Hallway Simulations in Virtual Environments

Binh Nguyen
Department of Computer Science
Augsburg College
Minneapolis, MN 55454
nguyenb@augsburg.edu

This work was supported by National Science Foundation grant CCLI-0309816.

Abstract

Virtual reality simulations have many applications in various fields. They have been used for a long time to simulate real world environments. Today, virtual reality environments have been rendered to be nearly like the real world. However, they are still imperfect because people still make judgements differently in the virtual world. Computer scientists have been working to find out how people judge and perceive distance in a virtual reality setting.

In this project, we addressed how people use their judgment and perception when a virtual environment was rendered in a flat-display screen. A hallway was rendered on a screen, with one circle on the floor and one circle on the ceiling. Some attributes of these circles include the size of the circles, the location of the circles, the color of the circles, and the presence of a projectile. The goal of the task was to align the circle on the floor with the circle on the ceiling. Each subject attempted the alignment with fifteen different circle configurations. Results show that people tend to overestimate distance in a virtual reality setting in front of a 17” flat-display screen.

1 Background

This experiment is based on previous work in virtual environments. Thompson et. al. [3] did an experiment to discover whether the image quality of the virtual environment affected how people judged distance. In this experiment, subjects performed a triangulated walking task. They were to walk in a specific direction. When instructed by the experimenter, they turned at a given angle and continued to walk toward the target until the subject believed he or she had reached the target. This experiment was done under four conditions: real world, panorama image, low-quality image, and wire-frame image. Results showed that in the real world subjects were able to walk toward the intended target, whereas in the other three conditions, subjects fell short of the intended target. The quality of the images made little difference in the magnitude of underestimation. Thompson believed that this result is caused by image compression in the virtual world.

Hu et. al. [2] performed two experiments to test whether visual cues have any impact in distance judgment. Three visual cues were used: stereoscopic viewing, interreflections, and shadows. In the first experiment, subjects were to move a block towards the table in the virtual environment without having the virtual block touch the virtual table. In the real world, a rod and wooden block were used to control the movement of the block in the virtual world. Between the sessions, the head-mounted displays were turned off to ease the transition between stereoscopic and binocular viewing. The test results were only accepted if subjects did not exceed the time limit and if the two objects did not touch each other in the virtual environment. In the second experiment, a virtual block was lowered toward a virtual table until it stopped at a particular point. Subjects were to slide their thumb and index finger along a triangular-shaped scale, with one finger on the base of the triangle and the other finger on the opposite side of the triangle, until they believe the distance between their fingers and the distance between the block and table were the same. In both of these experiments, various cues such as stereoscopic viewing, interreflections, and shadows were used. Results show that in the first task, stereoscopic viewing and shadows have significant impact on performance. In the second task, stereoscopic viewing, interreflections, and shadows were found to be strong distance cues.

Ellis et. al. [1] also ran experiments to discover how distance is judged. Studies were done by Ellis to see what type of viewing conditions affects judgment. In this experiment, subjects in the virtual environment were to move and position an LED pointer as close as possible above the apex of an inverted tetrahedron, while wearing a head-mounted display. Between each of the trials, the head-mounted display was aligned and calibrated. Three different views were used during this test: monocular view, binocular view, and stereoscopic view. The results showed that in the stereoscopic viewing condition, distance judgment was nearly accurate. In the monocular viewing condition, depth judgment was largely overestimated. Also, the monocular viewing condition produced a larger variance of distance judgment than the other two views.

2 Experiment

The program that was used in this experiment was written in OpenGL and C. It was executed on a Dell Dimension workstation running Debian Linux with a 3.00 Ghz Pentium 4 processor with Hyper-Threading Technology and 1280 MB of RAM. The monitor that was used was a 17 inch flat-screen display.

