Applications of Optical and Digital Endoscopy

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Abstract

The Media Research Group at the Faculty of Architecture is currently exploring the opportunities of visualization media such as optical endoscopy and computer aided simulation techniques. The research program focuses on the influence of such media in the design process on an architectural and urban level and on creative applications for the benefit of research and education. The Aspern case-study in the framework of the 2nd EAEA-Conference has been used as a pilot study for emerging applications for design simulation. This contribution compares the possible use of *optical* endoscopes and three types of computer programs which may be viewed as *digital* endoscopes.

Introduction

Endoscopes are essentially tools which allow us to see inside small spaces. An architect can use an endoscope to look into a scale model of a design. Endoscopes provide an insight which may approach an image of reality, with the possibility to look around, to test different proposals and to change design options with relative ease. The endoscope can be used for the presentation of designs, as a design tool and possibly as an instrument in perception research. Optical endoscopes consist of a lenstube providing a virtual image of an object. The place and direction of the endoscope (the point of view) determine what virtual image the endoscope-user perceives. The object of study is generally an existing or designed environment. New and developing techniques bring with them a specific terminology, a technical jargon which in time may, or may not be absorbed into language. Computer jargon has introduced concepts like: *virtual reality*, *artificial environments*, *interaction*, *full immersive worlds* [1], and even *cyberspace*. The boundary between scientific reality and futuristic wishful thinking is not always clear. Steuer [2] defines virtual reality as follows:

> "Virtual reality is a remote or artificially constructed environment in which one feels a sense of presence, as a result of using a communication medium."

Researchers using endoscopes tend traditionally to be more interested in optics and in technical aspects that can be linked to movie-making than in computer technology. However, the optical and digital techniques are more and more frequently used side by side.
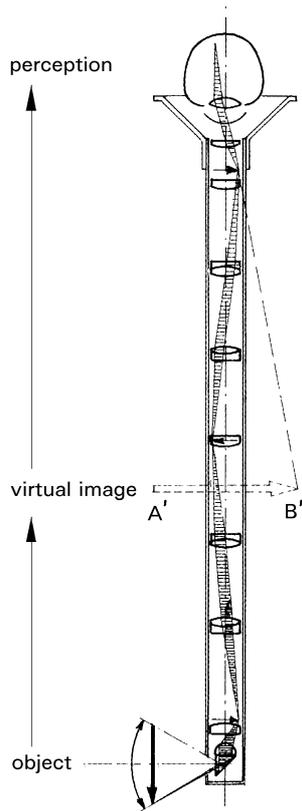
Fig. 1 Example of an optical endoscope.

From the point of view of Steuer's definition, endoscopy may be considered as a kind of *virtual reality*. In fact, endoscopy can give us a good photographic-image of a *virtual world* (a scale model) with *real time* possibilities to look around and to *interact*. In the same way it can be useful to view new spatial software products as *digital* endoscopes. Optical endoscopy and the upcoming computer applications have a number of aspects in common, the techniques of these *optical* and *digital* endoscopes can be compared.

Aspects of Endoscopy Techniques

The following comparative descriptions of four endoscopy techniques cover four aspects which influence their adequacy as instruments for design simulation: (1) the model, (2) the image, (3) navigation and (4) interaction. An endoscope is used to get images from a model at an imaginary eye level.

Making a model is a necessary step in the imaging process. Lighting and background are additional aspects of the model, they influence the final image significantly. The model is a spatial representation of an existing environment or of a design. Models can be relatively realistic or abstract. A scale model (for instance 1:200 for a cityscape model) will always be abstract to a certain

extent. It is impossible to create a completely reliable model of reality. Not all details can be made in the model. Sometimes a relatively high level of abstraction is to be preferred as it gives more adequate insight into the main aspects of a design.

The image is a result delivered by the endoscope. For presentation endoscopy one starts by thinking about the image. What must the image show, what must it look like? What kind of atmosphere or ambience do I want to present? The image for presentation is a product for presenting and explaining a design and it can effect important decisions, for instance, whether or not a design will be built. In contrast with presentation images, the image for research- and design endoscopy is a result of an experimental process. The image is not the final product, it is information for design-decision-making or for research (for instance a test-image for way-finding or perception research). In most cases images for design will be much more abstract than images for presentational use; they are not an end product but images created to test design options.

Navigation through the model gives a *dynamic perspective* of the environment. It can be free and direct or it can be pre-described and computed. Comparison of different models and/or evaluation by different participators can make reproducible and pre-described endoscope movements necessary. Navigation can take place in a flowing motion, but also by series of "stills". Attention should be paid to the orientation of the participators. It is very easy to lose track of where one is in the model.

