Solving Real-World Problems Virtually

Virtual reality conjures up images of futuristic immersive environments that exist primarily in the realm of science fiction. But virtual reality (VR) systems are already being used to solve real-world problems in many markets, including entertainment, education, medicine, basic science, engineering, and architecture.

Definitions of VR vary, but it is generally understood to be the experience of interacting through sensors and actuators with a synthetic environment containing realistic simulated objects. It features the 3D imagery common today but adds "3D audio" and haptic (touch) interface devices and the ability to manipulate the virtual environment.

"I view VR as fundamentally a new kind of computer/human interface technology, with the emphasis on human," said Linda Jacobson, VR evangelist for Silicon Graphics, Inc. (SGI) of Mountain View, California, the leading manufacturer of supercomputers to drive advanced VR applications. "We are creating a whole new set of problem-solving tools that allow the computer to adapt to our needs. Ultimately it's a whole new communications medium and a new way of creative expression."

According to a recent market study by Business Communications Company, a consulting firm based in Norwalk, Connecticut, VR is among the 10 most promising technologies currently under development. More than 300 companies sold $225 million worth of VR products and services in 1995. The company expects that, by 2000, the industry will be posting annual sales of more than $4 billion, averaging an annual growth rate of 33%.

One factor driving this rapid growth is the decreasing cost of computers with sufficient power to support VR applications. The graphics performance of high-end systems has improved sufficiently to lower the price/performance ratio for both low- and high-end systems. "Just a few years ago, usable VR was the domain only of those who could afford $10,000 to $50,000 display systems and computers costing about that much as well," said Juey Chong Ong of Digital Image Design (New York, NY). "Today you can purchase small graphics accelerators that cost under $3,000 and still give good performance." Improved display technology has also made VR systems more accessible, providing better resolution at lower cost, and making head-mounted displays (HMDs) much lighter.

Silicon Graphics/Airbus Industrie/Virtools

Figure 1. Designers at Airbus Industrie, Europe's largest aircraft manufacturer, use Silcon Graphics engines for highly realistic simulations of aircraft.

Full-immersion VR

There are essentially three levels of VR: high-end, fully immersive systems; mid-range, partially immersive systems; and low-end desktop systems. The first requires powerful graphics engines, such as SGI's Reality Engine or its Onyx Infinite Reality System.

Most people associate immersive VR with HMDs and cybergloves. But it is also possible to project imagery onto a large surface and then view it with 3D stereoscopic shutter glasses. This is the concept behind the Cave Automatic Virtual Environment (CAVE), developed by the National Center for Supercomputing Applications (NCSA) and the University of Illinois at Chicago's Electronic Visualization Laboratory in 1992. Now available commercially for about $1 million, most of which is the cost of the graphics computers, there are about 20 CAVEs or similar fully immersive VR systems in place worldwide.

According to Thomas DeFanti, NCSA's associate director for virtual environments, the chief impediment to widespread use of the CAVE is its substantial cost, as well as the need for a large room to house the system. So NCSA came up with a smaller, partially immersive version, called the ImmersiDesk, which is more transportable and more affordable, and is still a practical tool for interacting with and manipulating virtual models. Prices range from $150,000 to more than $500,000, depending on the choice of graphics hardware. Fakespace (Mountain View, CA), a leading supplier of VR technologies, offers a similar product, called the Immersive WorkBench, which projects images onto the surface of a table from underneath, so that they appear to float on the surface.

Desktop VR systems

Desktop VR systems, although less spectacular than the fully immersive systems, promise to put VR within reach of many more people. “The PC world is getting more capable graphics all the time, and people using them will certainly be able to do significant VR, although there will continue to be a high-end market for more specialized applications,” said Marc Raebert, president of Boston Dynamics (Cambridge, MA). For example, the new Nintendo 64 game, which retails for $200, contains more graphics horsepower than any PC currently on the market. SGI also offers a desktop system, called the Indigo Impact 1000.

Another factor that will pump new customers into the market is the virtual reality markup language (VRML), a universal description language that can be used to create interactive, multi-user interfaces for real-time simulations at shared Web sites. “The VRML 2.0 standard will propel VR technology to the forefront of interactive technologies being used to expand the horizon of the Web,” said Edward Hood, president/CEO of Vream (Chicago, IL), which develops VR software for PC systems.

