Do Textures and Global Illumination Influence the Perception of Redirected Walking Based on Translational Gain?

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ABSTRACT

For locomotion in virtual environments (VE) the method of redirected walking (RDW) enables users to explore large virtual areas within a restricted physical space by (almost) natural walking. The trick behind this method is to manipulate the virtual camera in an user-undetectable manner that leads to a change of his movements. If the virtual camera is manipulated too strong then the user recognizes this manipulation and reacts accordingly. We studied the effect of human perception of RDW under the influence of the level of realism in rendering the virtual scene.

Keywords: Virtual Reality, Locomotion, Human Perception.

1 INTRODUCTION

Virtual Reality (VR) allows the creation of infinitely large virtual worlds. Travel through such Virtual Environments (VEs) with hand based devices creates a mismatch between the movement of the virtual camera and the movement of the user in the real world. An approach to avoid this misalignment is to track the user's movement in a large walking area. This leads to better immersion and increases the user's presence [10].

However this technique is limited to the available real world space. Hence, Redirected Walking (RDW) has been proposed as a locomotion technique for large tracking areas where the virtual motion is manipulated in a clever way [6]. The movement of the virtual camera can be bent, stretched or compressed to manipulate the real human movement. Recently a RDW technique applicable to room-scale VR has been proposed [4]. RDW works because the visual perception dominates the proprioceptive and vestibular senses [1, 2, 11].

2 PREVIOUS WORK

Several researchers have shown that distances in virtual world are underestimated in comparison to the real world [3, 5]. The exact reason is still unclear [7].

Steinecke et al. [9] presented a locomotion guideline for RDW. Their technique uses different gain and compression factors for the translation, rotation and curvature to guide a user along a virtual path. The gain g_T for translation is defined as $g_T = \frac{T_{virtual}}{T_{real}}$ where $T_{virtual}$ is the virtual and T_{real} the real movement. They propose an interval for the values of g_T where the manipulation is not noticeable for most users. Later the interval was reduced to $g_T \in [0.86, 1.26]$ [8].

Steinecke et al. [9] shortly remarked that switching the rendering of the scene between textured, Gouraud shaded and textured with circles had no effect on the perception under different gain factors. Only in cases of drastically reduced optical flow users tended to notice the redirection less.

To our knowledge the influence of global illumination on the perception of redirection has not been previously investigated. We hypothetized that global illumination would create an larger optical flow and thus the users would notice redirection more.

3 EXPERIMENT

The purpose of this experiment was to understand if using textures and global illumination for rendering a virtual scene influences the human perception of redirected walking. We focused only on translational RDW and exposed the participants to four different rendering modes of a VE (cf. Figure 1).

3.1 Material and Setup

The experiment took place within a *Optitrack* motion capturing system with a 5m×8m capture area. The participants wore an *Oculus CV1* HMD connected to a backpack computer. The head's position was tracked by the motion capturing system while its rotation was directly obtained from the sensors of the HMD. A stationary server running the motion capture software communicated wirelessly with the participant's computer, providing the positional data. The server was also used to send commands to the VR application to switch seamlessly between the different conditions of the experiment.

3.2 Conditions

Each participant experienced the VE with nine gain factors and four rendering modes, which resulted into a total of 36 different conditions. Nine gain factors $g_T \in \{0.4, 0.55, 0.7, 0.85, 1, 1.3, 1.65, 1.8.2\}$ were derived from the locomotion guideline published by Steinecke et al. [9]. Originally, the step sizes between the gains were all 0.1. But this would have resulted in a too large condition count. Therefore we choose to use larger step sizes. The geometry of the scene was not changed during the experiment. The four rendering modes were:

- **Simple**: Flat colors and a reduced illumination model just taking diffuse shading into account. The *Unity 3D* illumination model was used. A directional and an ambient light source were present in the scene. The specular amount of the material was reduced to the minimum.
- **Simple & GI**: The local reflections are treated as for the simple rendering. Additionally, global illumination (GI) was added via baked light maps with direct shadows, ambient occlusion and indirect lighting.
- **Textures**: Textures were added to the surfaces of the geometry. The illumination model was the same as in the simple mode.
- **Textures & GI**: This mode fuses the GI with the texture mode.

3.3 Procedure

A total of $n = 20$ subjects (15 male, 5 female, average age 26) participated in the study. 60% had previous experience with VR.

