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Research Statement

Virtual environment (VE) technology has great potential to enhance the ability for people to perceive and interact with computer simulated environments. Ideally, people would perceive and interact with the virtual world the same way that they would a real environment. Subjective experience and empirical research, however, show that there are significant differences between real and virtual environments. My primary research goal is to understand why these differences exist and how they can be reduced or eliminated.

Research in this area is an inherently multidisciplinary task that involves both computer science and psychology. Significant technical knowledge is required to properly construct an accurate simulation of an environment. In addition, head and body tracking are required for a user to be able to naturally view and locomote through an environment. After an accurate virtual environment is created, expertise in psychology is required to construct experiments to quantitatively measure differences between how people perceive and act in real and virtual environments. Since virtual environments give researchers complete control over the visual information presented to users, psychologists are also interested in using the technology to perform experiments that are not possible or practical in the real world. If differences between real and virtual worlds can be eliminated, virtual environments may become a popular tool that psychologists can use to learn about human perception.

Virtual environments convey 3D space to users in a way that is much more compelling and realistic than traditional desktop displays. As a result, VE technology has great potential for use in numerous applications such as training, design and prototyping, education, and entertainment. All of these applications can benefit from the ability of VE users to accurately perceive and act in the space. Therefore, it is critical for the success of VEs that we understand how to convey information to users in a way that ensures that their perceptions and actions in the space are correct.

Research Focus

The majority of my research has focused on the perception of distance in virtual environments which use head-mounted display technology. People are able to make accurate distance judgments to objects in real environments but underestimate distances in HMD-based VEs by thirty to fifty percent. Despite a significant amount of research spanning multiple laboratories, the cause of the distance compression is unknown. Researchers have found evidence that the compression is not caused by the quality of the graphics, restricted field of view, type of distance measurement task, stereo cues, or the mechanics of the HMD itself. Although it is possible that future improvements in the quality and fidelity of HMD displays may reduce or eliminate distance underestimation, it is still important for psychologists to understand why the underestimation occurs and important for engineers to find solutions to the problem. Finding a solution to incorrect distance perception is particularly important because people frequently rely on distance perception in daily life. For example, accurate distance perception is a necessity for planning navigation. In addition, errors in distance perception may also have detrimental effects on the perception of size.

My doctoral work examined how improperly calibrated HMDs might contribute to the distance compression problem [4, 5]. An informal survey that we conducted showed that very few researchers calibrate their displays and many use calibration procedures which produce incorrect results. It was possible, therefore, that laboratories had systematic calibration errors which could have been causing the distance compression.

There are two distinct components to my dissertation research. First, I examined previous methods used to calibrate the geometry presented to users in HMDs. I developed procedures to measure and correct for geometric distortions which are common to many HMDs. These distortions include pincushion distortion due to the display's optics, minification and magnification, and the calibration of pitch (up/down rotation).

The second component of my dissertation work examined how these distortions impact distance judgments. The results of my research shows that pincushion distortion due to the lenses in the HMD and miscalibrated pitch do not influence distance judgments. My research also shows that minification and magnification can influence distance judgments. Minification and magnification occurs if the field of view used to render the graphics differs from that of the actual display. For example, minification can inadvertently occur if researchers trust field of view specifications that are actually overstated by the manufacturer. My work indicates that our HMD's specifications were overstated and that the resulting minification could make objects appear slightly more distant than they would in a correctly calibrated display. If the field of view is commonly overstated by HMD manufacturers, it is possible that numerous laboratories have unintentional minification in their HMDs, and this miscalibration may be partially masking the severity of the distance compression problem.

Since minification and magnification influence distance judgments, it is possible to use these distortions to artificially improve distance judgments. By artificially introducing minification, we can cause users to accurately perceive distance on average. My research also showed that this distortion goes unnoticed by HMD users. Therefore, my work provides one possible solution to the HMD distance compression problem.

Although the focus of my dissertation research was on distance judgments in HMD-based VEs, I have also researched how people find their position on a map after they have viewed landmarks in a virtual environment [3]. Another research project examined how people adapt to incorrectly rendered rotations in HMDs [1, 2]. Understanding how people perceive incorrectly rendered rotations is particularly important for researchers who want use incorrect rotations to allow users to explore a virtual space that is larger than the physical space they are walking in. Much like my distance perception research, these areas of research provided insights into human perception and immersive virtual environments.

Future Research

I believe that reducing differences between real and virtual environments is one requirement for increasing the utility of virtual environments and enabling computers to more effectively convey visual information to users. There are four research areas which I am planning on pursuing to achieve this goal.

In my first area of future research, I intend to examine how the physical field of view of a HMD affects distance judgments. Recent advances in HMD technology can provide users with a much wider field of view (150 degree horizontal) compared to older technology (40 degree horizontal). As new HMDs become available, we must understand how they might change users' perceptions of the space. Although field of view limitations similar to those seen in older HMDs do not affect real world distance judgments, it is possible that we might see different results in a virtual environment. If wide field of view displays do reduce distance compression, it will motivate more research to help us understand why a limited field of view influences distance judgments in a VE but does not influence similar judgments in a real world environment.

Second, I intend to examine the effect of first-person avatars on virtual environments. Since most HMD systems do not simulate a first-person body, they lack important visual cues which may impact users' sense of scale, location, and presence. We also know little about how these perceptions change with the presence or absence of an avatar. It is also unknown what detrimental effects an imperfect avatar might have on the perception of space. For example, does an incorrectly scaled first-person avatar affect distance perception? It is difficult and time consuming to create a perfectly scaled avatar and first-person avatars will likely become increasingly common. Therefore, this area of research is necessary for us to understand how accurate avatars must be for them not to have a negative impact on users' perceptions of the virtual space.

Third, my dissertation research has uncovered several new questions that should be examined further. Minification and magnification do change distance judgments, but this distortion changes numerous visual cues which contain distance information. It is unknown if one particular visual cue is causing a change in distance judgments or if it is a combination of visual cues. By examining this problem, we can begin to learn how people judge distances and how we might create even more subtle distortions to reduce distance compression. It is also currently unknown if people adapt to minification and magnification. If minification is used to eliminate distance compression for extended periods of times, it is possible that people may adapt to the distortion and eventually return to underestimating distances. If this adaptation occurs, minification may have limited usefulness for some applications. I also intend to further my research in pitched virtual environments. Although a pitched world does not change distance judgments in the virtual environment, it does change similar judgments in the real world. This result indicates that users rely heavily on the visual information instead of gravity in the virtual world. More research is needed, however, to fully understand how visual and proprioceptive information are combined in virtual environments.

Fourth, I intend to expand my research beyond distance judgments in HMDs to initiate a related line of inquiry into different display technologies and different spatial judgments. Despite all of the advantages of HMD-based VEs, the technology is still expensive and inaccessible to many people. Desktop and large screen displays are more accessible and can also benefit from the ability of users to make accurate judgments about the information displayed on the screens. Besides distance perception, there are other research questions related to the perception of size, shape, and orientation which need further investigation. Finally, realistic rendering techniques will continue to improve for all display technologies. Although improvements in rendering fidelity may be aesthetically pleasing, perception research is needed to quantitatively measure how changes in rendering affect users' perceptions of the displayed information. With this research, I hope to increase the utility and effectiveness of computer display technologies.

References

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