Distance Estimation in Virtual Environments Using Bisection

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1 Introduction

Systematic errors in perceiving distances in virtual environments (VEs) are one of the most interesting issues in perceptual studies of VEs. Some have studied the issue using blind walking (e.g., [Willemsen and Gooch 2002; Interrante et al. 2006]), and others have used time-to-walk estimates [Plumert et al. 2005]. Blind walking involves perception and action. Time-to-walk estimates involve perception and imagination. This study presents distance estimation experiments using a measure that relies only on visual perception, that of distance bisection. In distance bisection, subjects are asked to determine the midpoint of a distance interval between them and a target avatar in the virtual world by using a joystick to adjust the position of an adjustment avatar until the avatar is halfway between the subject and the target avatar.

Lappin et al. [2006] showed systematic errors vary across different common environment contexts when viewing the physical environment. In their study subjects were asked to view targets located 15m or 30m away and instruct an experimenter how far to walk to reach the apparent mid-point. The subjects' errors in this bisection task were reliably larger in a hallway context than in an open field context, where errors were negligible. The present study was designed to replicate Lappin et al. [2006] using VEs. Like the bisection judgments performed in physical spaces, the subjects performed the bisection judgments with high levels of accuracy in the virtual environments and the errors increased with increasing distances. But unlike the physical environment judgments, the virtual environment judgments did not vary across the hallway versus the open field context.

2 Methods

Two virtual environments were used in this study, an indoor hallway and an outdoor lawn (Figure 1). Both are replicas of physical environments on the Vanderbilt campus. Two avatars were added to each environment for the midpoint judgments, one a "Target Person" and the other an "Adjustment Person." The midpoint of the interval between the subject and the Target Person was determined by asking the subject to use a joystick to move the Adjustment Person back and forth until the subject believed that the Adjustment Person was halfway between them and the Target Person. The Adjustment Person locomoted using natural (motion captured) walking. Sixteen subjects were tested in a complete, balanced, within-subject design. Each made 16 judgments: two contexts (hall and lawn), two distances(15m and 30m), two viewing directions (at each end of the environment), and two walking directions (with the Adjustment Person walking away or towards the subject).

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Figure 1: Physical environments (left) and the corresponding virtual environments used in the experiments (right).

		15m		30m	
		Lawn	Hall	Lawn	Hall
AVE CE/Mdpt	Lappin	3.6%	9.7%	2.8%	6.2%
	Ours	2.6%	5.3%	-10.4 %	-11.9%
RMS SD/Mdpt	Lappin	3.7%	6.3 %	4.4%	8.1%
	Ours	8.1%	6.4%	8.5%	8.7%

Table 1: Comparison of our results with those of Lappin et al.

3 Results and Discussion

We analyzed our results in terms of constant errors (biases) and variable errors normalized by distance (Weber fractions). A repeated measures ANOVA on the constant errors found a main effect of only distance ($F(1,15) = 25.42$, $p < .01$). Subjects were more accurate in the 15m condition. Additionally, they tended to overestimate the midpoint in the 15m condition, but underestimate it in the 30m condition. A repeated measures ANOVA on the Weber fractions (SD/Midpoint) also showed a main effect of only distance ($F(1,15)=60.69$, $p < .01$). The Weber fractions were lower in the 15m condition.

Table 1 compares our results with Lappin et al. [2006]. The constant errors (CE) are shown as a percentage of the true midpoint for the average over all 16 subjects. Thus, we find no effect of environmental context in VEs, unlike Lappin et al. [2006], but our systematic errors and Weber fractions are similar in the 15m condition. In the 30m condition, our results are consistent with prior work that shows distance compression. These issues need further investigation. Our next step is to compare these results further with physical environments.

References

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