Dynamic Foveated Rendering for Redirected Walking in Virtual Reality

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1 INTRODUCTION

In this work we present a novel technique for redirected walking in VR based on the psychological phenomenon of *inattentional blindness*. Based on the user's visual fixation points we divide the user's field of view (FoV) into zones. Spatially-varying rotations are then applied according to the zone's importance and are rendered using foveated rendering. Our technique is real-time and applicable to small and large physical spaces. Furthermore, the proposed technique does not require the use of stimulated saccades [Sun et al. 2018] but rather takes advantage of naturally occurring major and minor saccades and blinks to perform a complete refresh of the framebuffer. We performed extensive testing with the analysis of the results presented from three user studies conducted for the evaluation. Results show that the proposed technique is indeed viable and users were able to walk straight for more than 100m in VE within the confines of $4x4m^2$ of PTS.

2 TECHNICAL OVERVIEW

A blended render of the VE is shown to the user with the help of two co-located cameras, Camfoveal and Camnon−foveal. Based on the results from our first user study, we have determined that the FoV for Camfoveal is $\delta = 60°$, and the rotation angle applied to the VE and rendered from Camnon−foveal is $13.5° > \theta > 0°$. For making a smooth transition from foveal to non-foveal zones, a circular alpha mask with smooth boundaries corresponding to $\delta = 60°$ is applied on the rendered image of Camfoveal, and the inverse of the same mask is applied on the rendered image of Camnon−foveal. Smoothing the boundaries results in a transition zone between foveal and non-foveal zones. The resulting masked renders are then composited into a final render displayed to the user (Fig.1 Left). A safety reset mechanism is also added for ensuring the user does not collide with objects in the PTS. In such cases, this prompts the user to turn in-situ by 180° while the VE is rotated by the same amount in the opposite direction. As demonstrated by the results from the subsequent two user studies, #2 and #3, the users fail to perceive any visual distractions or artifacts in the final composite render as they are preoccupied with a significant cognitive task on hand; which is almost always the case in VR applications.

The proposed system was developed using Unity3D game engine and the hardware used for its evaluation was HTC Vive Pro Eye HMD with integrated Tobii Eye Tracker. Using dynamic foveated rendering supported by NVIDIA RTX 2080Ti graphics card enables real-time performance. The pixels in the foveal zone are rendered at a higher resolution (1:1 sampling), in the transition zone at a medium resolution (4:1 sampling) and in the non-foveal (Peripheral) zone at a lower resolution (16:1 sampling).

3 EVALUATION

We performed 3 user studies for the evaluation. In user study #1 we determined the maximum rotation angle for the peripheral zone (13.5°) and FoV of the foveal zone (60°); in user study #2 we confirmed the results of the first #1; in user study #3 we assessed the efficacy of redirected walking using the proposed technique in a room-scale PTS of $4x4m^2$ within the context of a custom designed first person shooter game (Fig. 2 left) which contained long straight walks. Fig. 1 show examples of the physical (orange) and virtual (blue) paths for a user during the final study. The cyan colored box indicates the PTS and the camera icon in it corresponds to the user's position. As shown the user covered a distance of 54.2m almost in a straight line to reach the final goal. Furthermore, we compared the number of resets required for each user to reach their goal with and without using redirection as shown in Fig. 2. We also performed Kennedy's simulator sickness test after each study which showed an insignificant impact on the sickness experienced amongst the participants.

Furthermore, a one-way between groups ANOVA (α =0.05) with repeated measures was performed post user study #3 to compare the effects of with and without redirection on the dependent variables: (a) number of resets, (b) distance traveled in PTS, and (c) total time taken. These variables passed Levene's homogeneity test. Partial eta squared (η^2_p) is used to report the obtained effect sizes for each variable.

ANOVA showed a statistically significant difference between the number of resets when the game was played with and without using redirection ($F(1, 48) = 375.710$, $p<0.001$) with $\eta^2_p = 0.887$. Nonetheless, these results also showed a statistically insignificant

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