Input Interfacing to the CAVE by Persons with Disabilities

Drew R. Browning
Carolina Cruz-Neira
Daniel J. Sandin
Thomas A. DeFanti
John G. Edel
The Design Visualization Laboratory (DVL)
The Electronic Visualization Laboratory (EVL)
University of Illinois at Chicago

ABSTRACT

Common VR systems use head mounted displays that require duplicating user input devices in virtual space for interactive environments. A major advantage of projection based VR systems such as the CAVE is the ability of the user to see his/her own body and real objects in a virtual environment. This paper describes the development of specialized interfaces for virtual environment exploration by people who use wheelchairs. These real, tangible interfaces are intuitive and most appropriate for wheelchair simulations. Examples of these are interfaces that match the user's wheelchair dynamics for joystick or tiller operated electric wheelchairs. The importance of this research is in applications where proposed constructed environments are analyzed by users of wheelchairs. Additional applications include wheelchair mobility training and wheelchair controller design.

THE VIRTUAL REALITY CAVE

Virtual reality (VR) is created by a three dimensional computer graphics system using real-time interactive control and displaying viewer centered perspective. VR usually has panoramic binocular display with a large angle of view. These features are included in the immersive technologies of head-mounted displays (HMD), boom-mounted displays and surround-screen projection-based displays.

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 projectors are high resolution data type projecting stereo images on alternating fields. Active liquid crystal display (LCD) stereo shutter type glasses are worn by viewers to separate the alternate fields to the appropriate eyes, while viewer head position is tracked by an electromagnet sensing device attached to one of the pairs of stereo glasses. A Silicon Graphics Onyx with multiple processors generates the computer graphics for each projector. The viewer can move around the virtual environment and see his own body as he interacts with real and virtual objects.

THE REAL WORLD IN THE CAVE

Although projection based VR and Head Mount Displays share the essential features of a VR system, they differ in their ability to connect the user to the real world or to augment reality. At UIC we are developing interfaces to the CAVE that are real, tangible and intuitive [2].

Real Objects and Real Interfaces
With typical head-mounted or boom mounted displays the viewer is isolated from the real world. To see ones' own body parts in a virtual environment, those parts must be recreated graphically. [5]. A glove input device is often used to control a representation of the hand while interacting with the virtual world. Other real world objects must also be modeled in computer graphics to include in the virtual space. These objects might involve interface devices such as vehicle controls.

Superimposition of virtual objects and real objects is possible with the use of half-silvered mirrors in head-mounted displays [5]. Because the viewer sees through the virtual objects this technique is most useful for virtual objects in a real environment as opposed to real objects in a virtual environment. A useful application of this feature would be virtual overlays on real control panels for instructional purposes [7].

the interior of a mass-transit vehicle. Wheelchair securement devices such as the Seattle Red-belt can be used with a seat to mock up a wheelchair tie down, while the rest of the interior is modeled in VR. The user can analyze reach re belts as well as clearances in maneuvering his/her wheelchair into the tie-down area. Using real objects, with their al physical feedback and greater detail, a simulation can be made far more accurate.

Virtual Navigation
Larger spaces can be virtually navigated using a joystick interface. For example a person could virtually traverse the station platform while checking accessibility features. This joystick interface was built to simulate an electric wheelc attached to an existing wheelchair, manual or electric, or to any chair. The physical nature of this joystick interface c simulation very compelling. Although a "treadmill" style interface would be most appropriate for manual wheelchair approach was convenient and more universal.

Shared or Guided Experiences
The CAVE has the ability to augment reality for multiple viewers as well. Although only one viewer would be positi additional viewers need only wear the stereo glasses to see what the other people see. This is very important for colla as analyzing design models for accessibility or evaluation of a disabled client for reach limitations. Since only one p be tracked, priority must be given to the person who is evaluating distances. For evaluation of a transit model, the tra passed between the person in a wheelchair and the person who is checking clearances. For training or therapy situati guided through a session in a truly shared experience with effective communication, not second hand interpretation. also important for the potential occurrence of cybersickness and the need for intervention.

