MIXING VIRTUAL REALITY AND 2D VISUALIZATION

Using Virtual Environments as Visual 3D Information Systems for Discussion of Data from Geo- and Environmental Sciences

Björn Zehner

Helmholtz Center for Environmental Research - UFZ, Permoserstrasse 15, 04318 Leipzig, Germany
bjoern.zehner@ufz.de, bzehner@gmx.de

Keywords: Virtual environments, GIS, 3D interaction, 3D visual information system, Visualization, Geosciences.

Abstract: 3D stereoscopic visualization and virtual reality techniques are increasingly used for quality control, analysis and discussion of 3D geoscientific data in the oil and gas industry. They provide an excellent and easily comprehensible insight into complex 3D structures of the earth's subsurface. However, in many research topics in environmental and geosciences the analysis of data usually also involves data that might be better viewed in 2D. Examples are maps or histograms. The use of virtual environments as visual information systems for the efficient communication and discussion of complex multi-attribute data sets also requires 2D data to be visualized with a high quality. Further it is often not possible to show all the relevant information simultaneously and so an interactive virtual environment is required that provides an overview and the necessary interaction techniques to select additional information, e.g. from a database, to be visualized on request. This article describes the hardware setup installed at the UFZ Centre for Environmental Research and a software solution for how to use this setup efficiently to connect 2D data representations with 3D visualization and interaction.

1 INTRODUCTION

At the very end of the last millennium, oil & gas companies started to become interested in using virtual reality (VR) techniques. In order to investigate this method and obtain demonstration software, they financed research at public research institutions, such as the GMD German National Research Center for Information Technology (now part of the Fraunhofer Society, (Fröhlich et al., 1999)) or the Virtual Environment Technology Laboratory at the University of Houston (Harding and Loftin, 2000). Many companies, such as Norsk Hydro or ARCO, set up their own virtual environments and developed their own software ((Midttun et al., 2000), (Stark et al., 2000)). Due to the very expensive hardware needed at that time, little research has hitherto been done outside this industrial field, e.g. on the use of VR for visualizing data from applied geophysical investigations, such as ground penetrating radar or geoelectrical resistivity measurements (Zehner et al., 2001), (Zehner, 2002).

Nowadays large companies like Shell or Schlumberger own a number of visualization centres around the world and use commercial software, to quality control and analyze their data and discuss their models. Further, more than 500 Geowalls, a low cost

stereoscopic visualization environment, have been built at universities and elsewhere, allowing geoscientists outside industry to make use of advanced visualization methods (Johnson et al., 2006). Thus, current examples of the use of VR in geosciences have started to include more diverse subjects, such as the 3D integration of outcrop data with regional data (Johnes et al., 2009) or numerical simulations in geosciences (Billen et al., 2008). However, despite many topics in geo- and environmental sciences often inherently involving structurally complicated 3D data, the use of these 3D technologies has still not reached maturity outside of the oil & gas industry: the question is why.

Principally, VR-systems should be suitable for discussing geoscience issues because they make it easier for users with different backgrounds and for novices to understand the structures and spatial coherence: this article will therefore focus on their use in presentations and discussions. It first discusses what might be missing in current virtual environments to make them more useful for the geo- and environmental sciences (section 2) and then gives an overview of what is currently available to solve this problem (section 3). In section 4 the design of our purpose-built display system is explained and in section 5 the implementation and interaction.

2 WHAT IS MISSING?

The VR systems that are currently state of the art have been primarily designed only with 3D tasks in mind, such as design or assembly studies. When geoscience data are presented in such a system, the 3D data are shown in the original form and all other data need to be converted into 3D representations. While planning a visualization centre for the UFZ-Helmholtz Centre for Environmental Research, it became obvious that use cases in such research centres have different requirements. Investigations in geo- and environmental sciences often contain a large number of different data sets that are spatially distributed and it is often impossible to show all this information simultaneously. Therefore, scientists frequently use Geographic Information Systems (GIS). GIS connect a spatial 2D visualization (a map) with a relational data base that contains additional information about the objects shown on the map. The maps show the overall structure (e.g. the topography) and additional objects, such as streets, dwellings or borehole locations. If during a discussion additional information is needed on one of these objects, viewers can select this object and the information is shown.

