Proceedings of the Workshop on

integrative 3D visualization

Wiesbaden, Germany, 1994

Sponsored by:

Value Relay Centre
at
VDI/VDE-Technologiezentrum Informationstechnik GmbH

Idea, Organization and Editing:

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Foreword

Vision Simulators will soon revolutionize our everyday life by bringing us virtual objects that can replace current hardware like video monitors, keyboards and many others by projecting images into our normal field of view and allowing to control them by hand gestures recognized by a video camera.

This goes beyond current understanding of Virtual Reality in that it does not create an isolated cyberspace, but merges virtual objects into the real world by semi-transparent optics.

The basic concept of virtual objects is not really new; we all have them on our computer desktop and use them without ever noticing. New would be the desktop projected on a real desktop, or the screen virtually projected to whatever desired location by some "magic" hand gestures in 3D space.

These objects, we call them Virtualware, will replace current hardware and will therefore have a great impact on the industry. They will also make Virtual Offices more mobile and even less dependent on hardwired infrastructure.

Even the simple concept of image objects is of great advantage in already existing applications in military aircraft service and will be very helpful in improving medical treatments employing diagnostic online imaging. Technologies applied will be whatever kind of vision simulators as well as 3D operating systems.

This workshop was intended to encompass contributions to the areas of display systems and image recognition systems, as well as current military applications and future civil applications in medicine. Lessons on advanced flight simulation and novel medical treatments using real time diagnostic imaging gave a fascinating view on future applications. We believe that especially in medicine, big practical advantages may be gained with systems of a readily attainable level of sophistication.

The workshop was organized by the Value Relay Centre (VRC) for Research and Technology at VDI/VDE Technologiezentrum Informationstechnik GmbH (VDI/VDE IT), established by the European Commission to provide transparency mainly on EU-funded projects, improve access to results for external companies and institutes and assist in the process of exploitation. It took place on May 30, 1994. All papers were invited. The materials were collected afterwards and were updated to the latest possible status.

We hereby express our thanks to all who have contributed to this event, especially Mr. Geßner and Dr. Pett of Value Relay Centre and Dr. Erich Kiefer from Wiesbaden. We hope to have initiated many dialogues between participants and that further contacts may emerge with readers of these proceedings.

Berlin, 25.11.1994

Rolf Hainich

Contents

Real-Time and Near Real-Time Range Maps from Paired Video Cameras (ESPRIT 532)

Richard J. Fryer, University of Strathclyde, UK

Extraction of 3D image information form stereo camera pairs is of particular importance with applications related to human vision. The underlying EU project is not brand new, the results however are still very current, especially as they describe a hardware based approach. The machine is capable of analyzing scenes up to full video rate and gives remarkably accurate results even with complex scenes. Even more interesting, this hardware would probably fit on one chip in a modern VLSI design.
A second project outlined in the Article is ASP, a technique using active illumination with an LCD light modulator.

VIRIM: Massively Parallel Processor for Real-Time 3D Volume Visualization in Medicine

Jürgen Hesser, Universität Mannheim, Germany

This project is aimed at displaying three-dimensional volumes at high frame rates. Different from usual rendering algorithms which generate shaded surfaces only, this approach handles the display of complete 3D volumes up to 256*256*128 voxels, which offers great advantages in the field of medical applications. The machine has been realized as a DSP multiprocessor board and will be transformed int a VLSI design in the next step.

Berührungslose Steuerung durch Gestenerkennung

Christoph Maggioni, Siemens, München, Deutschland

Man-machine interfaces for Virtual Reality do not necessarily have to be clumsy and inconvenient. The approach presented relies on hand gesture and head movement recognition by cameras. Hand gesture can be used to give commands to the machine and to point. Head movement is utilized to control the angle and orientation of object presentation on a computer screen; the object shows different views dependent on where it is looked at from, like a real 3D object would do. This gives a strong and vivid 3D impression even without a stereo display. No goggles, no dataglove!

