HaptoSono: Navigating Virtual Environments through Haptic and Vibrational Feedback for Visually Impaired Users

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Introduction

Modern VR provides an immersive experience for users in many areas like entertainment, productivity, and education. However, the majority of applications do not tend toward visually impaired groups. Simply navigating the home screen in an Oculus requires vision. Non-visual feedback supplements visual feedback to provide an immersive experience for users. For visually impaired groups, interacting with a virtual environment requires heavy use of haptic and aural feedback. Investigating methods to allow these groups to enjoy virtual reality is a worthwhile endeavor to expand the number of potential users in virtual reality. In particular, this technology can lay the groundwork for putting more emphasis on non-visual feedback methods. Because of this need, we propose a technology we named HaptoSono. HaptoSono focuses on navigating a virtual environment with haptic and aural feedback, providing just enough information for a user to understand their environment in their immediate proximity as well as distant objects. We use an audio proximity system to alert users of approaching objects from far away as well as controller vibration impulses to allow for an understanding of immediate proximity.

In this paper, we analyze the use cases of having aural and haptic feedback and demonstrate how effective these are when navigating different VR environments. We tested five participants and were able to conclude the significance of proximity detection. We also drew inspiration from different literature and explained our expansion of their ideas. From our experience creating HaptoSono, we learned how to properly create technology for a marginalized audience and consider different use cases.

Background

Some current literature relevant to our problem space is Zhao et al. (2019). Their paper goes into detail about how VR can be more inclusive to those who are visually impaired. They proposed two types of solutions: a VR plug-in for users to download and use in different applications and a developer tool for VR designers to use when creating an application. Some features in their implementation were different types of lenses (magnification, bifocal, etc.) and other useful tools such as edge enhancement and depth measurement. However, all of these tools were primarily focused on the user's vision, rather than exploring other options for assisting visually impaired VR users. Although these features were shown to be useful in their study, this paper will explore other methods of assisting visually impaired users without the need for vision.

A piece of literature that exemplifies the idea of the "optimistic user vision" is Sleeper et al (2019). Reconsidering this definition of a user vision is necessary if technology is to become more universal and usable by more populations. Visually impaired groups struggle with fitting into the optimistic user vision of virtual reality as they are gatekept by a physical difference out of their control. If these groups are to enjoy virtual reality, work should be done to provide accommodations for them. For the scope of our study, this provides some motivation to explore non-visual feedback in a virtual environment.

Solution

For our application of HaptoSono, we created two different VR environments: a hallway scene and an obstacle course scene. We chose to implement these scenarios in Unity because the hallway scene gives an understanding of how someone would navigate a closed space using HaptoSono while the obstacle course scene gives an understanding of how the user will dodge objects in their way.

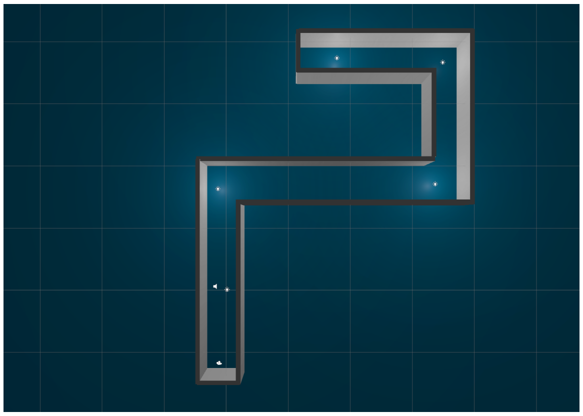

Figure 1: Overview of Hallway Scene

In the hallway scene (Figure 1), we had users travel from one end of the hallway to the other through one right turn and two left turns. This demonstrates how a user will navigate through the space using HaptoSenso. We predicted that the proximity sound would shine here as users could determine how far away they were from a wall and where they needed to go.

