# THE VIRTUAL REALITY CASEBOOK

EDITORS

CARL EUGENE LOEFFLER
TIM ANDERSON

VNR

VAN NOSTRAND REINHOLD
An International Thomson Publishing Company

New York • London • Bonn • Boston • Detroit • Madrid • Melbourne • Mexico City
Paris • Singapore • Tokyo • Toronto • Albany NY • Belmont CA • Cincinnati OH

Copyright © 1994 by Van Nostrand Reinhold, ISBN 0-442-01776-6

# CONTENTS

# DESIGNING VIRTUAL ENVIRONMENTS

Mark Bolas

This paper investigates the relationship between the design process and virtual environment systems. This relationship is explored in three sections: design with virtual environments, design for virtual environments, and design of virtual environments. Each category is discussed with examples drawn from my experience.

According to the American Heritage Dictionary, design means "to conceive, invent, contrive." It is useful to look at the relationship between the design process and virtual environment (VE) systems from three points of view:

- Design with virtual environments refers to the use of virtual reality to help solve a problem or invent something new.
- Design for virtual environments refers to the task of improving the hardware and software of VE systems themselves.
- Design of virtual environments is the creation of completely synthetic environments, or virtual worlds.

## DESIGN WITH VIRTUAL ENVIRONMENTS

Virtual environment systems can be used to enhance the creative ability of designers, engineers, and scientists. Quick prototypes can be made out of thin air; complicated combinations of parts can be arranged and rearranged without tools; mathematical analysis can be visually presented while the design process is occurring. In all cases, virtual reality is being used to enhance the speed and quality of the human creative process.

This is perhaps the most powerful and exciting current use of virtual systems—VR transforms the computer into a tool that amplifies human intelligence. This power is already being harnessed for a number of down-to-earth problems, as shown in the examples below.

## MOLECULAR MODELING

SRI International is using the Fakespace Data-Vision system with software from the University of California at San Francisco to visualize and work with molecular models and data. Users gain an intuitive feeling for their data by moving around and manipulating molecular models. Thus, virtual reality extends the three-dimensional design process into realms that are impossible for humans to perceive and are difficult to comprehend—such as the visualization and understanding of receptor sites in complicated protein structures.

## SCIENTIFIC VISUALIZATION

It has been notoriously difficult to give computers the innate human ability to match and recognize patterns in complicated situations. By presenting data to scientists through VR systems, the scientist's pattern-recognition ability can be used in data sets that are impossible to visualize because they are completely synthetic or of a nonhuman size.

For example, astronomical data provided by the Harvard-Smithsonian Center for Astrophysics is being visualized on a Fakespace Boom2 head-coupled viewer and a Silicon Graphics VGX computer at the National Center for Super Computing Applications in Urbana, Illinois. The Boom2 is a new addition to an ongoing, ten-year-old data-analysis project. Of the work, researcher Margaret Geller has said: "Even though I'm used to looking at this data, the thing that really strikes me is how clearly you can see the structures [in virtual reality]. I think this is going to have an influence on the statistical tools that we use."[1]

## COMPUTER-AIDED DESIGN

Product designers and architects are finding that enhancing computer-aided design (CAD) systems with aspects of virtual reality makes them easier to use and more accurate; they allow the user to visualize and manipulate models directly in three dimensions.

Alias Research has incorporated a Boom2 viewer with sophisticated software to create a general-purpose design and visualization system. The company believes it will be useful in many fields, including automobile design, architecture, and aerospace engineering. An exciting aspect of the system is the seamless interface it maintains between its existing mouse-based software and its VE modes. Users simply turn from their workstation and look into a Boom2 viewer when head-coupled interactive-viewpoint control is desired.

## JUST ANOTHER MEDIUM

When using virtual reality to aid in the design process, it is important to compare its strengths and weaknesses with those of other visualization systems. For example, blueprints and scale models often represent design data in ways that convey important information that can be lost in VR systems. Likewise, the palette and ease-of-use of VR systems cannot always match those of a pen and pad in the hands of a skilled design artist.

VR systems should complement, not replace, these other media. It is important to note that virtual reality is just another medium. It does not provide a perfect representation of a design and never will. It should be used as one of many design-visualization tools—in this way, a spectrum of viewpoints and insights will be achieved.

## DESIGN FOR VIRTUAL ENVIRONMENTS

There is a need for better-designed and more effective virtual environment systems. VE systems are new tools and need refinement before they achieve the ease of use and fluid feeling of more established design tools. Toward this end, the work at Fakespace has centered on building friendly and effective VR tools by creating better human-interaction metaphors for VR software, and by building higher-quality visual displays and interaction devices.

### METAPHORS FOR MANIPULATION

Just as the desktop metaphor allows users to interact easily with a computer's file structure, useful interaction metaphors are needed for virtual environment systems. Because Fakespace provides a VE software toolkit, the invention and analysis of such metaphors are important parts of our software design process. One example of this process is presented here: the creation and evolution of the "flying arrow" metaphor.

