# Projection-Based Virtual Environments and Disability

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**ABSTRACT**
The Electronic Visualization Laboratory at the University of Illinois at Chicago has developed a new virtual reality interface called the CAVE (CAVE Automatic Virtual Environment). It surrounds the viewer with projected images of a virtual environment. Three rear-projection screens make up three walls of a ten-foot cube that all but disappear when illuminated with computer graphics. A fourth data projector illuminates the floor for complete immersion. The viewer can move around the virtual environment and see his own body as he interacts with real and virtual objects.

This paper describes the use of a projection-based virtual reality (VR) interface (the CAVE) for persons with disability. It compares the projection paradigm with the more common VR technologies of head or boom-mounted displays and their associated position sensing techniques. In particular, advantages and disadvantages of the CAVE are discussed in terms of disability issues. These include shared or guided experiences, physical access to the technology, intrusiveness on the user and inclusion of real world objects in the environment. Finally, appropriate disability related applications for projection based virtual environments are considered in light of the inherent properties.

**VR DEFINED**
There are many varying definitions of Virtual Reality or degrees of complexity. For purposes of this paper a virtual reality system will be considered to be a three dimensional computer graphics system with real-time interactive control and viewer centered perspective. Additionally it has panoramic binocular display with a large angle of view. These features are essential for a powerful virtual reality experience:

- 3D computer graphics - computer graphics in a three dimensional coordinate space.

- real time interactive control - live navigation in a virtual environment or manipulation of virtual objects.

- viewer-centered perspective - the display changes with viewer's position using a head tracking system. Moving laterally can reveal the side of an object.

- panoramic display - head rotation reveals a surrounding virtual world.

- binocular display - each eye receives a unique view which the brain fuses to create a sense of depth.

- large angle of view - greater than 90 degree view of an environment perceived without head rotation . Viewer feels as though they are inside the virtual environment rather than looking through a window.

These features generally describe the immersive technologies of head-mounted displays, boom-mounted displays and surround-screen projection-based displays. A Head-Mounted Display (HMD) consists of a pair of miniature displays positioned in goggles or a helmet strapped to the user's head so that each eye sees one display. A boom-mounted display is like a head-mounted goggle display but is suspended from an articulated arm and is held to the viewer's face with handles. The arm acts as a counterbalance and also measures head position. Projection-based displays use rear projection screens to surround the viewer with large scale images. Although other technologies are described as virtual reality systems they do not include one or more of the above features. Such systems would be monitor-based (desk-top VR), wide-screen projection (IMAX, OMNIMAX etc.) and 2D computer graphic virtual interfaces.

A VR system can also involve the other senses: hearing, touch and smell. Three dimensional (localized) sound and tactile feedback can greatly enhance the degree of immersion but are beyond the scope of this paper.

**CAVE BACKGROUND**
The CAVE was conceived of in the summer of 1991 by Tom DeFanti and Dan Sandin, co-directors of the Electronic Visualization Lab at UIC. Since then, development of the CAVE has been the primary focus of doctoral student Carolina Cruz-Neira. Sound capabilities

projection from above. The fourth wall could be a screen with provisions for entering and exiting such as hinging the
and ceiling are both rear projected, the ceiling could be a screen as well. Projectors are high resolution data type proj
stereographic images on alternating fields. Active liquid crystal display (LCD) stereo shutter type glasses are worn b
separate the alternate fields to the appropriate eyes. Head position is tracked by an electromagnet sensing device. Hi
generating the computer graphics are connected to each projector and an additional workstation is used to synchroni
each screen. Various input devices have been developed for interacting with virtual environments including a wand a

**THE SURROUND-VISION PROJECTION PARADIGM VS. HEAD-MOUNTED OR BOOM-MOUNTED SYSTEMS**

Although the immersive technologies in comparison here share the essential features of a VR system mentioned abo significant inherent differences that can affect applications to people with disabilities. The areas of greatest concern connection to the real world, quality of the images and the impact these two have on cybersickness [7] (symptoms o motion sickness in virtual environments: nausea, disorientation, dizziness, etc.) and finally access to the technology.

**CONNECTION TO THE REAL WORLD**

One of the most significant differences of head-mounted and boom-mounted systems from projection-based VR is th former two the user is isolated from the real world when the display is in place.

Inclusion of Real World Objects - With typical head-mounted or boom mounted displays the viewer cannot see his/h virtual environment unless it is monitored by positioning hardware and then recreated graphically [3]. This is often c representation of the hand using a glove input device. Other real world objects must also be modeled in computer gr the virtual space. Such objects might involve control devices like wheelchair controls, a steering wheel and a dashbo would be included at the expense of rendering time.

