Subjective Usefulness of CAVE and Fish Tank VR Display Systems for a Scientific Visualization Application

Çağatay Demiralp David H. Laidlaw Cullen Jackson Daniel Keefe Song Zhang
{cad, dhl, cj, dfk, sz}@cs.brown.edu
Computer Science Department, Brown University, Providence - RI

1 Introduction

The scientific visualization community increasingly uses VR display systems, but useful interaction paradigms for these systems are still an active research subject. It can be helpful to know the relative merits of different VR systems for different applications and tasks. In this paper, we report on the subjective usefulness of two virtual reality (VR) display systems, a CAVE and a Fish Tank VR display, for a scientific visualization application (see Figure 1). We conducted an anecdotal study to learn five domain-expert users' impressions about the relative usefulness of the two VR systems for their purposes of using the application. Most of the users preferred the Fish Tank display because of perceived display resolution, crispness, brightness and more comfortable use. Whereas, they found the larger scale of objects, expanded field of view, and suitability for gestural expressions and natural interaction in the CAVE more useful.

The term "Fish Tank VR" is used to describe desktop systems that display stereo image of a 3D scene, which is viewed on a monitor using perspective projection coupled to the head position of the observer [Ware et al. 1993]. A CAVE is a room-size, immersive VR display environment where the stereoscopic view of the virtual world is generated according to the user's head position and orientation [Cruz-Neira et al. 1993].

Some related work compares Fish Tank VR displays with Head Mounted Stereo Displays (HMD) and conventional desktop displays. In [Ware et al. 1993; Arthur et al. 1993], the authors compare Fish Tank VR with an HMD and conventional desktop systems. [Pausch et al. 1997] showed that HMDs can improve performance, compared to conventional desktop systems, in a generic search task when the target is not present. However, a later study showed that these findings do not apply to desktop VR; Fish Tank VR and desktop VR have a significant advantage over HMD VR in performing a generic search task [Robertson et al. 1997]. [Bowman et al. 2001] compared HMD with Tabletop (workbench) and CAVE systems for search and rotation tasks respectively They found that HMD users performed significantly better than CAVE users for a natural rotation task. For a difficult search task, they also showed that subjects perform differently depending on which display they encountered first.

Bowman and his colleagues' work shares similar motivations to ours. We go beyond their work with a direct comparison of CAVE and Fish Tank VR platforms. Also, most of previous studies have evaluated VR systems by looking at user performance for a few generic tasks such as rotation and visual search on experiment specific, simple applications. For most of the real visualization applications it may be difficult to reduce the interactions into a set of simple, generic tasks. Consequently, it is not clear how well the results of these studies apply to real visualization applications. This point is elucidated in a recent study that presented the importance of application specific user studies using tasks that reflect end user's needs [Swan II et al. 2003]. In this study, the authors compare user performance for an application specific task across desktop, CAVE, workbench and display wall platforms. They found that the users performed tasks fastest using the desktop and slowest using the workbench. They have a good discussion of the tradeoff between application specific and generic user studies, stressing on the value of application-context based user studies using high-level tasks.

Figure 1: The visualization application running in the CAVE (left image) and on the Fish Tank VR display (right image).

We chose to perform an anecdotal study for two specific reasons: First, we believe application-oriented user studies using the domain-expert user's scientific hypothesis-testing process as a task to be evaluated can be complementary to user studies that utilize generic tasks and experiment specific applications. Second, we wanted to gain insights for designing future quantitative studies to compare user performance in CAVEs and on Fish Tank VRs.

2 Methods

Diffusion tensor magnetic resonance imaging (DT-MRI) is a new imaging modality with the potential to measure fiber-tract trajectories in fibrous soft tissues such as nerves and muscles. Our application visualizes DT-MRI brain data as 3D streamtube and streamsurface geometries in conjunction with 2D T2-weighted MRI sections. It is based on the work by *et al.* [Zhang et al. 2001]. We have the application running both in a CAVE and on a Fish Tank display. Five domain-expert users were asked to use it both in the CAVE and on the Fish Tank display. Our expert user pool was made of one neuroradiologist, one neurosurgeon, one computer science graduate student with an undergraduate degree in neuroscience, one biologist and one doctor, who is also a medical school instructor, with an undergraduate degree in computer science. Four of the users were male and one was female. Two of the users started with the Fish Tank version of the application and the rest with the CAVE version. Each user had their own task (or scientific hypothesis to be tested), which they described to us. They were asked to compare the platforms with respect to their purposes. They did so by talking to us while using the application. Most often we offered counterarguments, which helped to expose the reasoning behind the users' observations. The users were then asked to give an overall preference for one of the two VR systems.

3 Results

Overall, one user preferred CAVE and four preferred Fish Tank VR display. We summarize the users' comments as to relative advan-

tages of CAVE and Fish Tank VR systems below.
Comments on advantages of CAVE:

- Has bigger models, one can see more
- Has larger field of view
- More suitable for gestural expression and natural interaction
- Possible to walk around

On Fish Tank VR display:

- Has sharper and crisper images
- Constitutes more information, relationships between the structures are easier to see
- Feels more comfortable, non-claustrophobic and sitting is better than standing
- Works better for collaboration, especially with two people
- Pointing to objects on the screen is easier
- More time efficient to use; doctors prefer to work-and-go
- Would work better for telemedicine-like collaboration
- More intuitive for surgery planning because doctors are used to working with real or smaller brain sizes

Our first user was a neurosurgeon; he had used the application before. He uses DT-MRI data to study obsessive-compulsive disorder (OCD) patients and was particularly interested in studying changes that occur after radiation surgery, which ablates an important white matter region. He wanted to see the relation between the neuro-fiber connectivity and linear diffusion (streamtubes) in the brain. He strongly preferred using Fish Tank VR and did not find any relative advantages of the CAVE.

