Poster:
Generic Redirected Walking & Dynamic Passive Haptics: Evaluation and Implications for Virtual Locomotion Interfaces

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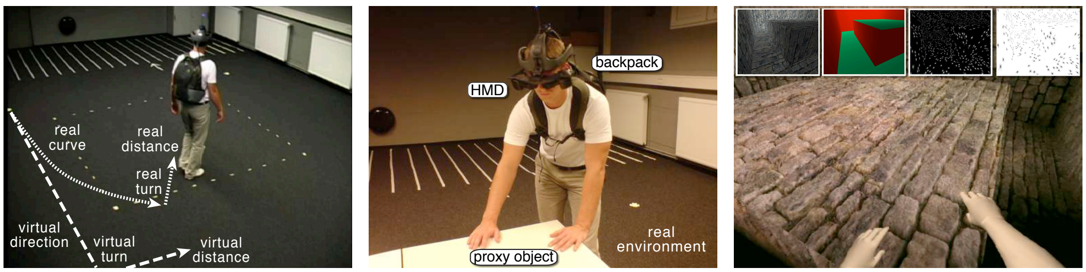

Figure 1: Virtual Locomotion Scenario: a user walks through the real environment on a different path with a different length in comparison to the perceived path in the virtual world (left). The user touches a real proxy object (middle), which is considerably smaller than the virtual object seen from the user's perspective (right) (alternative representations provide different levels of *optical flow* (insets) (right)).

Abstract

In this paper we introduce concepts for virtual locomotion interfaces that support exploration of large-scale virtual environments (VEs) by *real walking*. Based on the results of a pilot study we have quantified to which degree users can unknowingly be redirected in order to guide them through an arbitrarily sized VE in which virtual paths differ from the paths tracked in the real working space. We further introduce the concept of dynamic passive haptics which enables a user to interact with a VE. By means of this concept *any number* of virtual objects can be mapped to real *proxy objects* having similar haptic properties, i. e., size, shape and surface structure, such that the user can sense these virtual objects by touching their real world counterparts. Thus dynamic passive haptics provides the user with the illusion of interacting with a desired virtual object by redirecting her/him to the corresponding proxy object.

Keywords: Virtual Locomotion Interface, Generic Redirected Walking, Dynamic Passive Haptics

1 Introduction

Walking is the most basic and intuitive way of moving within the real world. Keeping such an active ability to navigate through large-scale virtual environments (VEs) is of great interest for many 3D applications demanding locomotion. Although these domains are inherently three-dimensional, most of the applications do not support VR-based user interfaces, least of all *real walking* through the 3D scenes is possible. Therefore, virtual locomotion interfaces are needed that support walking over large distances in the virtual world, while physically remaining within a relatively small space [5]. Many hardware-based approaches have been presented to address this issue. Unfortunately, most of them are very costly, while providing only a single user a notion of walking, and thus they will probably not get beyond a prototype stage.

In this paper we introduce a virtual locomotion interface that allows navigation within any large-scale VE by *real walking*. In contrast to [4] we have developed *generic redirected walking* concepts by combining motion compression, which scales the real distance users walk, rotation compression and gains, which make the real turns smaller or larger, and curvature gains, which bend the user's walking direction such that s/he walks on a curve (see Figure 1 (left)). We introduce the new concept of *dynamic passive haptics* which extends passive haptics [2, 3] in such a way that *any number* of virtual objects can be sensed by means of real *proxy objects* having similar haptic capabilities, i. e., size, shape and surface structure. Dynamic passive haptics provides the user with the illusion of interacting with a desired virtual object by redirecting him/her to the corresponding proxy object (see Figure 1 (middle) and (right)). The mapping from virtual to real objects must not be one-to-one. Since the mapping can be changed dynamically during runtime, a small number of proxy objects suffices to represent a much larger number of virtual objects.

2 Pilot Study and Results

For this purpose we have evaluated in how far the visual appearance of virtual objects may deviate from that of the real objects without the user noticing the difference, i. e., how visual perception dominates proprioceptive and vestibular cues [1].

