Analysis of Positional Tracking Space Usage when using Teleportation

Aniruddha Prithul* Eelke Folmer†

Department of Computer Science and Engineering
University of Nevada, Reno

ABSTRACT

Teleportation is a widely used virtual locomotion technique that allows users to navigate beyond the confines of available tracking space with a low possibility of inducing VR sickness. Because teleportation requires little physical effort and lets users traverse large distances instantly, a risk is that over time users might only use teleportation and abandon walking input. This paper provides insight into this risk by presenting results from a study that analyzes tracking space usage of three popular commercially available VR games that rely on teleportation. Our study confirms that positional tracking usage is limited by the use of teleportation.

Keywords: Virtual Reality, Teleportation, Locomotion

1 INTRODUCTION

For virtual locomotion, natural walking using positional tracking is considered to offer the most natural and immersive experience with a low chance of inducing VR sickness [1]. However, available walking space is often bounded by positional tracking constraints (i.e., 15x15 feet for Vive/Oculus) and available physical space, with most users only freeing up enough space to meet the minimum tracking space requirements [5]. An ongoing research challenge for virtual locomotion has been to explore alternative locomotion techniques (ALT) (see [1] for an overview) that allow users to navigate beyond tracking space boundaries in the most intuitive and immersive way without inducing VR sickness. Teleportation is currently the most widely used ALT used in conjunction with positional tracking input. Because it discontinuously translates the user's viewpoint, there is no optical flow which reduces visual-vestibular conflict and VR sickness incidence [7]. Despite wide adoption and ease of use, teleportation has been identified to exhibit some problems. First, compared to real walking, teleportation is considered to offer a low presence as it lets users do something that does not exist in real life. Second, the lack of optical flow in the viewpoint transition limits the user's ability to perform path integration (i.e. estimating distance travelled) which may cause spatial disorientation [2] though a small amount of optical flow can be added to mitigate this [3]. Third, discontinuous displacement of users can alter intended gameplay [8], and is especially a challenge for multiplayer games as it becomes difficult to predict or follow the path of other users when they teleport around. One solution for maintaining a continuous avatar presence is to switch perspectives [6].

In this paper we identify another problem with teleportation that to our best knowledge has not been investigated. When teleportation is used in conjunction with positional tracking, available walking space is a crucial factor in the user's decision whether or not to switch to using teleport. When a user is navigating towards a location that lies outside the tracking space, they may first try to walk to it, reach the edge of the tracking space and then switch to teleport to reach their destination. If users keep heading in the same direction, they are basically stuck at the edge and have no choice but to keep using teleport. Our user study provides insight into this problem.

*e-mail: aprithul@nevada.unr.edu
†e-mail:efolmer@unr.edu

2 POSITIONAL TRACKING STUDY

We used the HTC Vive, which offers a 1080x1200 per-eye resolution at 90 Hz and a 110° field of view. We configured our tracking space to have a size of 2.4m x 2.2m, chosen based on results of a survey conducted by Vive [5], which found this size to be most common. A TPCast wireless adapter was used to allow users to play the games untethered as a cable can impede movement within the tracking space. To power the HMD receiver, users wore a 354 gram 20,000mAH battery pack on their belt or pocket. A standalone script using OpenVR was used to access the HTC Vive's hardware for positional tracking data through SteamVR. The script saved separate CSV files for positional data, tracking space corner positions, and time elapsed. Positional data in the form of an (x,y) pair was collected once every 100*ms*.

We selected three different commercially available VR games:(*Arizona Sunshine*, *Budget Cuts* and *Vanishing Realms*) based on the following criteria: (1) they were all different in genre (e.g., a shooter, a puzzle/stealth and role playing game) and (2) all games received at least a 1,000 positive reviews on Valve's Steam digital distribution platform.

We recruited 7 participants (7 males, average age 25.0, SD=4.6) for our user study. All participants had experience playing 3D games with some having VR experience. The user study was approved by an IRB.

After explaining the aim of the study, we told the participants that the data was anonymized and that their position in the tracking space will be recorded. Participants played each of the three games in a randomized order, with approximately 15 minutes rest between each game. All games use teleportation using a controller activated by pressing the trigger or the touchpad. Budget Cuts uses a slightly different teleportation mechanism as it shows the user a preview of the area to be teleported to. Participants would typically first play a tutorial to familiarize themselves with the controls and the specific game mechanics. For each game, we selected a specific level or part to play that took approximately 10-15 minutes to complete.

