Physiological Signal-Driven Virtual Reality in Social Spaces

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ABSTRACT
Virtual and augmented reality are becoming the new medium that transcend the way we interact with virtual content, paving the way for many immersive and interactive forms of applications. The main purpose of my research is to create a seamless combination of physiological sensing with virtual reality to provide users with a new layer of input modality or as a form of implicit feedback. To achieve this, my research focuses in novel augmented reality (AR) and virtual reality (VR) based application for a multi-user, multi-view, multi-modal system augmented by physiological sensing methods towards an increased public and social acceptance.

Author Keywords
Virtual Reality; Augmented Reality; Physiological Sensing

ACM Classification Keywords
H.5.1. [Information interfaces and presentation]: Multimedia Information Systems – Artificial, augmented, and virtual realities.

INTRODUCTION
At this point of writing, I am still in my first year of PhD research, and most of my research plans are related to my PhD direction for the next 3 years. My current research plans are related to physiological signals in virtual reality (VR) applications. Specifically, my primary goal is to create a seamless combination of physiological sensing with virtual reality to provide users with a new layer of input modality or as a form of implicit feedback. This means obtaining data from external devices like eye trackers, heart rate monitors, or even brain sensing to be used as VR interaction mechanic. I am also currently exploring new interaction methods in VR such as new locomotion methods, collaborative platforms, and learning tools and would love to use these sensing methods to provide users with a new layer of interaction. Physiological sensing contains data of an individual's cognitive load and state of mind, and visualizing them in an immersive VR space opens new possibilities. Besides visualization, another important use of these data are for implicit feedback to directly affect the virtual environment. For my first year, I am concentrating on eye tracking methods in HMDs. Eye tracking lets us know the user's point of attention, stress level and their attention. I am looking into new calibration methods for accurate eye tracking in a VR environment as well as having full 3D gaze detection as opposed to 2D eye tracking in most commercially available eye trackers. VR applications extend widely into many fields like engineering, medicine, sports, military and so on. Furthermore, seeing as this year is where VR has reached its peak of popularity, there is no better time for further research and development in the field of VR. The immersion that VR offers together with physiological sensing can provide users with potentially new forms of application as well, for example experiencing a VR environment that changes our state of mind for the rest of the day.

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PREVIOUS WORK
Most of the previously conducted research focuses on AR development for use of manufacturing and machining simulations. I developed a factory layout planning tool that allows the user to conduct a table-top planning on the placement of machines to minimize the material travel time which can save millions of dollars in the long run. The system also calculates the optimum placement of workers based on several well-known layouts while simultaneously determining the total area occupied. I also worked on kinematic modeling of a robotic arm for offline robot programming in AR [1]. By reproducing the arm's movement virtually, engineers will be able to train it more effectively with correct visualization as opposed to online programming which can be dangerous. This system was able to generate the path for the robot's end effector and visualize it in AR while also generating a file for these coordinates to be used for the physical robot arm. To interact with the AR content, another work based on speech recognition was developed so that a seamless form of input can be used for the AR system. For example, during a machining simulation, the user needs to pay full attention on the screen and cannot shift it towards the keyboard. Speech recognition bridges this gap to allow full concentration on the machining process. This was found

during a computer numerical control (CNC) machining simulation process that recreates milling in AR with all the necessary parameters for the generation of G-codes. The CNC machining module was combined with the layout planning and robot arm module to create a fully functioning AR system that educates and teaches the user on a complete manufacturing phase[2].

CURRENT AND FUTURE WORK

Real Time AR ToolKit

My first work is related to AR development where I am developing a toolkit that visualizes augmented reality models in real time. The Real Time Augmented Reality Toolkit (RealArt) is a system that reads the models vertices and meshes directly and reproduces its AR counterpart. This is usually not possible unless the modeling software is hacked, or if the AR tool collaborates with the modeling tool [3]. Typically for most AR applications, users are required to create a 3D model, then export it as a supported file type such as OBJ, STL, and so on. The next step would then be to launch the AR program and import that model. Due to these cumbersome steps, product designers do not always prefer to use AR modelling. RealArt solves this issue by providing them a method to create and change a 3D model that is immediately reflected on the AR model. A haptic surrogate was also used to provide the designer with haptic feedback. Figure 1 illustrates a user using RealArt to modify the design of a mug and observing the changes on the overlaid AR model on the haptic mug surrogate.

