THE AERO-CAVE EXTENSION FOR MIXED REALITY COLLABORATION

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Abstract: Mixed reality environments, especially CAVES, are still very much restricted towards vision and sound as means of communication between dislocated engineers. For future applications of mixed reality collaboration caves in engineering, it is important to integrate more physical phenomena into the collaboration session. This paper will present an "Aero-Cave", the extension of a low cost cave, developed in a student project, with aerodynamics. It will be argued, that this extension might be helpful for some engineering design and maintenance tasks.

Keywords: human-machine interface, Aero-Cave,mixed reality, collaboration, immersion, immersive VR, orientation, VR

1.   INTRODUCTION

Mixed Reality (MR), as a linking technology to connect real physical phenomena to virtual, computer simulated phenomena, or vice versa, utilizes many different interfaces to fulfill the given tasks. Virtual Reality (VR) is getting more and more important in collaborative engineering environments. For the representation and manipulation of virtual existing models, e.g. the surface of mars, a chemical plant, or even a cabriolet, suitable environments are needed to simulate these workspaces. CAVEs, (Cave Automatic Virtual Environment, Cruz-Neira, 1992) are capable of cutting off the user's connection from the real world and concentrate the user senses to the impressions created by any desired virtual world.

At the university of Bremen different approaches to a virtual environment were developed in three parallel running student projects. For different ideas a certain technological solution was found (see fig. 1). MiCarpet simulated a ride on a flying carpet, moved by hydraulics and controlled by the user's bearing. MiCaDo led the user on a rafting journey through a jungle. The raft was controlled with a stick, with which the user could row along the river. MiCasa recreated real places like a museum and one floor of a university building, with the ability to move objects inside the VR-worlds with a device called A.R.M., an exoskeletal input device and a laser / camera input device to select the desired 3D object. All projects visualized the VR through a CAVE system, suited for their needs. MiCasa's CAVE was then chosen to

Fig. 1: MiCarpet's flying carpet | MiCaDo's raft | MiCasa's A.R.M & laser wand

be set up again in the rooms of the arteclab due to its quadratic and sturdy layout (see fig. 2). For convenience, only three sides are being projected. One side was left open to provide an easy access to the CAVE. The projection is based upon three ceiling-mounted beamers in connection with mirrors (see fig. 3).
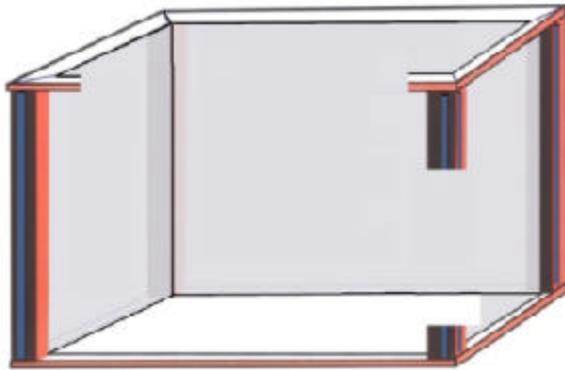

Fig. 2: Micasa's layout for a CAVE

This inner projection was necessary to adapt to the spacial condition found in the arteclab and resulted in a compact Virtual Environment (VE), representing a new platform for scientific research dealing especially with human-machine-interaction at the university of Bremen.

Fig. 3: Ceiling mounted beamer and mirror reflection

The spacial separation from the real world within the CAVE leads to a different experience of movements. The user is captivated in the middle of the CAVE and moves through the VR either with the means of a dancing pad style input device, a normal keyboard, or other devices used for the interpretation of movement. The simulated movement through a projected, moving VR occurs physically almost motionless and not sensible for the other senses. Besides the optical feedback and optical recognition of movement, neither the equilibrium nor tangible senses are involved. The "Aero-Cave" was implemented to solve one part of this problem. It simulates the airflow caused by every natural movement and creates the sensation of virtual wind to enrich the sensation of being within a virtual world.
It will be argued, that this immersive VR-system, as an extension for mixed reality systems, inheres several benefits for engineering collaboration platforms, especially for the orientation within VEs.

2. DESCRIPTION OF THE AERO-CAVE SYSTEM

Aero-Cave consists of three different modules. The first one is a software based distributed rendering engine, which derived from the former project. The Aero-Cave system utilizes a modification (mod) of Unreal Tournament 2003 (UT2003), which is capable to render the VR onto the four walls of the CAVE. This "Cubecams-Mutator", which was originally developed in the MiCasa project, has been advanced to additionally manage the wind system. MiCasa's CAVE was designed for a setup of four PCs projecting the VR via four beamers. Regarding to the open southern wall, only three will be used to render the VR, the fourth is used for the communication with the interface controlling ventilator 5 and 6 (see Fig. 5).