For all three games, if a participant died, they were instructed to continue playing from the current progression point.

2.1 Results and Conclusion

The CSV files that were collected for each user and game were imported into a custom R script for data analysis. We used a custom R script using bin2 from the ash library to generate heatmaps with contour lines from each participant's positional data set. The corners of the rectangular tracking space are shown as black dots on the heatmaps. The same variable range was used in the binning of all of the participants' positional data and was determined from all of the participants' data. The results are listed in Figure 1.

As can be observed, the heat-maps vary significantly between participants and between games. For example, participants P1, P2, P3, P4 and P6 on average seemed to move around more than P5 and P7 as is evident by that their heatmaps were more spread out. P5 and P7 were both experienced VR users. The heatmaps for

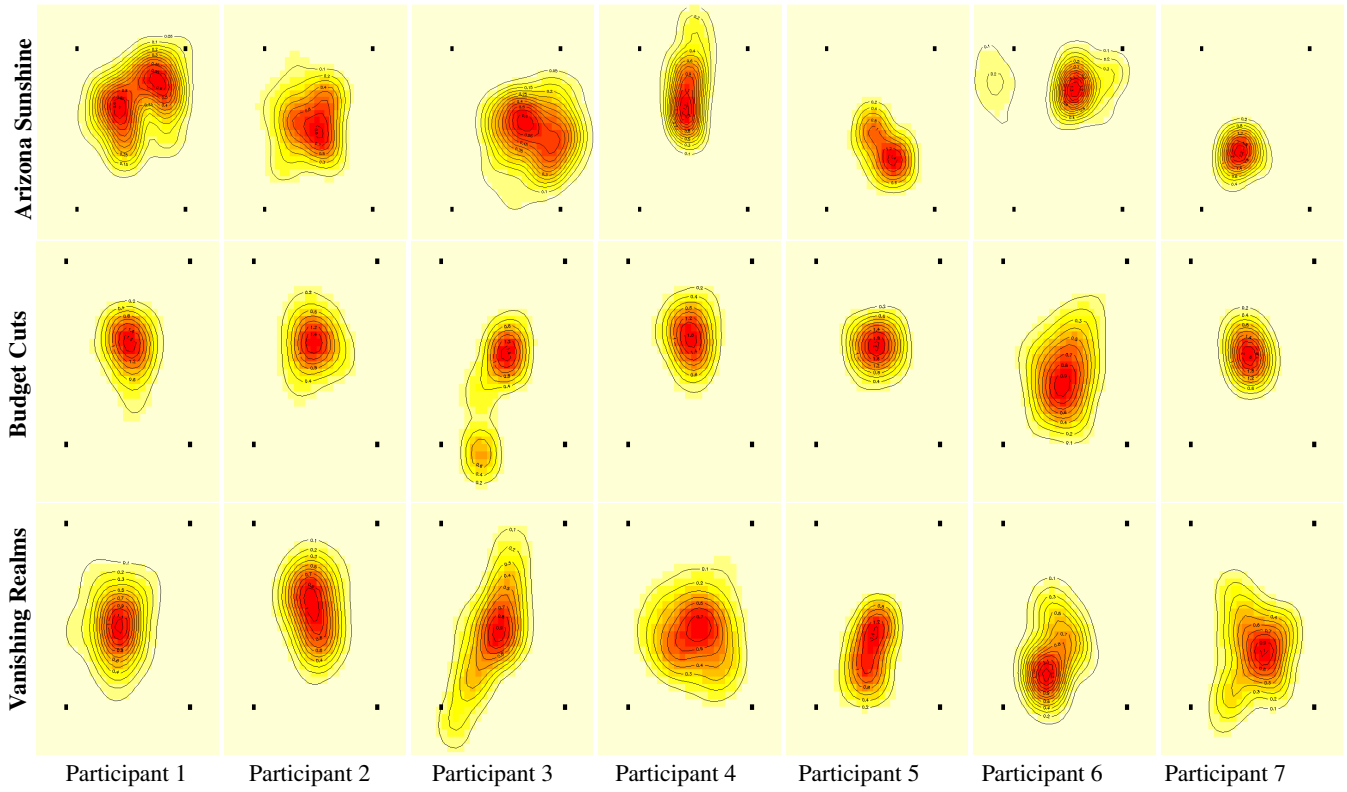

Figure 1: heatmaps showing positional tracking data for 7 users playing three different VR games. The columns indicate the 7 participants and the rows are the games that were played. The black dots indicate the four corners of the available tracking space. Darker red colors indicate a higher frequency of the user being in that location.