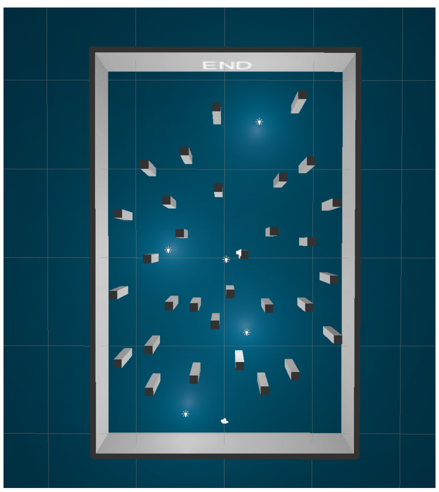

Figure 2: Overview of Obstacle Course Scene

In the obstacle course scene (Figure 2), we had users travel from one end of the course to the other while trying to avoid the pillars in their way. It was okay if the user ran into the pillars as the goal was for the user to get to the other side without getting stuck or lost in the space. We predicted that haptic feedback would be best here as the user would be interacting with many objects and could use touch to determine what was in their way.

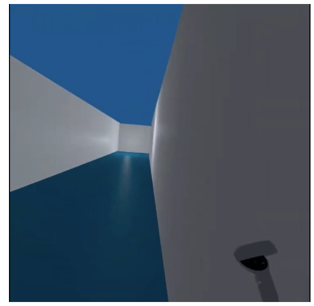

Figure 3: Inside of Hallway Scene

To create HaptoSono, we used different functions in Unity to allow for aural and haptic feedback to occur. For the aural feedback, we used a proximity detector that played a sound based on where the user is looking and their distance to that object. The closer the user got to the object they were looking at, the faster the sound would play. This was done using head cast rays from the Oculus headset that projected out 20 meters. If the user was outside this 20-meter range, then no sound would play, indicating that the space in front of the user is very much clear.

Figure 4: Inside of Obstacle Scene

For haptic feedback, we used colliders on scene objects that determined whether or not a controller collided with the object. If a controller was touching a wall, then that controller would vibrate. We also had it so that if the person themselves collided with an object then both controllers would vibrate. There was a script that determined which controller collided with the object so that we could vibrate that specific controller.

Methodology

For the purposes of our research, we wanted to make sure that our proposed solution was sufficient and easily accessible for visually impaired users. In order to do so we would ideally collect and record the feedback of visually impaired users after using our VR setup. However, since we were not able to find participants who would qualify to be clinically blind, we opted to physically obstruct the vision of our participants and collect their feedback on their experience. This setup had benefits since our users have the ability to compare and contrast the experience of traversing a VR scene with visual feedback and without any visual feedback but with one or both of our setup haptic and/or sonic feedbacks.

We collected data for 5 participants who all had to go through our 2 VR scenes using 3 out of the 4 feedback forms: Visual, Haptic-only, Sonic-only, and Haptic-Sonic. All participants had to go through both visual feedback and Hapto-Sono feedback. Subsequently, we randomly assigned each participant which of the singular feedback form they would be given to traverse a scene.