Interaction is a word often used for computer applications. Here it means the possibility to influence or manipulate the model or the endoscope movement. In a design process the possibility of interaction is a major aspect. Interaction is a form of communication between the designer and the design. The designer has a general idea which is tested in a model. The model gives information about how the design will work. This visual ‚feedback‘ is important for the designer. The ideas can be tested and the designer can respond to the images of his/her ideas. This cycle of imaging, testing and altering can be repeated a number of times until the designer is satisfied with the result. A model which is abstract and simple, which can easily be changed, is a useful model in a design process; such a model can be used in an interactive way.

Comparison of Endoscopy Techniques
Two main types of endoscopes are to be distinguished: optical endoscopes and digital endoscopes in the form of render-software in computers. Recent developments show three main groups of software for rendering: 3D-animation software, interactive ‚virtual-reality‘ systems based on 3D-vector models and

interactive ‚virtual-reality' systems based on photo-realistic panorama models. In the next paragraphs we will attempt to describe aspects of these types of endoscopes and to discuss the advantages and disadvantages of each, the specific research and visualization tasks they can perform and as far as possible the future possibilities of these media.

Optical Endoscopy

This is a technique for different visualization tasks. Most often the optical endoscope is used for presentations. In previous years the research of the *Media Sector* at Delft University of Technology has focused on the application of endoscopy as a medium for visualization and on comparison with other techniques such as the hand sketch and CAD [3a-b]. The Delft research program now aims to develop methods of use for endoscopy in the initial phase of the design process. The endoscope can be a good tool for *spatial sketching*. One can change a model *interactively*, this means: while you look at the image of the endoscope, you can change the model e.g. by moving blocks or applying *texture-maps*.
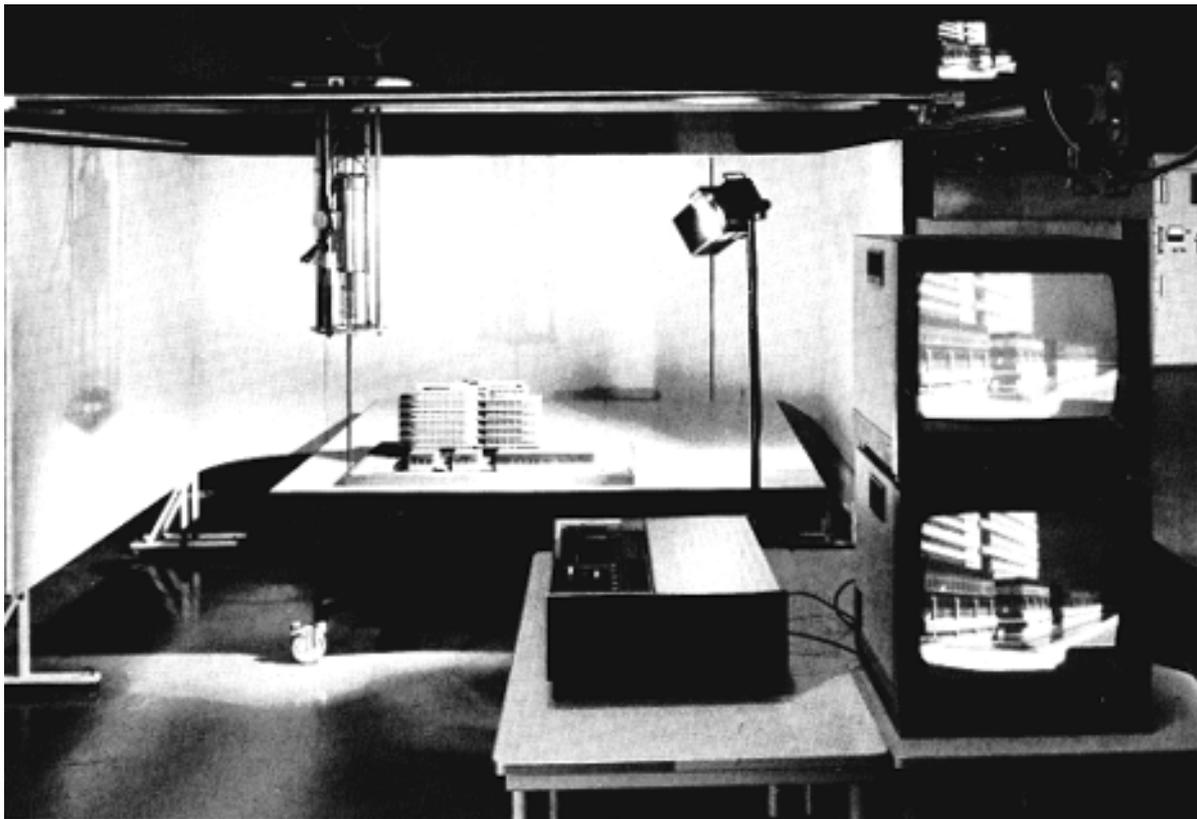

Fig. 2 The endoscope of the Media laboratory (Delft).