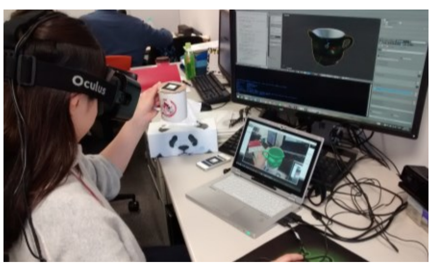

Figure 1. A user using RealArt to design a mug

VR for Multi-User, Multi-View

Since VR is becoming more mainstream, my primary research focus is on the development of various novel interaction methods. One of the main focus is on the social acceptability and collaborative nature that can be nurtured in a VR environment [4]. The collaborative layout evaluation and assessment in VR (CleaVR) system aims to achieve this by creating a shared VR environment that allows interior designers, engineers, and architects to discuss and generate a layout plan. To achieve this, an Oculus Rift HMD is equipped with a Leap Motion sensor to provide the user with direct hand manipulation for a more intuitive interaction. The user is able to pick and place furniture around in an environment by viewing it externally through orbital exocentric camera. With a swipe gesture, the user then switches into an internal view of the layout for an egocentric point of view. Since this is a shared environment achieved through Photon Networking, other users may join the scene and observe the changes made, as well as perform changes themselves. Figure 2 shows multiple users in the same design space.

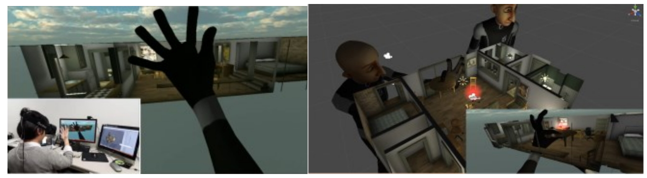

Figure 2. CleaVR system illustrating direct hand manipulation and collaborative design space.

Another work that is currently in development aims to understand how the sense of scale and perspective can prove beneficial in a VR environment, especially if the said environment is dynamic or constantly changing. The Humanoid Titan is a project idea that studies this approach as a method of educating others of the human anatomy. To achieve this, the Kinect sensor is used to capture the user's full body movement. However, the user does not observe the VR environment through the eye of the avatar, but through a scaled-down insect-like creature on the avatar itself. This allows the user to physically explore his or her own body by making the body itself as the actual terrain. The main implication of this study is that providing a different perspective to a user under an environment that constantly changes leads to a better understanding of the situation.

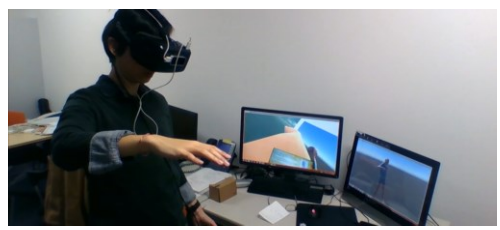

Figure 3. The Humanoid Titan System, where the left monitor shows the user's view of being on his arm, and the right monitor showing the avatar.

For example, a maintenance engineer is undergoing training to dissemble delicate machinery. By providing him with a scaled down perspective of being in a specific part of the machine, he can observe how this current modification affect the system internally. Figure 3 illustrates how the view of the user differs from the avatar.

