Effective Virtual Environments

Department of Computer Science | University of North Carolina at Chapel Hill | March 2005

The Challenge

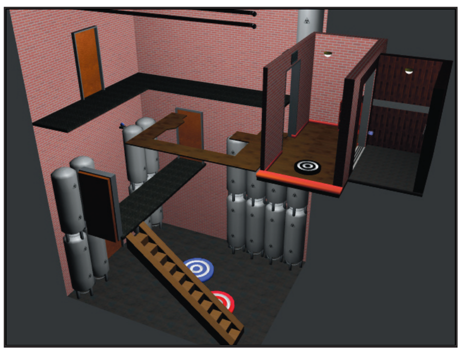
Immersive Virtual Environments (VEs) were first conceived in the 1960s. Over 40 years later, there are still more VE systems being used in research about VEs than as tools to solve real users' problems. Our goal is to make VE systems more effective for doing real work by:

- Developing new technologies and techniques for interaction,
- Evaluating the effects of these techniques on user comfort and performance and on the quality of the virtual experience, and
- Exploiting the adaptability of the perceptual system to improve system performance.

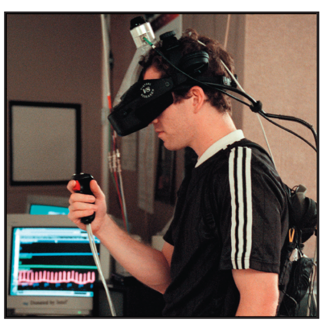
Selected Research Areas

Presence Measure

Presence has typically been measured using questionnaires. We have shown that quantitative physiological data, in particular heart rate and palm sweat, are valid, reliable, sensitive, and objective measures of presence. With this new measure, we have studied how frame rate, field of view, rendering quality, audio quality, and latency affect both presence and task performance.



We placed users in a stressful VE to elicit a physiological response in proportion to their level of presence.



A user wearing a head-mounted display and physiological measuring equipment. Heart-rate is shown in the computer monitor in the lower-left corner.

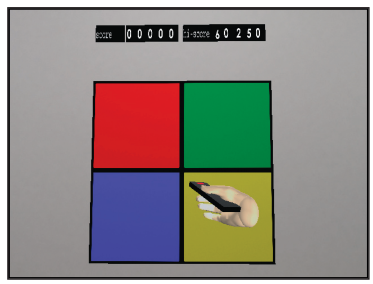
Locomotion

Since 1998, the EVE team has been developing and comparing locomotion interfaces – techniques for moving around in VEs. A separate flyer describes this work.

Haptics

One significant problem with most VE systems is that users cannot feel the virtual world they see. We have several avenues of research in this area.

Visual dominance over proprioception: Without a force feedback haptic display, a head-mounted display user's avatar may penetrate virtual objects. Some virtual environment designers prevent visual interpenetration, making the assumption that prevention improves user experience. However, this technique creates a discrepancy between visual cues (the seen position of the virtual hand) and proprioceptive cues (the felt position of the real hand). We investigated users' detection thresholds for visual interpenetration (the depth at which they see that two objects have interpenetrated) and sensory discrepancy (the displacement at which they notice mismatched visual and proprioceptive cues). We found that users are much less sensitive to visual-proprioceptive conflict than they are to visual interpenetration, and we are developing a technique that minimizes overall cue conflict.

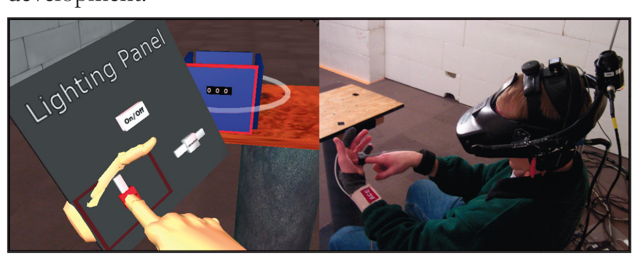


In our study, users were asked to play a game in the VE with the colored panels on the wall.

During the game, the virtual hand drifted from the real hand position. Users compensated to maintain a consistent visual scene. This user believes he is aiming at the panels directly in front of him.