In contrast with the digital models used in computer rendering programs, the model for optical endoscopy is physical, it is built with real materials. This *real model* in optical endoscopy has certain advantages and disadvantages. A

good choice of model materials, with respect to colour and texture, can influence the quality and spatial effect of the image. If the model is very detailed, extra attention will have to be paid to lighting. Irrelevant details can distract from the main features of a design. The amount of detail, color and material expression in the model all have to be in balance with each other and in the spirit of the presented ideas. Relatively abstract models can give a clear impression of the primary design aims. On the other hand, details and articulation are necessary for spatial perception. The surfaces of a model need a certain amount of ‚information‘ (for instance texture and structure) for them to be perceived properly. Gibson saw this phenomenon as one of the *cues* of visual perspective, which he dubbed *texture gradient* [4].

The quality of the final image, delivered by an optical endoscope in conjunction with a video or photo camera, is an important advantage of this technique. With video the image is immediately visible. The images can be easily distributed via slides, photos or videotape. The use of adequate video equipment is important for the quality of the video. The new generation of video cameras have become much smaller. In principle modern mini cameras can be moved directly through a model. Essentially an optical endoscope is a periscope with a lens tube connected to the camera. In recent projects in Delft we have worked without a tube, but with a movable mirror element connected directly to a mini camera, causing less loss of light.

The use of a computer as a pre- or post-production tool can enhance the possibilities of the optical endoscope. The post-production of still pictures with a computer (mixing "real" and produced reality with "paint" programs) can contribute towards a *Renaissance of Endoscopy* [5]. The scanned endoscopic images can be changed with image processing software, for instance to apply a reflection of a building in water. An attempt at pre-production with a computer was made in the Delft contribution for the Aspern-workshop on the occasion of the 2nd EAEA-conference in Vienna. Texture-maps of reduced façade patterns and real façades were applied to the model. Texture-maps were scanned with a computer from photos of buildings. The façade photos were originally in perspective. A computer photo-styler was used to straighten and to multiply the façade images. The façade textures were then printed on scale 1:200, and were glued onto the building blocks of the model. This use of texture maps gives the urban model a more architectural impression. The scale and the distances in the urban design can be judged much better with these textures which are flat but give a suggestion of depth. The use of different patterns, colours, structures and textures can enhance the resulting images.

Fig. 3 Optical endoscopic image for the Aspern workshop. Texture-maps of real façades were applied on the model.

Digital Endoscopy

Digital endoscopy is a technique to look inside a digital spatial model. The term for creating images by computer is *rendering*. A vector-model with spatial information in the form of co-ordinates and additional information of materials, textures and light-sources, can be rendered in order to get a perspective image. The rendering can be performed with differences in quality. Image quality is inversely proportional to render-speed. Some different methods of rendering are *flat shading*, *phong shading* and *ray tracing*. Flat shading is the fastest rendering mode, it shades each facet of the model based on its angle to the light source and the chosen view. Phong shading is used more than any other shading method. Phong shading calculates the correct colour for each pixel in the image. It can render highlights and shades, based on one or more light sources and materials. Ray tracing is the most sophisticated and realistic way of rendering, it takes account of many physical aspects e.g. breaking of light in water and reflection of light in objects. Ray tracing follows rays starting from the viewers' eye back through the model, and only image relevant rays are considered. Ray tracing is not a very fast way of rendering; it cannot be used very well for *real-time* rendering on normal desk-

top computers. The ray tracing technique can deliver high quality *still* images, for slide or photo presentations or time consuming, non-interactive computer animations. *Virtual Reality (VR)* is intended to be - by definition - a real-time process: while you navigate through the spatial model, the computer must immediately render the new images. Therefore most VR-programs use fast phong- or flat-shading. Texture maps [6] can be used in VR models, they do not influence the rendering speed significantly and give a better, detailed image. New developments in VR-models use the *radiosity rendering technique*. The radiosity method calculates light distributions starting from the light sources in the scene. With this method the image of light and shade on all surfaces of the spatial model can be pre-rendered. Such pre-rendered images of the light and the shade for each face in the model can be used as texture maps. This trick creates a fast rendering model with a relatively *natural* image of light on different materials. Despite all these ingenious computational rendering tricks, most virtual reality images look unconvincing. Many visual aspects of reality and of human perception are not taken into account. Nevertheless VR-technology can be useful for testing and designing architectural concepts and we may not have to wait a long time; the techniques are developing very fast.

