Design and Virtual Environments

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Abstract

This paper investigates the relationship between the design process and Virtual Environment systems. This relationship is explored in three separate categories: Design With Virtual Environments, Design For Virtual Environments, and Design Of Virtual Environments. Each category is discussed in general. Specific examples and discussion are drawn from the author's first hand professional experiences.

de-sign v.1. To conceive: invent: contrive[2]

It is useful to look at the relationship between the design process and Virtual Environment (VE) systems from three different points of view.

- *Design With Virtual Environments* refers to the use of Virtual Reality (VR) to help solve a problem or create a new invention.
- *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 - the virtual worlds.

Design With Virtual Environments

Virtual Environment systems can be used to greatly 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, VR is being used to enhance both the speed and quality of the human creative process.

This is perhaps the most powerful and exciting current use of VR systems - VR transforms the computer into a tool that amplifies human intelligence. This power is already being harnessed in a number of down to earth problems. For example:

Molecular Modeling:

SRI International is using the FSL Data-Vision system with software from the University of California at San Francisco[3] to visualize and work with molecular models and data. Users easily gain an intuitive feeling for their data by naturally moving around and manipulating molecular models. Thus, VR 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 customers the innate human ability to match and recognize patterns in complicated situations. By presenting data in a natural way to scientists via VR systems, the scientist's pattern recognition ability can be used in data sets that are impossible to directly visualize because they are completely synthetic or of a non-human scale and size.

For example, astronomical data provided by the Harvard-Smithsonian Center for Astrophysics is being visualized on a FSL Boom2 head-coupled viewer[4] and Silicon Graphics VGX computer at the National Center for Super Computing Applications in Illinois. The Boom2 is a new addition to an ongoing, 10-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."[5]

Computer Aided Design:

With the ability to visualize and manipulate models directly in three dimensions, product designers and architects are finding that VR-enhanced computer aided design (CAD) systems are easier to use and can more accurately represent their designs and models.

Alias Research has incorporated a Boom2 viewer with their sophisticated software to create a general purpose design and visualization system. They feel it will be useful in many fields including automobile design, architecture, and aerospace engineering. An exciting aspect of their 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.

General Comments on Design With Virtual Environments:

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

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

Design For Virtual Environments

There is an ongoing need for better designed and more effective VE systems. VE systems are young tools and need to go through a process of evolution and refinement before they achieve the ease of use and fluid feeling of more established design tools. Toward this end, the work and products at FSL have centered on building friendly and effective VR tools by creating better human interaction metaphors for VR software, and building higher quality visual displays and interaction devices.

Metaphors for Manipulation:

Just as the desktop metaphor allows users to easily interact with a computer's file structure, useful interaction metaphors are needed for VE systems. Because FSL provides a VE software toolkit, the invention and analysis of such metaphors is an important part 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 VE is the ability to easily 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 effectively control such motion. For example, the user with a head mounted display and a flex sensing glove can:

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

Each of these ideas was tried by FSL in conjunction with the VIEW Lab at NASA Ames Research Center and Stanford University in 1988. The goal was to develop better metaphors for movement through VE. While each of the above ideas had good and bad points, a detailed look at the point-to-fly metaphor is illustrative of the issues which 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, two problems were clearly identified.

First, when going around corners, users became confused because the point-to-fly gesture was counterintuitive 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.

A second problem observed 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 further off course they became, the further 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 to the development of 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 plane. The dynamics of this airplane also take the leaning of a user 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 very successful because users' performance increased and they required no instruction on how to fly through a space. The airplane served as a familiar reference that people could easily understand. If a plane banks left, it goes left - of course. This is not to imply that metaphors should be duplicates of familiar experiences. On the contrary, the follow-the-leader metaphor works because it is based on an abstract experience (i.e. human flight) that is easily understood.

Display and Interaction Devices:

In order to become widely accepted, VR hardware needs to be comfortable, easy to use, and accessible. Most VR displays ignore this requirement. The typical head-mounted display is heavy, and based on low resolution technology. This has caused much criticism of VR systems. Users complain that they cannot clearly see their work, and that they are encumbered by the weight and form factor of claustrophobic head-mounted displays.