Technologies for High-Performance Solid-State Image Sensors (ESPRIT 1572)

Albert Theuwissen, Philips, Eindhoven, Netherlands

As image recognition will be a key element to integrative 3D visualization, image sensors will be as well. Philips is one of only a few non-Japanese companies competing in this field. Their technology, however, is remarkable and offers advantages for professional applications, especially where high resolution, high speed or overexposure tolerance are important. Philips sensors are used in the Bosch-BTS HDTV cameras. The article gives an introduction to CCD technology and the frame transfer technology employed by Philips.

New Technologies in LCD Displays (ECAM 8597)

Robert Hartmann, Philips, Eindhoven, Netherlands

LCD displays may likely prove to be the most important technology for vision simulators. The Japanese are leading in this area, but there is a strong commitment at Philips to acquire a rising market share. Today, Philips produces B&W displays for projection systems; however, developments for other fields of application are intensely pursued. The article gives an overview on Philips? technology and perspectives in the area of LCD displays.

Integrative 3D Visualization

Developments towards Virtual Devices

Rolf Hainich, VDI/VDE-IT, Germany

Technology

New technologies in image processing and presentation have induced the next step in the evolution of user interfaces. Virtual reality (VR) goes beyond commonly used graphics by linking computer generated images to real world parameters such as point and angle of view, location and movement in space and physical interaction.

In the most common understanding of Virtual Reality, the user of the equipment is totally shielded from reality and interacts in a totally virtual environment ('Cyberspace'). However, we consider this to be only one variety. The Cyberspace concept may even contribute to brandmark VR as a gamehall technology of little practical use and distract one´s view from the really advantageous new applications in professional areas.

New aspects

For a variety of reasons, we feel that the most promising application of virtual reality will be the **generation of virtual objects merged into real scenes,** which can be achieved by a display using semi-transparent optics. Most of the present VR systems (except for some sophisticated military examples) cannot support this kind of application because they lack several necessary technical features; however, this is the application we consider to be most interesting. An open system, not hiding the environment like classical VR but only placing certain informations to the disposition of the user, provides a totally different quality.

Working hypothesis: the *Virtualware* concept

Virtual objects projected by an open VR system could easily replace a tremendous number of devices currently designed in hardware. We call this type of Objects ´**Virtualware**´. A simple and obvious example could be the transformation of the modern workstation computer user interface into a virtual desktop projected onto a real desktop surface carrying virtual objects like a keyboard, a display unit and virtual paper really to be written on with a sensor equipped pencil.

An even more simple but economically important application could be virtual TV's, especially for High Definition TV, because the image resolution there calls for screens about 2 meters wide, which are unpractical even in LCD or other flatscreen technology. Projection devices also suffer from severe physical limitations. With small and light VR glasses, this may be solved. The problem is resolution. The VR display must cover a large viewing angle and provide a resolution fairly exceeding HDTV standards. Some developments promise solutions to this. The other requirement is fast 3D warping to compensate for head movements. Recent developments in graphics chips are pushing the limits for these kind of operations far ahead and it seems a matter of short time to provide even a quite economical solution to this kind of problem.

Beneath virtual objects, VR equipment also offers novel and yet unmatched 3D capabilities to provide the perfect 3D movie display, something not practically possible by holography or conventional stereoscopy.

Other applications could be virtual control panels for more ´physical´ equipment like household machinery and cars, as well as all kinds of 'X-Ray-views', for example in a power plant where maintenance personnel could virtually look through walls and see every piece of installation together with sensor values and other useful information right at their original location. A first development in this direction has already been undertaken in the area of aircraft maintenance with the ´Crystal Eyes´ project. All of these applications require very high resolution, lightweight displays.

As they are software, virtual objects can be copied, shared and seen by different people at the same time. Therefore, Communication links are mandatory for a Virtualware display. Virtualware is open and communicative, not isolating. Different people may work with the same virtual objects, as well as objects may be made available to everyone by simple copying (copyright problems will arise, but this is already known with software).