3D-Animation Software

Three dimensional animation software is initially developed for the film industry and for *high-tech* industries like space-, aircraft-, weapons- and medical industries. Architectural use of CAD software started around 1980, use of 3D-animation software started ten years later around 1990. Now many architectural and urban design offices use CAD and 3D-animation software. There are distinct similarities between 3D-animation software and optical endoscopy. The software can produce a detailed rendered preview of the spatial CAD model. The images provided by 3D-animation software depend highly on the quality of the digital model and the set-up of lights. The digital light sources can be spotlights, omni-directional lights and ambient light. The lights can have different colour settings. The model can be prepared for the animation by assigning different material-descriptions to the geometry. These material-descriptions consist of parameters for colour in different lighting conditions (ambient, diffuse and specular) and other aspects like shininess, transparency and different kinds of texture. With these material descriptions virtually any material can be simulated.

To provide a *dynamic perspective* of the spatial model with the lights and different materials, the animation software uses a camera and a time-line. The camera conditions can be described with settings for the focus, and co-ordinates for the point of view and the direction of the view. On the time line the

different movements of the camera, the lights and objects in the model can be described. The whole method of making a 3D-animation consists of pre-description of movements between points in the model space and choosing settings and parameter values for every visual aspect in the final animation.
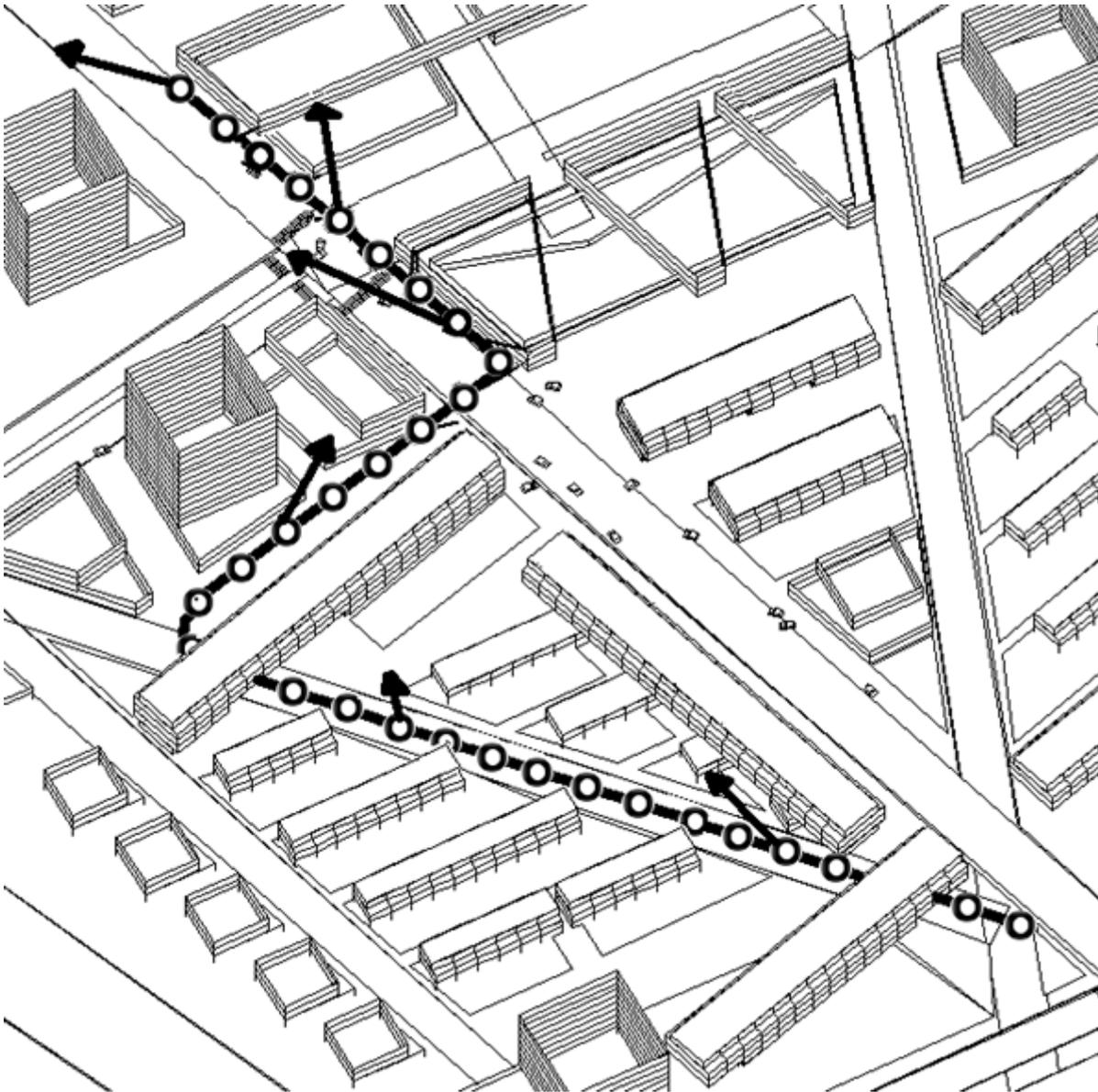
Fig. 4 The pre-described camera path of a computer rendered animation.