Use of half-silvered mirrors in head-mounted and boom-mounted displays can allow the user to see through the disp objects superimposed on a real environment [3]. The viewer would be able to see his/her own body but it might have effect of the virtual environment superimposed on it. A useful application of this feature would be virtual overlays o for instructional purposes. For example the sequence of operations in using a wheelchair could be highlighted with a overlays.

The CAVE also allows for combining real world objects in a virtual environment but with full surround vision and r unobstructed by the virtual environment. This last point is an advantage and a disadvantage. Although real objects w virtual images obstructing them there are times when it would be appropriate. If for example a virtual object was int of a real object or if one's hand passed behind the virtual object then the real object would occlude the virtual one. T could be avoided with planning and although virtual overlays would not be possible highlighting can happen with ot virtual outlining of a real object.

Shared or Guided Experiences - Another very significant advantage for the CAVE is the ability to have multiple vie one viewer would be position-tracked, as many as 12 viewers have routinely experienced the ten-foot CAVE at one t viewers need only wear the stereo glasses to see exactly what the other people see. For more than one person to shar reality experience with head-mounted or boom-mounted systems the display hardware must be duplicated for each u important for collaborative work such as analyzing design models for accessibility or evaluation of a disabled client limitations. For training or therapy situations the client can be guided through a session in a truly shared experience communication, not second hand interpretation. Guided sessions are also important for the potential occurrence of c need for intervention.

**QUALITY OF THE IMAGES**

Quality of the images presented in a virtual reality system can greatly influence the effectiveness of the experience. specific technologies affect the size of the visible image (angle of view) and the amount of detail in that image (visu

Angle of View - Head-mount or boom-mount displays have an angle of view of 140 degrees or less. If half-silvered field of view is restricted to less than 90 degrees [3]. The CAVE has full surround vision for a possible 360 degree a Although the stereo glasses will limit the binocular display area, some peripheral vision is still active.

interact or navigate at lower image quality. With head-mounted or boom-mounted systems the refined image could n without interaction. Furthermore freezing the image in a head-mounted display would cause disorientation [2].

First time users of virtual reality devices are often surprised and disappointed by the crudeness of imagery. In fact "a of the population that is 'aware' or 'interested' in the technology has yet to experience it [1]." This fact combined wit expected incidence of cybersickness in the general population is greater than that of military pilots (20 to 40%) [7] b the likelihood of general diffusion of the medium [1]. It also points to the importance of high quality images and non experiences.

Cybersickness - Although most research on visually induced motion sickness has been on sickness induced in vehicl (simulator sickness), it is assumed that the problems and findings generalize to other virtual environments [6]. Furth simulator sickness is a subset of the motion sickness experienced from travel through virtual environments, for whic more general term 'cycbersickness.' " [7].

Without a real world reference, getting lost in a virtual world (common with navigation capabilities) can be very dis lead to fear in the viewer and potential nausea [2]. In addition when the viewer is isolated from the real world care m avoid collision with real objects in the environment. The boom-mounted display makes reorientation convenient by let go of the handles and back away from the display. In a projection based system like the CAVE disorientation and an issue because the user's view is not isolated by the stereo glasses. The viewer can be immersed in a virtual enviro conscious of the real world surroundings.

Another possible source of cybersickness is position-tracking errors. Because the user can change position faster tha hardware can report, the virtual world may appear to lag behind the user's movement causing sensory conflict i.e. wh different from what is "felt" [5] [1]. In the CAVE only user displacement position changes cause major tracking erro position change causes minor projection errors [2] because the projection plane does not move with the viewer's pos in head-mounted displays). Lack of image quality or realism can also possibly contribute to simulation sickness [5] [ conflict.

These issues of cybersickness will be very important in applications involving people with disability, particularly th affect balance and equilibrium. Mobility training, for example, could take advantage of the ability to present differe environments conveniently to a client. But if that client is presented a situation that causes sensory conflict on top o condition then the exercise may be invalid if not harmful.

**ACCESS TO THE TECHNOLOGY**

Access to virtual reality interfaces by persons with disabilities is similar to the problems of access to computers in g aids have been developed over the last 13 years that accommodate people of all disabilities. Although many adaptiv keyboard related, the ones that can be used for VR systems would likely be cursor steering or navigation devices lik trackballs or simple switches that can be placed conveniently where the person could most easily use it. A techniqu more common is speech recognition. Another common adaptive input device that would be easily implemented in th Pointer. Used by persons with quadriplegia this ultrasonic device is strapped to the user's head for cursor steering. S tracker would normally be mounted to the CAVE user's head, gaze monitoring is automatic.

