Towards Context-Sensitive Reorientation for Real Walking in Virtual Reality

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ABSTRACT

Redirected walking techniques have been introduced to overcome physical limitations for natural locomotion in virtual reality. Although subtle perceptual manipulations are helpful to keep users within relatively small tracked spaces, it is inevitable that users will approach critical boundary limits. Current solutions to this problem involve breaks in presence by introducing distractors, or freezing the virtual world relative to the user's perspective. We propose an approach that integrates into the virtual world narrative to draw users' attention and to cause them to temporarily alter their course to avoid going off bounds. This method ties together unnoticeable translation, rotation, and curvature gains, efficiently reorienting the user while maintaining the user's sense of immersion. We also discuss how this new method can be effectively used in conjunction with other reorientation techniques.

Index Terms: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities; I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction techniques; I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual reality

1 MOTIVATION

Enabling natural exploration of interactive virtual environments in a manner similar to the way people move in the real world is highly desirable for many practical applications. While physical walking in a tracked space has many advantages over other locomotion methods, the physical dimensions of the tracked area ultimately constrain the size of the virtual environment that can be explored.

Redirected walking attempts to address this issue though subtle manipulation of the mapping between physical and virtual motions to steer the user away from the boundaries of the physical space. For example, one might introduce a rotation "gain", rotating the virtual view faster or slower than the corresponding physical movement. For these manipulations to remain unnoticed, the applied gains should stay below human sensitivity thresholds. Typically there is also a need for periodic reorientation of the users when subtle redirection fails to prevent them from exiting the physical workspace.

In practice, users are rarely abandoned to wander aimlessly through the virtual environmnet, but are rather meant to become part of an unfolding interactive scenario while maintaining a degree of agency. General purpose reorientation techniques that intrude upon the scenario context, interrupt the flow of the virtual narrative. For example, Williams et al. [3] proposed a *reset* technique that directs the user to physically turn while the view in the virtual world remains frozen. Arguably, such a technique can be quite disruptive in a reasonably fast-paced scenario.

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To make reorientation less intrusive Peck et al. [1] introduced the idea of *reorientation with distractors*. They used a virtual hummingbird to grab the user's attention, triggering head rotations that were used for reorientation. While the use of distractors does not seem to have adverse effects on navigation and wayfinding, general purpose distractors are still likely to appear out-of-place within the context of the virtual narrative and their frequent use can be bothersome.

Here we present an ongoing project attempting to overcome these issues more organically, spawning reorientation events in the virtual world narrative. We analyze methods to improve efficiency of reorientation techniques and introduce the *Rotate-and-Walk* technique designed to be a more efficient alternative to existing approaches. We illustrate the utility of this technique type and show how it can be seamlessly integrated into the simulation scenario. We also discuss the use of this technique in conjunction with other reorientation methods for a seamless, complete redirection experience. Finally, we present an outline of future user studies to investigate research questions raised in this paper.

2 REOREINTATION TECHNIQUES

2.1 Rotation-Only Techniques

Redirection with distractors as well as most other reorientation techniques proposed to date rely exclusively on rotation gains to manipulate relative orientation between virtual environment and the tracking area. In that sense we can classify these techniques as *Rotation-Only*.

The efficiency of Rotation-Only reorientation procedures is limited by keeping the rotation gains below the sensitivity thresholds to ensure that users are not very likely to notice the manipulation. This relative inefficiency can lead to excessively long interactions with distractors [2] and it is also difficult to provide convincing scenario-consistent motivation for large and repeated in-place rotations.

One way to improve reorientation efficiency is to use higher rotation gains. It may be possible to initiate high-impact events within the virtual world narrative, keeping the user preoccupied and, therefore, less likely to notice larger discrepancies between real and virtual rotations. In a tactical training simulation, for example, the user may be less likely to notice increased rotation gains after hearing a commotion and being forced to abruptly duck and take cover.

2.2 The Rotate-and-Walk Technique

The rotation-only approach can potentially be improved by combining rotation gains with other redirection methods such as curvature and translation gains for greater efficiency. *Curvature gains* can be used to slightly rotate virtual environment when the user performs translational movement. As users tend to use visual feedback to correct their heading, this manipulation results in curved physical paths while maintaining the illusion that users are maintaining their course in the virtual world. *Translation gains* can be used to scale visual movement in virtual environment relative to the user's physical movement effectively repositioning the boundary of the tracking area closer to or away from virtual targets.

