Further Development of the Responsive Workbench

Bernd Fröhlich Berthold Kirsch
Wolfgang Krüger Gerold Wesche

Dept. of Visualization and Media Systems Design
German National Research Center for Computer Science
Sankt Augustin, Germany
E-mail: `bernd.froehlich@gmd.de`

January 17, 1995

Abstract

The Responsive Workbench [8] is designed to support end users as scientists, engineers, physicians, and architects working on desks, workbenches, and tables with an adequate human-machine interface. Virtual objects are located on a real "workbench". The objects, displayed as computer generated stereoscopic images are projected onto the surface of a table. The participants operate within a non-immersive virtual environment. A "guide" uses the virtual environment while several observers can watch events by using shutter glasses. Depending on the application, various input and output modules have been integrated, such as motion, gesture and voice recognition systems which characterize the general trend away from the classical multimedia desktop interface.

The system is explained and evaluated in several applications: A virtual patient serves as an example for non-sequential medical training. The car industry benefits from areas like rapid prototyping for exterior design and interactive visualization and examination of flow field simulations (virtual windtunnel, mixing processes). Visualization and verification of experiments with mobile instrument deployment devices in outer space missions are another fascinating application. Architecture and landscape design are another discipline well suited for the workbench environment.

1 Motivation

The standard metaphor for human-computer interaction arose from the daily experience of a white-collar office worker. For the last 20 years desktop systems have been enhanced more and more, providing tools such as line and raster graphics, WIMP(Window Icon Mouse Pointer) graphical user interfaces and advanced multimedia extensions. With the advent of immersive virtual environments the user finally arrived in a 3D space. Walkthrough experiences, manipulation of virtual objects, and meetings with synthesized collaborators have been proposed as special human-computer interfaces for the scientific visualization process. Specific interfaces, originally developed for pilots and telepresence tasks, became available to the ordinary user (see [7], for example).

The dream of the ultimate medium, which uses all channels of human perception, has guided the efforts of user interface design towards these virtual reality systems. Unfortunately, head-mounted displays, body-tracking suits, and force-feedback exoskeletons are obstrusive. These systems separate the users from each other. Especially in scientific visualization applications, comprehensive attempts have been made to overcome these drawbacks. The BOOM systems allow for easy-to-use walkthrough and object manipulation experiences [3]. The surround-screen projection-based virtual environment CAVE [2] was designed for several users to become immersed with their whole body in a virtual space.

All these approaches to future user interface systems have one point in common: design of an (almost) universal interface based on the most advanced computer and display technology available.

Another approach to the design problem for future human-computer interfaces is rigorously centered on the users's point of view. Myron Krueger pioneered this attempt with his work on non-immersive responsive environments [7]. Application-oriented visualization environments have been proposed and built to support a specific problem-solving process. The computer acts as an intelligent server in the background providing necessary information across multi-sensory interaction channels (see [4], [10], for example).

We developed the Responsive Workbench concept, first described in [8], as an alternative model to the multimedia and virtual reality systems of the past decade. Analyzing the daily working situation of such different computer users as scientists, architects, pilots, physicians, and professional people in travel agencies and at ticket counters, we recognized that there is only small acceptance of a simulation of working worlds in a desktop environment. Generally, users want to focus on their tasks rather than on operating the computer. Future computer systems should use and adapt to the rich human living and working environments, becoming part of a responsive environment.

2 System description

During the analysis of the working environment and of the behaviour of the specialists, we recognized that the (cooperative) tasks of this class of users relies on a “workbench” scenario. The future impact of desk-like user interfaces in general has been discussed in [9]. Using a beamer, a large mirror and a special glass plate as table top, we built an appropriate virtual environment.

Virtual objects and control tools are located on a real “workbench” (see Figure 1).

Figure 1: Set-up for a stereoscopic display of virtual objects on a desk

The objects, displayed as computer generated stereoscopic images, are projected onto the surface of the workbench. The projection parameters are tuned such that the virtual objects appear above the table. Depending on the application, various input and output modules can be integrated, such as motion, gesture and speech recognition systems. A responsive environment, consisting of powerful graphics workstations, tracking systems, cameras, projectors and microphones, replaces the traditional multimedia desktop workstation.

The most important and natural manipulation tool for virtual environments is the user's hand. Our environment depends on the real hand, not a computer-generated representation. The user wears a data glove with a Polhemus sensor mounted on the back. Gesture recognition and collision detection algorithms, based on glove and Polhemus data, compute the user's interaction with the virtual world objects.

To get correct stereoscopic rendering from any location around the workbench the system must keep track of the guide's eye positions. We realized this by mounting a Polhemus sensor on the side of the shutter glasses. It delivers position and orientation data for the head, allowing the system to calculate the position of each eye. Additional collaborateurs see the stereoscopic images with only slight distortions as long as they stay close to the guide.

