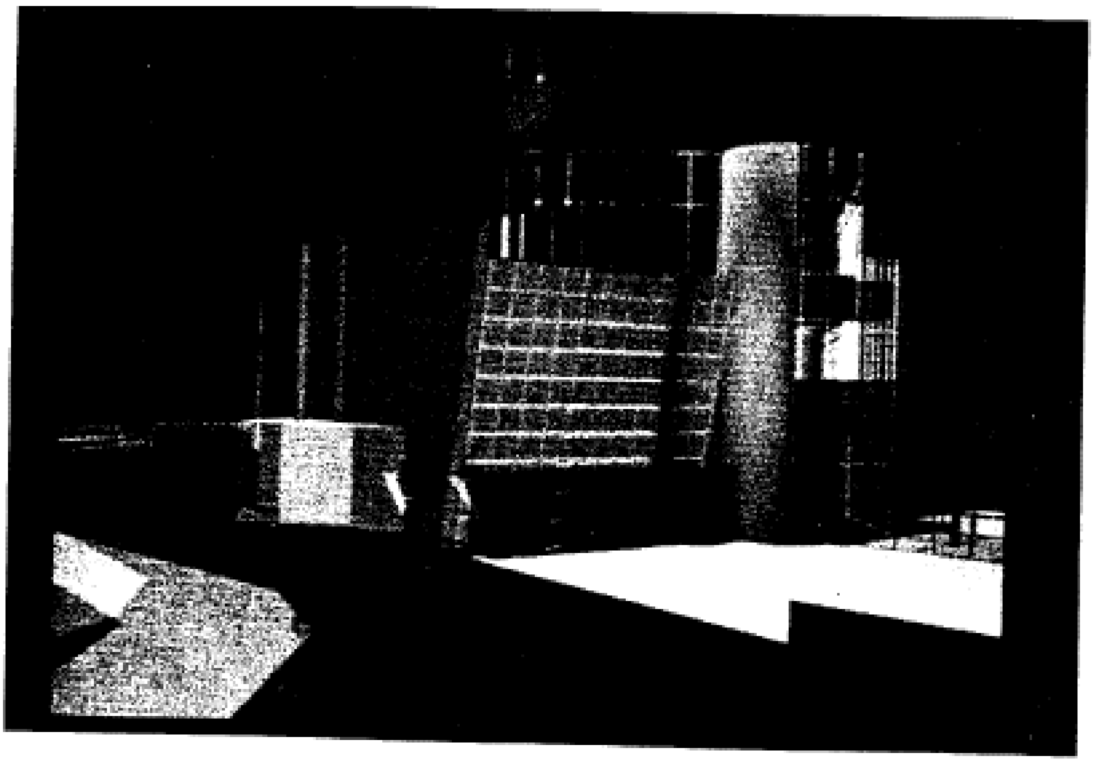

Figure 2 Stereo image

1.3 Animations for more information and better 3D evaluation

Various existing visualization programs offer the possibility to generate animations. If you want to show the 'computed' animations you need equipment to record and play them. If you want to convey your 'message' properly in a short time, it is advisable to first lay down the story, the animation, in a story board for example. With an animation you can represent a 'static' design in various ways (Figure 3). You are also able to transform the design in the animation (dynamically) into another design. As opposed to a single picture, which can only be used to show a product, an animation is extremely appropriate to illustrate a process or a movement.