If the investigations involve complicated 3D structures that can not be presented on a map, this overall paradigm has to be extended from two to three dimensions and virtual environments become the ideal discussion platform due to the stereoscopic visualization and the direct interaction in 3D space. However, much of the additional information that belongs to the objects that are shown in the virtual environment involves data which can inherently be better visualized in 2D, such as areal images, soil columns or log plots. All these data need to be at the user's disposal during discussion and accessed by making selections.

Another important topic where additional 2D visualization helps is the orientation of the users which becomes complicated when finding their way within a structurally complicated virtual model of several kilometres in size in each direction. 2D visualization could help with this task by showing a map of the area with an icon that indicates where and at what depth the users are currently located and in which direction they are looking.

3 PREVIOUS WORK

Little work and software is available that really combines 3D visualization and 3D interaction with the option to augment the virtual scene with 2D information. Broadly the work can be split into three cate-gories: Showing virtual 2D widgets in 3D space, using additional gadgets such as PDAs and hand-held computers, and using video wall controllers, such as BARCO's Transform-A/XDS-1000 or Vista's Spider that are explained in Figure 1.

One example which shows virtual 2D widgets in 3D space is the Inside Reality Software from Schlumberger. This has been designed for working with data in virtual environments. For the system control, the standard XMotif style window interface is shown on planes in 3D space and interaction is done by pointing at the different menus and icons with a ray.

The Virtual Environments group at the Fraunhofer Society in Birlinghoven has developed several examples of the use of tracked PDAs ((Simon et al., 2005), (Holtkämper et al., 2007)) and Tablet PCs (Holtkämper et al., 2007) in virtual environments. This approach has been mainly used for system control, but could also be used to show additional 2D information which would, due to the small displays, only be available to very few people.
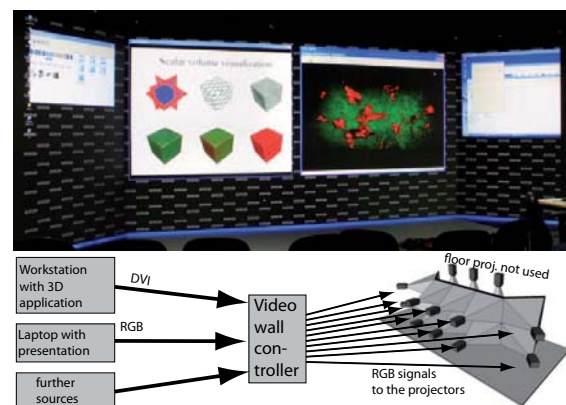

Figure 1: Our projection-based display system run by a video wall controller (VWC). Different computers, e.g a workstation with a stereoscopic visualization application (here showing a volume visualization in the right window) and a laptop with an explanatory powerpoint presentation (here shown in the left window) are connected as external sources to the VWC which does the image generation for the projectors and solves problems, such as edge blending. While allowing the use of standard software on the display, this essentially means using the display as a big monitor instead of as a virtual reality display.