User interfaces for immersive VEs:

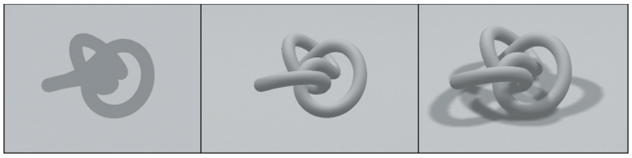
Passive haptic props, such as physical tablets or paddles, are often used to provide touch feedback for user interfaces (e.g. button and slider panels) in VEs. However, carrying a physical prop can be cumbersome. We have developed a user interface for VEs that uses the non-dominant hand itself to provide haptic feedback to the dominant hand while it interacts with widgets on a virtual control panel. Initial usability studies indicate that the technique has potential and warrants further development.



A user interacts with a virtual interface panel by touching his non-dominant hand.

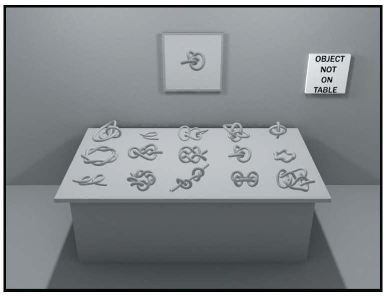
Lighting Quality

VEs often require that performance tradeoffs be made among rendering quality, simulation precision, audio quality, etc. We have investigated the impact of lighting quality on presence



A knot rendered with uniform ambient lighting (left), with a directional spot light but without shadows or interreflections (middle), and with shadows and interreflections (right).

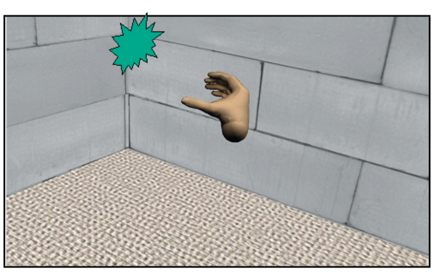
and task performance in VEs. Our investigations of lighting quality showed that people react to lighting in VEs the same way that they react to lighting environments in the real world. Surprisingly, for some tasks we tested, higher quality lighting led to lower performance.



Users view a target object that is rendered in one of three styles. The target object disappears and users are then shown a table of objects all of which are rendered in the same style as the target or another style. The task is to point at the target object if it is on the table or to signal if it is not. We recorded user speed and accuracy.

Audio

Does a complex audio system that includes head-related transfer functions and lower audio latency enable a user to localize a sound source more accurately, more quickly, and more directly? Do accurate reflections improve the ability to localize a sound source? We are running studies to investigate these questions. One study compares AuSIM's anechoic system to the DirectX anechoic system, and a second study compares AuSIM's sound-reflecting system to the DirectX anechoic system.



User's hand approaching an invisible sound source, shown here in green.

New Research Directions

Simulation quality: If users are shown a physical simulation, how accurate does it need to be? We will investigate users' detection thresholds for distortions applied to collision response in rigid body dynamics simulations.

Depth perception: Research has shown that VE users systematically underestimate distances to virtual objects, but the reasons are not yet known. This study investigates whether the presence of a shadow cast from a target object to the surface on which it sits improves depth perception.

Latency: Perception of latency in head-mounted VEs degrades performance, impedes usability, and causes simulator sickness. However, the level where latency begins to affect users is still unknown due to technological limitations. We will investigate using a custom-built system that corrects for latency in the horizontal direction.

Vibrotactile feedback: It has been shown that passive haptics increase users' spatial memory in a maze navigation training transfer task. However, a passive-haptic environment cannot always be constructed. We will investigate the effectiveness of using vibrotactile feedback (vibrating pager motors) for haptic feedback in VEs.

Project Leaders

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Selected Publications

Kohli, L., and M. C. Whitton. "The Haptic Hand: Providing User Interface Feedback with the Non-Dominant Hand in Virtual Environments," *Proceedings of Graphics Interface 2005*, May 2005. To appear.

Burns, E., S. Razzaque, M. Whitton, M. McCallus, A. Panter, and F. Brooks. "The Hand is Slower than the Eye: A Quantitative Exploration of Visual Dominance over Proprioception," *Proceedings of IEEE Virtual Reality 2005*, (Bonn, Germany March 2005), IEEE Computer Society.

Zimmons, P. "The Influence of Lighting Quality on Presence and Task Performance in Virtual Environments," Ph.D. dissertation, University of North Carolina at Chapel Hill, 2004.

Meehan, M., B. Insko, M. Whitton, and F. P. Brooks Jr. "Physiological Measures of Presence in Stressful Virtual Environments," *ACM Transactions on Graphics* 21(3): 645-652. (Proceedings of ACM SIGGRAPH 2002, San Antonio, Texas).

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