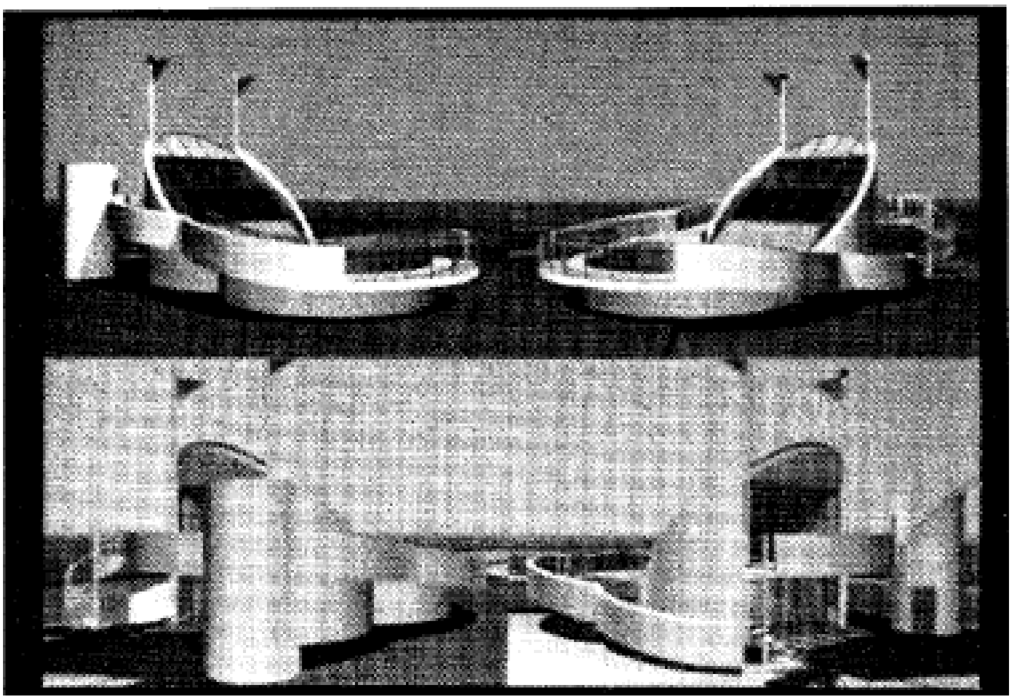

Figure 3 Animation

1.4 Holograms as a portable interactive presentation medium

On a hologram several related (stereo) pairs of images are store on vertical strips. These images can be related in such a way that the hologram shows a movement that is similar to the movement of the eye point along a straight horizontal line. Furthermore it is also possible to show a (limited) change in the design in this way. With the help of the computer colour holograms can be generated as welt. This is done by combining a red, a green and a blue hologram into one single hologram. Colour shows more contrast in a hologram and this improves its quality. Thus, holograms combine the advantages of stereo images and animations, which further enhances the perception of depth. Computer-generated holograms can also be improved by applying horizontal strips, besides vertical strips, as well ('squares' remain). This will allow movement of the eye point in both horizontal and vertical directions. It will be obvious however, that this would increase the number of necessary images, and therefore the total calculation time, enormously. Special programs have been developed for generating the right holographic images. These are finally brought together with the help of specialistic equipment and projected on to the final hologram.

One of the important added values of holograms is that they are portable and interactive. The viewer can look at the object from any chosen eve point, whereas e.g. an animation is characterized by a predetermined sequence of images.
Computer holograms however, are still mainly used for an 'original' presentation of a final design or a product.
Research and development in the field of computer holography are carried out in close co-operation with DHL (Dutch Holographic Laboratory).

2. Virtual Reality; a more natural use of CAD systems

Virtual reality systems can be used for modelling, presenting and evaluating a 3D design. The most important techniques that are used in our VR system are stereo images, real time animation, a sensored interface and a 3D mouse. The sensors of the interface make use of, amongst other things, magnetic fields to determine the position and movement of the eye phone and the 3D mouse. With the help of the sensors the animation can be controlled and manipulated.

The user sees what he is doing via the eye phone (Figure 4) which applies stereo image technique so that depth can be perceived. The 3D pointer, represented e.g. by a hand or an arrow, can be moved within the 3D computer model by means of a'glove' ('data glove') or a 3D mouse. This data glove, with the feature to recognize gesture or the 3D mouse with various buttons, may be used to control a movement, to select a command (e.g. 'move', 'pick' or 'drop') or to select an object in space (Figure 5). The performance of virtual reality systems depends on quantitative design aspects (e.g. size, complexity) and qualitative design aspects (e.g. colour, light) and also on the processing power of the design system. This performance is important in connection with the generation of stereo images in a real time animation.

