The Design and Evaluation of a Lightweight Multi-View Interaction Metaphor for 3D Visualization in the CAVE

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1 Introduction and Related Work

We explore the design of a multi-view interaction metaphor for 3D visualization in the CAVE. We then present the results of a formative evaluation of a "Wizard of Oz" [Kelley 1984] prototype. Although there has been significant prior work on 2D and 3D desktop applications utilizing multiple views, little prior work exists for multi-view systems in immersive virtual environments such as the CAVE, despite the clear advantages enjoyed by desktop analogues. Immersive 3D environments pose unique challenges for such a system. Since the contents of such views are themselves 3D, it is unclear whether users will be able to easily read views independently of one another, as in a naive implementation they might become intermingled; even in a system that is conscious of this problem, some vantage points may cause depth ambiguity problems which make it difficult to read each view. In addition, interaction techniques for controlling and managing such views must be explored. Thus, formative empirical testing is warranted to determine the viability of such a system.

Desktop-based visualizations, such as VisTrails [Bavoil et al. 2005], frequently employ multiple views, as do popular commercial 3D packages such as AutoDesk Maya. One study [Plumlee et al. 2005] found that multiple windows should be used for tasks in which visual comparisons must be made between parts that have greater complexity than can be held in working memory; this empirical evidence motivates our approach. A pop-through button system in the CAVE lets users create snapshots that can be used to travel quickly to the location and orientation at which the snapshot was created [Zeleznik et al. 2002]. Our work is the first to address simultaneous setup, control and management of multiple views in immersive virtual reality environments such as the CAVE, a setting that poses unique challenges.

2 Design and Evaluation

On the basis of the challenges outlined above, we established the following design goals for the overall user experience: (G1) simultaneous readability: it is important that users be able to read multiple side-by-side views without abnormal effort - views should not intersect, and if line-of-sight superimposed, users should be able to distinguish them; (G2) lightweight view management: since views will frequently be created on the fly as part of an ongoing scientific workflow, view management techniques should be simple and lightweight so as to minimize the cognitive burden on the user's workflow; (G3) the system should support core scientific workflow scenarios; (G4) scalability: the system should take advantage of the multiple walls available in the CAVE and scale well to a significant number of simultaneous views. See Representative Image 1 for detailed design and a user interaction scenario.

Our prototype was implemented in CavePainting [Keefe et al. 2001] in a four-wall CAVE with four 1024x768 projectors. Two related visualizations of the aerodynamics of bat flight were employed; one shows fluid flow, pressure and vorticity around a bat wing; the other shows the kinematics of muscles, bones and tendons during flight. Five participants, aged 23-36 and familiar with such visualizations, were recruited from bat biology, visualization, and human-computer interaction research groups at Brown University. All participants reported playing video games with some frequency; three participants had experienced the CAVE at least once. Participants wearing 6-DOF head-tracked, stereoscopic glasses, first had time to familiarize themselves with the CAVE. They then were given a walkthrough of our "Wizard of Oz" prototype; users executed commands by describing their intended interaction out loud, at which point we then updated the prototype to a new frame showing the appropriate state. Participants were asked to think aloud during the study, and to say which features they liked or didn't like, and what they might like to add or remove. They were encouraged to view the scene from different locations and orientations, to get a sense of how the views overlapped from various vantage points. After the session, averaging 30-60 minutes, each participant completed a post-questionnaire.

Overall, participants liked the approach, with four of the five participants rating it "Easier" or "Much Easier" to use than visualization interfaces they had previously experienced. All five participants reported that multiple views would be useful and that it was not confusing to have multiple views juxtaposed when the vantage point caused multiple views to be combined in the line of sight. Participants furthermore reported that segmenting the separate views was not difficult in general, and in such corner cases in particular. All five participants said that fading background views in such cases might be helpful but was not strictly necessary. Three participants liked the view management techniques presented, including the automatic behaviors and the marking menu, while two felt additional changes might be needed. One participant felt that 6-DOF mice were too "hands off" and that hand gestures would be a more natural way to manipulate views. Another felt the UI elements should be larger and closer to the user to make them easier to target. He was also concerned about how views change size depending on orientation, saying that he would prefer constant view size. This result appears to support the value of lightweight view management, but additional design work may be needed to address some of the concerns mentioned. All five participants reported that it would be nice to "zoom in" to a specific view for a fully immersive experience on a single view, and to "zoom out" to see multiple views as well. Two users reported they would like to superimpose views in 3D to visualize differences between similar views.

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