The National Institute of Standards and Technology is experimenting with many VRML-based simulations on the Web, including car welding and scientific visualization. In December, SGI introduced the first VRML-based 3D cartoon series, “Flook,” now airing on its redesigned Web site (http://vrml.sgi.com). VRML is also ideal for educational applications, according to Eben Gay, president of ERG Engineering (Southboro, MA), which designs VR systems for museums and schools that allow users to explore cell biology, computer networks, and archaeological sites.

One of the biggest markets for desktop systems is medical VR applications, according to Chris Watkins of Algorithm (Atlanta, GA), which specializes in developing real-time VR systems using lower-end equipment for entertainment and some scientific applications. And Ong believes that some of the best opportunities are offered by existing applications, which could be recast for desktop systems. Doing so, however, will require devising new solutions for computationally demanding tasks such as collision detection, the calculation of perspective, and the simulation of physical effects.

Emerging applications

The entertainment industry is one of the largest markets for VR, but as users become more familiar with the technology and its capabilities, others are rapidly emerging. “One could compare [VR] to the laser when it was first developed,” said Ben Mall, vice president of business development for Kaiser Electro-Optics (Carlsbad, CA), a leading manufacturer of HMDs. “There weren’t a lot of immediate applications for it then, but today its use is tremendous in commercial, industrial, and military markets.”

One popular application is virtual prototyping, which proponents say can dramatically shorten the time it takes to move a new design into production. Ford Motor Company (Dearborn, MI) uses a “walk-up VR station” to allow designers to analyze instrument visibility and the driver’s field of view in new vehicle designs. General Motors (Detroit, MI) uses a CAVE to visualize automobile interiors.

Researchers at Caterpillar (Peoria, IL) are using VR to improve the design process for heavy equipment, such as wheel and backhoe loaders. Bechtel (London, England) builds virtual models of large construction projects, enabling sites to be viewed from many vantage points, problems to be anticipated, and detailed design reviews to be conducted. Japan’s Matsushita (Osaka, Japan) devised a virtual kitchen to assist people in choosing appliances and furnishings for Tokyo’s cramped apartments.

Lori Freitag, a computer scientist at Argonne National Laboratory near Chicago, constructed a CAVE simulation in collaboration with Nalco Fuel Tech (Naperville, IL) that will be used to design pollution control systems for commercial boilers and incinerators. The system uses a relatively simple computational model, but the scientists plan to develop a full-scale fluid-dynamics model that gives nearly real-time response.

Another key area is scientific visualization and modeling. John Fowler, a scientist with Los Alamos National Laboratory, developed an immersive VR system to enable users to explore 3D computational grids. The National Coordination Office for High-Performance Computing and Communication, an umbrella organization that includes 13 agencies, is sponsoring research in which VR techniques are used to provide sensory feedback as the tip of a scanning tunneling microscope travels over the surface of sample virtual materials.

“VR is very exciting and empowering for physicists, because they can create a virtual environment based on both abstract and real-world data,” said Jacobson, adding that input from the scientific community is vital to further development of VR applications. “And as scientists and engineers become more cognizant of the tools that are available to them, the people who make the tools will better understand what the tools need to be able to do." For example, dVISE, a core system developed by Division (San Mateo, CA), allows scientists to link VR environments with other programs; the system calculates the effect of changing conditions and feeds the results straight back into the virtual environment.

Medical and surgical applications are also popular because VR can provide a more realistic training environment than conventional simulations. Boston Dynamics and Virtual Presence (London, England) both employ VR for surgical training. Cine-Med (Woodbury, CT) has developed a "Virtual Clinic," featuring computer-generated visual and tactile feedback, to simulate endoscopic procedures. The simulated organs react much like real ones, and users can interact in real time with the endoscopic instruments.

One Cine-Med project enables cardiac surgeons and anesthesiologists to move through the heart's chambers and the coronary arteries; the simulation can even be altered to mimic disease conditions. Kaiser Electro-Optics is developing a new HMD for heart surgeries, to be used in conjunction with a stereo endoscope.