UT2003 was designed to be easily modified through a script language called UnrealScript. Almost every aspect of the game can be controlled with this object oriented system. New objects, like a new trigger class can be created easily and placed within the map editor. "WindTriggers" were used to add virtual wind to maps. They posses two values, which determine direction and power of wind in the proximity of the trigger (see Fig. 4).
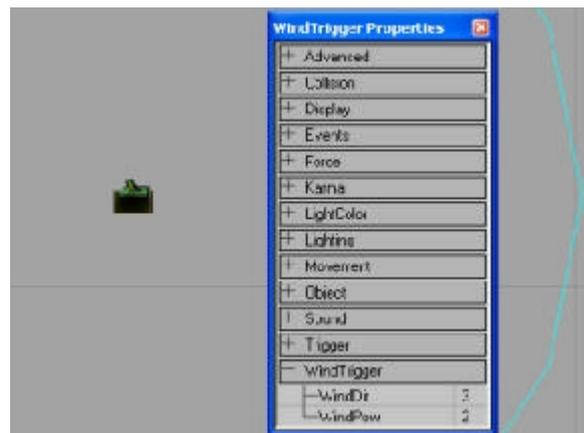

Fig. 4: A WindTrigger with properties shown

WindTriggers can be modified in their size and can overlap to form a closed area. WindTrigger enhanced maps are recognized by the "cubecams-Mutator". It was altered to receive and send special UDP packets to control the wind system, which is the second part of the Aero-Cave system.

This wind generating system consists of a scalable number of ventilators and interfaces. For the given situation eight ventilators controlled by four interfaces for the parallel port were installed, in a circular constellation onto the frame of the CAVE (see Fig. 5). In this case low cost propellers and electric motors known from model aircrafts were used due to their small, but efficient design for the generation of airflow. They are interchangeable with more powerful ventilators, if needed. All ventilators were calibrated onto the middle and onto the subject's head to maximize the sensation of airflow.
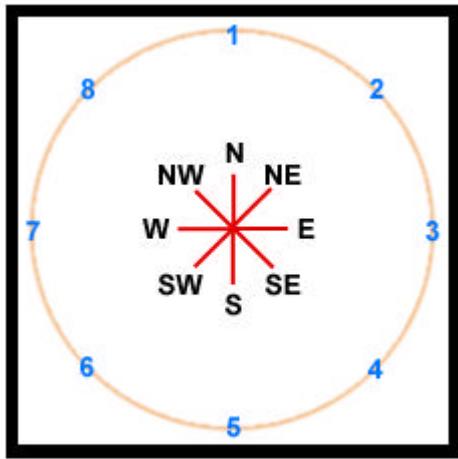
Fig. 5: Positions of the eight ventilators

The interfaces bridge the gap between software and hardware. One interface (see Fig. 8) controls two ventilators via eight ports, four for each ventilator. For different speeds, the ventilators are driven with the aid of resistors and relays, chosen to get a fluid transition between the eight possible velocities. For each ventilator three resistors with different values were connected in parallel, but switchable through relays, resulting in seven throttled states of velocity for each ventilator. The fourth port switches a relay without resistor, resulting in maximum velocity for the ventilator (see Fig. 6).
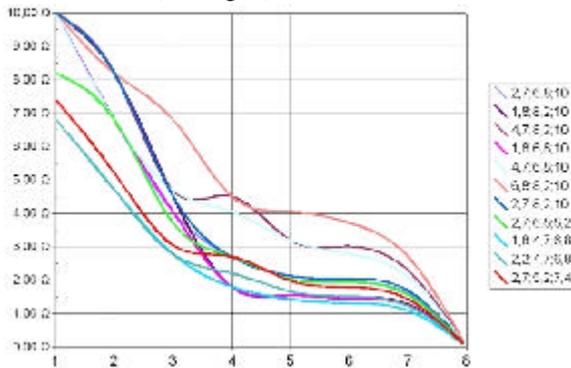

Fig. 6: Different set-ups and resulting resistor values

Module three connects game engine and hardware interface. "Aeron" is intermediating between the ports on the hardware level and velocities and directions on the software level. UnrealScript is not capable of communicating directly with the parallel port, because the integration of dynamic linked libraries (DLLs) is reserved to licensees.

Communication between UT2003 and Aeron is based upon UDP. After running the server, Aeron will connect to it, assumed that all settings are made correctly (IP and UDP-port of the UT2003 server),

Fig. 7: GUI for Aeron

see Fig. 7), by pressing "Verbinde" (connect). From this point, Aeron and UT2003 will exchange UDP packets in order to control the velocity of the ventilators according to the computed values.