As can be seen from the few examples mentioned, **virtual reality has a great potential of saving energy and raw materials** by replacing hardware by Virtualware. Another very important benefit of this technology will lie in better ergonomics and improved safety in many fields, including medical, industrial and aerospace applications.

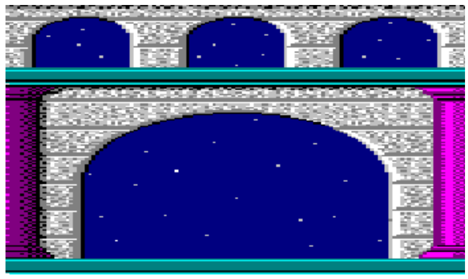
The essential basic technologies for these applications are

- Highspeed image computing
- Very high resolution, lightweight, miniature displays
- Accurate, cheap and convenient position sensors.

While high speed computing rapidly improves, display technology is still unsatisfactory, and position sensing leaves a lot to be desired as well.

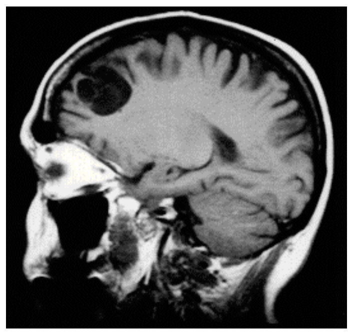
A classification of virtual objects

Virtual Objects : Images



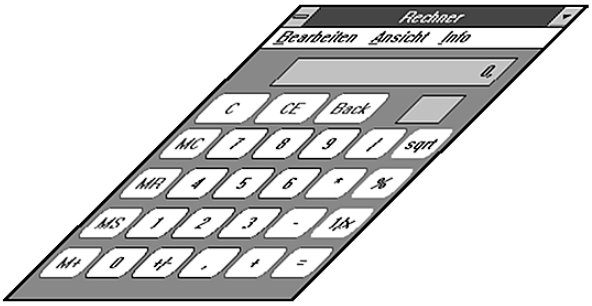
Devices

Images: 2D
- Image,
- Cross-Section

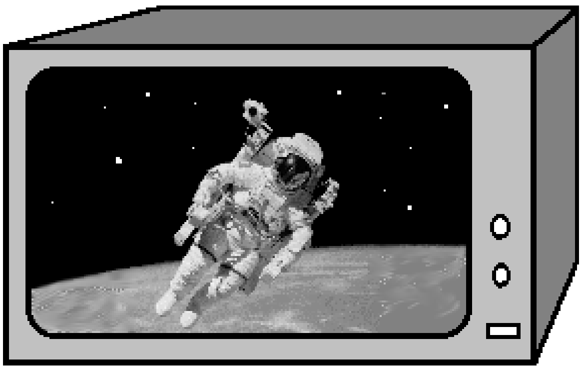


3D
- Volume
- Surface
- Solid

Devices = Images with Controls



2D - Typical 'Windows' screen object
- Virtual 2D display device
- Virtual Paper



3D - virtual device with depth/volume
- virtual 3D display window

most applications for virtual devices will only require 2D or 2.5D presentation in the real 3D space.

==> Virtual Devices (*Virtualware*) may soon replace many items currently done in Hardware.

Display

Display devices for VR will become an important key technology with a large market, especially as they will replace many traditional screen displays.
A satisfactory resolution for many applications would be about 2 million pixels (e.g. approx. HDTV quality or six times conventional TV or computer displays) if a sufficiently large part of the field of view is covered and especially if pixel density is more concentrated at centre. This would allow for an image sharpness that sufficiently matches ergonomical requirements.

Displays offering this resolution currently use cathode ray tubes which are, although yet very small, still too heavy for a convenient layout. They may however prevail in professional applications for a short time.
Future constructions may perhaps utilize small, high resolution liquid crystal devices. The problem with these is to provide sufficiently small pixel cells. Another solution could be the Retina Scanner, directly writing a laser beam image into the eye. Problems here are with compensating for eye movements and providing cheap blue laser chips. We expect technological and design problems with these devices to be resolvable within a few years.