Cybersickness and Real World References
Real world references assure a viewer of their balance and equilibrium. Losing a sense of location and orientation in lead to fear in the viewer and potential nausea (cybersickness) [4,6,9,11]. In a projection based system like the CAVI nausea are less of an issue because the user's view is not isolated. The viewer can be immersed in a virtual environm conscious of the real world surroundings and their own body.

Cybersickness can be very important in applications involving people with disability, particularly those disabilities t and equilibrium. If VR is used for mobility training, the user must be able to deal with the potential isolation of a vir the user cannot maintain their equilibrium in VR, the training will not only be useless, it could also be harmful [1,12

INPUT DEVICES FOR VIRTUAL REALITY

Access to virtual reality interfaces by persons with disabilities is similar to the problems of access to computers in ge with physical disabilities the input devices of greatest concern have been the keyboard and mouse. A variety of keyb aids and substitutes are now available. These devices are typically used for text and numeric data entry and cursor st reality these functions also exist with an emphasis on three dimensional cursor steering or navigation.

Another common adaptive input technique is head control. With this technique an ultrasonic device is strapped to th cursor steering. Since a position tracker would normally be mounted to the CAVE user's head, gaze monitoring is au position-tracking, gesture recognition techniques can be used for head gesture, hand gesture or wand gesture as an al method. Gestures can be small and subtle or large and obvious.

The Digital Wand
Until recently we have used a prototype wand input device that contains a position sensing device and three digital b position sensing device is the same as the device attached to the stereo glasses for head position monitoring. The thr simply wired in parallel to the buttons of a mouse attached to one of our workstations. In many ways it can function cursor steering in three dimensions. Navigation is accomplished by pointing in the desired direction of travel while p appropriate button to move. Object manipulation is accomplished by pointing at the object and intersecting it with a extension.

Our first wand was quickly constructed of a plastic flashlight case with the switches and position sensor mounted ins repairs were difficult because the switches had to be removed each time the sensor was changed. A second wand wa doing this we could take advantage of the wide variety of devices and software available on the market. For example now include a mouse input and game port. Many types of joysticks for flight simulators or other game software exis addition a wide variety of digital and analog I/O boards are available at reasonable prices.

Using the PC interface also meant that the many adaptive input devices available for persons with disability could be environments. For example chin operated track balls or foot operated joysticks can replace typical mouse operations numeric input specialized keyboards are available that replace or augment a standard keyboard (expanded keyboard, latches, key guards). Even simple switches that can be placed conveniently where the person can most easily use it n accessible.

Software is also available that can replace or make a standard keyboard more usable (character scanning virtual keyb input switch, key repeat eliminators, sticky keys, macro keys). Of course voice input systems hold great potential for aspects of the virtual reality interface by persons with movement limitations and are readily available for the PC at p falling. Head control software may also be adapted to the CAVE environment.

Initially the PC communicated with five workstaions controlling the CAVE through a shared memory network. How have replaced these single processor workstations with a multiprocessor machine. This machine, a Silicon Graphics internal shared memory. Although we can continue to communicate between the PC and the onyx using the shared n decided in favor of serial communication for reasons of simplicity and cost. Analog devices are connected to the PC to digital converter board installed in the PC. A box actually connects the I/O board in the PC and the input devices. way to connect multiple input devices and conditions the inputs for the I/O board parameters.

Analog Wand Development

A new wand prototype was developed for the PC interface that includes a thumb operated force type joystick along v device and three switches. This joystick produces two analog values as the user applies force in a particular direction joysticks (as opposed to displacement type) are used in flight sticks on military aircraft. These small devices take up well suited to hand held devices. Its two dimensions of control can be programmed for any applications where contin appropriate. For example navigation can now be accomplished by pointing the wand in the direction of travel and co with pressure on the joystick.

