Angle of declination manipulations and their effects on distance judgments in virtual environments

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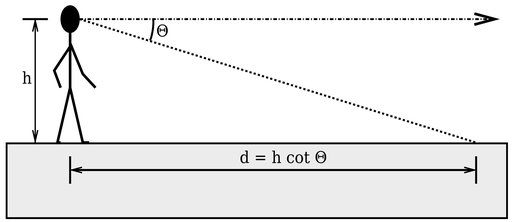
Introduction

► The angle of declination from the horizon to a location on the ground plane, when scaled by eye height, can be used to determine absolute distance to targets on the ground plane.

► We manipulated this cue in two different ways with an HMD-based virtual environment and measured how the manipulations changed egocentric distance judgments:
1. We tilted the virtual world up 5.7 degrees
2. We minified the visuals provided to the user



Background

► Distances are typically underestimated in HMD-based environments compared to real environments. Therefore, we will manipulate the angle of declination in a way that should increase the perceived distance to targets.

► Ooi et al. found that tilting the world down with prism glasses changes distance judgments in the real world. Tilt changes the angle of declination when the horizontal with respect to gravity is used.
- ► Does tilt also change distance judgments in the virtual world?

► Minifying graphics in an HMD decreases the visual angle between the horizon and target. The angle is not changed, however, if people measure the angle proprioceptively with head rotations.
- ► Does minification change distance judgments in the virtual world? Do tilt and minification change distance judgments differently?

Experiment Results & Discussion

Tilt experiment

Baseline condition

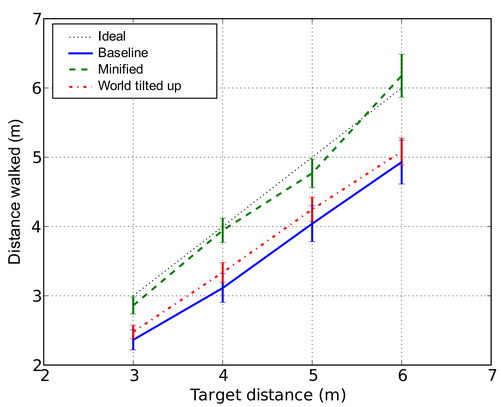
Tilt world up 5.7 degrees

Baseline condition: Subjects judged targets to be 80% of their actual distance on average when using the HMD with no manipulations. This result is consistent with many other studies that have found distance compression in HMDs.

World tilted up condition: Subjects judged targets to be 84% of their actual distance when the world was tilted up. This result is not significantly different from the baseline condition ($F(1,21)=0.03$, $p=0.86$). Unlike our experiment, Ooi et al. found that tilt influences real world distance judgments. There are several possible reasons for this difference:

1. People may rapidly adapt to the tilted virtual environment
2. The HMD may increase uncertainty in the proprioceptive or vestibular cues for the horizontal.
3. Perhaps the HMD increases the minimum distance at which tilt is effective. Ooi et al. found tilt was the most effective at target distances of 6 and 7.5 meters.

Experiment design:
- Nvis nVisor SX HMD
- Direct blind walking
- Targets on floor at 3,4,5,6m
- Baseline: 13 subjects
- Tilt: 12 subjects
- Minification: 12 subjects



Minification experiment

Minified by 30%

Minifying the graphics displayed in the HMD by 30% reduces the angle of declination by approximately the same amount as the tilt manipulation. This manipulation also changes other cues such as familiar size.

Subjects walked an average of 98% of the way to the targets. This result differs significantly from the baseline condition ($F(1,21)=5.94$, $p<0.05$). These results are similar to a previous experiment by Kuhl et al. that also found that minification can increase the perceived distance to targets on the floor.

Conclusions

► Tilt does not influence distance judgments in virtual environments in the same way that it does in the real world (Ooi et al).

► Minification increases the perceived distance to targets in HMDs.

► Different manipulations that change the angle of declination result in different changes in perceived distance.

► More work is needed to understand how the angle of declination is used:
- ► Which reference frame do people use?
- ► How do people measure the angle of declination?

References

► Ooi T. L., Wu, B., and He, Z., J. 2001 Distance determination by the angular declination below the horizon. Nature 414 (Nov.), 197--200.
► Kuhl, S. A., Thompson, W., B., and Creem-Regehr, S., H. 2006. Minification influences spatial judgments in virtual environments. In Proc. Symposium on Applied Perception in Graphics and Visualization, 15--19.

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