Helmet displays for use in helicopters and other aircraft have recently been introduced and already offer many of the features described above. The defence industry is therefore important in the transformation of the VR Idea into professional applications.

Optics

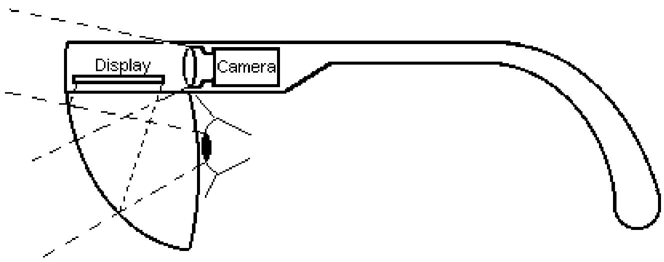
Optical construction is very important for light and convenient VR glasses of high quality. Current designs are often very primitive and clumsy.

A proper design should not disturb normal sight at all, yet offer the capability of projecting virtual images over the entire field of view. This sounds ambitious but has already been done by placing the displays to the side or over the eyebrows, out of view, and mirroring the picture by half-reflective elements placed before the eyes. The transmissivity of the mirror elements may be kept very high if dichroitic or holographic mirrors are used together with narrow band light sources.

Focusing is also an important point. Most 3D systems cause headache because the apparent distance seen by image divergency does not match the required eye adaptation. An appropriate focusing system should solve this problem.

Optical distortion may be compensated for electronically resulting in cheaper optics, but may as well be exploited to more efficiently map the available pixels to the human field of view in order to have more density and sharpness at centre. This would reduce the total number of pixels required and also improve image appearance.

Interface
(Vision Simulator)



Object display => light, high resolution glasses,
possibly with LCD screens,
CRT, or scanners

Object positioning => Head position sensors

Conventional
- Optical triangulation
- Ultrasonic
- Acceleration sensors

New methods (Camera based)
- Head recognition
- 64> Scene/Viewpoint recognition

5

Object insertion >4> Real scene acquisition (Camera)

5

94> Masking techniques
Additional Mask Display (LCD)

Interaction => Hand recognition (Camera)

Adaptive Display/Rendering strategies (inlays etc.)

5

Fine positioning 94> Eye tracking

Position sensors

In the field of relative position sensing, there are many companies capable of creating excellent products. Absolute coordinate sensing is however still a problem. The most common solutions use electromagnetic fields (Polhemus-sensor) or camera recognition of light spots connected to the target object. The latter are more accurate, but have difficulties with obstacles in the lightpath.

An intelligent **visual orientation system** based on image processing, may however be a much better solution and might induce a radical change in the ergonomic constraints of VR. It will be important that virtual objects can be defined to appear at a certain place and stay there and only there, which means that they have to disappear when the place or room is left, but reappear when it is reentered.
This requires the recognition of environments, which can be achieved by cameras attached to the Display, in conjunction with appropriate image processing.

Such a system, would indeed also be useful as a very precise and direct position sensor, simply by exploiting the geometrical object data gained from the recognition process. While probably being a bit slow, it could be greatly improved by adding cheap and accurate acceleration sensors to keep track of fast movements, a technique already used in aircraft simulators to improve the efficiency of triangulation and eye tracking systems.

Object merging

Camera systems are also important for the ability to place virtual objects in a way that they could eventually be covered, partly or completely, by real objects. Otherwise, the resulting scenery could be very irritating. For example, a virtual keyboard should not hide the user´s hands, or it would be unusable. The right measure for this would be to recognizing objects by a stereo camera and cut out an appropriate shape from any virtual image supposed to stay in the background.

Image presentation will also be improved significantly by covering direct view to real world in those directions where virtual objects are located. This would simply keep them from appearing translucent. A cheap black-and-white LCD could cut out reality at locations of virtual objects. However, this would greatly contribute to the weight of the equipment.

The merging and orientation techniques mentioned, demand an entire knowledge of the real scenery, thus requiring two cameras, ideally taking pictures from the very locations of the user´s eyes.