The Responsive Workbench setup generates a very effective 3D impression which is due to the negative parallax, the wide angle of view and the head tracking. None of the users suffered from motion sickness using the workbench which happens often with head mounted displays. This seems due to the non-immersive nature of our approach. People still have fix points in their environment so their senses don't get irritated.

Figure 2: Cooperative work of a physician and a student

3 Applications

Based on current research projects in the field of computer graphics, human computer interfaces and visualization, the following applications have been embedded in this new type of environment following the suggestions of the involved end users.

3.1 Medical applications

3.1.1 Nonsequential training

This scenario is based on a real sized model of a patient. Figure 2 shows the model in a teacher/student scenario. The patient's skin can become transparent, making the arrangement of the bones visible. Now the surgeon or student can pick up a bone with the data glove and examine its joints, or take a closer look at the bone itself. The virtual patient could be examined in any detail through the zoom operation. Covered parts could be set free by removing the obscuring bones or organs with the hand or by making them transparent. Especially important for the understanding of many processes inside the human body are their dynamic aspects. We implemented two primary cases: the spatially exact reconstruction of the beating heart and the blood flow inside the transparent heart.

3.1.2 Simulation system for ultrasound heart examinations

This research project has been developed in close cooperation with the Center for Pediatry of the University of Bonn, Department for Cardiology, Germany. A typical user team is made from a radiologist, a surgeon and a visualization specialist.

Originally, the project was designed on a multimedia workstation. Recently we started to implement the system on the Responsive Workbench to meet the requirements of the surgeons for a virtual environment. They want to see the organ of interest and the measurement process in real or magnified size from all points of view in 3D space. They also would like to compare the simulation with the images on TV screens originating from the scanning process.

Detailed visualizations of the beating heart can be explored as interactive animations. The user can rotate the model in order to examine the structural and dynamic features of the heart. Different visualization modes (i.e., transparent, with/without blood circulation) are available. The complex interior structures and dynamics of the heart, valves, and blood can thus be examined (see Figure 3).

Figure 3: Examination of the blood flow in a human heart

3.2 Architecture and design applications

For the design and discussion process in architecture, landscape and environmental planning we implemented a basic testbed for demonstrations:

An architectural model is shown on the workbench, in our case the area around the buildings of our research institute. In front of the table two architects discuss the model,

Figure 4: Virtual windtunnel scenario for car manufacturing applications (aerodynamical study model ASMO-II).

moving around buildings or other objects, such as trees in the virtual world. Additionally, lightsources can be set by the data glove to simulate different times of the day.

3.3 Applications in the car industry

In cooperation with scientists and engineers of the research department of Daimler-Benz AG, Stuttgart, we implemented two applications concerned with fluid dynamic simulations on supercomputers.

3.3.1 Virtual windtunnel

This application realizes the virtual windtunnel scenario [1] (see Figure 4) in the Responsive Workbench setting. The simulation data is taken from a finite element program running on a supercomputer or a highend workstation. In a preprocess the data points from the finite element mesh are resampled to a regular grid to speed up particle tracing. Particle tracing directly on finite element meshes is more accurate, but the additional computational cost restrict the number of particles, which could be handled simultaneously. The geometry data is also extracted from the finite element mesh and somewhat polished by a modeling system, e.g. by adding textures. A few precomputed streamlines are added as an overview of the flow field.

The stylus serves as a particle injector to examine any area around the car in detail. The particle generation rate and their lifetimes are adjustable. The velocity values of the flowfield are globally scalable even if this is physically not realistic.

3.3.2 Mixing process

The dynamics of the mixing process, generated by a supercomputer simulation, are visualized with the aid of fluid particles as rendering primitives. The essential physical properties to be visualized are the velocity field, pressure, temperature and fuel distribution. The mixing process is strongly time-dependent, so the data rate is much higher. The visualization shows the particle flow with color coded temperature during the injection process. These particle paths are precomputed during the finite volume simulation. The current implementation focusses on the interactive real-time exploration of the temperature and pressure distribution inside the cylinder with arbitrary cutting planes. The cutting plane is attached to the stylus which allows easy positioning. The finite element data is again converted to a regular grid, which serves as a 3D texture on the SGI Reality Engine 2 rendering system.

3.4 Simulation and control of outer space experiments

In cooperation with Deutsche Forschungsanstalt für Luft- und Raumfahrt e.V. (DLR) and other partners a mobile instrument deployment device prototype (IDD) will be developed. A mobile IDD is a small microroboter for positioning of instruments on Mars or other space bodies to explore the near vicinity of the landing location. It is not possible to test the IDD under martian conditions or to control it on Mars directly. The first project stage studies the possible walking styles of an IDD and identifies the necessary data for a precise simulation of its behaviour. In a later stage the Responsive Workbench is meant to display remotely sensed terrain data including the position of the IDD and the lander for simulation and planning of experiments.