Our second user was a biologist who was also trying to see correlations between white matter structure and linear diffusion in the brain. His interests were not confined to a specific anatomical region. He was the only user who preferred the CAVE over Fish Tank display.

Our third user was a doctor and a medical school instructor with an undergraduate degree in computer science. She evaluated the application from teaching and learning perspectives.

Our fourth user was a computer science graduate student with an undergraduate degree in neuroscience. He looked at the application to see correlations between white matter structures and linear diffusion in the brain, similar to our second user. He said that he preferred Fish Tank VR because 2D sections have higher resolution and the models look crisper on the screen, which helped him see the correlations easily.

Our last user was a neuroradiologist working on MS (multiple sclerosis) disease. He wanted to see the 3D course of neurofibers along corpus callosum. He was able to see what he was looking for in both the platforms.

All users also found 2D sections to be very helpful in both platforms. They said they were familiar with looking at 2D sections, which help them to correlate and orient the 3D geometries representing diffusion with the brain anatomy.

4 Discussion

The higher perceived display resolution, crispness, brightness, and more comfortable use were considered useful on the Fish Tank VR. On the other hand, users found the larger scale of objects, expanded field of view, and potential use of gestural and natural interaction useful in the CAVE. We believe that each of these factors is worth investigating in order to quantify their effects on user performance. Some of these factors have already been studied quantitatively: for example, recently Kasik *et al.* showed the positive effect of a crisp display on user performance [Kasik et al. 2002].

We still believe that application-oriented user studies using the domain-expert user's hypothesis-testing process as a task to be evaluated can be complementary to user studies that evaluate generic task performance on experiment specific, simple applications. However, this approach is difficult to implement: First, one needs many application-oriented studies to find meaningful patterns and generalize them; second, finding enough expert users with similar hypotheses can be very difficult.

In light of the experience we gained through this study, we hypothesize that Fish Tank VR displays are preferable over CAVEs for exocentric tasks, as they physically separate user's reference frame from the application's. As an initial attempt to test this hypothesis we will conduct a formal quantitative user study in which we will compare the user performance between CAVE and Fish Tank VR for an exocentric search task on a simple, experiment specific application. However, we will also give a greater emphasis on the task's relevance in real visualization applications.

5 Summary

We presented results from an anecdotal user study with five domain-expert users. They used a scientific visualization application both in a CAVE and on a Fish Tank VR platform. While the higher perceived display resolution, crispness, brightness and more comfortable use were considered useful on the Fish Tank VR, users found the larger scale of objects, expanded field of view, and potential use of gestural and natural interaction useful in the CAVE. Overall, one user preferred CAVE and four users preferred Fish Tank VR.

References

ARTHUR, K. W., BOOTH, K. S., AND WARE, C. 1993. Evaluating 3d task-performance for fish tank virtual worlds. *ACM Trans. Inf. Syst. 11*, 239–265.

BOWMAN, D. A., DATEY, A., FAROOQ, U., RYU, Y. S., AND VASNAIK, O. 2001. Empirical comparisons of virtual environment displays. Tech. rep., Virginia Tech Dept. of Computer Science, TR-01-19.

CRUZ-NEIRA, C., SANDIN, D. J., AND DEFANTI, T. A. 1993. Surround-screen projection-based virtual reality: the design and implementation of the cave. In *Proceedings of the 20th annual conference on Computer graphics and interactive techniques*, ACM Press, 135–142.

SWAN II, J. E., GABBARD, J. L., HIX, D., SCHULMAN, R. S., AND KIM, K. P. 2003. A comparative study of user performance in a map-based virtual environment. In *Proceedings of IEEE Virtual Reality 2003*, 259–266.

KASIK, D. J., TROY, J. J., AMOROSI, S. R., MURRAY, M. O., AND SWAMY, S. N. 2002. Evaluating graphics displays for complex 3d models. *IEEE Comput. Graph. Appl. 22*, 56–64.

PAUSCH, R., PROFFITT, D., AND WILLIAMS, G. 1997. Quantifying immersion in virtual reality. In *Proceedings of the 24th annual conference on Computer graphics and interactive techniques*, ACM Press/Addison-Wesley Publishing Co., 13–18.

ROBERTSON, G., CZERWINSKI, M., AND VAN DANTZICH, M. 1997. Immersion in desktop virtual reality. In *Proceedings of the 10th annual ACM symposium on User interface software and technology*, ACM Press, 11–19.

WARE, C., ARTHUR, K., AND BOOTH, K. S. 1993. Fish tank virtual reality. In *Proceedings of the conference on Human factors in computing systems*, Addison-Wesley Longman Publishing Co., Inc., 37–42.

ZHANG, S., DEMİRALP, Ç., KEEFE, D., DASILVA, M., LAIDLAW, D. H., GREENBERG, B. D., BASSER, P., PIERPAOLI, C., CHIOCCA, E., AND DEISBOECK, T. 2001. An immersive virtual environment for dt-mri volume visualization applications: a case study. In *Proceedings of the conference on Visualization 2001*, IEEE Computer Society Press, 437–440.