3D-animation software is created to produce *final* images and films for presentational or instructive use. Nevertheless this software can also be used as a research tool or as a design tool. Some animation programs can be seen as CAD-modelers extended with animation facilities. These programs provide a good visual interaction between the model and the designer. This extended use of 3D-animation software is only possible if the designer has much initial knowledge of the possibilities of the program and if the program provides

functions for changing the model in an relatively easy way. The perspective preview, provided by most new 3D-animation programs, can also be used as feedback for the designer during the design process. After setting every aspect of the model and the navigation through the model, the final rendering process can start. The computer renders every image and makes an animation of them. Depending upon the type of computer, the amount of images and the image quality, this rendering costs seconds or weeks. After this waiting time, the film can be shown or recorded on videotape.

Interactive VR-Systems based on 3D-Vector Models

These systems can use the same kind of spatial models as CAD-programs and 3D-animation software. However, most CAD and animation models have so much information that they become too slow to be rendered in real-time. The model for virtual reality has to be reduced. The geometry in CAD models uses many faces which do not improve the final image, these faces must be deleted or changed. A lot of geometry in details can be reduced by using texture maps. A whole façade of a building in a model of a city can be represented by a texture-map consisting of a scanned photo or a drawing of the façade. This reduces the geometry-information in the model and speeds up the real-time rendering process. With these *reduced-geometric* models virtual-reality systems can render the perspective images of the model much faster. The user of the software can navigate through the model by either using the mouse pointer, a *joy-stick*, or other spatial pointing devices. The image can be shown on a computer-screen as a flat perspective image, but the computer can also render two images at the same time to display a stereoscopic spatial image. This stereoscopic image can be perceived via ‚head mounted displays‘ or from a 3D-computerscreen. In this case the screen alternately provides a left-eye-image and a right-eye-image at a frequency of 120 Hertz. A pair of glasses with liquid crystals (which can turn from transparent into black and reverse at a very high speed) separates the left and right eye view at a frequency of 60 Hertz. This stereoscopic 3D-computerscreen in combination with the special glasses gives a very sharp spatial view. The glasses do not weigh as much as the *head-mounted-displays* and they do not separate you from *real-reality*.