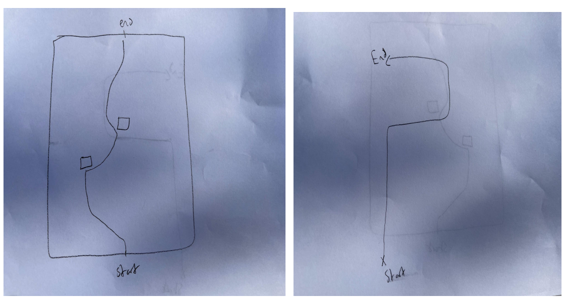

Figure 5: Sketch of Perceived Paths Taken by a Participant

Evaluation/Findings

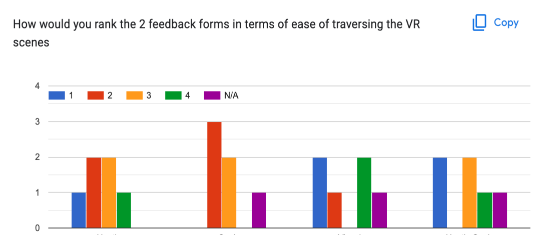

Figure 6: Chart of Likeability For Each Form Tested

Out of all the feedback received, our 2 equally most preferred forms of feedback were visual feedback and the Haptio-Sono feedback combined (Figure 6). Following that, we found that participants overwhelmingly preferred the sonic feedback over the haptic feedback. During our qualitative questioning, we even found that users actually found the sonic feedback to be more useful when making sure that they were not running into obstacles or walls when traversing each of our scenes. *"The thing is it gets the job done. It would be great If I could see the scene but if not* ***the sonic feedback particularly was very effective in helping me traverse the scene****."* A few users recommended applying the aural feedback from the headset to the controllers through vibrations.

Users found it easier to navigate through the hallway scene than the obstacle course. This could be due to the linearity of a hallway and the uncertainty of the total environment of an obstacle course. It is also difficult to learn about all parts of a more complex scene like an obstacle course since a user needs to physically navigate through and touch every object with a controller to accomplish this.

Limitations

Our research is heavily limited by the fact that we have a limited number of participants due to availability and time constraints. We believe that if we had more participants we would get more nuanced thoughts on the efficiency of our system and what aspects of it were necessary for achieving a very efficient feedback system.

Additionally, we noticed that the participants' familiarity with the Oculus and VR also had a significant impact when they were participating in our research. Unfamiliarity with the setup may have caused some sort of barrier when trying to make the most of our Hapto-Senso system. We also believe that the evolution of the Oculus controllers forms a significant barrier, particularly for the haptic side of our feedback system. We believe that pioneering technology such as that of Lopes et al. *"Interactive Systems Based on Electrical Muscle Stimulation"* would really augment the experience of our setup for visually impaired users if they were to feel a force feedback through electrical muscle stimulation as opposed to just experiencing a vibrational impulse through the controllers.

Conclusion

The virtual reality space is a quickly growing field with exciting possibilities. With millions of virtual reality headsets available in a commercial setting, it is easy to see its unlimited potential. However, it is easy to overlook groups of users that miss a crucial criterion to use modern virtual reality: sight. By introducing our study, HaptoSono, we demonstrate simple aural and haptic feedback to describe a virtual environment is enough to successfully navigate hallway and obstacle course scenes. Through user interviews, we found that aural feedback was more helpful than controller haptic feedback as it provided a larger range of understanding than just the immediate proximity of the controllers.

If we were to continue working on this project, we would combine both haptic and aural feedback used in this study by having a proximity sensor integrated into the controllers. This way, this would not conflict with any other sound that may be in a virtual environment. This can be combined with our original vision for the haptic feedback system by having the controller fully vibrate while colliding with an object. Also because of time constraints, we were unable to create additional scenes for participants to explore and interact with using HaptoSono. If we had more time, we would explore other scenes that involve open-world exploration and object interaction. With this in mind, future work should include a similar proximity system for controllers, get users further acquainted with the technology, and explore ways to test non-visual feedback in VR.

To see a more in-depth view of our study, watch this video to see how we had participants navigate through both scenes.

Contributions

Beza: Helped with coding up the algorithms for sensing walls and obstacles to trigger sonic and haptic warnings. Helped design research methodology and run studies on participants. Helped to design, collect and analyze feedback from participants.

Isaaq: Created both Unity scenes for participants to navigate (hallway and obstacle course). Coded proximity system using ray projections and controller vibrations using colliders in the environment. Led all coding/activities using Unity. Initialized setup for study by enabling/disabling certain features (Visual, Haptic-only, Sonic-only, and Haptic-Sonic). Assisted in creating methodology for testing participants. Explained project in final demo.

Devon: Recruited participants for our study and helped find certain relevant API for creating headset ray projections and controller vibrations in Unity. Directed the "Wizard-of-Oz" design demo for our project idea.

References

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