To take advantage of the full arsenal of available redirection methods, we propose a new type of reorientation technique that can

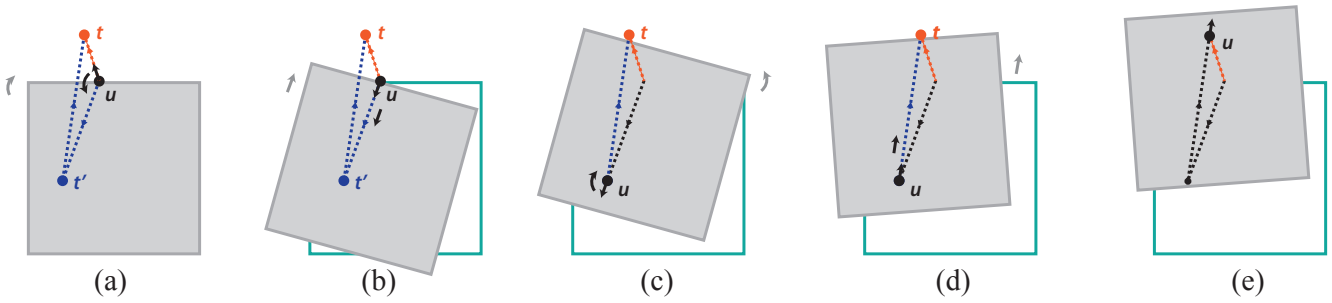

Figure 1: The Rotate-and-Walk reorientation technique. (a) user u heading to target t reaches the boundary of the tracking area and is directed to a secondary target t'; (b) through (e) illustrates changes to the tracking area's configuration with respect to the virtual world as the user clears target t' and eventually reaches the original target t. Changes correspond to the user's visual perspective, i.e. the tracking area changes position and orientation relative to a stable virtual environment. For simplicity no curvature gains are shown.

be labeled as *Rotate-and-Walk*. It involves temporarily directing user attention to a newly introduced side-objective that would naturally take precedence over the original goal. As the user attends to this side objective, an opportunity arises to manipulate the mapping between the virtual environment and the tracking area using using all three types of gains discussed above. Figure 1 shows an example where the user reaches the boundary of the tracked space before arriving to the intended target. In this particular example, the Rotate-And-Walk technique creates a temporary diversion and then for simplicity uses only a combination of rotation and translation gains to ensure that user can successfully reach the original target.

Placement of temporary objectives within the bounds of the tracking area helps ensure sufficiently large physical rotations. Rotation gains are applied proportionally to the amount of physical rotation, therefore larger physical rotations lead to greater reorientation efficiency. When the user is directed to walk to a new target, it can be shown that the total physical rotation will be higher compared to the case where the user simply rotates towards the new target and back. The Rotate-And-Walk technique also introduces additional translation in the real environment that can potentially be exploited for reorientation via curvature and translation gains. In the example above we assume a greedy heuristic that maximizes translation gains within the bounds of empirically calculated noticeability thresholds and applies them along the user's travel direction (Figures 1(b) and 1(d)). When the user is generally travelling towards the original target, physical translation is scaled up; when the user is travelling away from the original target, physical translation is scaled down. From the virtual environment prospective this effectively results in the tracking area "sliding" towards the original target along the axis defined by user's current direction of travel.

The Rotate-and-Walk technique can be naturally integrated into the virtual world narrative. Consider for example a virtual character strategically placed at the secondary target location. When the user's position calls for a reorientation procedure, the virtual character may beckon the user to approach the avatar for purpose of assistance, or other narrative-germane activities.

3 Planning for Reorientation

Weaving reorientation events into the fabric of a simulation in a natural, organic manner requires a certain degree of sensitivity to the scenario context. For instance, if the narrative flow is about to shift into an essential fast-paced phase, it may be beneficial to preemptively reorient the user in order to minimize the chance of interruption at critical moments.

Another important goal is to avoid using the same reorientation procedure repeatedly. Peck et al.[2] reported poor user ratings for situations in which the same reorientation method was applied too often. Compiling a sufficiently large repertoire of various reorientation methods may help alleviate this problem.

It is noteworthy that context-sensitive reorientation methods may also restrict their applicability to certain pre-planned locations. As an example, if an implementation of the Rotate-and-Walk technique involves a particular virtual character, the method can only be used when the character is situated in the user's vicinity. This type of dependency helps tie reorientation events into the storyline, but can also restrict the applicability of a particular method when urgent reorientation is required.

A complete reorientation planning algorithm should have access to an array of various methods to spawn a reorientation event. Ideally there would be a mix of location-dependent events that can be more seamlessly integrated into the scenario and location-independent events to urgently deter the user from leaving the bounds of the tracked space. The context sensitive algorithm should be able to select and time reorientation events depending on a multitude of factors including availability of pre-planned event triggers in the user's vicinity, the current context of the interactive scenario, the history of previous reorientation events, and the user's current position relative to the tracking area boundaries.

4 Future Work

We are currently working on exploring the issues discussed in this paper in a series of user studies. First, we plan to explore to what extent can the notability thresholds for rotation gain be relaxed when applied in conjunction with an high-impact event that abruptly changes the dynamics of the simulation scenario (such as taking cover under sudden fire). Second, we plan to evaluate the effectiveness of the Walk-And-Rotate technique. Third, we are working on applying the ideas discussed in this paper to design a prototype system that combines a variety of reorientation techniques embedded within a training narrative to enable naturalistic, uninterrupted exploration of a relatively long virtual course.

References

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