A key element of a virtual environment is the ability to move in three dimensions, often by letting the user "fly" through the air, gaining a bird's-eye view. This freedom of movement presents the VE designer with a difficult task: how to allow the user to control such motion effectively. For example, users with head-mounted displays and flex-sensing gloves can:

- Point and fly toward an object with speed proportional to hand position;
- Grab at empty air, and pull along in the direction of the grab;
- Swing their arms by the sides of their bodies and translate through the VE as if walking forward;
- Hold their arms straight out and fly through the virtual environment like a bird.

I tried each of these ideas in conjunction with the VIEW lab at NASA Ames Research Center and Stanford University in 1988. Our goal was to develop better metaphors for movement through virtual environments. While each of the above ideas had good and bad points, a detailed look at the "point to fly" metaphor illustrates the issues that must be addressed when designing a VE metaphor.

To test the point-to-fly metaphor, users were placed inside a virtual test track and instructed to fly around the track as quickly as possible. By observing the users and using lap times as a measure of performance, we identified two problems.

First, when going around corners, users became confused because the point-to-fly gesture was counter-intuitive to the familiar experience of driving a car. Automobiles rotate the user's frame of reference as a turn is being made, while the point-to-fly metaphor does not. Users would point around a corner, but forget to turn their body in a corresponding manner.

The second problem was that some users would lean into turns as if on a motorcycle, while continuing to point straight ahead, thinking this would cause them to turn. The farther off course they became, the farther they would lean while continuing to point straight ahead. While this works on a motorcycle, no rotation takes place with the point-to-fly gesture.

These observations led us to develop the follow-the-leader metaphor. Basically, this is the same as the point-to-fly metaphor except that a virtual airplane is placed in front of the user. This airplane indicates where the user is flying; thus, as the plane moves around a corner, it visually leads the user to turn around the corner to follow the lead of the plane. The dynamics of the airplane also take the user's leaning into consideration. As the user leans left, the plane banks left and turns further than it would with no lean.

This metaphor proved to be successful, because users' performance increased and they required no instruction on how to fly through a space. The airplane served as a familiar reference. If a plane banks left, it goes left. Although metaphors need not duplicate familiar experiences exactly, the follow-the-leader metaphor works because it is based on an experience (flying an airplane) that is easily understood.

## DISPLAY AND INTERACTION DEVICES

To gain wide acceptance, virtual reality hardware needs to be comfortable, easy to use, and accessible. Most VR displays ignore these requirements. The typical head-mounted display is heavy and based on low-resolution technology. Users complain that they cannot see the images clearly, and that they are encumbered by the weight and claustrophobia.

Alternative display designs are currently being pursued. The University of Illinois has created a multisided video projection room called the Cave. While inside the Cave, one user sees stereoscopic images coupled to his or her head position and movement. Other participants in the Cave see the same images, but do not have head-coupled perspective control. The Cave appears to be comfortable to use and well suited for collaborative design work.

The Boom2 is a head-coupled display that uses a counterbalancing mechanism to achieve a weightless and comfortable interface.[2] It is based on a pair of custom displays that achieve resolution that is higher than that of high-definition TV (1,280 x 1,024 pixels per eye). It uses optical encoding technology to provide head tracking that is noise free, with very little tracking delay.

Because the Boom2 is not head-mounted, it is easy to use, making it a tool that designers (and others) are eager to incorporate into their work. It is similar to a telephone handset in that the user can enter an environment without needing to suit-up, and can easily share it without adjusting settings. The Boom2 is also designed for public viewing areas since it takes little floor space, can accommodate a large volume of users, and is very robust.

The Cave, HMDs, and the Boom2 are all forms of virtual environment displays. It is important to realize that VR hardware will take many different forms as it becomes comfortable and effective for a variety of uses.

## DESIGN OF VIRTUAL ENVIRONMENTS

The design of virtual environments is perhaps the most exciting and challenging VR design task. One reason it is so difficult is that the designer must abandon the physical environment of everyday perception and the characteristics of other media to embrace the nature of virtual environments.

To fully gain a feeling for the nature of a virtual environment system, it is useful to approach it as a new medium for artistic expression. From this viewpoint, many virtual environment demonstrations seem trite. For instance, a three-dimensional representation of an office, complete with filing cabinets, sidesteps the true nature of virtual reality by using only existing concepts and images.

While working with VR pioneer Scott Fisher at the NASA Ames VIEW laboratory and studying at the Stanford University Design Program, I experimented with the VIEW system in order to explore the nature of this medium called virtual reality. I created and experienced many different worlds for hours at a time. It was only through such extended immersion that I was able to come close to feeling this new medium.

To conduct a more abstract investigation of the medium, I undertook the task of interpreting various works of art in a virtual reality system. One environment that was created, *Flatlands* (see figures 12-1 and 12-2), is an interpretation of a work by Piet Mondrian called *Composition with Line*. Mondrian's piece consists of a series of black horizontal and vertical lines of differing lengths against a white background.