Vanishing Realms and Arizona Sunshine were more spread out than for Budget cuts (except for P5). An explanation for this could be that those games required users to fight lots of enemies, and which might require users to move around more to dodge attacks. Budget cuts has fewer enemies that can often be eliminated using stealth (throwing a knife at them from a distance). Because it is a stealth game, and the teleport preview can be used to spy on areas that the user cannot see directly, it actually encourages the use of teleportation and generally requires very little walking, which is a notable difference from the other two games. The levels in Budget cuts are also fairly small with users moving between floors using an elevator which doesn't require a lot of walking, unlike Arizona Sunshine where the level the participants played was elongated with users mostly navigating in a single direction. As a result for Arizona Sunshine, the heatmaps were often centered close to the border of the tracking space (P3,P4) or in a corner (P1, P5, P6, P7).

A quantitative analysis of tracking space utilization was done by binning the positional data of each participant that lies within the rectangular tracking space into 1600 bins (40 by 40). The section of tracking space that a bin represents is considered utilized if it is not 0. The fraction of bins that were utilized is the user's tracking space utilization rate. An analysis of tracking space utilization showed that at most 52% of the available tracking space was used (P3, Vanishing Realms) and at a minimum 7% (P7, Arizona Sunshine) and on average 26% of available tracking space was used. A visual analysis of the 21 heatmaps shows that 11 were in the center of the tracking space, 5 at the edge and 5 in a corner. If we exclude the maps for Budget Cuts, which doesn't require users to walk a lot, 14 maps remain with 5 centered at the center, 4 centered at an edge and 5 in a corner.

Though this was a small study, we believe it largely confirms the issue with teleportation that we discussed in introduction. With teleportation available to them, users largely abandon walking, either because it is faster than walking or more likely because they find themselves stuck at the edge of the tracking space where the opportunity for walking is limited. Even to travel small distances, users must use teleportation, which could be detrimental to presence. Our results are especially surprising given that participants could play each game untethered and weren't limited in mobility by cables, which maybe more common for consumer VR. This project was supported by NSF grant 1911041 and NIH Award P20GM103650.

References

[1] M. Al Zayer, P. MacNeilage, and E. Folmer. Virtual locomotion: a survey. *IEEE trans. on visualization and computer graphics*, 2018.

[2] N. H. Bakker, P. O. Passenier, and P. J. Werkhoven. Effects of head-slaved navigation and the use of teleports on spatial orientation in virtual environments. *Human Factors*, 45(1):160–169, 2003.

[3] J. Bhandari, P. MacNeilage, and E. Folmer. Teleportation without spatial disorientation using optical flow cues. In *Proceedings of Graphics Interface*, pp. 162 – 167. 2018.

[4] J. Bhandari, S. Tregillus, and E. Folmer. Legomotion: Scalable walking-based virtual locomotion. In *Proceedings of VRST'17*, pp. 18:1–18:8.

[5] J. Feltham. Vrfocus: Htc: People will use 'a smaller space' for vive's room scale tracking, `https://www.vrfocus.com/2015/11/htc-people-will-use-a-smaller-space-for-vives-room-scale-tracking/`.

[6] N. N. Griffin and E. Folmer. Out-of-body locomotion: Vectionless navigation with a continuous avatar representation. *Proceedings of VRST '19*, 2019.

[7] N. N. Griffin, J. Liu, and E. Folmer. Evaluation of handsbusy vs hands-free virtual locomotion. In *Proceedings of CHI PLAY*, pp. 211–219.

[8] J. Martindale. Digital trends: How should we move around in VR? nobody has figured it out yet. `http://www.digitaltrends.com/virtual-reality/vr-locomotion-movement-omni-hover-junkers`, July 2016.