The Implementation of a Novel Walking Interface within an Immersive Display

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Abstract

Locomotion interfaces pose a large challenge for designers of immersive virtual environments. While treadmills and other actuated interfaces can be integrated with spatial displays or head-mounted displays, they are expensive or they constrain walking to one direction. In this technical note we demonstrate the integration of a passive walking interface integrated with a CAVE™-like display. The Wizdish is a new concept for walking interfaces. Users wear low-friction shoes and "walk" on a dish-shaped apparatus. By tracking the feet and integrating a redirection algorithm we have constructed a locomotion interface that reproduces some aspects of walking whilst removing the need for the user to operate any hand-held controller.

Keywords: Locomotion interfaces, full-body interfaces, immersive virtual environments.

Index Terms: I.3.7 [Three-Dimensional Graphics and Realism]: Virtual Reality

1 Introduction

The ability to locomote through the environment is necessary in most virtual environment systems. This can be achieved in many ways, but the majority of virtual environment systems, both immersive and non-immersive, use a joystick or button control, where the user makes some action with their hand to effect locomotion. Whilst locomotion can be very efficient with such interfaces, they are not natural, in the sense that they are not like really walking through the environment. For example, Usoh et al. showed that to maintain a high reported sense of presence in an immersive virtual environment (IVE), really walking was superior to a virtual walking metaphor, which was superior to a flying metaphor where the user operated a button to enable locomotion in the direction that they were looking [14]. Furthermore, such metaphors engage the hand, when the hands might usefully be used for another task. They might also constrain the user to look in the direction that they want to go.

Whilst it is possible to set up a tracking system to work in a very large space, most facilities are constrained to a few meters walking area, and thus there have been several attempts to build walking interfaces where the user makes walking actions, but does not physically move. We will review these interfaces in Section 2, but note that mechanical systems to support locomotion can be expensive or can impose constraints on motion.

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In this technical note we demonstrate the integration of a novel walking platform, the Wizdish, into a CAVE™-like display. The main concept of the Wizdish is that the user wears low-friction shoes and makes a walking-like motion inside a dish where their feet slide toward the dish bottom. Although it is not a natural walking motion, and although it takes some training to become accustomed to use, it reproduces the effort required to locomote and retains some of the proprioceptive cues of real walking. To integrate the Wizdish, we track the position and orientation of the feet using a Vicon motion capture system.

Because our CAVE™-like display, the UCL ReaCTor, only has three walls, in addition we have used redirected walking so that as the user walks they are automatically steered such that they face the centre wall rather than the side walls.

We present a short feasibility study with a few testers to demonstrate that the interface works. Based on this we suggest some avenues for further development, and the potential to integrate this with other types of demonstration.

2 Background

Locomotion is one of the primary tasks that 3D user interfaces need to support [16]. Two commonly used locomotion metaphors are "point or look to fly" where the user presses a button to enable locomotion along the direction they are pointing or flying, and "joystick locomotion" where they operate a joystick to turn and then drive their position forwards and backwards [1]. In both cases one of the hands needs to hold a device.

One ideal for locomotion interfaces is that they should only use the feet for input. This has led to a number of interfaces being developed where the user mimics walking by stepping in place (e.g. [11][13]). These techniques can reproduce some of the proprioceptive cues of motion, but the user might not be making significant motions and might not be exerting the same effort. However they are easy to implement.

To reproduce the physical effort of walking, several different technologies have been used. The first technology is the standard linear treadmill [2]. This provides for motion, but because it is linear, some rotation control must be supported. Omni-directional treadmills have been built [3], but are currently an expensive solution to the problem. Several alternative engineering solutions have been proposed, such as robot foot plates [6][17] or mobile foot plates [8], but these are not commonly available as of yet. Treadmills such as the Sarcos Treadmill can reproduce the effort of walking on non-planar surfaces **Error! Reference source not found.**. The Sarcos Treadmill can tilt and an active mechanical tether can apply forces to the torso of the user to simulate constraint or inertial effects.

Other technologies that reproduce the physical effort of walking, include the Sarcos Uniport or static bicycles. In such systems, a steering control must be added as leg motion is effectively constrained to one direction.