An UDP message from Aeron consists of the keyword "AERON" followed by the side, which this client controls. After sending the first packet, Aeron awaits an answer. UT2003 receives the first package and is now able to track the sender. It returns the side followed by the power for ventilator a and b, separated by a comma. Aeron receives the UDP packet, changes the velocities of the connected ventilators and sends the first message again. This loop executes as long as the server exists, or can be halted by pressing "Trenne" (disconnect).
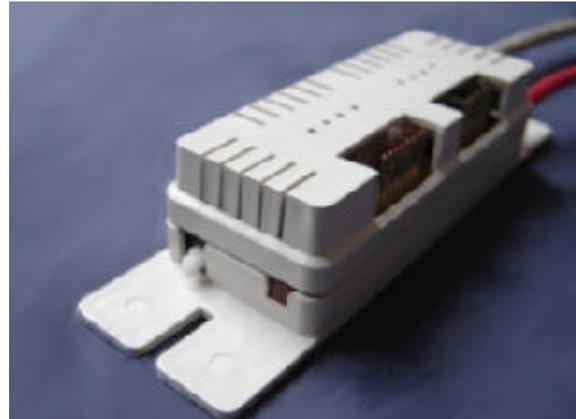

Fig. 8: Hardware interface for the parallel port

This rough overview of the Aero-Cave system demonstrated the hardware and software premises for an advanced CAVE system, of use for new studies within an air enhanced environment.

3. EXPERIMENTAL SETUP

"In what degree will wind affect the orientation of humans, while navigating through a VR?" To solve this question, a level was built and an experiment conducted.
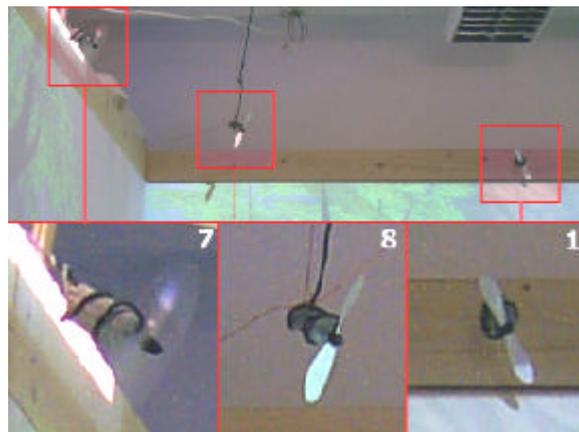

Fig. 9:Running and resting ventilators, cf. Fig. 5

Subjects entered the three sided CAVE, and took a seat on a chair in the center (see Fig. 11), facing the northern wall. Equipped with a keyboard they controlled the movements within the VR. They were not able to turn around with the given controls, just the basic movements described in table 1, and in addition jump via the space key.

Num 7	Num 8	Num 9	*NW*	*N*	*NE*
Num 4	Num 5	Num 6	*W*	*RUN*	*E*
Num 1	Num 2	Num 3	*SW*	*S*	*SE*

Table 1: Keyboard controls

The Aero-Cave system reacts on those movements with an airflow emanating from the corresponding direction, e.g. moving to the north will result in a response from the northern ventilator. Depending on the movement's velocity, either a small (while walking), medium (while running) or high (while jumping) amount of airflow will be cast.
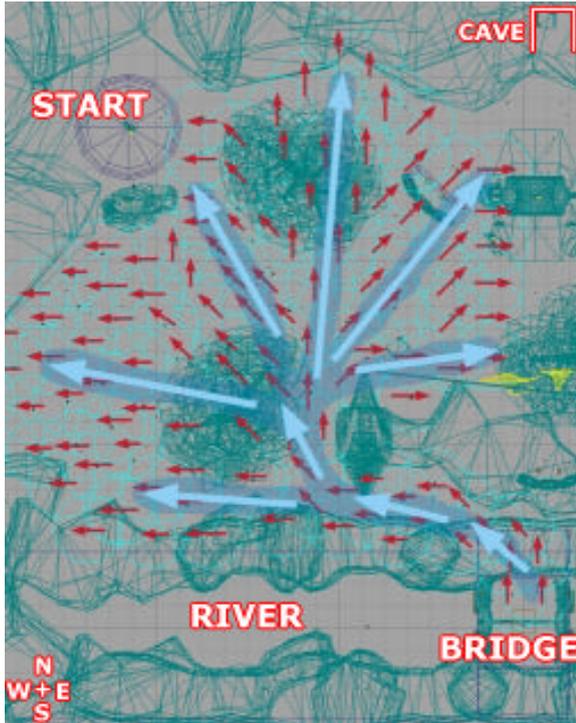

Fig. 10: Map used in the experiment

Fig. 10 shows a blueprint of the map used in the experiment. Red arrows mark the position and direction of WindTriggers. Blue arrows clarify the overall direction, and the invisible path described by the WindTriggers. The task given was: "Follow the wind!". Due to the inability of turning the world via controls, it is necessary to turn the head towards the desired directions. Because of the missing wall and the mostly southern wind directions, the subjects often had to rely on the information gathered from the sensations of airflows within the CAVE.

