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Development of Computer Assisted Virtual Environment (CAVE)

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Abstract

In the last decade, the term "virtual" appears not only in many branches of industry but has become a common part of life. It represents something that is created using a computer, looks realistic, but does not exist in the physical world. Examples are various scientific simulations, training, but also cinematography or the game industry. Gradual development enabled the creation of a virtual environment called CAVE. In this article, we discuss the development of our computer assisted virtual environment solution.

Keywords: CAVE, Virtual reality, visualization, computer modelling.

Introduction

The first CAVE was assembled by Thomas DeFanti and Dan Sandin back in 1991. It was later improved by Carolina Cruz-Neira. The main idea of this project was to develop such an environment that could erase the limitations of virtual reality. These were mainly low image resolution, isolation from the real world and the inability to simultaneously share virtual experiences with multiple users [1].

CAVE is essentially a virtual reality environment. It consists of a VR room in the shape of a cube and a varying number of walls, sometimes even a floor. These then form projection screens. The user typically wears a VR headset, head-up display (HUD) or 3D glasses and interacts through input devices such as wands, joysticks or data gloves. If the system has two walls, it is a V-CAVE, (the name comes from two screens, which form the letter v) [2]. If it has three small walls, it can also be HIVE [3], the so-called low-budget solution, suitable mainly for teaching purposes. 3 walls, or 3 walls with a floor, usually represent professional solutions. The concept of 4 walls is not used as users could easily lose their orientation and get confused. This solution would also require additional manipulation and calibration as 1 wall would have to be rotatable to allow users to get in and out of the CAVE. This situation could then lead to errors. Cave systems differ in many parameters: size, audio system, projection system, tracking system.

CAVE stands for various solutions such as:

- Computer Assisted Virtual Environment
- Computer Automated Virtual Environment
- Computer-Aided Virtual Environment
- Cave for Automated Virtual Environment

First solution

At the outset, it should be mentioned that CAVE is not a ready solution. It is a complex system and allows many variables to represent different devices. The first CAVE solution included three walls and a gamepad for user movement/interaction. The scheme is shown in Figure 1, photo of CAVE is on picture 2.

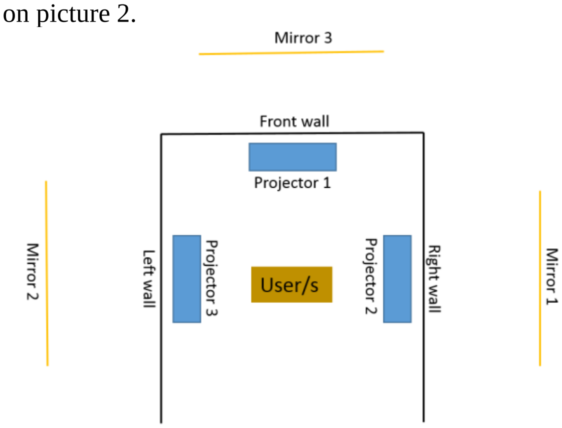

Figure 1 – First CAVE scheme

Figure 2 – CAVE environment

The technology consisted of the following hardware and software items:

Hardware

- 3 walls - projection surfaces are made of gray acrylic mats, while suppressing reflection.
- Cluster of 3 PC´s - one PC for each wall, including synchronization module, separate output for left and right eye, one switch for all 3 PC to ensure outlook.
- 3 mirrors – metal surfaces without cover glass, they cannot be touched, because of sensitive layer, even fingerprints leave a permanent mark that is reflected on the walls.
- 3 active 3D HD projectors with long lenses - stereo synchronization at front projector. 3D active projection separates the image for the left and right eyes by transmitting the two images at different times.
- Active 3D glasses with RF transmitter - connected to front projector.
- Wireless gamepad.
- Control computer with RF transmitter for gamepad, software and 3 network adapters for: cluster, tracking software, global network.

Software

- Cluster Launcher and calibration programs based at CAVELib - Calibration pattern for projector settings, functionality check of stereo 3D projection, shut down cluster of 3 PC.
- Projector remote control software – control panel enables to turn on and off all projectors, this is highly recommended, because manual switching can move projectors and visualization may be disturbed.
- Visualization software – all 3D models are loaded, constrains are defined, visualization scene is created and exported via plugin.
- Startup software – exported data from visualization software are synchronously loaded to projectors and walls.

Updated solution

After a few years, we tried to extend the technology to include a floor and a tracking system. The tracking system allows the user to immerse himself more in the scene. The scene is adapted to the user, e.g. if he tilts his head, turns, sits or squats.