Multi-User VR

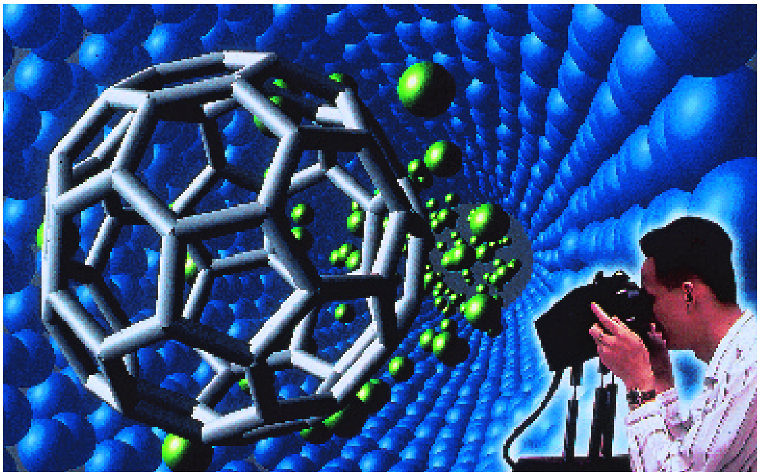
New, multi-user VR systems are attracting strong interest in industry. Fakespace recently introduced its Duo System product, which allows multiple users to view imagery, each in the proper perspective. Last year, Panoram Technologies (Burbank, CA) unveiled its GVR-120 Reality Centre, which provides high-resolution displays (more than 3 million pixels) on an ultrawide, wraparound screen for group viewing.

VR systems intended for high-end entertainment applications, such as feature films and commercials, sometimes allow live video of an actor to be overlaid on a virtual set in such a way that the actor appears to be interacting with the set. For example, Discreet Logic (Montreal, Quebec) offers a virtual set system called VAPOUR, which combines virtual set and blue-screen technology to enable users to immerse actors or other "characters" in 3D environments.

The industry is also interested in networking virtual environments, so that a design team's CAVE in Los Angeles could be linked with another CAVE in Detroit. All participants would be immersed in the same virtual environment, interacting in real time with the same virtual models. This capability would add considerable value to the technology, particularly for companies involved in high-end virtual prototyping. "As the display devices and processors continue to improve, the emergence of multi-user networked environments is inevitable," said Mall.

However, extremely high bandwidth is required to transmit such large amounts of data at acceptable speeds. According to DeFanti, if complex images are to move fluidly in stereo, the images for each eye must be refreshed 20–30 times per second; if there are multiple users, this rate must be multiplied by the number of users. "You need fire hoses to connect these systems, not the drinking straws we now have," said Jacobson.

Division has come up with a practical solution to the problem, according to Mike Smith, vice president of marketing. "A common misperception is that [networking] does require huge bandwidth," he said. "That perception comes from things such as videoconferencing and screen passing, where entire graphic screens, which are huge amounts of data, are passed to other locations." Division's solution is to duplicate the graphics database, so that the only information that needs to be transferred between two locations are commands to perform tasks, which are then echoed to the sending location.



Oak Ridge National Laboratory/Fakespace

Figure 2. At the Oak Ridge National Laboratory, researchers navigate through a simulation of molecules flowing through an atom-thin carbon tube to study the performance and characteristics of nanomachines. The imagery is generated with a desktop display from Fakespace.

McDonnell Douglas (St. Louis, MO) is studying the possibility that networked virtual environments would allow geographically dispersed teams to hold more frequent design reviews. SRI International (Menlo Park, CA) has a SHAVE (Shared Virtual Environment) system that enables several users to collaboratively investigate and interact with the same virtual environment through a variety of interfaces, including HMDs, hand-held displays, and desktop systems. Digital Image Design is working on integrating VR with 3D computer animation, envisioning future computer animation software as a collaborative, networked environment where an animator in New York City, for example, might collaborate with a director in Hollywood.

VR is still an immature technology, but its potential benefit to many areas of science, engineering, and technology has already been demonstrated, and it is becoming a valuable tool for solving the increasingly complex problems of the modern world. "We're definitely at the beginning of this quest for immersion," said Jacobson. "Nevertheless, there is a vendor structure in place. People can buy these products without taking a big risk."