Wheelchair Simulation

Although wheelchair simulations could be performed using the capabilities of the wand joystick we decided to devel wheelchair displacement style joystick that can be mounted to the armrest of a chair or wheelchair. Navigation with t programmed to accurately simulate electric wheelchairs of many sorts. For conventional electric wheelchairs pushin produces forward travel while reverse travel would be controlled by pushing the stick backward. Pushing the stick fu direction increases the speed of travel. Left/right movement of the joystick would rotate the user relative to the virtu turning the wheelchair. Simply stated, pushing the joystick in the desired direction of travel will turn and move the w direction at a speed proportional to the displacement of the joystick. Alternatively an omni-directional wheelchair ca programming the joystick such that pushing the stick in the desired direction of travel will move the wheelchair in th turning.

Other electric wheelchair dynamics can be simulated as well. For example different wheelchair configurations (front design, size of caster etc.) or controller designs (sensitivity, oversteer, understeer, smoothing etc.) can be programme [3].

Problems

The cables necessary to connect input devices to the computers are a serious problem. The viewer using a wheelchai not to run them over or get tangled in them. We are currently considering ways to eliminate as many cables as possib communication such as rf or infrared. Initially this will replace cables to controls other than the position sensing dev likely depend on manufacturer developments to become wireless). Without eliminating all cables the user will still b minimizing the number of cables we will reduce the weight and ready ourselves for wireless tracking technology.

Another problem for wheelchair users is that the tracking hardware uses magnetic fields to work. Large bodies of me traffic. For a transit system to be viable for its users, a large enough percentage of the facilities must be accessible.

The Design Visualization Lab currently has a proposal in to the Chicago Transit Authority to develop strategies for m
wheelchair accessible. Innovative new ways to raise patrons to platform level at elevated stations need to be devised
method of making a station accessible is to install an elevator. At many CTA's stations, this would require widening
support structure to accommodate the increased width of an elevator. This would require tearing down private and pu
making the job prohibitively expensive. By surveying state of the art accessibility equipment and developing new id
solve the problem. The Cave would be used extensively in this process to view and evaluate models of existing cond
new access methods. Tremendous amounts of time and money could be saved in the design and prototyping phases o
working bugs out of potential solutions before they are sent to an engineering firm for final planning.

Mass Transit Interior Design

At UIC we are continuing to develop accessible vehicle interiors. Models of the University campus shuttle bus and v
vehicles have been built for evaluation in VR. Bringing these models into the CAVE has allowed us to evaluate inter
wheelchair accessibility. The wheelchair lift area can be inspected for clearance and the stanchions checked for posit
having the primary investigator wear the head tracking device, accurate clearance measurements can be made aroun
objects and virtual objects.

Instruction for People Using Wheelchairs

It also makes possible instruction before a person learns to run a wheelchair. In the safe environment of the Cave, yo
which may be fatal outside of VR. You can also try maneuvers which one is afraid to try for fear of injury, ie. crossin
intersection. In the case of teaching people to use a powered chair, much of the fear and danger can be removed from
making the transition easier [10].

The Cave can be used for teaching ambulatory persons how people in wheelchairs function in everyday life. Designe
their ideas before committing to manufacture, and Architects can see how much space is required around a chair for
Employee sensitivity training could be much more effective if participants viewed boarding a bus from the position o
wheelchair.

EQUIPMENT

Currently the CAVE consists of the following major hardware: Silicon Graphics Inc. Onyx/RE2 with Silicon Graphi
Interface Board. - controls and generates graphics for each screen. Electrohome Data Projectors - one per screen. Ste
"Crystal Eyes" LCD glasses - one pair per viewer. Polhemus or Ascension Technology "flock of Birds" 3D Position
- one for the stereo glasses, one for the input device. Systran Corporation "Scramnet" - high speed fiber optics comm
Measurement Systems, Inc. - subminiature joystick, force operated, model 462

Input devices
Wand - hand held navigation tool with three buttons and a joystick. Flight stick - similar to aircraft control. Wheel ch
joystick - can be attached to any chair with arms.