Manual Interaction

Cameras attached to a display could not only give a direct means of virtual/real scene fitting. They might also be utilized to monitor the user's hand movements and gestures, allowing for direct interaction with virtual objects, such as pressing imaginary keys, moving objects or defining new objects out of virtual menus projected into space. Because people could hardly be convinced always to wear datagloves, this is a fairly important issue. Tactile feedback is not possible with this approach, but is also not necessary in most cases.

Eye tracking

Some applications, require an accurate and artifact free positioning of virtual objects. Parallactical errors, e.g. angle differences that result from looking through the display more straight or more sideways, should be eliminated. This requires the introduction of an eye tracking system which determines the viewing direction by sensing the position of the pupilla. Such systems are still expensive in the professional area. Cheap setups for cameras and camcorders have however emerged recently. What we are talking of here has to be much faster and more accurate, but this is simply a matter of chip complexity.

Other applications of an eye-tracking system would be:

- Creating picture inlays of higher resolution in the centre of vision, like with the FOHMD flight simulator display.

- Exploiting eye-pointing in an advanced user interface.

- Automatic adaptation of the display system for best sight in every constel-lation.

Realization

As we have seen, a display for the Virtualware concept will be a fairly complex system, involving up to four microcameras with image processing (two scenic cameras and two eye trackers) and up to four displays (two high resolution colour screens and two mask displays),
not to mention acceleration sensors, possible acoustical interfaces, infrared communication links etc.
Miniaturization will be feasible, since there are already numbers of affordable microcameras and other very small devices on the market. Processing power, however, will be high and will probably be placed outside the interface.

An intermediate step to this will be a system for stationary professional use like in medicine, where the display might still be acceptable at weights up to 300 grams while the computing equipment could be placed in an extra rack.

Necessary Software for Vision Simulators

Object Presentation

- Rendering
- Correction of display optics
- Adaptive resolution

Insertion

- Image adaptation
- Masking

Positioning

- Image/scene recognition
- Acceleration or other sensor interface
- Anticipative positioning

Interaction

- Hand recognition
- Eye tracking
- Voice
- Others

Operating System

- Standardized software interface for object presentation and interaction (3D-Windows)

Our current Activities

We are currently promoting an initiative aimed at virtual real time diagnostics to support surgical operations (under the working title `Real Time Transparency'). This promises to be an application where technical parameters are less critical and the benefits will, in research projects, easily outweigh the still extraordinary costs of prototype setups. The project also exploits the latest developments in diagnostic machinery for fast 3D imaging.

We see this as a market oriented approach, based on a **vision of future products and fields of application** rather than particular technologies, therefore promising to induce the development of real products rather than generating mere research results that often don´t ever leave the laboratory.

Markets

We believe that for highly complex products, there are only three markets that can provide for the amortization of development costs of new technology: Military, Office and Home.

Other professional applications (medical, industrial, architectural etc.) will only create niche markets in comparison.

With defence budgets under pressure, western industry has to rethink its abstinence in some markets, especially the camcorder market, where most basic technologies for VR are located. While the Japanese are seemingly reluctant to enter the new area, they may be counted on when large volumes are possible.

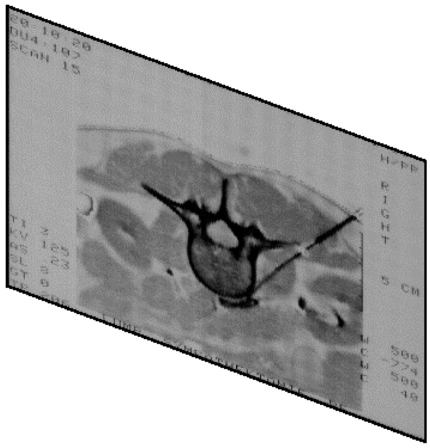
Although we see medical applications as an ideal area of experimentation, also with lower technical requirements than office or even home applications, the billions to be invested into the new technology may **only** be amortized with millions of pieces sold. Being 100 or 1000 times smaller than the office or home markets, medical, architectural and other niche markets will never accept product costs 100 or 1000 times as high.