Virtual reality applications, both the software and the hardware, are still developing very fast. The question is how we can use this technique for spatial research and design. As an example of an initial attempt of applying virtual reality techniques to urban design we want to mention a preliminary study for the Delft contribution to the Aspern-workshop on the occasion of the 2nd EAEA-conference in Vienna. A digital-3D-model of an urban design for Aspern (a city extension of Vienna) was constructed with similar *faces* of 6x3
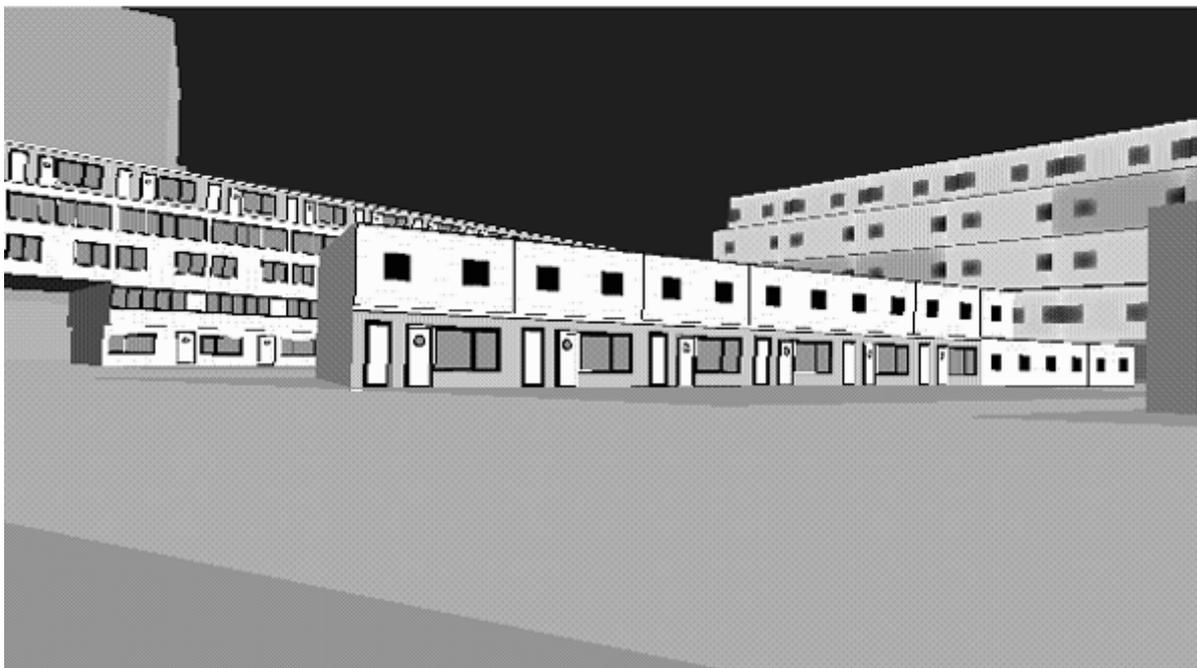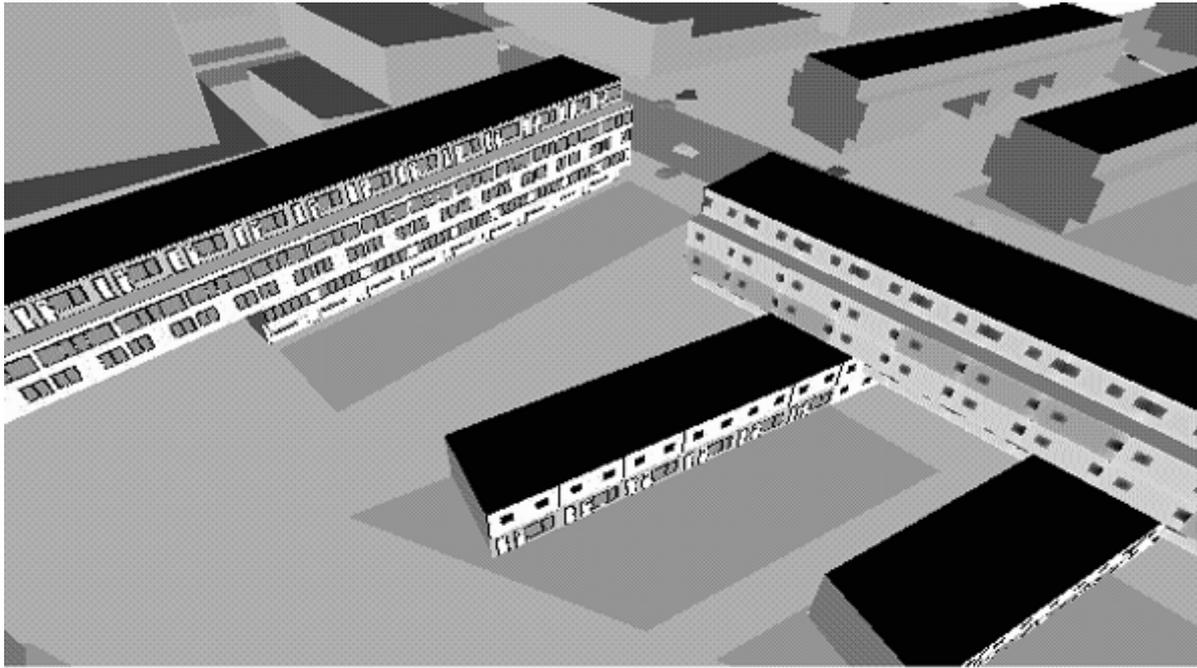
Fig. 5 Digital endoscopic images for the Aspern workshop. Bird's eye view and pedestrian view of the interactive model.