Social VR Locomotion

Several other ongoing projects are investigations on new methods of navigating a VR environment. As of this moment, there is still no clearly defined best method for locomotion in VR, as it has always been a balance between motion sickness and immersion. There are currently two research ideas that aim to tackle this issue. AnyOrbit is a collaborative project that uses eye tracking to perform an orbital-like movement [5], similar to the one used in CleaVR. The navigation system is based on a torus, with the center point of rotation being the point of which the user is looking at. Head angle is then used for the actual orbital movement. This allows the user to always orbit around the point of interest, which can be useful for story telling in VR or 3D model inspection where we know the user's point of interest. Figure 4 shows a user orbiting around the desired point of focus.

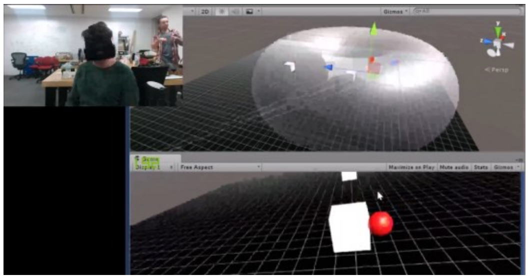

Figure 4. AnyOrbit navigation where the user's gaze point is shown as the red ball. The user can select to orbit between cubes depending on the gaze point.

The other research idea is to develop a navigation method which aims to create a more socially acceptable form of navigation for VR while striking a balance between motion sickness and immersion. As VR usage becomes mainstream, it could be just a matter of time before VR is used in public places like the subway or bus. In such cases, finding a method that allows us to navigate a VR environment without drawing too much attention becomes another issue. Most current research relies on the walking in place (WIP) method for locomotion as it is understandably more realistic and has proven to cause relatively less motion sickness [6]. However, WIP methods cannot be used for an extended period of time, and is not the most viable method to be used in public environments.

Physiological Sensing in VR

Physiological sensing includes a wide array of sensing methods such as electrooculography (EOG), heart rate, blood pressure and many more. For the current VR research, my focus is on eye tracking and its connection with the VR environment. Most of the current usage of physiological sensing is more towards monitoring changes, and rarely used as an actual input modality or implicit feedback. Eye tracking in particular, is the natural evolution of VR and will most likely be incorporated in future generations of VR HMDs. However, one of the main limitations with current eye tracking is that the system is only able to track 2D eye movement [7]. Eye tracking systems provides the position of our gaze for the x-axis and y-axis, but depth of focus remains an unexplored area. To achieve eye tracking in VR, a custom prototype was built that incorporates Pupil Labs trackers into the cavity of the Oculus Rift as shown in Figure 5.

Figure 5. The installed Pupil eye trackers in the Oculus Rift.

Simple machine learning algorithm is then used to estimate the depth of focus. Transparent Reality is a research idea that uses the calculated depth as a novel input modality in VR. Since the system is able to recognize the depth of gaze, layers of information can be placed on different depths that can be activated based on the user's focus depth. Some of the potential application include creating a heads up display (HUD) as a front semi-transparent layer so that the user's focus will always be in the main scene and can view the HUD by changing the focus as shown in Figure 6.

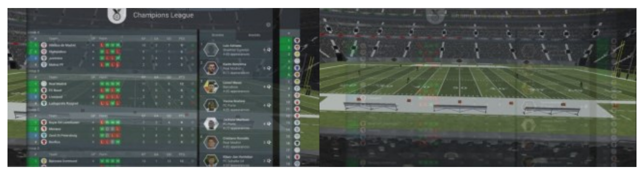

Figure 6. Example of Transparent Reality for a sports scoreboard.

Another application is also for creating a layer that shows the physical world. Transitioning between them thus becomes easier and more natural, which is suitable for discussions in VR space. The second project that stem from this implementation is GazeSim [8], that simulates foveated rendering, which is an interesting implementation for VR, seeing as how VR is synonymous with the requirement of powerful hardware. Foveated rendering is able to reduce these requirements by only rendering the specific virtual scenes with high fidelity while keeping the rest of the scene blurred. Furthermore, traditional foveated rendering is achieved with blurring out a 2D scene, but recognizing the user's focus depth allows for a more natural depth of field effect. GazeSim is demonstrated using a gear assembly test scene that allows the user to focus close to inspect specific gears of the assembled model based on gaze depth. The gear that is being inspected will then be moved to a front layer, whereas the remaining assembly is blurred from the user's view as shown in Figure 7.

