Using Non-Photorealistic Rendering to Reduce Cybersickness in Virtual Reality

Sarah Coufal
Bryn Mawr College
scoufal@brynmawr.edu

Mentor: Victoria Interrante
University of Minnesota
interran@cs.umn.edu

Introduction

Virtual reality (VR) can be used in many application areas such as education, job training, design, and more. Unfortunately, many users experience cybersickness, or feelings of nausea, eye strain, and dizziness when using VR technology. Although the exact cause of cybersickness is not known, cybersickness symptoms are associated with sensory mismatch due to vection, which is the visual illusion of movement (Davis et. al 2015). The objective of this research is to examine the relationship between visual input and cybersickness. We predict that reducing the detail in a scene will mitigate cybersickness symptoms.

Previous Work

There have been previous studies that explore this question of cybersickness and visual input. In 2015, Davis et al. conducted an experiment to compare the onset of cybersickness in two rollercoaster experiences. One of the rollercoasters had a higher level of detail and realism compared to the other rollercoaster. The ratings of nausea reported by the participants of the study indicated that the more detailed rollercoaster was more cybersickness inducing. They concluded that higher levels of graphic realism and greater optical flow are more likely to cause symptoms of cybersickness.

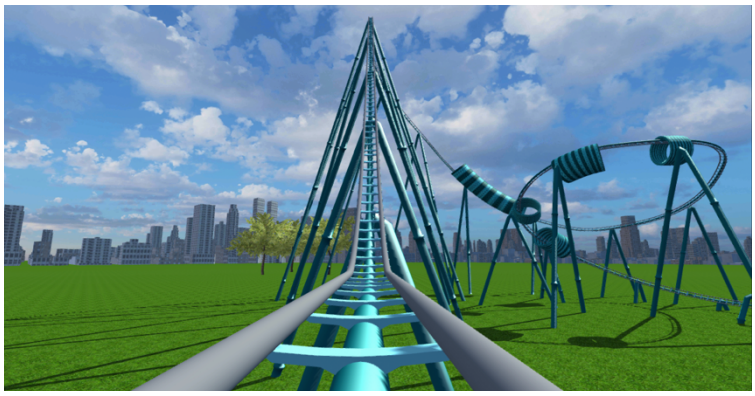
A study by Pouke et al. (2018) compared two conditions of visual detail: modern graphics and detail reduction through cel-shading. In this study, they designed two near-identical VR applications, which differed only in their graphical styles: one was “high-realism” while the other was “no-detail”. The participants were divided into two groups and moved through a preprogrammed path in an outdoor museum scene, rating their sickness throughout the test. They found weak (not statistically significant) evidence that the high-realism condition was more cybersickness inducing than the no-detail condition.

One concern is that these papers do not mention latency, suggesting that they did not consider this in their studies. Latency is a delay between user input and displayed output and is known to be associated with cybersickness. A more detailed scene would require greater processing power, resulting in a lower frame rate and more lag. Since these studies do not specify if they controlled for latency, it could be contributing to cybersickness.

Scenes

Since cybersickness is often associated with motion, we wanted to create environments where the participants are moving either actively, meaning they control their movement, or passively, where their movement is preprogrammed. We developed two scenes; both were built using the game engine Unity.

The first scene is a hospital building which the user can navigate through using the joystick on their controller. The user can open and close doors by pointing the controller at the door and pushing the trigger button. The hospital model was obtained from the Unity asset store and expanded so that it has more rooms and a more complicated layout. It contains a lobby, several different examination rooms, recovery rooms, offices, and an MRI room. This scene will be used to test active motion.



For the second environment, we created a rollercoaster so that the participants can experience passive motion. The rollercoaster model was found on Sketchfab, and we added detail such as texture to the tubes, as well as trees, mountains, and a cityscape in the background so that there is more visual stimulus in the scene.

Outline Shader

To reduce the detail in the scene, we implemented an outline shader from an online tutorial. The shader uses the depth and normal buffers to generate outlines. The fragment shader samples adjacent pixels, and if the values are very different, an edge is drawn.

Modifications were made to the original shader so that rather than only drawing a line when the normal difference is above some threshold, the outputted color is a function of the normal difference. This means that when the normal difference is near the threshold, it will output a shade of gray rather than making a binary decision between black and white.

The statistics bar in unity suggests that the frame rates are consistent with or without the filter. However, a more in-depth statistical analysis should be done to verify that we are controlling for latency.

Experiment

The participants will be assigned to one of four groups:

Group 1: hospital, no outline filter
Group 2: hospital, outline filter
Group 3: rollercoaster, no outline filter
Group 4: rollercoaster, outline filter

Two different measures of cybersickness will be used in the experiment: the Simulator Sickness Questionnaire (SSQ), which asks the participants to rate the severity of several different symptoms. We will also use the Fast Motion Sickness Scale (FMS), rated on a scale from 0 (no sickness) to 20 (severe sickness) several times throughout test.

The participants will first fill out a Simulator Sickness Questionnaire to record their pre-test level of cybersickness.

For the participants assigned to the hospital scene, they will be asked to find a unique item that is located somewhere in the hospital. Once they find this item, they will be prompted to find another item, and will continue searching for items throughout their whole test. The purpose of this task is not to measure their performance in finding the items, but to ensure that they are moving throughout the hospital, which is more likely to induce cybersickness. They will report their FMS score each minute and will stay in the environment for 10 minutes, although they are permitted to drop out earlier if they feel severe sickness.

For the participants assigned to the rollercoaster scene, the participants will ride the rollercoaster 10 times through, or less if they are experiencing severe sickness. They will report their FMS score at the end of each ride.

All participants will fill out a post-test SSQ, and the SSQ score will be calculated based on the difference between their pre and post test scores.

Future Work

Unfortunately, there was not enough time to run the experiment on human subjects during the research experience. The experiment will be run at some point in the following months.

Acknowledgments

This work was funded by a grant through the Computing Research Association for Women's (CRA-W) Distributed Research Experiences for Undergraduates (DREU) program. Special thanks to my mentor Dr. Victoria Interrante.

References

Davis, S., Nesbitt, K., and Nalivaiko, E., 2015, "Comparing the Onset of Cybersickness Using the Oculus Rift and Two Virtual Roller Coasters," 11th Australasian Conference on Interactive Entertainment (IE), Y. Pisan, K. Nesbitt, and K. Blackmore, eds., Sydney, Australia, Jan. 27–30, Vol. 167, pp. 3–14.

Pouke, M., Tiiro, A., LaValle, S. M. and Ojala, T., "Effects of Visual Realism and Moving Detail on Cybersickness," 2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR), 2018, pp. 665-666.

Hospital model: https://assetstore.unity.com/packages/3d/environments/hospital-medical-office-modular-165327

Rollercoaster model: https://sketchfab.com/3d-models/roller-coaster-06a750a284104d76ba6a05c2b0f5ccf3

Outline shader: https://roystan.net/articles/outline-shader.html