Scientific Visualization Leads To The CAVE

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Imagine being able to stand inside a human heart and watch blood flow around you. Or, imagine test-driving a car, before it actually has been built.

Through the wonders of the CAVE (Cave Automatic Virtual Environment), the first technology to widely exploit immersive virtual reality (VR) environments, people can do just that. The "wow" technology was pioneered at the University of Illinois at Chicago's (UIC) Electronic Visualization Laboratory (EVL). CAVE is a trademark of the Board of Trustees of the University of Illinois. EVL is an interdisciplinary graduate research laboratory that combines art and computer science with advanced networked visualization and collaboration tools and technologies. Since the early 1970s, the lab has been recognized for its leadership in computer graphics. EVL, a unique collaboration between UIC's College of Engineering and the School of Art and Design, is one of the oldest formal interdisciplinary efforts between art and engineering in the U.S. Through its combination of the two disciplines — engineering and art — EVL serves as an excellent example of collaborative university research.

CAVE Adaptations

From the CAVE's development at EVL, other products and services have emerged, ranging from immersive virtual rooms, to software libraries to desktop/office-sized displays to anatomical teaching devices for medicine. Its success in the marketplace is due to its unique collaborative components — science, coupled with vision, design and computational steering. Together they are helping solve complex problems. The CAVE name was first commercialized and licensed to Pyramid Systems and is currently licensed to Mechdyne Corp. of Marshalltown, Iowa.

In immersive CAVE environments, people walk inside a room surrounded by large wall-size projection screens, wearing special glasses that allow the CAVE 3-D graphics to be seen with three-dimensional depth. The glasses are synchronized with the projectors so the images appear to be in front of their eyes. People then can walk around virtual objects, see objects float by, as well as peer inside a world where reality and illusion come together. The ImmersaDesk®, which was developed in 1995 at EVL, is a derivative of the CAVE system. This system uses one screen, positioned at an angle, like a drafting table — people look forward and down instead of all around. The system was less expensive than the original CAVE since it didn't require building a room within a room. Pyramid Systems commercialized the ImmersaDesk system, which also followed through to Mechdyne Corp.

Software Solutions

Researchers at the University of Calgary's Sun Center of Excellence for Visual Genomics have taken CAVE technology in a new direction. Viewers who study the Sun Center's life-sized, human model called CAVEman, are looking at a marvel of visual reality technology. The anatomical digital atlas offers students, scientists and medical personnel a high-resolution view inside the human body. The technology has been used at the University of Calgary since 2002.

Christoph Sensen, Ph.D., professor at the Centre for Advanced Technologies, University of Calgary Faculty of Medicine, says, "We are developing a Java 3D™-based human body model for research, education and clinical applications." The final result of the virtual reality development will be a next generation 4-D (designating space and time) visual window that will show genetic components of diseases like cancer, diabetes and Alzheimer's.

Sensen says, "Using our CAVE models, we will soon be able to simulate diseases for which we have no examples here in Alberta and teach our students how to treat them." CAVE technology is also used to treat various phobias, including the fear of heights and spiders. Since people absorb most of their information through visual stimuli, a CAVE experience, which is being used in multiple ways in industry, can be a phenomenal way to impart information. An in-depth CAVE experience, for example, involves a basic four-screen (three walls and a floor) immersive room and a small graphics computing cluster.

Jeff Brum, vice president of marketing and business development at Mechdyne Corp., says, "While the costs can go into the millions of dollars for complex, six-sided, high- resolution rooms, the result in any CAVE is a compelling experience. When we have navigated to the edge of a virtual building or stood on the virtual space station looking down at Earth, many first-time CAVE users experience a real sense of vertigo."

Virtual Manufacturing

The CAVE's virtual applications allow people to address a wide range of challenges like creating better crops for improved harvests and better safety features on cars.

> *"Designers can sit in life-sized vehicles and create better sight-lines and other safety components. It also allows manufacturers to "see" production lines before the products are rolled out so potential changes can be built in early in the planning process.*

Car companies have incorporated these features by developing virtual prototypes that help get the products into the marketplace sooner. The technology is also a cost benefit since virtual prototypes give companies an excellent alternative to building expensive physical prototypes.

Conceiving the World's First Projection-Based Technology with Walls and a Floor

It was a long journey from the development at EVL in the 1990s to the wonders of today's virtual reality applications. Tom DeFanti, Ph.D., a distinguished professor emeritus at UIC now a research scientist at the University of California, San Diego's California Institute of Telecommunications and Information Technology (Calit2), co-conceived the CAVE system in 1991 with fellow UIC researcher and art professor Daniel Sandin. Carolina Cruz-Neira, an EVL Ph.D. student at the time, wrote the initial versions of the CAVE software library, and shares credit for the invention of the CAVE system.