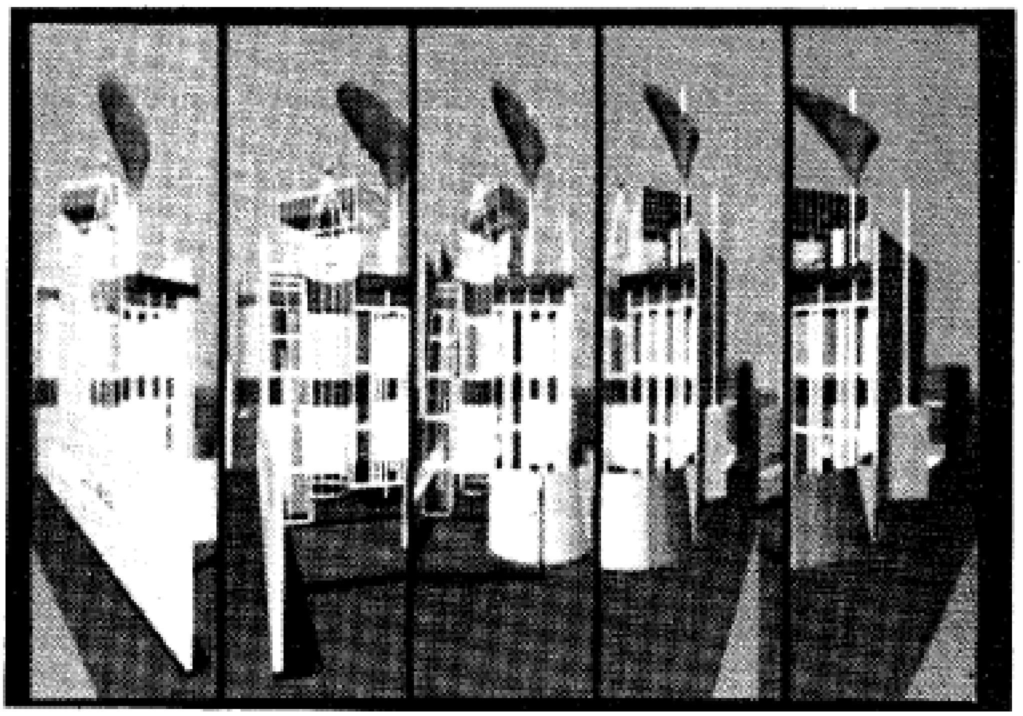

Figure 4 Hologram

Figure 5 Virtual reality system

2.1 Multi-user Design System

Virtual reality systems can he used by several participants in the design process who are thus able to work on a 'virtual building, scale 1:1'. Telecommunication and multi-tasking techniques (e.g. glass fibre cables) may be used here to have a number of participants working together in a design simultaneously. An architect might look around in the design model together with the principal and the constructor, each remaining at his own office. Any changes can be processed and evaluated in consultation. Technically speaking the construction of such a system configuration is possible already. For the time being it is called a "Multi-User Design System". In this way, several participants in the design process may work together with the same VR-CAD system, still being able to do their modelling at different locations. So in order to achieve this, it must be possible to construct a telecommunication network between the 'Mother CAD system', with the design and programs, and all the 'Child CAD systems', that should be able to work with the design model and programs locally or from a distance. Research and development in this field are being carried out in Co-operation with Division Ltd. and a number of participants in two internationally known projects: "Het Huis van de Toekomst" (The House of the Future) and "Het Kantoor van de Toekomst" (The Office of the Future).

2.2 Cardinal Virtual Reality System

To actually make research and development in the domain of virtual reality possible, we have acquired a complete VR system: ProVision by Division Ltd. One of the main reasons to invest money in this particular system, was the invitation to also participate actively in its further developments, Based upon the first successes, it has recently been decided to update the system with regard to resolution, colour, speed and flexibility. The ProVision system consists of 8 transputers that are linked by a network and 2 i860 parallel processors that are needed to generate stereo images at animation speed. Approximately every 1/15th second this system is able to refresh the images of a design consisting of 10,000 polygons in 64,000 different colours and a resolution of 320 x 200 pixels. A PC with a specific interface card may be used here as a file server. It is used to store and retrieve design files and may also be used for specific applications (e.g. building a model without the aid of the VR system). The sensors, Polhemus tracking devices, are able to detect movements in 6 different degrees (translation along and rotation around the x-, y- and z-axes). These sensors are attached to the eyephone and the 3D mouse so that the position and the posture of the hand as well as the head may constantly be determined. The eye phone gives the user visual feedback. It consists of two small back-lit LCD screens with a resolution of 320 x 200 pixels and a maximum of 64,000 colours. The 3D mouse with command buttons was preferred to the more expensive, less suitable data glove, since the latter is less robust, more difficult to use and has to be calibrated (adjusted) for every new user. With the 3D mouse several commands may be chosen: either by pressing the buttons, or by pointing at the virtual buttons with the 3D pointer. The position and the posture of the 3D mouse, as detected by the sensors, provide the necessary input for the intended commands.