meters representing a front and a backside façade for each house in the urban plan. A small *library* with façade-maps was created. The façade maps are small images of *typical* house façades consisting of 60x30 colour points. Each colour point representing a detail of the façade of 10x10 centimeters. Using a virtual reality program it is then possible to navigate through the model of Aspern. By using the mousebuttons and by pointing to different parts of the perspective screen image, one can in principle look and move
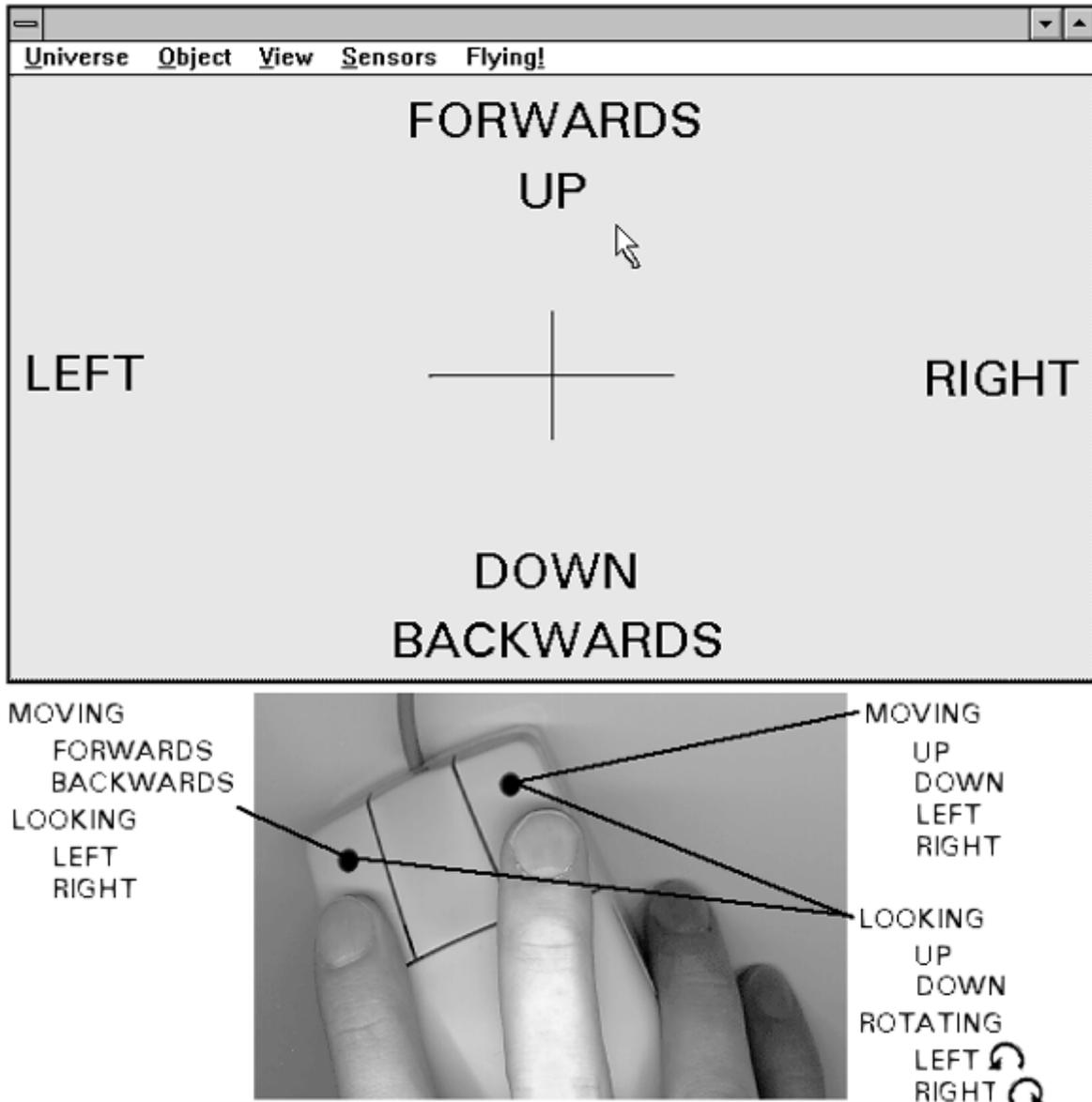
Fig. 6 Method of navigation through a Virtual Reality model by means of different mouse ‚direct‘ and ‚click‘ combinations.

anywhere one wants. Using the façade library one can select different façade elements for the house one is looking at. Clicking the mouse changes an element instantly. This is an initial version, a first step toward further development of a possible instrument that may facilitate discussion and decisionmaking concerning urban concepts. This first test gives a fast spatial insight, with different points of view, and with the possibility to change aspects of the model in *real-time* and *interactively*. At this moment the quality and reliability of the images and the perspective projection of the façades is still poor.

1. taking overlapping photos
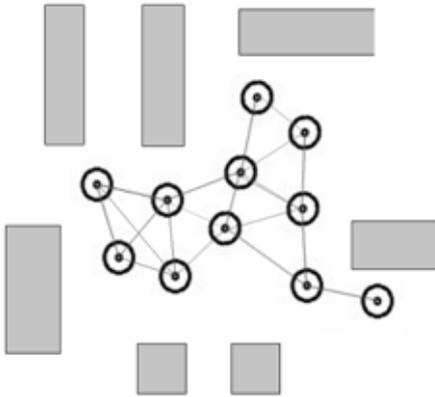   with a 35mm. camera.
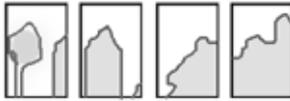
2. photos digitized on a Photo-CD.

3. blended photos, 'stitched' to a
   360 degree panoramic image.

4. The panorama with a movable and
   zoomable view-window.

5. More panoramic 'nodes' can be connected
   giving the opportunity to move around
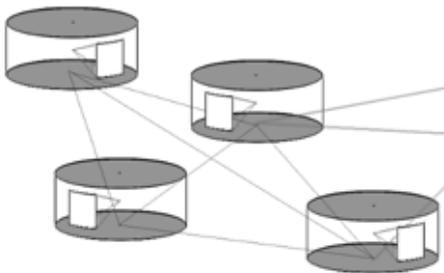   in the environment.