There were several options for tracking systems to choose from:

1. Camera and vision-based algorithm for tracking markers placed on the user's head

2. Magnetic tracking system

3. Optical tracking system with active markers using multiple viewing angles

We decided on an optical tracking system. The CAVE now contains 3 walls, a floor, 4 projectors, 4 mirrors and the optical tracking system (8 IR cameras). The schematic is shown in Figure 3. The final arrangement is in Figure 4.

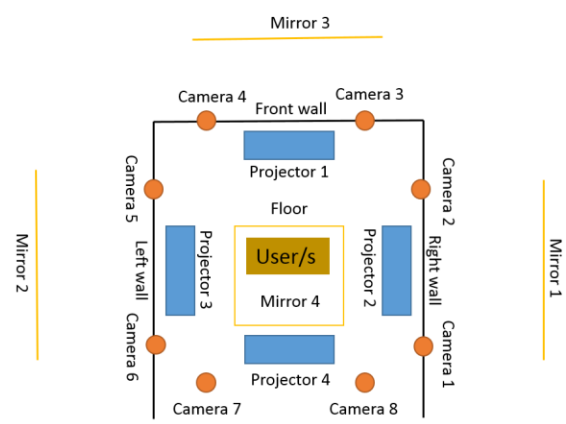

Figure 3 – Updated CAVE scheme

Figure 4 – Updated CAVE environment

The technology has been expanded to include the following hardware and software items:

Hardware

- Floor - gray floor covering, similar in shade to the walls.
- I PC for the floor added to the cluster.
- 1 smaller mirror added - placed on top of the construction.
- 1 active 3D HD projector with short lens added.
- 6 tracking marks added to the 3D active glasses – 3 on each side.
- 3 tracking marks added to wireless gamepad.
- Optical tracking position system – 8 cameras with active IR flashes including image evaluation and data export to tracking software.

Software

- Cluster Launcher - updated for 4 PC´s.
- Tracking software - multi-camera rigid body tracking, 3 markers minimum per rigid body for 6 degrees of freedom can track over 300 rigid bodies in real time.
- Tracking communication – data from tracking system and gamepad are converted to data for visualization software.
- Projector remote control software – updated for 4 PC´s.

Conclusion

The constant development of technologies and their open source interfaces means that new possibilities are open, and at first glance, incompatible technologies are capable to cooperate after the programming of various applications and interfaces. This is also the case with the CAVE device. New technologies make it possible to replace acrylic walls with digital LCD monitors and panels. It is also possible to replace the gamepad with other devices, e.g. gloves that would move the user to new realms of immersion in the scene, especially if it were a scene that would require detailed interaction of human fingers. 3D models that are used in scenes no longer need to be laboriously and time-consumingly modeled. They can also be obtained by laser scanning technologies of real objects and modeled in reverse (faster) and used in scenes after synchronization.

This technology is used in many areas of industry, for example in architecture when optimizing the shapes of virtual buildings. In the automotive industry, it is possible to optimize uniform workplaces within the production hall, but also to examine and optimize the interior of the car. In the medical field, it can be used to simulate the functions of the human body, as well as operations.

A special chapter in the testing of this technology are children under 6 years old, who show less fear than when using VR glasses. It was a simulation where we tried to teach these children how to cross busy roads. Even many adults did not experience dizziness and fear as when using VR glasses and were fully able to immerse themselves in virtual reality.

CAVE technology has the potential to successfully save production and operating costs for many manufacturing companies across a wide range of industries and can also contribute to teaching techniques applied to different age categories of the human population.

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References

[1] Cruz-Neira, Carolina & Leigh, Jason & Papka, Michael & Barnes, Craig & Cohen, S.M. & Das, S. & Engelmann, R. & Hudson, R. & Roy, Trina & Siegel, L. & Vasilakis, C. & DeFanti, T.A. & Sandin, Daniel. (1993). Scientists in wonderland:

A report on visualization applications in the CAVE virtual reality environment. 59 - 66. 10.1109/VRAIS.1993.378262. J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.

[2] Jeffrey Jacobson, "Using caveut to build immersive displays with the unreal tournament engine and a pc cluster", I3D '03: Proceedings of the 2003 symposium on Interactive 3D graphics, pp. 221-222.

[3] Daniel Cliburn, John Krantz, "Towards an effective low-cost virtual reality display system for education", J. Comput. Small Coll 2008, pp. 147-153. (3) Siddhesh Manjrekar, Shubhrika Sandilya, Deesha Bhosale, Sravanthi Kanchi, Adwait Pitkar, Mayur Gondhalekar: CAVE: An Emerging Immersive Technology - A Review, 2014 UKSim-AMSS 16th International Conference on Computer Modelling and Simulation, ISBN 978-1-4799-4923-6.