Alternative display designs are currently being pursued. The University of Illinois has created a multi-sided video projection room called the Cave. While inside the Cave, a single user sees stereoscopic, head-coupled images. Other participants in the Cave see the same images, but do not have head-coupled perspective control. The Cave appears to be well suited for group design meetings and comfortable to use.

The Boom2 is a head-coupled display that uses a counterbalancing mechanism to achieve a weightless and comfortable interface. It is based on a pair of custom displays that achieve resolution which is higher than HDTV (1280 X 1024 per eye). It uses optical encoding technology to provide head tracking that is completely noise free, with very little tracking delay.

Because the Boom2 is not head-mounted, it is extremely easy to use, making it a tool designers and our other clients are willing and eager to incorporate into their real work. It is similar to a telephone handset in that the user can enter an environment without the need to suit-up and can easily share it between researchers without the need to adjust settings. The Boom2 is also designed for public viewing areas where it takes little floor space, can accommodate a large volume of users, and is very robust.

The Cave, head-mounted viewers, and the Boom2 are all forms of VE displays. It is important to realize that VR hardware will take many different forms over the following years as it becomes comfortable for a variety of design uses.

Design Of Virtual Environments

The design of virtual environments is perhaps the most exciting, and challenging VE design task - the creation of completely synthetic environments. One reason this is such a difficult challenge is that the designer must abandon the physical environment of everyday perception and the characteristics of other media in order to completely embrace the nature and character of virtual environments.

As an Artistic Medium:

In order to fully gain a feeling for the nature of a virtual environment system, it is very useful to approach it as a new artistic medium for expression. Seen from this viewpoint, many VE demonstrations seem trite. A three dimensional representation of an office, complete with filing cabinets, sidesteps the true nature of VR by only using existing concrete concepts and images.

In order to conduct a more abstract investigation of the medium, the author undertook the task of interpreting various works of art in a VR system. One environment that was created is called *Flatlands* and is an interpretation of a work by Piet Mondrian called *Composition with Line, 1917.* Mondrian's original work consists of a series of black horizontal and vertical lines of differing lengths against a white background.

While Mondrian's work was inherently two dimensional, *Flatlands* creates an environment that can only be appreciated in a three dimensional environment. When standing inside a virtual art gallery, the original Mondrian painting 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 fun 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.

Flatlands is used as an example of an attempt to design a virtual environment which fulfills the nature of the VR medium. A quote from Mondrian reminds us of the importance of this mandate:

"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."6

As an Entertainment Medium:

It is interesting to realize that while the VR 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 much richer and demanding than existing video games. While a conventional game requires the designer to create a two dimensional video environment, the nature of VR requires that a completely interactive and rich environment be created.

FSL is working on different aspects of using VR as an entertainment medium. Software must be created which creates dense and rich virtual environments based on a small number of parameters. A world of this type was demonstrated by Creon Levit at Siggraph '91. Levit's work *Tapeworld* placed each participant in a room filled with string-like and tape-like formations that were uniquely created based on a randomly generated values. This world demonstrated the power of algorithmic generated environments.

[1] Fake Space Labs, 935 Hamilton Avenue, Menlo Park, CA 94025 (415) 688-1940. Work has been supported by the Stanford University Design Program; NASA Ames Research Center VIEW Lab; NASA Ames Research Center NAS Program.

[2] The American Heritage Dictionary of the English Language, William Morris Editor, Houghton Mifflin Company, 1969-1980.

[3] MidasPlus visualization software courtesy of Tom Ferrin, UCSF.

[4] I.E. McDowall, M. Bolas, et al, Implementation and Integration of a Counterbalanced CRT-based Stereoscopic Display for Interactive Viewpoint Control in Virtual Environment Applications, SPIE 1256, 1990.

[5] Supercomputing Review, January 1992.

[6] Robert Goldwater and Marco Trevegeds, Artists on Art, New York, Pantheon books, 1972.

Biography for Mark Bolas

Mark Bolas is president and founder of Fake Space Labs - a product design firm that specializes in practical and effective virtual environment tools. Mr. Bolas holds a Bachelor's degree in Physics and a Master's degree in Mechanical Engineering.
He is currently a Stanford University Lecturer in product design, a joint art and engineering design program. His work includes a 4 year affiliation with the VIEW laboratory at NASA Ames, the development of the Boom2 and Molly telepresence systems, and countless days wandering about virtual worlds of his creation.