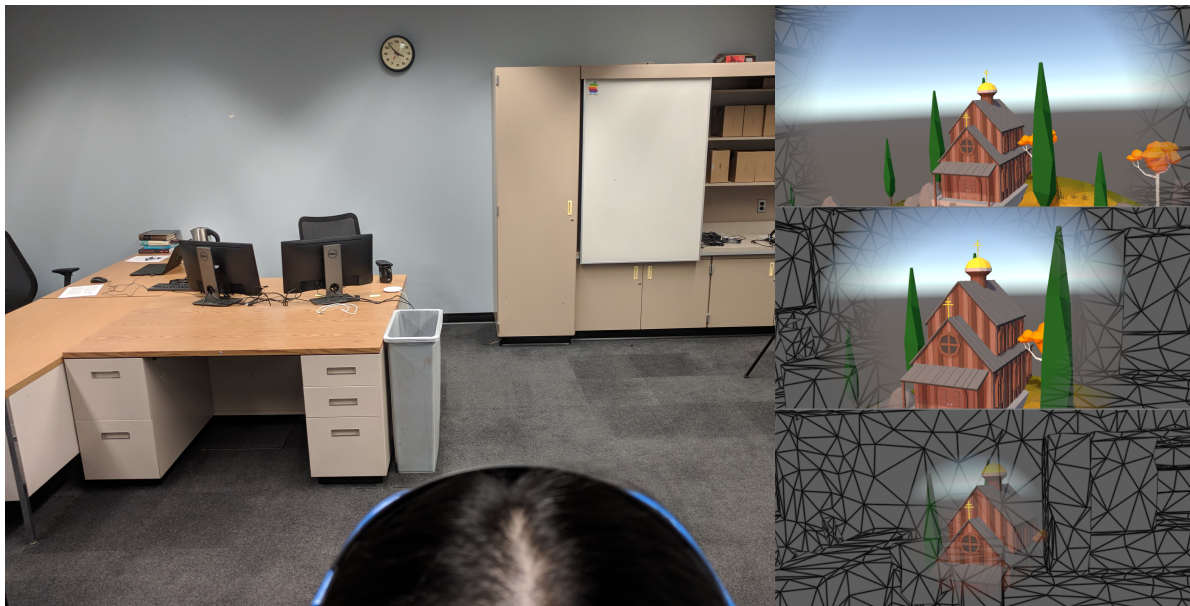


Combining Dynamic Field of View Modification with Physical Obstacle Avoidance

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(a) Real World

(b) Virtual Environment

Figure 1: (a) A virtual reality setup that allows the user to walk within a “room-scale” space bounded by the furniture and walls. (b) During movement, the displayed field of view of the virtual environment is dynamically reduced, revealing a wireframe 3D mesh of the physical environment. This provides a stable reference frame to mitigate motion sickness while simultaneously providing spatial cues that can help prevent collisions with real world obstacles.

ABSTRACT

Motion sickness is a major cause of discomfort for users of virtual reality (VR) systems. Over the past several years, several techniques have been proposed to mitigate motion sickness, such as high-quality “room-scale” tracking systems, dynamic field of view modification, and displaying static or dynamic rest frames. At the same time, an absence of real world spatial cues may cause trouble during movement in virtual reality, and users may collide with physical obstacles. To address both of these problems, we propose a novel technique that combines dynamic field of view modification with rest frames generated from 3D scans of the physical environment. As the users moves, either physically and/or virtually, the displayed field of view can be artificially reduced to reveal a wireframe visualization of the real world geometry in the periphery, rendered in the same reference frame as the user. Although empirical studies have not yet been conducted, informal testing suggests that this approach is a promising method for reducing motion sickness and improving user safety at the same time.

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1 INTRODUCTION

Virtual reality (VR) technologies have experienced widespread proliferation over the past several years. However, the effectiveness of VR applications and the rate of public adoption is currently limited by the fact that many users experience physical discomfort during and/or after their use, with symptomatic characteristics indicative of motion sickness. Users who encounter motion sickness may discontinue the experience early or potentially stop them from trying a VR system again in the future. Although the etiology of virtual reality motion sickness is still an area of active study, a visual-vestibular mismatch between the user’s physical movements and the displayed motion in the virtual world is known to be strongly associated with increased levels of motion sickness. Unfortunately, in most VR systems, it is only possible to physically move within a relatively small area. Therefore, the vast majority of VR applications must rely on virtual locomotion techniques (e.g., using a handheld controller) even though many users experience discomfort during their use.

Numerous methods have been proposed to mitigate motion sickness in virtual reality. For example, studies have indicated that that introducing a independent visual background may reduce simulation sickness [4]. Dynamically reducing the displayed field of view (FOV) in a head-mounted display was also shown to provide advantages to reduce motion sickness during artificial locomotion [1] [3].