4 UFZ'S DISPLAY SYSTEM

Our head-tracked stereoscopic display system is mainly used for collaboration and presentation. So one major driving factor for design has been high image quality/high resolution and a large screen to support an audience of several people. Further the aim
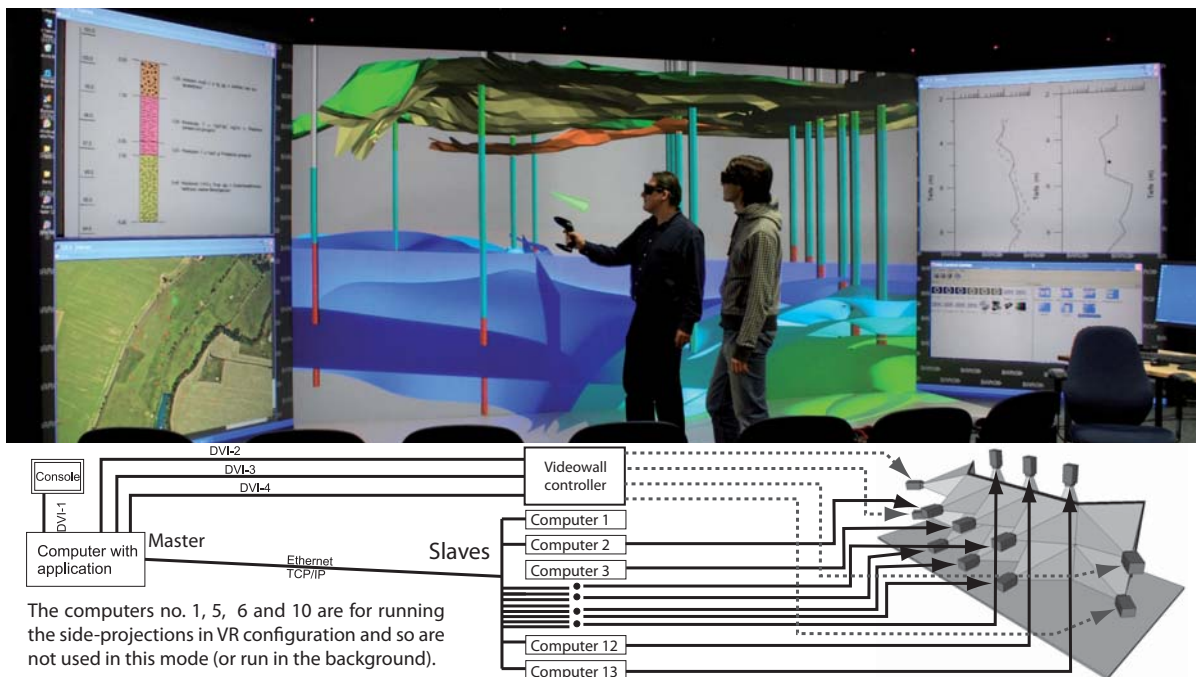
Figure 2: Picture of the UFZ's visualization centre used in mixed mode at the top and the corresponding hardware setup at the bottom. On the rear screen and on the floor a 3D model is shown with which the users can directly interact in virtual space. This part of the system is run by a computer cluster. On the side wings additional 2D information is shown upon the user's request, such as detailed borehole information on rock types or graphs of physical values (windows at the top of the two side wings). The users choose which information is shown by selecting the corresponding objects in the virtual model. A map (bottom left wing) always indicates the orientation of the display in the virtual world and so helps when working with data sets that show geographical information ranging across several kilometers.

was to employ the system for a wide range of use cases, some of them using it as a CAVE while others as a simple 2D presentation system. The system has an approximately 6x3 meter large main screen and corresponding projections on the floor and side-wings. In order to achieve a high resolution of approximately 6400x1800 pixels (after subtracting the pixels for edge blending) and a good image quality, 13 SXGA+ projectors are used to run this system. Figures 1 and 2 show pictures taken in our display system and sketches of the overall technical setup. Rendering is done by a cluster of up to 13 workstations, one for each projector, and/or via a video wall controller. In the UFZ's visualization centre, rendering can be done in three different modes.

1. The first is to run the system purely as a virtual reality system using a cluster of 13 workstations.

2. The second uses a video wall controller for the main screen and the side wings (see Figure 1).

3. The third mode uses a combination of the first and the second one.

Figure 2 shows the configuration of the third mode that serves as the basis for augmenting virtual real-

ity and 3D interaction with 2D views of data. From the cluster, nine computers are used to generate the images for the main screen and the floor. This part of the display provides a virtual environment. On the side screens the video wall controller is used to show 2D information that has been generated as graphical output on a remote machine.

5 IMPLEMENTATION

In order to demonstrate a system that mixes virtual reality and 2D visualization to visitors at our visualization center a sample implementation has been programmed. Software development currently comprises three or four basic elements: The open source scenegraph OpenSG (Reiners et al., 2002), the commercial software VRED from PI-VR GmbH which is based on OpenSG, and Nokia's (Trolltech's) Qt toolkit for developing GUIs and Plugins for VRED. For processing 3D scientific data, we use the Visualization Toolkit (VTK, (Schroeder et al., 1996)).