A first test served to find out how well the participants estimate the distance they walk in reality while experience the VE. Each participant was instructed to walk a specific distance (given in meters)

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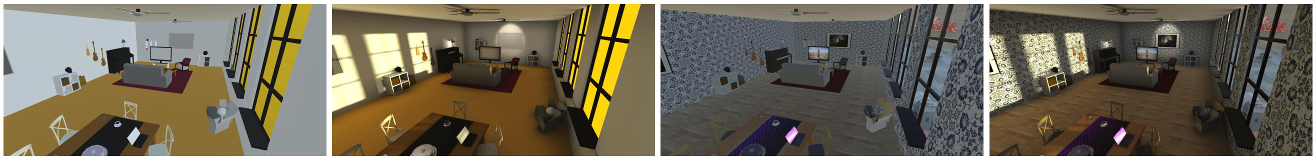

(a) Simple (b) Simple & GI (c) Textures (d) Textures & GI

Figure 1: The appearances of the scene: **(a)** is the most reduced version using mainly diffuse shading while **(b)** uses the global illumination (GI) and light maps. **(c)** additionally has textures instead of one color per object. **(d)** is the most realistic one since it uses both textures and GI.

and then to stop. The actually walked distance of the participant was compared to the requested distance. We assumed that differences in overestimation influences the perception of RDW. After this test all participants were instructed with a virtual slide in the VE for the second part of the experiment. Then, each participant was exposed to every condition in a random order for counterbalancing.

For each of the 36 conditions, the participants were randomly placed in a room in the VE with the appropriate condition and instructed to move to another position in the same room. Once at this position, the participants had to perform one of three predefined actions (push a button, pull a lever or walk to a green area). Afterwards the participants were teleported to a "neutral room" without any gain factor. There the participants were asked if they perceived any gain or compression of their movements which was rated on a five point likert scale (range "not noticeable" to "very strong noticeable"). After their rating, the participants were repositioned and teleported to the next room with a new condition.

3.4 Analysis of the Results

In the first test the participants overestimated their covered distance by an average of -6.03% ($sd = 0.15$).No correlation was found between this test and the second part of our study.

We found that the influence of a textured and illuminated VE is not significant compared to the simple initial VE. An analysis of variance (ANOVA) with an error rate of $\alpha = 5\%$ demonstrates that the difference between the conditions *Simple, Simple&GI, Textured and Textured&GI* is not significant ($F = 1.0$; $P = 0.39$). Figure 2 summarizes the resulting ratings. The scale is numbered from 1 = not noticeable to 5 = very strong noticeable. The results are close together which is also indicated by the ANOVA. The strongest effect for the *Textured* condition was observed for a gain factor of 1.3 when compared to the other rendering conditions ($\alpha = 10\%$;$F = 2.54$; $P = 0.11$). Finally, we found a significant difference between the conditions 1.0 and 1.3 ($\alpha = 5\%$;$F = 6.25$; $P = 0.013$).

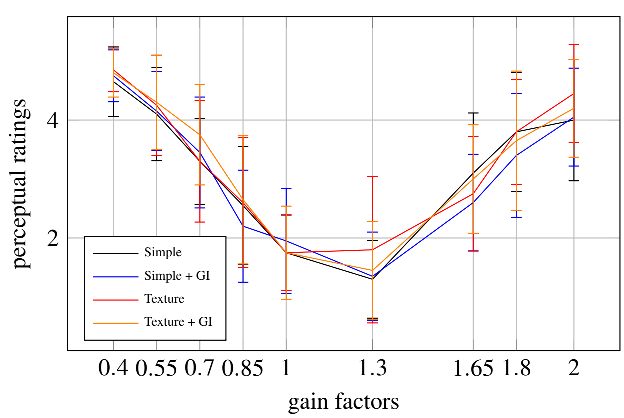

Figure 2: The average perceptual ratings for each condition with standard deviation

4 Discussion and Future Work

We conclude that the human perception does not change when a person uses RDW in a textured or globally illuminated Virtual Environment. The study was designed to have larger step size beyond the previously reported thresholds of 0.85 and 1.3 [8] since we expected effects in this range. For a future study it would worthwhile to decrease the step size around the neutral gain factor of 1.0.

Another interesting fact is that most of the people perceived the translation gain $g_T = 1.30$ as the most neutral. In this case the real movement and the virtual displayed motion showed the least difference based on the subjects ratings. This aspect can be explained by the under estimation of distances where the virtual world seems more compressed than the real world [3,5]. As a consequence a 30% larger virtual walking area could be used for future VR application without the user noticing any uncomfortable mismatch to his or her real movements. This would result in a more efficient usage of the available walking space.

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