This technique, also known as “tunneling,” has rapidly become standard practice and has been implemented in numerous commercial applications such as Ubisoft’s *Eagle Flight* and *Skyrim VR*. A recent paper has also found evidence that users feel more comfortable in a virtual environment with a rest frame, which is part of the virtual environment that remains fixed in relation to the real world [2]. Some VR applications (e.g., *Google Earth VR*, have combined dynamic FOV modification with rest frames, resulting in a “tunnel-vision” effect where a fixed virtual environment is displayed in the periphery, usually with a fade effect around the seams of the virtual world imagery in the center of the display.

With the introduction of the HTC Vive, “room-scale” VR experiences became possible using consumer-level equipment. In these setups, natural walking is possible within the physical dimensions of a single room (e.g., 5m x 5m), resulting in a more comfortable user experience. However, most virtual environments are much larger than the available physical space, and so these applications commonly use a hybrid approach that combines both natural and virtual locomotion. This approach requires that the user maintain awareness of their locations in both the virtual environment and the real world simultaneously. Otherwise, the user may crash into physical obstacles such as walls or furniture. Furthermore, collisions may occur even when users are attempting to remain in the center of the room while primarily using virtual locomotion, because they will often “drift” when physically turning in place. As a result, virtual overlays, also known as “chaperones,” are commonly displayed when the user approaches the boundaries of the physical space. While this can prevent a potential collision, their use is visually intrusive because they are overlaid on top of the virtual environment. Additionally, chaperones are generally represented as bounding boxes around an empty rectangular space, which does not correspond to the practical constraints of VR setups “in the wild,” which may contain complex boundaries and interior obstacles.

In this paper, we present a novel technique that attempts to address both motion sickness and physical collision avoidance simultaneously in “room-scale” VR setups that involve both virtual and physical locomotion. Similar to the approaches described previously, dynamic FOV modification is combined with the concept of rest frames. However, instead of an abstract virtual imagery in the periphery, we display a wireframe mesh that was generated from a 3D scan of the physical environment (see Figure 1). The user’s viewpoint in the wireframe model retains a 1:1 mapping from the motion tracking system; no virtual locomotion is applied. Therefore, users can experience the benefits of dynamic FOV modification (reduced motion sickness) while also maintaining awareness of their location in the physical world. This approach is less intrusive than a virtual overlay, because the physical boundaries are only visible in the periphery during motion. In the following sections, we describe the design and implementation of this technique and discuss opportunities for future research.

2 TECHNIQUE OVERVIEW

Our proof-of-concept prototype, shown in Figure 1, was tested using an Acer Windows Mixed Reality Headset. The software was implemented in Unity using VR Tunneling Pro, an open-source asset that provides several variations of dynamic field of view modification [5]. We modified the default “3D cage” functionality with a 3D mesh of the physical environment. To generate the custom model, we first used a Matterport professional camera to scan the lab space. Although the scanner can generate a high-quality scan with photorealistic textures, this level of detail was not necessary. In fact, a high-fidelity representation would likely negatively impact both system performance and the perceptual effectiveness of the visual effect due to dense optic flow in the peripheral regions. Instead, we found that a wireframe model with unlit, solid color triangular faces provided a more comfortable experience. Therefore, we removed

the textures and used quadric edge collapse decimation to reduce the polygon count. The face color, line color, line width, and polygon count are all parameters that can be tuned. However, we found that 5,000 polygons yielded real-time framerates and visually acceptable results for an approximately 6m x 9m room.

During the VR experience, the FOV restrictor can be displayed with a multitude of variations. The maximum amount of restriction, velocity mapping, and percentage overlap for the fade effect can be modified based on user preferences. In our current implementation, the FOV modification is activated based on either translational and angular velocity in the *virtual environment*. Additionally, the magnitude of restriction and the visibility of the physical environment model are coupled. However, it would also be useful to manipulate the visibility of the wireframe mesh based on physical movement in the *real world*, when collision avoidance is especially important. Furthermore, other weighting parameters, such as the distance to the boundaries and obstacles, could also be investigated. The visual appearance of the wireframe mesh (e.g., color, line thickness, etc.) could also be enhanced when a physical collision becomes increasingly imminent. As such, we are very interested in exploring the design space of these techniques more deeply in the future.

3 DISCUSSION

This paper presents an initial proof-of-concept that combines dynamic field of view modification with a rest frame representation of the physical environment geometry. In our implementation, the 3D scan of the lab space was conducted offline, and therefore the collision avoidance benefits will only apply to fixed obstacles and walls. However, inside-out tracking and environment mapping technologies are becoming increasingly integrated with consumer virtual and augmented reality devices. We expect that it will be possible to implement the proposed technique in headsets with real-time 3D scanning capabilities in the foreseeable future, thereby introducing the possibility of dynamic obstacle avoidance. However, we believe it is still valuable to explore the design parameters and perceptual characteristics of these techniques despite the limitations of current-generation equipment.

The design of FOV modification can also be extended in future work. Currently, the FOV restrictor can only be formed in a circular shape of a set radius, as implemented in VR Tunneling Pro. To the best of our knowledge, in the context of reducing VR motion sickness, prior research has only examined circular FOV restrictors. We believe that asymmetric field of view modification that considers different visual regions (e.g., vertical, horizontal) or even non-traditional shapes (e.g., nose cutouts) is an underexplored and promising research direction.

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