In this experiment, a hallway was rendered on a screen, with one circle on the floor and one circle on the ceiling. This experiment was done to see how people use their judgment and perception when a virtual environment is rendered on a flat-display screen. Ten subjects participated in the experiment with different circle configurations including the circle's position, size, color, and the usage of a projectile as a visual cue. The subjects were told to align the circle on the floor with the circle on the ceiling (Figure 1) using the keys on the keyboard by either pressing I to move the circle on the floor forward or pressing K to move the circle on the floor backward. The circle on the ceiling was fixed. When the user aligned the circles, the user proceeded to the next configuration by pressing the Escape key on the keyboard. The user went through fifteen configurations in this experiment (Table 1).

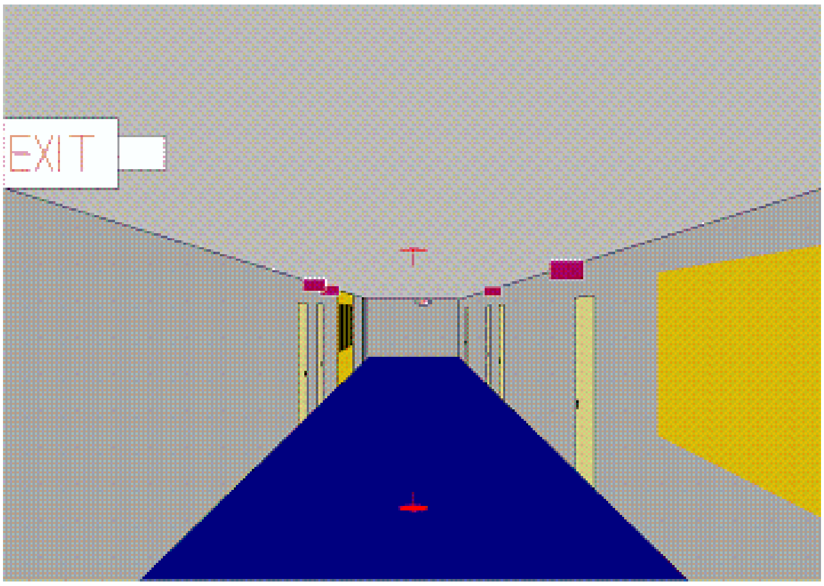

Figure 1: The circle on the floor aligned with the circle on the ceiling.

3 Results

In the first set of configurations of this experiment, three different ceiling disk positions were used: 15', 20', and 25' from the viewpoint (Figure 2). All of the disks were red and were 4" in radius. Results showed an average 6.92' overestimation of distance in placing the lower disk for 15', 10.25' overestimation for 20', and 8.83' overestimation for 25'. Although the error was not a linear function of the distance from viewpoint, the distance was significantly overestimated in all three situations.

Color	Size	Projectile	Placement
Red	4’	No	15’, 20’, 25’
Red	6’	No	15’, 20’, 25’
Red	2’	No	15’, 20’, 25’
Blue	4’	No	15’, 20’, 25’
Red	4’	Yes	15’, 20’, 25’

Table 1: The fifteen circle configurations.

