Aperture Based Selection for Immersive Virtual Environments

Andrew Forsberg, Kenneth Herndon and Robert Zeleznik
Brown University site of the
NSF Science and Technology Center for
Computer Graphics and Scientific Visualization
Providence, RI 02912
(401) 863-7693; {asf,kph,bcz}@cs.brown.edu

ABSTRACT

We present two novel techniques for effectively selecting objects in immersive virtual environments using a single 6 DOF magnetic tracker. These techniques advance the state of the art in that they exploit the participant's visual frame of reference and fully utilize the position and orientation data from the tracker to improve accuracy of the selection task. Preliminary results from pilot usability studies validate our designs. Finally, the two techniques combine to compensate for each other's weaknesses.

KEYWORDS: interaction, selection, immersive virtual environments, direct-manipulation, 3D widgets.

INTRODUCTION

Selection techniques indicate to an application which object or objects a participant wishes to interact with in a virtual environment (VE). We present two novel techniques for selecting objects in a VE called *aperture* and *orientation*. The techniques apply to our test application, an immersive VE for visualizing a computational fluid-dynamics dataset in which users select and directly manipulate components of 3D widgets [1] to control visualization tools [3]. The techniques use input from a single six degree of freedom (DOF) input device. We discuss the motivation for their design and important technical details.

PREVIOUS WORK

A variety of direct-manipulation techniques exist in immersive virtual reality applications for selecting objects. The most common are the metaphorical *touch* and *laser pointer* [4]. The touch technique allows the participant to place a 3D cursor (representing the tracked hand) on or inside a target object in the VE. A gesture (e.g., with a glove input device) or button click signals to the application to select the target object. The laser pointer technique utilizes ray intersection to determine which object(s) to select. This method is attractive due to its low computational cost and ease of implementation.

In practice, the effectiveness of these techniques is limited by imprecision and noise in the tracking system as well as instability in the participant's hand. Our evaluation studies of the laser pointer technique find that there is typically ± 5 degrees of rotational noise when a participant tries to hold the tracker steady and aim at a target object. Consequently, small objects even a short distance away are difficult to select reliably or consistently. Similarly, positional noise adversely affects the usability of the touch technique (± 1.5 inches). Also, the touch technique can only be used to select objects that are within reach.

The *spotlight* technique [5] is a variation of the laser pointer technique. It reduces the effects of noise and object-size problems by using a conic selection volume. Because all the objects within the conic selection volume may be selected, however, a *disambiguation metric* for choosing a single object from the set of candidates may be required. In addition, the spotlight technique also depends on sufficient visual feedback for effective use; in particular, feedback indicating the volume of the spotlight cone is necessary.

Zhai's silk cursor [6] is a variation of the touch technique which selects objects that fall within a transparent cubic volume. User's are permitted greater error when specifying which object they wish to select and the transparent cursor provides visual cues as to the location of target objects positioned behind, within, and in front of the cursor. Problems with this technique include choosing an appropriate cursor size, providing a disambiguation metric, and selecting objects beyond the user's reach.

The selection techniques we present are specifically designed to reduce the effects of aiming, positioning, and reachability problems.

APERTURE SELECTION

The aperture selection technique is a modification of the spotlight selection technique. In aperture selection, the apex of the conic selection volume, the *from point*, is set to the location of the participant's dominant eye and the *direction vector* of the cone is the vector from that eye through the tracker's location (represented in the VE by a cursor). The aperture cursor is a circle of fixed radius and a crosshair that is aligned with the film plane (Figure 1). The size of the selection volume is determined by the distance between the eye point and the aperture cursor. A participant can adjust the scope of the selection by moving her hand in and out, thus changing this distance.
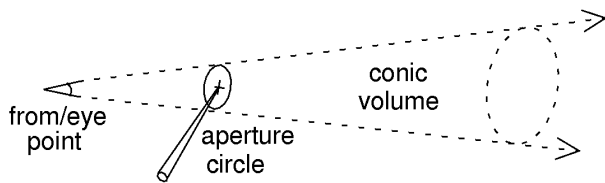
Figure 1: The conic volume of the aperture selection technique is described by the eye point and aperture geometry.