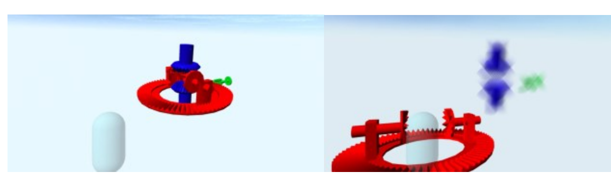

Figure 7. Example of GazeSim for a gear assembly.

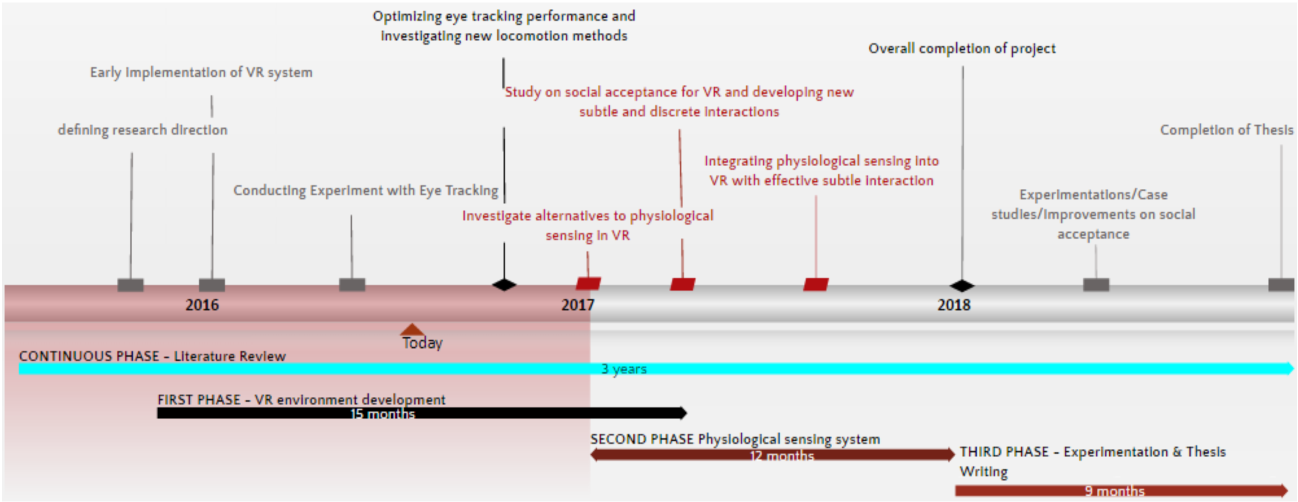

Figure 8: Gantt Chart for future works

Future Research

The implementation of physiological sensing in VR research has plenty of rooms for further exploration. Furthermore, as VR becomes more and more socially acceptable, unique forms of interaction becomes a more of a necessity. VR systems being used in public environments could simply be a matter of time, and when that time arrives, it is difficult for users to interact with the virtual environment without having to also carry a controller around. Head position would be the only form of input, which is quite limiting and cannot be used for complex navigation or other forms of interaction. A subtler and more discreet form of interaction would be preferable. This is where physiological sensing methods becomes a viable alternative, as these signals are discrete and unobtrusive by nature and cannot be observed by others. However, one of the main hurdles would be determining the right sensing methods where the user can directly manipulate. For example, eye tracking is a method where we can naturally control, however, heart rate is not a signal where we can control precisely. Nevertheless, these data can also be used to directly influence the virtual environment itself in a more implicit manner.

CONCLUSION

The field of VR is still in its infancy despite existing for several decades, and has only recently emerged as a viable tool for consumers instead of constrained to research purposes. For that reason, developing new interaction methods to create a more socially acceptable VR experience will soon become a necessity.

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