Figure 3 shows the main components necessary for this software. At the heart of it is a 3D visualiza-
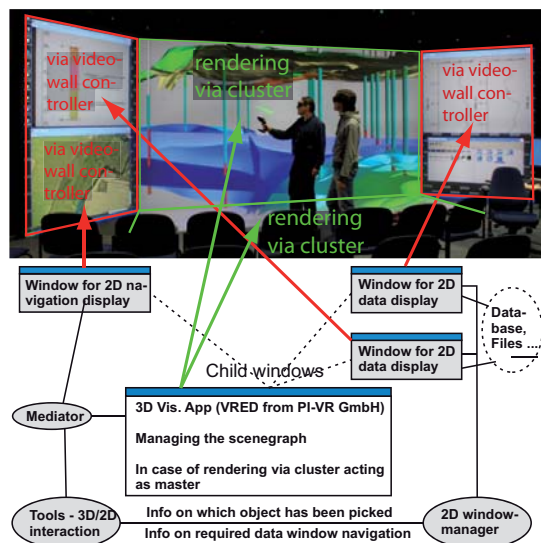
366

Figure 3: The different software components necessary to run the system in the mixed mode as is shown in Figure 2.

tion application that manages the scenegraph, including camera transformation, and provides functionality for operating on the scenegraph and adjusting the rendering attributes. Further it implements the functionality to act as a master for the computer cluster that represents the slave computers.

In order to show supplementary 2D information, additional child windows are added to VRED which are shown on the display using the video wall controller: Two for rendering additional data and one for showing a map and indicating with a glyph how the user is oriented within the whole scene (See Figure 2). The windows for showing data implement a common interface that provides functions for scrolling up and down, zooming in and out or loading data. They are steered from a 2D window manager which is controlled by the 3D interaction device.

5.1 3D Interaction

An essential component is the set of tools that have been implemented for system control and interaction with the objects in 3D space. In the UFZ's display system interaction is done with a so-called Flystick from Advanced Realtime Tracking GmbH, an interaction device that has 4 buttons and a small bidirectional joystick on the top, and another button at the bottom. The tracking system evaluates the position and the orientation of the Flystick and the status of the buttons and the joystick. Data transmission is done via the open source VRPN toolkit (Taylor et al., 2001). The four buttons on the top of the Flystick are used to switch between different tools. Which tools are avail-

able can be configured in a so-called tools-manager class. The tasks that can be done with the tools can be placed in four different groups:

- Navigation
- Interaction with objects in 3D space, such as translating objects or moving clipping planes
- Selection of objects for which additional information should be shown in the 2D windows
- Steering the 2D windows.

All tools are derived from a few simple base classes that are linked to the different buttons of the Flystick. The navigation is linked to the small joystick on the top. By pushing it forward, the users fly in the direction they point and by pulling it back, they fly backwards. Moving it to the left and right turns them. For direct 3D interaction, tools are provided to translate objects or to move objects temporarily which then snap back to their original positions. This can be very helpful during discussions when some of the objects disturb the view.

When looking at the 3D distribution of scalar data, multiple isosurfaces are often generated and the ones that are near to the viewer often hide the ones behind them which disturbs the view of the 3D course of the scalar field. As an example of data-analysis supporting 3D interaction we have implemented a solution where the user can use 3D tools to define a clipping region by manipulating the 3D widget that is shown in Figure 4. A rectangular parallelepiped is defined by 8 cubes at its corners and represents the volume of interest. Outside of this volume the isosurfaces are clipped, and so are not visible. A small sphere can be moved within the defined volume that represents the point where 3 additional axis-parallel clipping planes inside the volume intersect, so that chair-cuts can be interactively defined within the volume. In Figure 4 in both cases the left front upper octant, which lies near to the viewer is clipped away.

For the manipulation of this widget, two tools are provided. The first is for translating the cubes at the corners and so for reshaping and transforming the volume of interest. The second tool is for defining the chair-cut: translating the sphere moves the 3 clipping planes within the volume while picking one of the cubes at the corner selects which octant should be clipped away and makes the necessary adjustments to the clipping planes. In this way the user can analyze the course of the different isosurfaces around a borehole as shown in the lower picture of Figure 4.