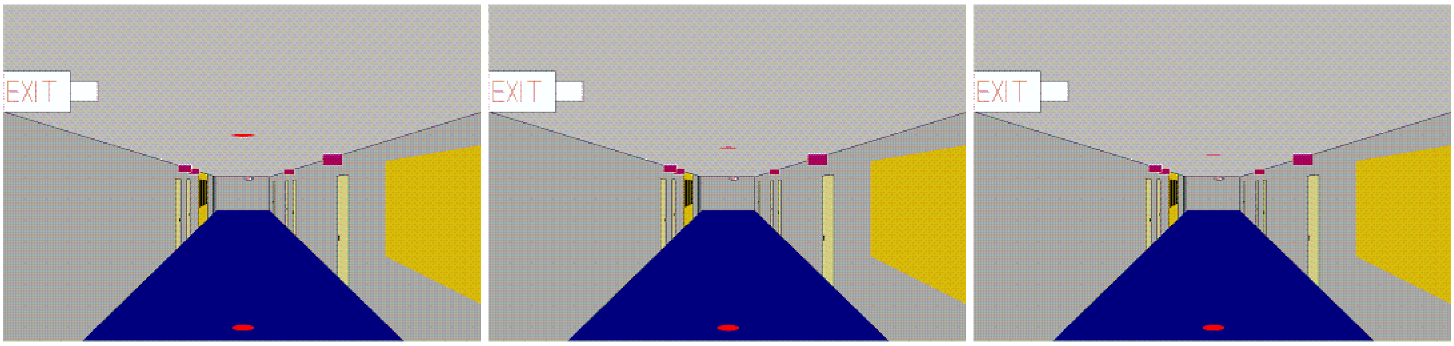

Figure 2: The first set configurations of this experiment.

Disk color was changed to blue in the next configuration. Results were similar to those using the red disks. This suggests that color does not affect distance perception.

Next, three different size disks were used: 2”, 4”, and 6” (radius). All of the disks were red and the ceiling disks were 20’ away. Results show that there was a 12.08’ overestimation for 2”, 10.25’ overestimation for 4”, and 5.08’ overestimation for 6”. These results suggest that larger object size leads to estimations that are more accurate.

Finally, we added a projectile sticking out of the circular objects on the ceiling and on the floor. All of the circles were red and were 4” in radius. Results show an 6.67’ overestimation for 15’, 5.83’ overestimation for 20’, and 6.67’ overestimation for 25’. This reinforces the results in terms of positioning, but it also shows that the usage of this additional feature increases the accuracy of distance estimation.

Although there were a few cases where distance was underestimated, almost all of the distances were overestimated. In the configuration with the 4” red circle placed 15’ away, the range of errors was between 1.52’ and 13.63’ with median of 7.42’. As the circle was placed further away, the range gets wider. The same 4” red circle that was placed 25’ away produced a range between 0.27’ and 22.13’ with median of 8.43’. Similar results were produced for the 4” blue circle. When comparing the circle’s size, the largest circle has the range closest to the actual distance. The 6” red circle placed 25’ away produced ranges between an underestimation of 4.27’ and an overestimation of 16.73’ with median of 5.20’. The 2” red circle placed 25’ away produced ranges between 2.25’ and 23.35’ with median of 15.00'. When comparing results with the use of a projectile, the circle with the projectile produced slightly better results. The 4" red circle with a projectile that was placed 25' away produced ranges between an underestimation of 0.77' and an overestimation of 22.08' with median of 6.61'. It is interesting to note that individual subjects did not produce consistent overestimations throughout the fifteen circle configurations of the experiment.

4 Conclusion

Results show that people tend to overestimate distance in a virtual environment in front of a 17" flat-display screen. In addition, parameters such as the circle's size and the presence of a projectile affect the results of this experiment. These results are similar to the results of the previously discussed experiments (Section 1). Although people make judgements differently in the virtual world, there are some factors that help improve judgement in the virtual world. In the future, this experiment will be conducted using a head-mounted display to compare how people judge distance in front of a flat-display screen versus using the head-mounted display in an immersive environment. Hopefully, this experiment will help us learn how to improve virtual environments so that distance judgements more closely match those made in the real world.

References

[1] Stephen R. Ellis and Brian M. Menges, *Judgments of the distance to nearby virtual objects: Interaction of viewing conditions and accommodative demand*, Presence **6** (1997), no. 4, 452–460.

[2] Helen H. Hu, Amy A. Gooch, Sarah H. Creem-Regehr, and William B. Thompson, *Visual cues for perceiving distances from objects to surfaces*, Presence **11** (2002), no. 6, 652–664.

[3] William B. Thompson, Peter Willemsen, Amy Gooch, Sarah Creem-Regehr, Jack Loomis, and Andrew Beall, *Does the quality of the computer graphics matter when judging distances in visually immersive environments?*, Tech. Report UUCS-02-015, Computer Science Department, University of Utah, 2002.