Interfaces to system

IBM PC 286 Clone- general purpose hardware/software interface. Analog to digital board - 12 bit resolution, 150 M
single ended analog input channels, 2 analog output channels, 24 bit programmable digital I/O.

CONCLUSION

The CAVE is an important and effective design tool for evaluating environments and products. The ability to include
in a virtual environment sets the CAVE apart from other VR systems which entirely replace the viewer's environmen
experience a VR simulation with more than one person, the CAVE allows for shared or guided evaluations which ca
effective. Joystick navigation in the CAVE is a natural interface for all people as well as those who use joystick cont
wheelchairs. Additional adaptive input devices may also prove to be beneficial to nondisabled CAVE users. This allo
smooth transition to the virtual world. The CAVE is accessible to a larger percentage of the population by virtue of i

Technology Challenge Grant.

AUTHOR'S ADDRESS
Drew R. Browning, Assoc. Prof.
Director, Design Visualization Laboratory
UIC School of Art and Design m/c 036
929 W. Harrison, Chicago, IL 60607
E-MAIL drew @ uic.edu

REFERENCES

[1] Biocca, F. Will Simulation Sickness Slow Down the Diffusion of Virtual Environment Technology? Presence, Vo
Summer 1992, pp 334, 337-338.

[2] Browning, D.,Cruz-Neira, C., Sandin, D.J., DeFanti, T.A. CAVE, Projection-Based Virtual Environments and Di
Proceedings Virtual Reality and Persons with Disabilities - 1993, California State University (CSUN) Center on Dis

[3] Collins,T.J., Kauzlarich, J.J. Analysis of Parameters Related to the Directional Stability of Rear Caster Wheelcha
Virginia Rehabilitation Engineering Center, 1987

[4] Cruz-Neira, C., Sandin, D.J., DeFanti, T.A. Surround-Screen Projection-Based Virtual Reality: The Design and I
the CAVE. 1992,pp 2-3, 9.,11

[5] Cruz-Neira, C., Sandin, D.J., DeFanti, T.A., Kenyon, R., and Hart, J.C. The CAVE, Audio-Visual Experience Au
Environment. Communications of the ACM, June 1992, pp 67-72

[6] DiZio, P., and Lackner, J.R. Spatial Orientation, Adaptation, and Motion Sickness in Real and Virtual Environme
Volume 1, number 3, Summer 1992, pp 323

[7] Feiner, S., MacIntyre,B., Seligmann,D. Knowledge Based Augmented Reality. Communications of the ACM, Vo
July 1993, pp 53-62

[8] Figueiredo, M., Bohm., Teixeira,J. Advanced Interaction Techniques in Virtual Environments. Computers and G
number 6, 1993, pp 655-661

[9] Hettinger, L.J. Visually Induced Motion Sickness in Virtual Environments. Presence, Volume 1, number 3, Summ
306-307

[10] Inman, D. Oregon Research Institute

[11] Kennedy, R.S., et al. Profile Analysis of Simulator Sickness Symptoms: Application to Virtual Environment Sy
Volume 1, number 3, Summer 1992, pp 296

[12] McCauley, M.E. and Sharkey, T.J. Cybersickness: Perception of Self Motion in Virtual Environments. Presence
3, Summer 1992, pp 311, 313

[13] Sandin, D., Browning, D. Evaluating the Visual Aspects of Product Design: Simulating Ergonomic Studies Fro
Realities; Manufacturing Research Center at the University of Illinois, May 1991

[14] Trimble, J. Virtual Barrier Free Design. Team Rehab. Nov 1992

Return to my home page: http://www.evl.uic.edu/drew