Effects of field of regard and stereoscopy and the Validity of MR simulation for Visual Analysis of scientific data

Wallace S. Lages* Virginia Tech, USA UFMG, Brazil
Bireswar Laha† Stanford University, USA
Wesley Miller‡ Brown University, USA
Johannes Novotny§ Brown University, USA
John J. Socha¶ Virginia Tech, USA
David H. Laidlaw‖ Brown University, USA
Doug A. Bowman** Virginia Tech, USA

ABSTRACT

We report the findings of a study designed to evaluate the effect of stereopsis and field of regard (FOR) in two different mixed reality (MR) simulation platforms: a head-mounted display (HMD) and a CAVE. We compared the performance of participants on two levels of stereopsis (mono and stereo) and two levels of FOR (90 degrees and 270 degrees) using a variety of scientific visualization tasks. Among the findings, we observed that not all the effects were consistent between the platforms. Stereo alone or in combination with higher FOR improved completion time on both platforms. However, adding stereo solely reduced the accuracy of the participants on the CAVE and improved on the HMD. Our findings extend prior knowledge on the contribution of visual fidelity components and suggests potential limits on MR simulation between platforms.

Index Terms: I.2.10 [Vision and Scene Understanding]: 3D/stereo scene analysis —Perceptual reasoning; H.5.1 [Multimedia Information Systems]: Artificial, augmented, and virtual realities—Life Cycle; I.3.7 [Three-Dimensional Graphics and Realism]: Virtual reality—

1 INTRODUCTION

Prior research has shown that VR systems can improve the perception of spatial relationships [5] and shapes [3]. These properties are specially useful in many engineering and scientific domains which require users to deal with complex data. If we consider VR systems as part of a reality-virtuality *continuum*, it is possible to decompose them into individual immersion components which hold objective levels of fidelity when compared to the real world [1]. Knowing the effect of changing these levels can help us design more cost-effective systems and also learn how valid are the results obtained by simulating a VR system using another one (MR Simulation).

In this work we present the results of a study evaluating the effects of changing display fidelity levels in the context of visual analysis of biological datasets. We ran an experiment controlling stereopsis and field of regard in a CAVE and in a head-mounted-display (HMD). This paper adds to the prior knowledge by showing how the effect of these components vary between platforms: While greater levels of fidelity were associated with better performance in time, we discovered that stereo can have a detrimental effect on HMD accuracy. We also observed that the contribution of the studied variables do not have the same intensity or weight between the platforms. In the next section, we review some previous work investigating the validity of visual MR Simulation.

*e-mail:wlages@vt.edu
†e-mail:laha@stanford.edu
‡e-mail:wesley_miller@brown.edu
§e-mail:johannes_novotny@brown.edu
¶e-mail:jjsocha@vt.edu
‖e-mail:dhl@cs.brown.edu
**e-mail:bowman@vt.edu

2 BACKGROUND AND RELATED WORK

While there are many studies looking into the effects of field of view (FOV; the size of the visual field in degrees of visual angle that can be viewed instantaneously), field of regard (FOR; the total size of the visual field in degrees of visual angle surrounding the user) and Stereopsis in a single platform, and many that compare whole platforms, few tried to make comparisons between different platforms while controlling the visual fidelity components.

Swan et al. [6] investigated stereopsis, movement and frame of reference on the performance of tasks on a 3D battlefield map. Four platforms were compared: a desktop, a CAVE, a workbench, and a Wall. They did not find any main effect of stereopsis across all tasks, which they attribute to the fact that the map was essentially flat. A later study considering stereopsis and display size by Chen et al. [2] found out that in some tasks, participants were more accurate with a monoscopic view. The authors reason that the reduced accuracy on stereo conditions might be explained by several confounding factors, among them eye strain. Unlike Swan et al. we did find evidence that stereo reduces the task completion time in both platforms studied. Similar to Chen et al. we found that stereo can hurt accuracy but this only happened in the HMD, which was not studied by them.

With respect to FOR, Laha et al. described the results of an experiment designed to investigate the effect of FOR and head tracking (HT) in two MR Simulation platforms: HMD and CAVE [4]. The tasks comprised the visual analysis of three volumetric datasets from the biology domain. The authors found that higher FOR reduced completion times and also two interactions between FOR and HT. In our study, we did not find any main effect of FOR on time or accuracy, but we found main effects of FOR on Difficulty and Confidence.

3 EXPERIMENT

The goal of our experiment was to observe the consistency between effects across platforms with the same levels of display fidelity. Two platforms were used in this study: A NVis SX111 head mounted display and a four-sided CAVE. Both platforms were equipped with an ultrasonic wireless tracking system from Intersense (IS-900) [1].

For each platform we had two levels of field of regard (FOR): 90 degrees and 270 degrees, and two levels of stereo (ST): on and off. These three independent variables (Platform, field of regard and stereopsis) were arranged in a factorial design. Each participant, was then asked to perform 15 tasks related to a biological dataset. For each task we measured the completion time, grade, subjective

[1] www.intersense.com

confidence and difficulty. We controlled the levels of FOR by displaying two black walls extending from the participant's head at the desired angle (either 90 or 270 degrees).

In the experiment we used uCT scans of two carabid beetles. A scan of a *Pterostichus* beetle was used for training and one from the genus *Platynus* for testing (Figure 1).

