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Combining Passive Haptics with Redirected Walking

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Abstract

Two large problems faced by virtual environment designers are lack of haptic feedback and constraints imposed by limited tracker space. Passive haptic feedback has been used effectively to provide a sense of touch to users (Insko, et al., 2001). Redirected walking is a promising solution to the problem of limited tracker space (Razzaque, et al., 2001). However, these solutions to these two problems are typically mutually exclusive because their requirements conflict with one another. We introduce a method by which they can be combined to address both problems simultaneously.

Key words: passive haptic feedback, locomotion

1. Introduction

We explored two orthogonal virtual environment (VE) issues: lack of haptic feedback and limited tracker space. Previous work has proposed promising solutions to each of these problems.

Insko, et al. showed that passive haptics (the use of real physical props to provide haptic feedback for virtual objects) are an easy way to provide a sense of touch for static objects in a VE and significantly enhance a user's experience [1]. However, passive haptics require that the position of an object in the VE always correspond to the position of a real object in the real world. Anything that decouples an object's position in the real and virtual worlds (for example, using a joystick to move around the VE) makes passive haptics unusable.

Real walking is a more presence-enhancing locomotion technique than either walking-in-place or flying [4]. However, real walking requires a tracked space as large as the VE. Since the VE is usually larger than the physical environment, real walking limits a VE's possible size. To address this problem, Razzaque, et al. proposed and demonstrated the effectiveness of *redirected walking* [3]. With redirected walking, the virtual world is imperceptibly rotated around the center of the user's head so that as the user explores the potentially infinite VE, he unknowingly walks along curved paths within the limited tracked space.

Both passive haptics and redirected walking are promising solutions to their respective problems, but they impose conflicting constraints on the VE. Passive haptics require positions in the VE to stay coupled with

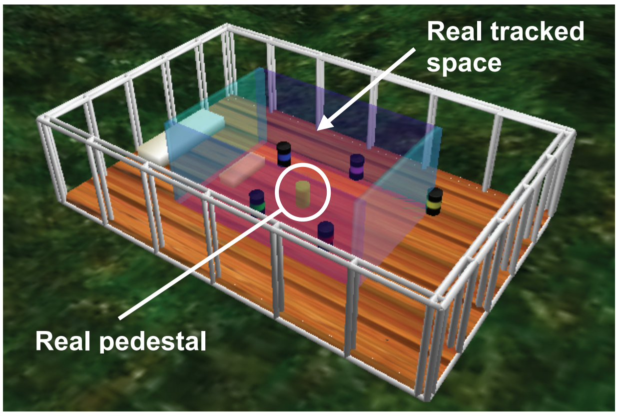

Fig. 1. A view of the virtual environment with the five striped virtual pedestals. A box indicating the size of the real tracked space is superimposed, along with the position of the real pedestal in the center.

positions in the real world. Redirected walking, by its nature, breaks this coupling by rotating the virtual world with respect to the real world.

Unsatisfied with the inability to implement both passive haptics and redirected walking in a given VE, we developed a method to combine them.

2. The Idea

Passive haptics do not actually require a strict one-to-one mapping from positions in the VE to positions in the real world. They do require that a virtual object intended to provide haptic feedback map to a position in the real world that contains a real object. Likewise, every open space in the VE must map to open space in the real world. This mapping could be many-to-many, opening up the possibility that passive haptics could be used even if real and virtual world positions became decoupled.

3. Implementation of a Simple Example

Using the idea behind redirected walking, we can rotate the VE so virtual objects line up with their real-world counterparts. However, this application of redirection requires a precision unnecessary for typical redirected walking – the objects must line up as closely as possible.

As a proof of concept, we dramatically simplified this problem. Our virtual world consisted of a room that was completely empty except for five cylindrical pedestals, chosen for their rotational symmetry (Fig. 1). The real world consisted of empty space except for one cylindrical object intended to provide haptic feedback for all five virtual pedestals (Fig. 2).

Fig. 2. A user touches the one cylindrical object intended to provide haptic feedback. The Styrofoam walls mark the limits of the tracked space.

To bring a virtual object into alignment with its real counterpart by using a pure rotation (one without any translation), the rotation point must be equidistant from the real and virtual objects (so they lie on a circle centered at the rotation point, see Fig. 3).

Only rotation about the user's head will be imperceptible, so the user must move to one of these rotation points and turn his head (more redirection is possible when the user's head is turning). We gave users a task that required them to do so. Users were told that droids had stolen a precious gem collection. To recover the gems, all the droids needed to be activated and destroyed. To activate a droid, users needed to place themselves inside its transporter beam. The beams were placed such that they were in the plane of potential rotation points. When the user reached the beam, a droid appeared, and the user jabbed at it with a neutralizer until it was destroyed. The droid traced out a path that required the user to look back and forth several times.

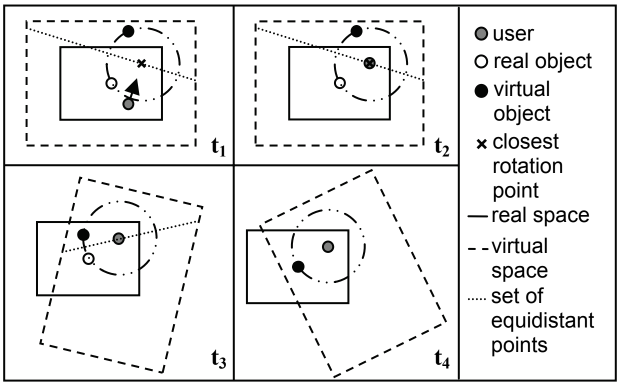

Fig. 3. t_1) User guided towards rotation point, equidistant from real and virtual objects; t_2) user reaches rotation point; t_3) user turns head, virtual world rotates imperceptibly; t_4) real and virtual objects aligned

Users inevitably did not turn precisely about the ideal rotation point. The system tolerated error below a certain threshold, but if it became too large, the user was directed to another transporter beam around which the virtual world could be rotated again to more closely align the real and virtual objects.

4. Conclusion

The technique worked quite well in an informal pilot test. Eight to ten users walked around a VE (8.26m x 13.12m) in a much smaller tracked space (4.13m x 6.56m) and touched five virtual pedestals, which were actually the same pedestal in the real world. Even those users who were told how the system worked were unable to detect the manipulation.

For a more complex VE, this technique would require much more sophisticated user route planning. Adequate route planning may even be impossible for dense environments, especially if objects of different shapes and sizes are used. However, we wish to extend this technique to be useful in environments other than our simple proof of concept. We may explore adding translations to the redirection algorithm so users will not have to pass through a perfect rotation point.

Also, our current method relies on dynamically specified waypoints that the system knows the user is trying to reach. Future research may explore implementing this technique for an arbitrary path, perhaps by using the path prediction proposed by Nitzsche et al. [2].

5. Acknowledgments

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