A total of 8 (7 male and 1 female) subjects participated in the study. Three of them had experience with walking in VR environ-

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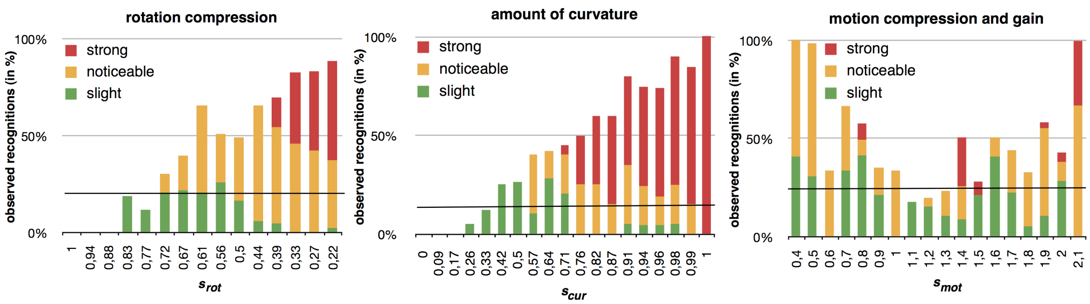

Figure 2: Evaluation of the generic redirected walking concepts for (a) rotation compression factors s_{rot}, (b) amount of curvature s_{cur} and (c) motion compression/gain factors s_{mot}. Different levels of perceived discrepancy are accumulated. The bars indicate how much users have perceived the manipulated walks. The horizontal lines indicate the thresholds as described in Section 2.

ments using an HMD setup. The users' paths always lead them clockwise or counterclockwise around the table which is represented as virtual block in the VE (see Figure 1 (middle) and (right)). The participants were equipped with a HMD backpack consisting of a laptop PC (slave) with a GeForce 7700 Go graphics card and battery power for at least 60 minutes (see Figure 1). We used the WorldViz Precise Position Tracker.

In order to support generic redirected walking concepts as well as dynamic passive haptic strategies, we have modulated the real and the virtual environment by means of the following independent variables:

- **Rotation compression/gain factor** s_{rot} describes the compression/gain of a user's head rotations, i. e., when the user rotates the head by α degrees the virtual camera is rotated by $s_{rot} \cdot \alpha$ degrees.
- **Amount of curvature** s_{cur} denotes the bending of a real path. While the user moves the camera rotates continuously enforcing the user to walk along a curve determined by a segment of a circle with radius r, where $s_{cur} := \frac{1}{r}$. The curve is considered for a normalized distance of $\frac{\pi}{2}$m. In the case that no curvature is applied $r = \infty$ and $s_{cur} = 0$.
- **Motion compression/gain factor** s_{mot} denotes the scaling of translational movements, i. e., 1 unit of physical motion is mapped to s_{mot} units of camera movement in the same direction.
- **Object compression/gain factor** s_{obj} denotes a uniform scaling transformation applied to virtual objects or the entire VE.
- **Level-of-detail (LoD)** represents the degree of realism for the virtual scene. As illustrated in Figure 1 (right) (insets) the scene can be altered from having relief-mapping based on high-quality textures to flat, textured walls and flat-shaded walls.
- **Optical flow** gives indications about the motion of objects within a visual representation. We apply textures to the surfaces of the virtual room which only contain small circles. The number, size and lifetime of the circles can be changed: many circles which do not disappear provide plenty of optical flow, whereas few circles with short lifetimes provide only little optical flow.

We use the above variables in our generic redirected walking concepts, and we have evaluated how they can be modified without the user noticing any changes.

The results are summarized in Figure 2, which shows how strong users have noticed the application of the factors described above. Based on these results we formulate guidelines in order to allow sufficient redirection such that the user neither perceives the redirected walking nor the dynamic scaling of objects:

1. Rotations can be compressed/gained up to 30%,
2. distances can be downscaled to 15% and upscaled to 45%,
3. users can be redirected such that they unknowingly walk on a circle with a radius up to 3.3m,
4. objects/VE can be downscaled to 38% and upscaled to 45%.

Indeed, perception is a subjective matter but with these guidelines only a reasonably small number of walks is perceived as manipulated.

3 Conclusion

In this paper we have introduced software-based solutions to provide low-cost virtual locomotion interfaces. The interface has been designed according to guidelines which we have identified on the basis of the results of a pilot study. With our approach it becomes possible to explore arbitrary VEs by real walking. The challenge of natural traveling in limited tracking space has been resolved sufficiently by redirected walking approaches, whereas dynamic passive feedback provides the user with the possibility to touch virtual objects respectively associated proxy objects.

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