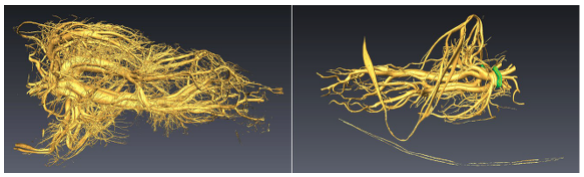

Figure 1: Isosurfaces used in the study. Left: *Pterostichus* (used for training), Right: *Platynus* (used for main study)

We recruited 41 participants for this study from the university community. One was used as a pilot and the remaining were distributed into the 8 groups. None of the participants reported prior knowledge of biomechanics or experience in the analysis of volume datasets. There were 12 females and 29 males.

4 Results and Discussion

We report here the significant results found. We plotted mean grade as a function of mean completion time for the 8 conditions in the study (Figure 2). Points in the top-left area of the plot have higher performance levels (better grade with smaller time) while points in the lower-right have the worse performance (lower grades and longer times). The points represent the center of each condition on the study, and were obtained by calculating the 20% trimmed mean of each group. The arrows depart from the highest fidelity condition towards the lower fidelity ones. Colored bold lines indicate where significant differences were found for time or grade metrics, for at least one task. Mean standard deviation for time was 8.43s and for grade 6.59 points.

It is possible to observe that both platforms display a similar arrow pattern. The tip of the arrow (green circle) is the highest fidelity condition for each platform (Stereo with FOR 270). The remaining conditions were obtained by reducing FOR, Stereo or both. Comparing the two groups we see that the HMD occupies a higher position but farther to the right. This means that, in overall, participants using the HMD obtained better grades at the expense of time.

The effect of simultaneously reducing Stereo and FOR was similar in both platforms. The lines between On-270 and Off-90 are almost parallel. One might speculate that simulation along this line would be very similar (disregarding the initial offset). The difference, however, appears when only Stereo is reduced: even though completion time increases on both platforms, on the HMD the grade decreases while on the CAVE it *improves*. So, while in HMD the highest fidelity condition is clearly the best one, in the CAVE no condition seems to be the best considering both speed and time.

In addition, none of the conditions seem comparable between the platforms, except for time in the lowest fidelity setting (mono with FOR 90). Also, we could not find any evidence that reducing FOR alone changes the performance either on time or accuracy (thin lines on the plot). It is important to notice that we have used a between-subjects design with 5 participants per group. A more powerful experiment might add to these results.

5 Conclusion

We presented a study of the effects of stereopsis and field of regard in the performance metrics (time and accuracy) of participants using a CAVE and a HMD. Overall, higher levels of display fidelity improved the participant's performance. However, we found evidence that stereo can adversely affect the accuracy on the CAVE.

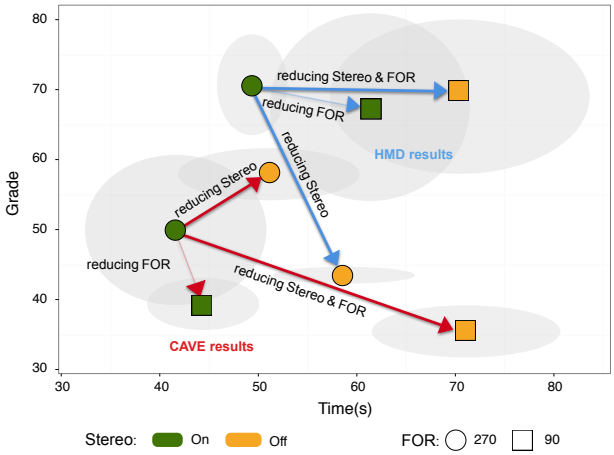

Figure 2: Platform-Performance plot showing the average Time and Grade for each condition. Red lines connect the conditions on the CAVE. Blue lines connect the conditions on the HMD. Conditions with stereo are in green, while monoscopic conditions are in yellow. FOR values are indicated by circles or squares (270 and 90 degrees respectively). Bold colored lines indicate where a significant difference was found. Ellipses around each point indicate the standard deviation for each group. Bold colored lines indicate where a significant difference was found. There was no evidence that changing only FOR affected time or grade.

The different effects observed in our study indicate that these platforms might not be able to support MR simulation on its fullest extent.

Acknowledgements

The authors wish to thank the anonymous reviewers for their input. This work was supported by NSF (1320046, 1319606 and 0938047), Virginia Tech Research Computing's Visionarium Lab, and the Brazilian National Council for Scientific and Technological Development.

References

[1] D. A. Bowman and R. P. McMahan. Virtual reality: how much immersion is enough? *Computer*, 40(7):36–43, 2007.

[2] J. Chen, H. Cai, A. P. Auchus, and D. H. Laidlaw. Effects of stereo and screen size on the legibility of three-dimensional streamtube visualization. *Visualization and Computer Graphics, IEEE Transactions on*, 18(12):2130–2139, 2012.

[3] C. Demiralp, C. D. Jackson, D. B. Karelitz, S. Zhang, and D. H. Laidlaw. Cave and fishtank virtual-reality displays: A qualitative and quantitative comparison. *Visualization and Computer Graphics, IEEE Transactions on*, 12(3):323–330, 2006.

[4] B. Laha, D. A. Bowman, and J. D. Schiffbauer. Validation of the mr simulation approach for evaluating the effects of immersion on visual analysis of volume data. *Visualization and Computer Graphics, IEEE Transactions on*, 19(4):529–538, 2013.

[5] P. Schuchardt and D. A. Bowman. The benefits of immersion for spatial understanding of complex underground cave systems. In *Proceedings of the 2007 ACM symposium on Virtual reality software and technology*, pages 121–124. ACM, 2007.

[6] J. E. Swan, J. L. Gabbard, D. Hix, R. S. Schulman, K. P. Kim, et al. A comparative study of user performance in a map-based virtual environment. In *Virtual Reality, 2003. Proceedings. IEEE*, pages 259–266. IEEE, 2003.