"Dan and I conceived of the CAVE hardware; I named it; we built prototypes, and Carolina and other students wrote software drivers and applications for it," DeFanti explains. In describing how CAVE has helped make the world a better place, Sandin says, "It is the first technology that provides a life-sized improvement in visualization since viewer-centered perspective was developed in paintings in the Renaissance. This is especially true with images on the floor, which gives users a true sense of presence like they are standing in, and are surrounded by, a virtual world."

CAVE Paves the Way for Numerous VR Applications

When one of Mechdyne's predecessor companies, Pyramid Systems, first learned of the work at UIC, it licensed the CAVE technology for commercialization. Next on the agenda was collaboration between research and industry. "Pyramid and UIC jointly promoted the CAVE at conferences and trade shows, supporting each other's research and development efforts," says Brum.

In 1994, three years after the technology was developed, Pyramid licensed the CAVE name and began commercializing the immersive environment concept. Five years later, Fakespace Systems acquired Pyramid and was subsequently acquired by Mechdyne. In 2006, Mechdyne acquired VRCO, a software company that licensed the original CAVE software library called CAVELib from UIC, putting all of the original CAVE components in one company.

DeFanti points out that CAVE technology originating at UIC has paved the way for a number of virtual reality offshoots.

"All of the subsequent technologies use concepts that are derivative in some sense of the original CAVE," DeFanti explains. "The success of the CAVE technology can be evidenced by Mechdyne's growth."

Mechdyne's 120 employees are spread out among its headquarters in Marshalltown, Iowa, an Ontario, Canada office, a software development office in Virginia Beach, Va., a Houston office, and an office in Leicestershire, England, which is spearheading growth in Europe.

By the late 1990s, with less than 100 immersive rooms in the world, some organizations found that the cost to set up supercomputers to drive a dedicated CAVE display was too cost-prohibitive. Users needed more flexibility to expand and justify the use of fully immersive environments.

"The idea to allow the side walls to push outward to create angled and flat wall screens, came from that feedback," says Brum.

This display, known as FLEX, is sold by Mechdyne and is now the largest configuration for immersive displays that the

company sells. Brum points out that FLEX is a successful design component, but it has not replaced the immersive experience of CAVE systems.

“We regularly sell CAVEs to those who only want the experience of being surrounded by virtual imagery,” he says.

Since the early 1990s when the CAVE concept was developed, it has gone through several advances based on performance and need. Digital projector technology, introduced in 2000, is even more astounding. The digital projections on each screen now have a resolution of 1400 x 1050 or about 6 million pixels on four screens. Compound that with the fact that CAVE has evolved to five- and sixsided systems. The higher resolution of the images and the additional sides in these enhanced CAVE environments provide a more realistic virtual environment, offering a vivid display of spatial relationships and improved information discovery.

“We have begun tiling high resolution projectors on each wall, which has led to our building the two highest resolution virtual reality environments in the world,” says Brum.

One of these enhanced systems is at Los Alamos National Laboratories in Los Alamos, N.M. Possessing five sides and amazing 43 million-pixel resolution, “La Cueva Grande” at Los Alamos has been used for a range of research projects since February 2006. The Los Alamos immersive environment can simulate everything from high energy explosions to the “dinosaur-killer” comet believed to have caused the mass extinction of dinosaurs 65 million years ago.

The highest resolution virtual reality environment is located in the Virtual Reality Applications Center at Iowa State University in Ames, Iowa. Originally built in 2000 by Mechdyne, Iowa State’s C6 was North America’s first six-sided immersive CAVE-like environment. In 2007, its resolution was upgraded to 100 million pixels, offering the highest resolution of imagery in any CAVE-like environment in the world — about 16 times the resolution of a typical immersive room. The enhanced C6 system can be used for showing students how photosynthesis works, giving researchers magnified views of 22,000 different genes, or for training soldiers for combat.

DeFanti and colleague, Greg Dawe, who designed and built the ImmersaDesk and the production model CAVEs at EVL, recently finished the StarCAVE in UCSD’s Atkinson Hall. It is a 17-screen, 34-megapixel/ eye pentagonal-shaped CAVE with excellent polarizing-preserving rear projection and a floor. It features the use of inexpensive lightweight circular polarized glasses that feel more like sunglasses than goggles.

CAVE’s advanced technology has changed the way people work and learn by showcasing new ideas in a virtual environment. Imagination and innovation, hallmarks of CAVE, continue to play a giant role in opening the way to new collaborations in industry, science and education.

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