The aperture requires the participant to indicate a position along her line of sight. In preliminary tests, participants held the tracker in one hand and the aperture geometry was drawn at the corresponding position in the VE. We found that this induced considerable arm fatigue. To alleviate this, we mounted the tracker on a drumstick prop and placed the aperture geometry at the end of a virtual representation of the stick in the VE. Anecdotal evidence from additional tests indicated that this was less fatiguing because participants could keep their arm in a more restful position by their side (Figure 2).

The advantages of the aperture selection technique are: 1) it closely mimics both how we point at distant objects in the real world and the familiar desktop metaphor of positioning a cursor on top of a target object; 2) it incorporates volume selection as used by the spotlight technique to reduce the effects of tracker and user-induced noise; and 3) the screen is less cluttered because no visual feedback is required other than the aperture cursor itself, though highlighting selectable objects can help users determine exactly what they are selecting. In contrast, the spotlight technique requires a transparent outline for the selection cone to aid the user in comparing the current direction of the selection cone with the position of the target object.

Figure 2: Using the drumstick prop in an immersive virtual environment.

An important consideration for this technique is the choice of a from point for the selection volume. Logical possibilities are the positions of either of the participant's two eyes or an average of these points. However, since all of our test subjects exhibited ocular dominance [2], the only option which avoids perceptual confusion was to use the participant's dominant eye. When the cursor is visible only from the non-dominant eye, we dynamically switch the from point to that eye. We found that our subjects generally liked this selection technique, but some complained that when they attempted to select distant objects, they would focus on that object and could perceive two distinct images of the aperture in the foreground. This phenomenon, due to parallax in the stereo view, may be significant for some applications, but can be resolved by closing the non-dominant eye.

As in the spotlight technique, we use a disambiguation metric to choose among multiple candidate objects when single object selection is desired. Thus it is difficult to select one of a set of closely-spaced objects. Also, because the cone has infinite extent, it is not clear what actions are appropriate when very distant objects are selected.

APERTURE WITH ORIENTATION
In the real world, we orient our hands to match the orientation of a target object in some way before we manipulate the object (e.g., grabbing a book or coffee mug). We can similarly use the 3D orientation information provided by the tracker to augment the aperture technique for selecting objects in a VE. By this method, if multiple objects fall within the conic volume of the aperture, we select the object whose orientation most closely matches the orientation of the tracker. Orientation information provides the primary disambiguation metric. If all candidate objects have similar orientations, we resort to the basic aperture technique disambiguation metric.
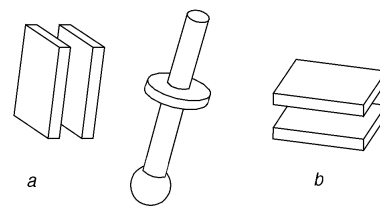

Figure 3: Orientation selection technique. a) shows the cursor orientation that would select the rake frame. b) shows the orientation that would select the cylindrical slider.

In our application, we provide visual feedback to aid in matching orientation by drawing two parallel "plates" with the aperture geometry. A user positions and orients these plates around an object to select it.

REFERENCES
1. D. Brook Conner, et al. Three-dimensional widgets. *Computer Graphics (1992 Symposium on Interactive 3D Graphics)*, 25(2):183–188, March 1992.

2. Hugh Davson. *Psychology of the eye*. New York: Academic Press, 1980.

3. Kenneth P. Herndon and Tom Meyer. 3D widgets for exploratory scientific visualization. In *Proceedings of UIST'94*, pages 69–70, November 1994.

4. Ken Hinckley, Randy Pausch, John C. Goble, and Neal F. Kassel. A survey of design issues in spatial input. *Proceedings of UIST'94*, pages 213–222, November 1994.

5. Jiandong Liang and Mark Green. JDCAD: A highly interactive 3D modeling system. *Computers and Graphics*, 18(4):499–506, July/August 1994.

6. Shumin Zhai, William Buxton, and Paul Milgram. The "silk cursor": Investigating transparency for 3d target acquisition. *Proceedings of CHI'94*, pages 459–464, April 1994.