Basic technology developments for such markets are therefore not recommendable. In these areas, technology from other areas has to be adapted. However, the results that can readily be achieved in medical applications, can lay the foundation for new technological trends.

Simple but efficient products are necessary in this stage to promote the Introduction of the technology:

A possible Medical Application

Display of images from **online diagnostics** at their Location of origin would result in great ergonomical advantages in surgery under NMR, CT and ultrasonic imaging.



- NMR, Ultrasound and CT deliver black&white images of 128x128...512x512 pixels

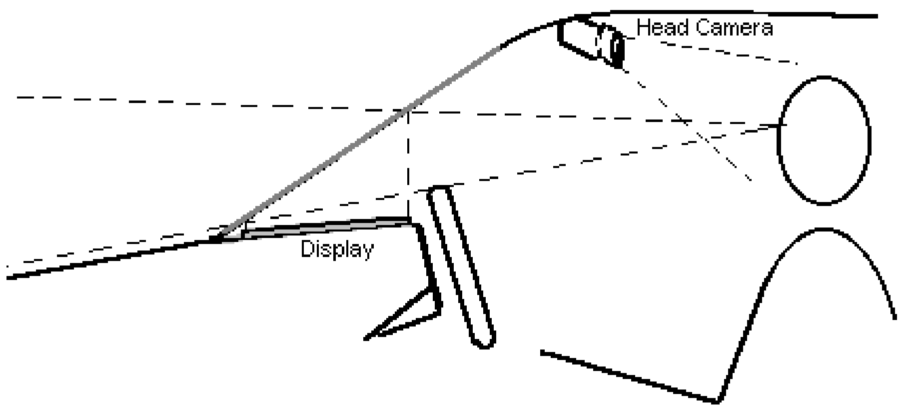
  => Standard resolution, b&w displays

- Objects are flat (simple cross sections)

  => - Simple rendering algorithms (multiple cross sections possible)

This might be a first good product. Office applications and virtual TV's may follow later, they require higher resolution, better position sensing and more computing power.

A possible Automotive Application



Overhead Display of Infrared and RADAR Images in the windscreen, done with a large LCD installed flat on top of the control panel.

=> requires an exact image overlay to the real sight and works quite similar to the techniques discussed above.

Essential for this is head position sensing, best done by an infrared camera.

Products in this area might also be expected quite soon.

Future developments

The complex VR system outlined above could make up a complete personal communicator, replacing everything from TV over computer to wireless telephone.

The first machines like this will, however, be desktop multimedia computers, whose first incarnations are already in the stores.

Really new would be the reduction of large hardware to a mere human interface, saving lots of material, which is good for the environment but bad for everyone not having the appropriate technology. A threat to our technological position will arise here, if we leave this to the Japanese only, like the camcorder market.

Environmental Considerations

Environmental and economical advantages of Virtualware technology will be immense. Today, fast changing technology obsoletes equipment every 2-5 years. This will not be different with VR equipment, but in the virtualware concept, only very small amounts of physical equipment will be discarded, while virtual devices are simply reprogrammed. Virtual paper has the potential of really replacing its physical counterpart because ergonomic constraints are better met than with present concepts.

In conjunction with a communications network supporting virtual offices and work at home, not only office buildings will become obsolete in great parts, but working places will as well be reduced to a minimum, if Virtualware replaces traditional hardware and filing concepts, and, if working conditions become independent of location.

Conclusion

The evolution of information technology tends to minimize hardware and connect the human interface as closely to the human senses as possible. Replacing Hardware by Virtualware and reducing the remaining parts, would be a logical step in this direction.

This Technology might, in the long run, save material and costs while offering an overwhelming lot of new possibilities. Its openness to the environment versus the concealedness of classical VR, along with its communicative capabilities will lead to new applications not yet even thought of.

While many traditional products will be made obsolete, being present in the new markets evolving from the developments outlined, will be crucial for the survival of our information technology industry. Any efforts in this direction should therefore be broadly supported.

Rolf Hainich