2.3 Modelling techniques

Every CAD model is the result of a modelling process on a CAD system. Different CAD systems and different users produce as many different results. When modelling, attention should be paid to qualitative aspects (use of colours, light) as well as quantitative aspects (size and complexity). During the design phase of the model attention will have to be paid to administrative aspects (as little input as possible) and procedural aspects (input as late as possible). Also, decisions will have to be taken about to what degree components should be specified, about the geometry (shape, size and topology), about the characteristics of the components (type, appearance and behaviour), about the adjustments etc. All these decisions will have to he taken in a process of weighing the pros and cons. The capacity of the system, the ability of its user as well as the final goal of the model will have to be taken into account then. Research and development in this field are taking place in co-operation with students. So far, this has resulted in a first VR modelling system, with a simple modeller to build up 3D models. The most important functions in this system are the options 'insert'; to read in existing models, 'move'; to move objects, the option 'change'; to edit attributes or other characteristics and finally the option 'size', to change the dimensions of an object.

2.4 Evaluation techniques

To improve the quality of buildings in the future, design proposals presented during the designing stage ought to be evaluated in an objective manner. A number of aspects may be considered here: functional, technical, organizational, aesthetic, ergonomic and physical aspects. Virtual reality systems may play an important role in the evaluation of all these aspects. For us, the VR system will be used in the first place for evaluation of lighting aspects of a design.

We can also use the presentation capabilities of the VR system to evaluate aesthetic and ergonomic features. The modelling possibilities may of course be used to (re)construct the model that has to be evaluated. The big interest in our visual environment has led to research into, and the development of models and programs to simulate this phenomenon. One of the results is DIM: an integrated model for daylight and artificial light which, based upon the exact physical laws that describe the behaviour of light in a specific environment, can produce realistic images of a model.

2.5 DIM (Digital Illumination Model)

DIM consists of three programs that enable its user to evaluate, alphanumerically and visually, the perception of daylight as well as artificial light in a building. The program, originally developed by ABACUS at the University of Strathclyde, uses an extended 'radiosity' model. The output of the program consists of a database in which all figures have been recorded that have to do with the intensity of light, the luminance and the spectral distribution. Next, this alphanumerical output can be displayed in a visualization or as tables. The generated images are high fidelity and give a reliable impression of the authentic situation. The radiosity approach has the major advantage that the complete lighting conditions for the entire 3D model are generated at once. Its result does not depend on a specific position taken by the spectator or on a specific viewing angle. Therefore it can be used in a VR model. In this way real time movements in realistically presented environments are made possible.

4. Conclusions

Many situations are conceivable in which it is better, cheaper or even necessary to simulate three dimensional space, rather than making use of real physical spaces. E.g because they are inaccessible, too remote or too hazardous. Maybe these spaces have vanished, maybe they do not exist vet or will even never exist at all. Polar outstations, lunar homesteads, orbiting space stations or off-shore oilrigs are examples of spatial environments which are significantly remote. Obviously it would be convenient and economical (e.g. for the preparation of labour) to make use of appropriate 'simulations' i.e. a 'virtual reality', instead of being 'on site'.
Environments that have been contaminated by radioactivity or ravaged by fire or regions that are biologically inhospitable are examples of hazardous surroundings. As a rule it is too dangerous and too expensive to restore security to them, and so simulations offer a solution here as well.
There are three categories of nonexistent environments:

1. environments which will never exist (e.g. science fiction films)
2. environments of architectural or historical interest, which existed once, but have now disappeared
3. future environments as presented in designs by architects or urban planners

Development of VR systems offers, the opportunity to get acquainted with simulated surroundings in a unique way, quite unlike before. Unfortunately, in most VR Systems there is a disappointing representation of reality caused by inadequate application programs. The technical possibilities for a multi-user (VR) design system exist, but the level of realism that can be simulated determines whether these systems will really be used and accepted. In order to reach a high level, experiments will have to be carried out in which attention should he paid to theoretical backgrounds as well as to practical use within the technical possibilities.

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