Effective Virtual Environments: Redirected Walking

Department of Computer Science | University of North Carolina at Chapel Hill | March 2001

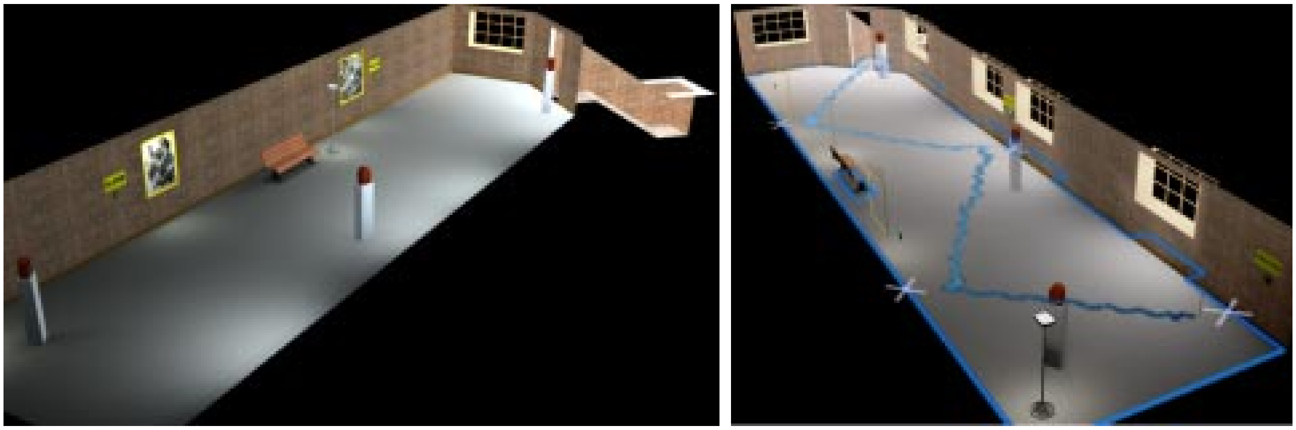

Figure 1. Two views of the virtual environment. Users pushed the green buttons below the four yellow signs on the walls. In the view at right, a user's path and the outline of the room have been superimposed.

The Challenge

One of the many design parameters of a virtual environment (VE) system is how a user moves from one virtual place to another. Which method of locomotion is the most effective? Previous research has shown that really walking in VEs is better than flying, where users point a hand controller in the direction they wish to travel. Real walking is more natural and results in a greater sense of presence (the feeling of being in the virtual environment versus being in the laboratory). Our wide-area optical tracking system allows us the rare opportunity to study real walking in VEs.

One problem with real walking is that we cannot represent virtual rooms that are larger than our tracking area.

The Technique

Redirected Walking addresses this limitation by interactively and imperceptibly rotating the virtual scene about the user. The rotation causes the user to walk continually toward the furthest wall of the lab without noticing the rotation. The user does not notice because we take advantage of the limitations of human perceptual mechanisms for orientation and movement sensing. In the extreme, Redirected Walking could cause users to walk in a large circle in the lab, while they think they are walking in a straight line in the virtual environment.

Figure 2. The view users see in the headset as they walk towards the button to close the windows. An antique radio, used for presenting pre-recorded instructions, is in the foreground.

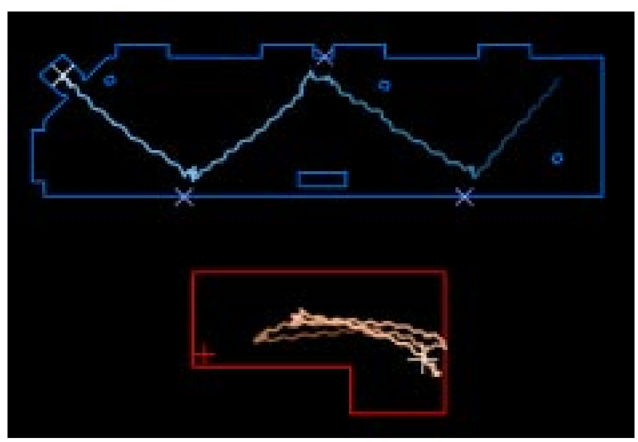

Figure 3. Overhead views of the path of a user performing the task in the VE (upper in blue) and in the tracker space (lower in red). Note how the user walked in a zigzag pattern through the virtual room while walking back and forth within the tracker space. The tracker space and VE are drawn to scale.

Implementation and Pilot User Study

We explored the viability of Redirected Walking with a pilot user study. We wished to know if we could induce enough rotation to turn users and enable large VEs, while keeping the rotational distortion low enough that users would not notice the distortion nor suffer any increase in simulator sickness. We found no showstoppers.

Task. The task was a simulated fire drill. Subjects wore a head-mounted display with stereo headphones that presented the visuals and spatialized audio. Subjects were immersed in a virtual room approximately twice the size of the tracker area. Subjects were asked to push four buttons mounted on the virtual walls in order. Each button triggered a response related to the fire drill scenario: (1) practice, (2) sound the alarm, (3) close the windows, and (4) activate the fire suppression system.

Theory

Humans rely primarily on vestibular, visual, and auditory cues for balance and orientation. Humans also use these senses to determine whether they themselves are moving (self-motion) or if the objects around them are moving (external-motion). If we maintain consistency between visual, aural, and vestibular cues, users should not sense the world moving arbitrarily around them.

Each ear's semi-circular canals act approximately as three orthogonal rotational rate gyros; they sense the high-frequency components of a person's angular movement. The visual and auditory systems sense low-frequency components. Because our VE system does not employ devices that induce vestibular cues, such as a motion platform, we avoid injecting high-frequency rotational distortion.

Even while standing still, users unknowingly rotate their heads and torsos with the virtual scene. We hypothesize that users' own balance mechanisms are responsible for this. While walking, in attempting to stay on a virtual trajectory that they perceive as straight, users unwittingly veer in the direction of the induced rotation.

Future Work

This work presents several opportunities for further investigation:

- Can imperceptible rotation be used in cave displays, to keep users from seeing the open back wall of a cave?
- Does improving VE system parameters (tracking-rate, frame-rate, latency, etc.) increase the amount of distortion we can get away with?
- What is the minimum size tracking area we need to fool users into walking in a complete circle, thus allowing for infinitely extended VEs?
- Previous research has shown tethers (that connect the headset to the computer equipment) are a severe constraint, and cause breaks-in-presence. Will a wireless and wearable VE system improve the user's experience?
- Can we distort users' linear acceleration to change their walking distance without them noticing?
- How does 3D audio—as compared with non-spatial audio—change the effectiveness of redirected walking and VE systems in general?

Selected Publications

Razzaque, S., Z. Kohn, and M. Whitton. "Redirected Walking," *Department of Computer Science technical report TR01-007*, University of North Carolina, 2001.

Usoh, M., K. Arthur, M. C. Whitton, R. Bastos, A. Steed, M. Slater, and F. P. Brooks Jr. "Walking > Walking-in-Place > Flying, in Virtual Environments," *Computer Graphics: Proc. SIGGRAPH '99*, Los Angeles, Calif., 8–13 August 1999, 359–364.

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