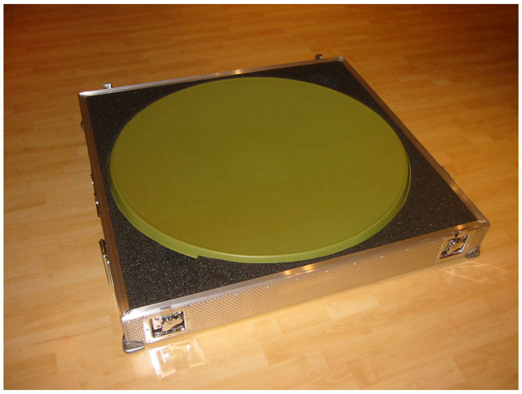

Figure 1: The Wizdish surface.

Figure 2: The low friction shoes.

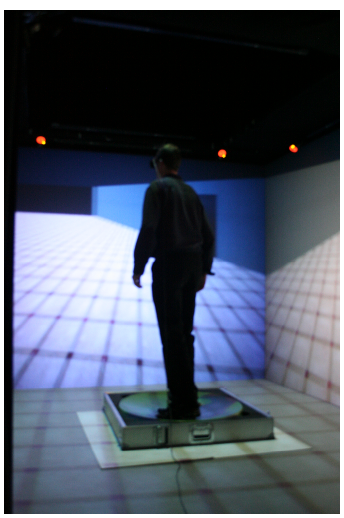

Figure 3: A user walking on the Wizdish within the UCL ReaCTor.

The technology most similar to our proposal is the Virtual Perambulator [7]. In this setup the user wears sliding devices on their feet. The user does need to be suspended from a harness or stand in a hoop. With our prototype, the user does not need to support themselves on a frame or bar, as the walking motion is stable and in place. However, as noted in Section 6, a frame, such as those found on treadmills, might be required for safety reasons as it does take some practice to perfect the walking technique.

The other technique used in our implementation is redirected walking [9], a technique that has previously been applied in an IVE with 3 vertical walls [10]. This technique is applied to avoid a situation where the user faces or wants to travel in the direction of the open wall of the display. This is achieved by slowly rotating the environment such that the user's gaze direction is moved towards the centre of the display surface.

3 WIZDISH

The Wizdish, is a dish-shaped surface, upon which someone can walk [18]. The current Wizdish prototype is 830mm wide by 900mm long. The depth in its centre is 80mm. If the user wears low-friction shoes, then, because of its shape, if they step away from the centre, their foot will naturally slip towards the centre of the dish. The dish itself is shown in Figure 1. The surface is concave and almost spherical, with the radius of curvature of approximately 960mm. Currently the dish is mounted in a flight case for portability, but it could be embedded in any suitable supporting structure.

To walk on this surface, the user wears low friction shoes. The current prototypes are constructed from Heelys™, with animal fur on the front of the sole which provides very low friction, see Figure 2. The coating of the dish and the surfaces of the shoes are under development. Users who walk on the dish need to slip one foot forward and one foot back simultaneously. Once their feet are apart, they then slide them in the opposite direction. Informally, people have referred to this as "skating", but the motion is actually unlike skating, as one is not pushing off one foot, but moving both simultaneously. The feet do not lift off the dish whilst doing this motion.

4 WIZDISH INTEGRATION IN AN IVE

The dish itself can be set in the middle of an IVE, see Figure 3. To create a locomotion metaphor we track each foot. The UCL ReaCTor has an integrated six-camera Vicon motion capture system. Some of the markers are visible in Figure 2. The Vicon motion capture system is used to capture the location and orientation of both feet, while an Intersense IS900 system tracks head position and orientation.

The locomotion algorithm is based on 3 principles:

- Locomotion is derived only from the forward motion of the feet. With the Wizdish locomotion technique, as one foot is slid forward, the other will slide backwards across the dish. The locomotion algorithm must discount any backwards motion of the feet.
- Steering is implemented naturalistically, such that to turn the user must simply turn and walk in a different direction.
- Because the UCL ReaCTor has only 3 walls, a redirected walking technique is implemented to keep the user's centre of view as central as possible within the UCL ReaCTor's range of view. The redirected walking algorithm is based only on the user's gaze direction, and not on their walking direction, although typically these will be similar.

The inputs to the walking algorithm are:

- The gaze vector (H) derived from the orientation of the Intersense MiniTrax headtracker worn by the user.
- The motion vector of each foot, calculated as the per-frame position difference, with 3D position information tracked through the Vicon motion capture system (V_L and V_R).
- The orientation of each foot as read via the Vicon motion capture system. The orientation of each foot is used to determine whether the motion of the foot is in a forwards or backwards direction, with only the forward component being used to contribute to forward velocity.