The tool that connects 2D and 3D visualization is derived from the pick-tool and makes use of two additional classes. The first allows it to evaluate which screen of the display the pointing ray intersects and
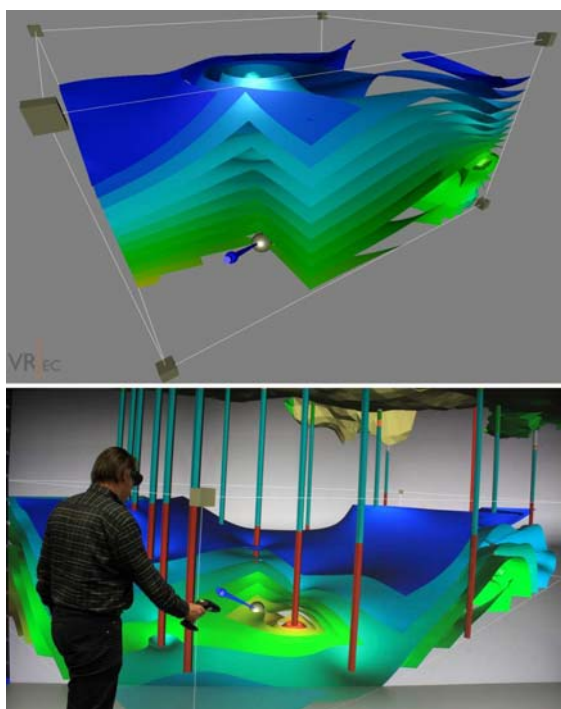
Figure 4: Example of the direct interaction with the 3D model in virtual space: Definition of a clipping box and a chair cut through a data set (isosurfaces) using a 3D widget, at the top as a screen shot and at the bottom showing a person interacting in our display system.

the second is the 2D window manager class. Depending on which screen has been intersected, different actions are performed: If the intersected screen is one of the side screens, the user must keep the button pressed and can then use the joystick, that is normally used for 3D navigation, to scroll and zoom the 2D window on the corresponding screen. If the intersected screen is the main screen showing the 3D model, the program checks for the intersection of the ray with the scene and reports the picked object to the 2D window manager, so that the suitable supplementary information can be shown on the side screens.

5.2 2D Information Display

For our 3D analogy of GIS functionality we can not use a commercial system as these only support 2D spatial representations. Instead we directly use the scengraph that describes our 3D visualization and within each node is associated with a unique name. Upon making a selection in 3D space, this name is used as an identifier and passed to the 2D window manager which then retrieves the additional information from the database. Depending on the nature of the information a suitable widget is chosen and the in-

formation is shown in one of the 2D windows on the side wings. Figure 5 shows an example of the application of this functionality, using the above-mentioned tool to connect 2D and 3D visualization.
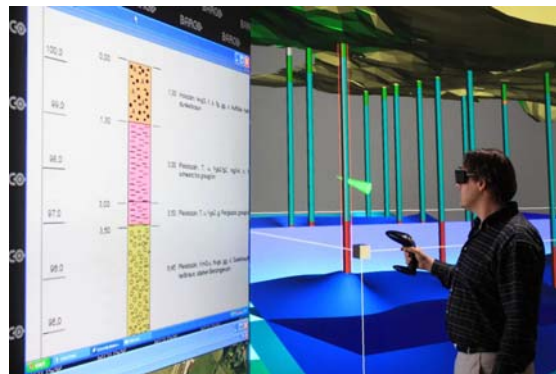

Figure 5: Example of requesting additional information on one of the objects shown in 3D space. The person picks one of the boreholes in order to see the additional 2D information, which is shown on the left screen.

5.3 2D Navigation Display

With regard to navigation, the information from the 3D interaction device goes through a mediator which passes it to both the 3D window/3D display and the 2D navigation window. The current position and orientation is always projected into the map view. The 2D navigation window then displays a map of the region and indicates the user's position and orientation using an arrow glyph.

6 CONCLUSIONS

This article first explains why current virtual environments need to be extended to be able to show non 3D data, such as maps and graphs, if they are to be used as visual information systems for complicated 3D geoscience data sets with multiple attributes, just as Geographic Information Systems are used for discussing 2D data today. As one possible solution a system has been described that combines hardware and software and provides virtual reality capabilities, such as user-tracking, stereoscopic visualization and direct interaction in 3D space and that can augment the information given in the 3D model interactively with supplementary data, using additional windows. For demonstration purposes real data are loaded which stem from the initial site analysis of a project that deals with direct gas injections for stimulation of the biological degradation for remediating organically contaminated groundwater (Beckmann et al., 2007).