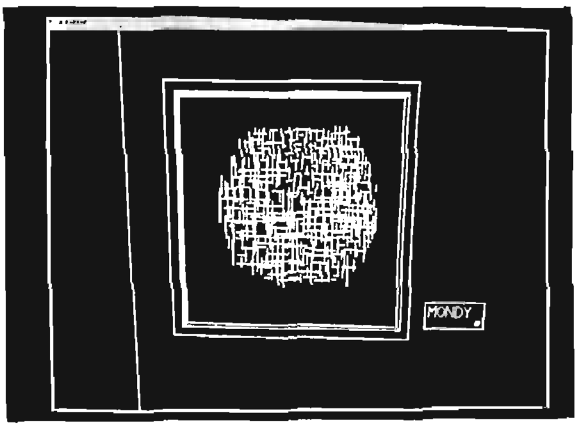


Figure 12-1. *Flatlands* is based on Mondrian's *Composition with Line*.
• Credit: Mark Bolas.

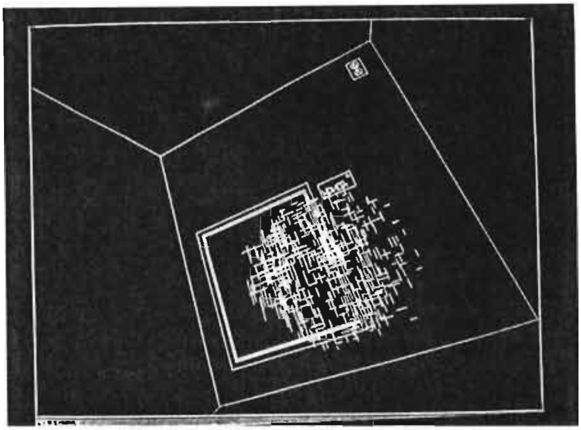

Figure 12-2. *Flatlands* can be appreciated only in a three-dimensional environment. • Credit: Mark Bolas.

While Mondrian's work was inherently two-dimensional, *Flatlands* creates an environment that can be appreciated only in a three-dimensional environment. *Flatlands* consists of the same set of elemental lines found in the Mondrian painting. When standing inside the virtual art gallery, the Mondrian appears to be hanging on a wall in a frame. As the user flies into the painting, the perspective shift causes the painting to disintegrate into a collection of abstract lines that form a huge three-dimensional sculpture. The painting becomes a forest of lines to fly through and experience—the lines continuously defining space and challenging the user to visually interpret the patterns formed by perspective shifts. The experience highlights two essential characteristics of the virtual environment medium: the ability to disregard physical laws and concentrate solely on form, and the recognition of and respect for the user's continuous ability and desire to choose new points of view.

*Flatlands* is one example of an attempt to design a virtual environment that fulfills the nature of virtual reality as a medium. Mondrian reminded us of this mandate when he said, "Painting occupies a plane surface. The plane surface is integral with the physical and psychological being of the painting. Hence the plane surface must be allowed to declare itself, must not be falsified by imitations of volume. Painting must be as flat as the surface it is painted on."[3] The painter should never try to imitate the three-dimensional world on a two-dimensional canvas. It seems ironic, then, that when the empowering tools of virtual environment systems are available, we limit ourselves to trying to emulate our lowly three-dimensional world.

## VR AS AN ENTERTAINMENT MEDIUM

We must develop software that creates dense and rich virtual environments based on a small number of parameters. A world of this type was demonstrated by interactive artist Creon Levit at SIGGRAPH '91. Levit's work, Tapeworld, placed each participant in a room filled with unique stringlike and tapelike formations that were based on randomly generated values. This world demonstrated the power of algorithmic generated environments.

While industry is rushing to develop VR game systems, the real task will be to fill these systems with interesting and entertaining environments. This task is challenging because the medium is more demanding than existing video games. While a conventional game requires the designer to create a two-dimensional video environment, the nature of virtual reality requires a rich, interactive environment.

**Mark Bolas** is president of Fakespace, Inc., 935 Hamilton Ave., Menlo Park, CA; telephone: (415) 688-1940; fax: (415) 688-1949.

## Note

My work has been supported by the Stanford University Design Program, NASA Ames Research Center VIEW Lab, and the NASA Ames Research Center NAS program. MidasPlus visualization software courtesy of Tom Ferrin, University of California, San Francisco.

Parts of this essay were adapted from a presentation at ICAT '92: *The Second International Conference on Artificial Reality and Tele-Existence*, July 1-3, 1992, at Tokyo, Japan.

## REFERENCES

1. Margaret Geller, *Supercomputing* Review, January 1992.
2. I. E. McDowall et al., "Implementation and Integration of a Counterbalanced CRT-based Stereoscopic Display for Interactive Viewpoint Control in Virtual Environment Applications," *Stereoscopic Displays and Applications: Proceedings of the SPIE*. Conference held February 12, 1990. Santa Clara, Calif.: SPIE, 1990, vol. 1256: 136-46.
3. Piet Mondrian, quoted in *Artists on Art*, Robert Goldwater and Marco Treveg, eds., New York: Pantheon, 1972.