The magnitude of the walking motion is scaled by the dot product of the motion vector and the forward direction vector of the forward-moving foot. This ensures that only forward motion is accounted for regardless of which foot is moving forward (Figure 4). The resulting motion is then scaled by a constant factor of 2.5, a value which we had found empirically to give a good sense of walking at natural speed based on the foot movements.

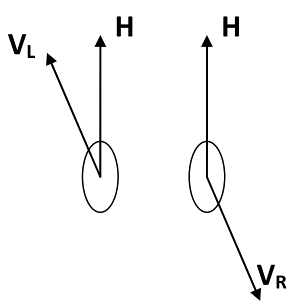

Figure 4: Motion of the feet using the Wizdish: as the left foot moves forward (**V_L**), the right foot slides back (**V_R**). The dot product **$V_L \bullet H_L$** is positive and is used to scale the forward motion vector **V_L**

A redirected walking algorithm is used to try to keep the user's gaze orientation towards the central vertical wall of the display. This is accomplished by slowly rotating the environment such that the user's fixation point moves towards the centre of the range of view. As in previous implementations [10], the rate of such redirection rotation should be sufficient to prevent the user looking at the gap in the display surface, whilst not so great as to be overly noticeable to the user. To accomplish this goal, the redirected rotation is scaled by the magnitude of the locomotion. The scaling is done so that if the user does not walk no redirection takes place, whilst increasing degrees of redirected rotation take place with greater locomotion speeds and greater angle offsets between the gaze direction and the centre of the range of view. Thus the rotation rate is computed as the locomotion rate (in metres per second) × gaze angle offset × constant scale factor. The constant scale factor was determined empirically such that it was small enough for redirected rotation not to be overly noticeable by the user, but large enough to allow sharp turns to be navigated without the user having the gap in the display surface in their field of view. A value of 0.1 was found to satisfy these requirements.

5 Feasibility Study

Four members of our laboratory, including two of the co-authors, tested the system. The third co-author is the developer of the Wizdish and has considerable experience using it. The shoes were of EU Size 45, which fitted all four; other sizes were available for testing but were not needed. Two of the four had previously walked on the Wizdish for ~5 minutes without visual feedback, two had not. The two that had not used the system before needed approximately 5 minutes to get used to the walking motion and feel comfortable. During this time, they would need to have an assistant nearby to offer occasional support. One common action we would see was that initially a user would only move one leg at a time. All were able to make the two legged motion after some practice.

After familiarization, each user completed a circular loop around one part of a figure eight corridor. This path required both straight and curved segments. Each user completed the circuit. With the calibration as is, each user commented informally that walking was more tiring than real walking. This might indicate that attention would need to be paid to the velocity scaling and possibly the friction properties of the surface itself.

6 Discussion & Conclusions

Each user in our feasibility study was able to locomote about the environment. The two notable features were that they didn't need to use any hand controls, and they didn't have to orient themselves inside the UCL ReaCTor. The redirection mechanism thus worked well, and the tracking of the feet decoupled head direction from the walk direction.

It is worth stressing that the motion is only similar to a walking motion, and it takes a few minutes time to get used to. However we note there is some similar training required even with linear treadmills. Thus the Wizdish may be most useful for training scenarios, games or other simulations where long exposures are necessary.

We have not paid attention yet to calibration of step sizes, or the continuity of head motion, a concern for walking techniques examined in detail in [15]. We have also not yet tuned the parameters for the redirection technique. We note that the feet rise when separated meaning that each stride may be more effort than a normal stride. We have not measured or compensated for this effect. We would also be very interested in perception of distance travelled with this technique.

For deployment in public situations, some form of frame would be desirable for safety reasons. We note though, that even linear treadmills in gyms have such frames, but most users do not need to hold them when walking or running; their primary use is if the user stumbles. In our experience, the walking motion on the Wizdish is stable after a few minutes practice.

As previously noted, the current dish and shoes are prototypes, and thus in the future we will be experimenting with different dish radii and coatings. We will also be experimenting with different shoe coverings, removing the need to use wheeled shoes. The next prototype will also be perfectly spherical, with a radius longer than normal leg length, unlike the current prototype. We expect the next prototype will have much less friction than the current one.

We also want to mount the dish next prototype with the rim flush with the floor. This will require us to make a raised platform for inside the UCL ReaCTor and make minor corrections to the wall calibrations. Alternatively the Wizdish might work well with a head-mounted display. In this case the redirected walking technique would not be needed.

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