A popular input device for VR systems is the data glove. This 3D position-tracked device also reads the articulation used for both navigation, by pointing a finger in the direction of desired travel, and manipulation by grasping virtual CAVE a position-tracked wand input device with four buttons is used in a similar way. Navigation is accomplished b direction of travel while pushing the appropriate button. Object manipulation is accomplished by pointing at the obj it with a virtual wand extension. An alternative navigation technique would be to use the thumb operated joystick in separate wheelchair style joystick that can be mount to the armrest of a chair.

With 3D position-tracking, gesture recognition techniques can be used for head gesture, hand gesture or wand gestu input method. Gestures can be small and subtle or large and obvious. The system could adapt to the needs of the ind display is of course the primary output device but it could be augmented for persons with vision disabilities by local output, localized (3D) sound and tactile feedback.

The CAVE is not wearable technology but rather an room-like construction with a projector associated with each of
floor. A ten-foot cubic CAVE occupies approximately 600 square feet of floor space and needs thirteen feet of ceilin
reason the CAVE is not very portable. Entering it is like entering a room that is raised 6" off the floor (for constructi
ramped for wheelchair access. So far the CAVE has been built in two sizes, a seven-foot cube and ten-foot cube. Sin
walls can cause damage, the person using a wheelchair must be conscious of their position. The ten-foot cube feels r
more comfortable to maneuver in. The stereo glasses have the head-tracking sensor mounted to them and a cable tetl
upper corner of the CAVE. The viewer using a wheelchair must be conscious of this so as not to run it over and get t
Another problem for wheelchair users is the fact that the tracking hardware uses magnetic fields to work. Large bodi
electrical signals such as those found on an electric wheelchair cause interference and non-linearities in the data. For
maneuvering is better accomplished through virtual navigation.

**COST**

The advantages of the CAVE come at a price. Although number of screens implemented can be varied, the more the
of major hardware:

Silicon Graphics Inc. VGX workstations - one per screen. Electrohome Data Projectors - one per screen. One Silicon
Iris - master controller. StereoGraphics "Crystal Eyes" LCD glasses - one pair per viewer. Polhemus 3D Position Me
one for the stereo glasses, one for the input device. or Ascension Technology "flock of Birds" 3D Position Measurin
Corporation "Scramnet" - high speed fiber optics communication.

**APPLICATIONS**

Although scientific visualization has held the spotlight as efforts focused on debuting the CAVE at SIGGRAPH '92,
development of the CAVE, applications for people with disability and accessible design were planned for. Research
environments to study the human factors of 3D design was conducted under a grant from the Manufacturing Researc
University of Illinois [8]. Current development in applications using the CAVE for persons with disability is in the a
assistive technology.

In developing design applications it was apparent that a convenient way to bring Computer-Aided Design (CAD) mo
was important. Many models already existed or would be designed on 3D CAD systems for use in virtual environme
applications for the CAVE were scientific visualization or algorithmically generated, there was no standardized data
The Drawing Interchange Format (DXF) developed by Autodesk, Inc. was chosen because it is widely used, flexible
to interpret. Graduate student Lewis Siegel wrote DXFLib.a, a Library written for the Silicon Graphics programming
which when linked to a C program allows the programmer to easily load, draw and save DXF files.

To allow people using wheelchairs to navigate virtual environments a wheelchair joystick interface was built to simu
wheelchair. It can be attached to an existing wheelchair, manual or electric, or to any chair. Although a "treadmill" st
be most appropriate for manual wheelchairs [9], a joystick approach was convenient and more universal. Both the w
interfaced to the CAVE through a PC clone. The PC also serves as the sound interface.

An ongoing application is the design of accessible vehicle interiors. Models of the University campus shuttle bus and
vehicles have been built in our CAD system and converted to DXF format. By bringing these models into the CAVE
out" using a wheelchair. The wheelchair lift area can be inspected for clearance and the handrail checked for position
check the fare-box reach distance and turning clearances for entering the isle. By maneuvering into the tie-down area
securement device is within reach. Although not implement yet we will be able to make changes while in the CAVE.
too far, we can point at it with the wand and bring it closer. If a stanchion is in the way we can move it to a new loca

In the area of assistive technology applications are being developed for evaluating somatic experiences on cognitive
severely disabled children. Virtual reality experienced in the CAVE can allow children to explore, create, play and le
environments and virtual worlds. It is an objective reality that is malleable. They can visit places that would otherwi
impractical or too dangerous. These three dimensional panoramic worlds can be customized to the individual and the
computer can monitor the interaction of a child in the environment and make changes as needed.

**CONCLUSION**

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