Fig. 7 Method of creating a Virtual Reality model based on photo-realistic panorama models.

Interactive VR-Systems based on Photorealistic Panorama Models

The third *digital endoscope* described in this text has a totally different approach to creating and representing a *virtual world*. Interactive virtual-reality-systems based on photo-realistic panorama models do not use vector geometry as a model. The panorama is like a painting or photograph that surrounds the viewer. The concept of a computer-generated panorama photo viewer is quite new and can be seen in a software product called *QuickTime-VR*. As a design tool this program has limited possibilities as there is little opportunity for interaction. The process of creating a panoramic world consists of four steps:

1. Pictures or computer rendered files of a 360° view are necessary. These pictures can be taken with an ordinary mirror-reflex camera with a 35mm lens on a tripod;

2. The photos are scanned into a computer;

3. A program called the ‚stitcher' connects the pictures and produces a 360° panorama;

4. The panorama can be seen as if one is standing inside, in the middle, and performs like a static endoscope. One can pan and zoom as with a telephoto lens, looking around the panorama from a single spot. By assigning certain places in a virtual environment as so called hot-spots one can jump to another panorama.

Quicktime-VR emphasizes the difference between a non-interactive *image* (in this case a panorama around a fixed point) and a potentially interactive *model* which may be altered and from which different images of design options may be computed. A model may be the subject of design manipulation and experimentation. An image is a result and may be used for presentation and explanation.

Conclusions

The development of endoscopic techniques, both *optical* and *digital* is continuing. The usefulness of endoscopy is likely to increase. On the one hand this is because of specific advancements within the fields of the two types of endoscopy mentioned. For *optical endoscopy* the introduction of digital video systems and optic fibres is likely to increase the existing possibilities. For *digital endoscopy* faster and more efficient rendering techniques in combination with the evolution of real time Virtual Reality can be expected to offer new impulses for design simulation. As we have attempted to illustrate the coupling of these systems, such as for instance the pre-production and post-production enhancement of optical endoscopy, may lead to new approaches

and applications. In the coming time it will be worthwhile to continue exploring further possibilities of the existing techniques and to consider new potentials for architectural and urban endoscopy.

Notes and References

[1]   Immersive is a term that refers to the degree to which a virtual environment submerges the perceptual system of the user in computer-generated stimuli. The more the system captivates the senses and blocks out stimuli from the physical world, the more the system is considered immersive.

[2.] Steuer, J., "Defining Virtual Reality: Dimensions Determining Telepresence, in: *Journal of Communication* 42(1992)4, p. 73-93.

[3a] Does, J. van der (et al.), *Overdracht en simulatie, onderzoek naar de waarde en betekenis van mediatoepassing bij architectonische simulaties.* Delft: Delftse Universitaire Pers, 1990.

[3b] Does, J. van der, "Visualization by means of Endoscope, Computer and Hand-drawn Techniques" in: Seppo Aura, *Endoscopy as a Tool in Architecture*. Tampere, 1993, p.167-180.

[4]   Gibson, J.J. *The Perception of the Visual World*. Cambridge: The Riverside Press, 1950.

[5]   Martens, B. "A Renaissance of Architectural Endoscopy?" in: Seppo Aura, *Endoscopy as a Tool in Architecture*. Tampere, 1993, p. 143-152.

[6]   Texture mapping is a powerful technique for adding realism to a computer-generated scene. In its basic form, texture mapping lays an image (the texture) onto an object in a scene. More general forms of texture mapping generalize the image to other information; an ‚image' of altitudes, for instance, can be used to control shading across a surface to achieve such effects as bump-mapping.

[6a] Catmull, Ed. *A Subdivision Algorithm for Computer Display of Curved Surfaces*. University of Utah (PhD Thesis), 1974.

[6b] Heckbert, Paul S. "Survey of Texture Mapping", in: *IEEE Computer Graphics and Applications,* (1986)11, p. 56-67

[7]   For this article several internet WWW-pages were consulted to get information about the following programs:
      AutoCad, Arcos, Alpha, Allplan, Arc+, Architrion, MicroStation and MiniCad (3D-modellers);
      Virtus WalkThrough, Strata Virtual 3D and Avril, (3D-viewers);
      World Tool Kit and World-Up (3D-virtual reality programs);
      QuickTime-VR (3D panoramic viewer).

[8]   Biocca, Frank; Levy, Mark R. (ed.). *Communication in the Age of Virtual Reality*. Hillsdale: Erlbaum, 1995. This book provided information for some recent developments of virtual reality.