We have not yet evaluated the system quantitatively. As visitors to our center often lost their orientation when navigating within large scale virtual models (even the ones that actually modeled it), it is clear that an additional 2D map view which shows the current location and orientation is a great help. The same goes for providing additional 2D information needed to discuss the data set. We have yet to evaluate if our approach, using the peripheral parts of our display for showing this information is superior to other approaches, e.g. those involving hand-held PCs. However, we usually have several visitors simultaneously and so it is preferable to show the additional 2D information on large screens. Problems with the system as shown are the wide angle of view where it is difficult to maintain an overview of the information on all the screens. Furthermore people sometimes complain about the 3D visualization abruptly ending on the side of the main screen.

ACKNOWLEDGEMENTS

REFERENCES

Beckmann, A., Gerhardt, M., Zittwitz, M., Martienssen, M., Krieg, R., Geistlinger, H., and Schirmer, M. (2007). Das OXYWALL-Projekt: Anwendung eines Verfahrens zur Direktgasinjektion von Sauerstoff zur in situ Sanierung von organisch kontaminierten Grundwässern. *Zeitschrift Altlasten Spektrum*, (4):153–159.

Billen, M., Kreylos, O., Hamann, B., Jadamec, M., Kellogg, L., Staadt, O., and Sumner, D. (2008). A geoscience perspective on immersive 3d gridded data visualization. *Computer & Geosciences*, 34:1056–1072.

Fröhlich, B., Barrass, S., Zehner, B., Plate, J., and Göbel, M. (1999). Exploring geoscientific data in virtual environments. In David, E., Gross, M., and Hamann, B., editors, *Proceedings of the 10th IEEE Conference on Visualization (Vis99)*, pages 169–173.

Harding, C. and Loftin, B. (2000). Visualization and modelling of geoscientific data on the interactive workbench. *The Leading Edge*, 19(5):506–511.

Holtkämper, T., Scholz, S., Dressler, A., and Bogen, M. (2007). Co-located collaborative use of virtual environments. In *Proceedings AAPG Annual Convention and Exhibition 2007*.

Johnes, R., McCaffrey, K., Clegg, P., Wilson, R., Holliman, N., Holdsworth, R., Imber, J., and Waggott, S. (2009). Integration of regional to outcrop digital data: 3d visualization of multi-scale geological models. *Computers & Geosciences*, 35:4–18.

Johnson, J., Morin, P., and Keken, P. V. (2006). Geowall: Stereoscopic visualization for geoscience research and education. *Computer Graphics and Applications*, 26(6):10–14.

Midttun, M., Helland, R., and Finnstrom, E. (2000). Virtual reality, adding value to exploration and production. *The Leading Edge*, 19(5):538–544.

Reiners, D., Voss, G., and Behr, J. (2002). Opensg: Basic concepts. In *OpenSG Symposium 2002*.

Schroeder, W., Martin, K., and Lorensen, B. (1996). *The Visualization Toolkit, An Object-Oriented Approach to 3D Graphics*. Prentice-Hall Inc.

Simon, A., Dressler, A., Krüger, H.-P., Scholz, S., and Wind, J. (2005). Interaction and co-located collaboration in large projection-based virtual environments. In *Proceedings of INTERACT 2005*, pages 364–376.

Stark, T., Dorn, G., and Cole, M. (2000). Arco and immersive environments, part 1: The first two generations. *The Leading Edge*, 19(5):526–532.

Taylor, R., Hudson, T., Seeger, A., Weber, H., Juliano, J., and Helser, A. (2001). VRPN: A device-independent, network-transparent VR peripheral system. In *Proceedings of the ACM Symposium on Virtual Reality Software & Technology 2001 (VRST 2001)*.

Zehner, B. (2002). *Anwendung immersiver Visualisierungssysteme zur Exploration geophysikalischer und geologischer Daten, Ph.D Thesis*. Rheinische Friedrich-Wilhelms-Univesität Bonn, Germany.

Zehner, B., Alteköster, C., and Kümpel, H.-J. (2001). Visualization of 3-D GPR surveys: Application of virtual reality in geosciences. *European Journal of Environmental and Engineering Geophysics*, 6:141–152.