Fig. 11: Experiment in progress

The map was built with a trap to clarify the origin of the subject's orientation. If the subject does not sense the airflow correctly, chances of reaching the goal were small. The goal, a bridge over a mountain torrent , as seen in Fig. 10, is hard to reach, because the river cannot be seen due to the missing projection of the southern wall.

The experiment started with the subject's familiarization with the controls and situation within the CAVE. During the experiment each tested subject was able to follow more or less fast the invisible track, which was formed by airflows. All 14 subjects were able to accomplish the task and not one of them fell into the river.

4. CONCLUSION & PERSPECTIVES

The orientation on the basis of wind generated within the Aero-Cave system has been proven. The system was capable of producing airflows of different magnitudes from eight directions, which enhanced the immersion significantly.

Airflow generated by movements within the VR in conjunction with location dependent WindTriggers creates an overall sensation of ambient air and wind, blowing from the virtual into the real world, imitating effects of real movements in a real environment. This enhanced environment is able to simulate many different scenarios featuring increased vividness and immersion. Immersive VR systems, VEs and VR are used for exploration (see Fig. 12) and training purposes, often to simulate dangerous situations in a safe environment. For critical situations, e.g. a hull breach on a space station, the simulation of airflows could be of crucial interest. The emerging airflow due to the loss of atmosphere could indicate the location of the breach.

A platform like the Aero-Cave system could be of use in the progress of creating large buildings with elaborated venting systems. To understand the relationships of airflows within a great building, an examination executed on site would be a preferable option to locate windy spots and identify the degree of draughtiness .

Two or more (limited by the maximum number of players in UT2003) Aero-Cave systems can be connected via LAN or internet, allowing two users to explore one VR simultaneously, sharing the same aerial experience.

The Aero-Cave could be connected to real sensors to measure wind directions and velocities at a real location, as shown in Fig. 13, to recreate the scenery

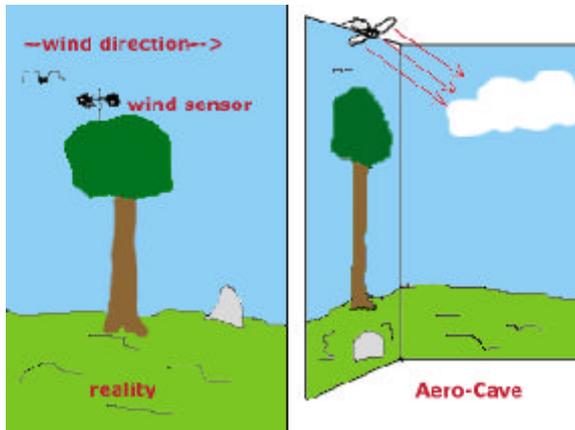
Fig. 12: Exploration of a 3D-world

Fig. 13: MR application in theory

and the aerial condition in VR.

These theoretical applications can be seen exemplary and demonstrates the potential of the Aero-Cave system. This system should be seen as a preview for future VEs, which will be much more immersive and real than today's.

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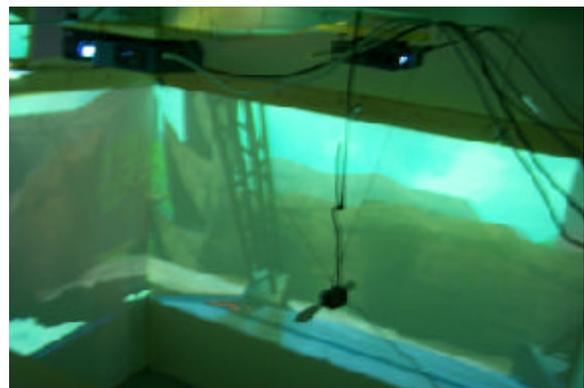Robben, Bernd (2004). *MiCaDo: mixed reality cave.* artec paper 4, Bremen, http://www.arteclab.uni-bremen.de/alp/Micado.pdf

Fig. 14: Aero-Cave snapshots