An IDD prototype vehicle has been developed by Transmash, St. Petersburg. It consists of three container segments which are coupled by two traverses. In its smallest position the size of the IDD is about 35x20x7 cm. The IDD moves by rotation of the container segments which hold the instruments. The IDD has been further developed by DLR and the University of Duisburg (see Figure 5).

Dynamics and kinematics are simultaed using “MOBILE” [5], a multibody modeling system.

A computer controlled crawling or walking style can be developed in the Responsive Workbench environment. The main problems are: which moving styles are possible, which information (sensors) is needed to control speed, direction and walking style or to program autonomous movement (reaction on obstacles, keep a given direction etc.) of the IDD robot [6].

Following the successful simulation of a save walking (crawling) path in the virtual environment at the ground station, the driving code is sent to the IDD operating on an other planet. Data measured by the IDD and the lander will e sent back to calculate the next steps and to update the visualization. This control loop is necessary to syncronize the remote and the virtual environment.

Typical operating sequences for an IDD are the approach to a preselected site, appropriate positioning of the instruments at the object, preparation of the object for measurements, measurement procedure, aquisation of a surface sample and analysis, digging to acquire a sub-surface sample and analyse it, return material to the lander for further analysis, provide additional information for the selection of the next site.

Figure 5: IDD TEM1 implemented by DLR and Uni Duisburg

Figure 6: The computer model of the IDD

The operating sequences are prepared and tested in the virtual environment. The lander station sends its data to the ground station. These data is used to construct the actual virtual world where the scientist acts. The scientist decides on the next action, teaches the new goal by i.e. pointing to the target site and runs the experiment within the virtual world. If the experiment has been successful the appropriate commands are sent to IDD on the planet. When the new situation on the planet has been incorporated into the virtual world the next sequence can start.

4 Conclusions

The RW system is designed to demonstrate the ideas and power of future cooperative responsive environments. Further applications under consideration running on this virtual workbench will be the simulation of air and ground traffic on airports, a training environment for complicated mechanical tasks, e.g., taking apart a machine for repair, landscape design and environmental studies via terrain modeling, and physically based modeling of virtual objects ("virtual clay"). These applications also rely on the workbench metaphor, but require specific interaction and I/O tools.

5 Acknowledgments

This work relies on the discussion with scientists and engineers of the research department of Daimler-Benz AG, Stuttgart, and physicians of the Centre for Pediatry of the University of Bonn. Especially, we are grateful to Prof. Redel for his involvement in this new field.

We thank our colleagues and students Stefan Banse, Manfred Berndtgen, Thorsten Fox, Klaus-Jürgen Quast, Peter Rohleder, Thomas Sikora, Josef Speier, Wolfgang Strauss, Jürgen Wind and Jürgen Ziehm for their extraordinary involvement in SW/HW management and modeling.

This work is partly supported by the Department of Research and Technology (BMFT).

References

[1] S. Bryson, C. Levit, "The Virtual Windtunnel", *IEEE CG&A '93*, July 1992, 128-137.

[2] T.A. De Fanti, D.J. Saudi, C. Cruz-Neira, "A Room with a View", *IEEE Spectrum*, Oct. 1993, 30-33.

[3] I.E. Dowall, M. Bolas, S. Pieper, Fisher, J. Humphries, "Implementation and Integration of a Counterbalanced CRT-based Stereoscopic Display for Interactive Viewpoint Control in Virtual Environment Applications", *Proc. SPIE* 1256.

[4] M. Green, R. Jacob, "SIGGRAPH '90 Workshop Report: Software Architectures and Metaphors for Non-WIMP User Interfaces", *Computer Graphics*, July 1991, 229-235.

[5] A. Kecskemethy, "MOBILE User's Guide and Reference Manual", Fachgebiet Mechatronik, Universität Duisburg, 1993.

[6] B. Kirsch, U. Schnepf, I. Wachsmuth, “RoboVis - a Scenario for Using Virtual Reality Techniques in Learning Robot Development”, *VISWIZ Report 4*, GMD, 1993.

[7] M. Krueger, “Artificial Reality II” *Addison-Wesley*, Reading, Massachusetts, 1991.

[8] W. Krüger, B. Fröhlich, “The Responsive Workbench”, *IEEE Computer Graphics and Applications*, May 1994, 12-15.

[9] W. Newman, P. Wellner, “A Desk Supported Computer-based Interacting with Paper Documents”, *Proc. of ACM SIGCHI*, May 1992, 587-592.

[10] J. Nielson, “Noncommand User Interfaces”, *Communications of the ACM* 36, No. 4, (April 1993), 82-99.