Bimanual Task Division Preferences for Volume Selection

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1 Introduction and Related Work

Using both hands for 3D interaction allows users to transfer ingrained interaction skills, significantly increase performance on certain tasks, and reduce training [Bowman et al. 2005]. Guiard's framework of Bimanual manipulation states that different classes of bimanual actions exist [1997]. The Bimanual Asymmetric classification consists of both hands, performing different actions, coordinated to accomplish the same task. The Bimanual Symmetric classification involves each hand performing identical actions, either synchronously or asynchronously. Latulipe et al. compared a symmetric, dual-mouse technique for manipulation of spline curves, to two asymmetric dual-mouse techniques and a standard single-mouse technique. The symmetric technique performed best and was most preferred by participants [2006].

In this research, we focus on developing and quantifying a novel selection technique specifically for visualizations of three dimensional volumetric data that use splat-based rendering [Jang et al. 2002]. Although many 3D interaction metaphors exist [Bowman et al. 2005; Steed 2006], they may not be suitable to use with splat-based rendered areas since the rendered objects are not precisely defined by their natural borders as are polygonal objects found in traditional virtual environments. The result from a previous study found that an asymmetric technique reduced fatigue best, but a symmetric synchronous technique was the more accurate [Ulinski et al. 2007]. In this study we developed and evaluated Two-Corners Asynchronous, a novel bimanual symmetric asynchronous selection technique, that encompassed the properties from a bimanual asymmetric technique that led to reduced fatigue and the properties from a symmetric synchronous technique that led to best accuracy performance, resulting in a technique with hypothesized high performance in both criterion.

2 Selection Techniques

We compared three selection techniques that utilize a 3D box for selection that is positioned, oriented, and resized differently for each technique. The selection area was the volume within the 3D box. The *Hand-in-Middle technique* is a bimanual asymmetric technique where the middle of the box is held by the non-dominant hand, controlling position, and the dominant hand uniformly scales the box by moving relative to the non-dominant hand [Ulinski et al. 2007]. The *Two-Corners technique* is a bimanual symmetric synchronous technique, with hands holding opposite corners synchronously controlling position, orientation, and scale of the selection box [Ulinski et al. 2007]. The *Two-Corners Asynchronous technique* is a bimanual symmetric asynchronous technique, with both hands performing the same tasks either alternately or together. The non-dominant hand holds the bottom front corner, of the box, while the dominant hand holds the opposing upper back corner. The combined position of both hands directly controls the position, orientation, and size of the selection box. The difference between this technique and the Two-Corners technique is that this technique allows the user to lock either the non-dominant or dominant hand in order release the box from that hand. The other hand then controls the box, thereby transforming the Two-Corners symmetric technique into an asymmetric technique for that period of time.

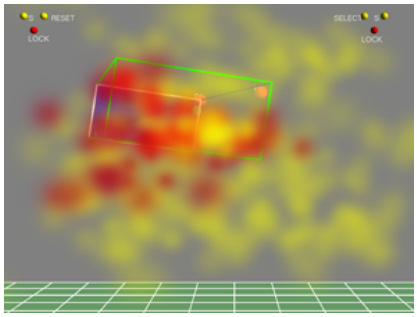

Figure 1: Performing a selection.

3 Experimental Study

Three selection techniques for volumetric data were evaluated: Hand-in-Middle (HIM), Two-Corners (TC), and Two-Corners Asynchronous (TCA). The Selection Method was manipulated within subjects, balancing the order using Latin square. Two Polhemous FastTrak magnetic trackers with 6 degrees-of-freedom (DOF), and three joystick buttons attached to each, served as the 3D input devices. The purpose of this study is to determine whether the symmetric asynchronous (TCA) technique will cause less fatigue than the symmetric synchronous (TC) technique and perform better than the asymmetric (HIM) technique. We hypothesized that users will prefer the symmetric techniques (TC and TCA) above the asymmetric technique (HIM), with the symmetric asynchronous technique (TCA) preferred more than symmetric synchronous technique (TC). Also hypothesized is that the asymmetric technique (HIM) will perform the fastest.

A total of 32 university students (17 females, 15 males, mean age=20.50, SD=3.73) participated in the study. Participants were pre-surveyed for demographic information, experience in 2D and 3D interaction, and completed the Guilford-Zimmerman Aptitude Survey Part 5: Spatial Orientation [1948]. We evaluated the techniques using a sparse/occluded arrangement of splats, or colored volumetric spheres, within arm's reach. Sparse/occluded refer to splats, marked for selection, that are far apart and visually blocked. For each trial, participants were presented with a series of splats and used the selection box to select spats marked for selection. Button and splat selection feedback were provided. Participants were instructed and led through five sample trials of the task, permitting questions. Participants completed ten testing trials of the selection task as quickly and as accurately as possible. Selection accuracy scores and completion times were logged for

VRST 2007, Newport Beach, California, November 5–7, 2007.
© 2007 ACM 978-1-59593-863-3/07/0011 $5.00

each trial. Participants completed the TLX workload Assessment questionnaire [Hart and Staveland 1988], the self-Perception of Accuracy, Ease of Use, User Comfort, and Ease of Learning questionnaires, all based on a 7-point Likert scale, for each task. Participants then reported the preferred method for eleven categories on the User Preference questionnaire. An open-ended questionnaire ended the session.

4 Results

A 3 x 2 analysis of variance (ANOVA) was used on each measure to test for the main effects of selection method and of testing type. Differences of User preference ratings were tested using the Chi-square test. Post-hoc tests, with a least significant difference test, and F and χ^2 tests used α=0.05 level for significance. There were no significant findings among groups in the pre-experimental measures. The ANOVA for mean accuracy scores showed a main effect of selection methods $F(2, 1316) = 3.473$, p=0.003, η^2 = 0.01. A post-hoc test indicated that the accuracy scores of TC (M= 17.16, SD= 15.32) and TCA (M=16.51, SD= 17.99) are significantly higher than HIM (M= 13.95, SD= 21.05). The results show that Two-Corners Asynchronous (TCA) was as accurate as Two-Corners (TC) and performed significantly better than Hand-in-Middle (HIM). The results of an ANOVA show a significant main effect due to selection methods for task completion times, $F(2, 1316) = 9.44$, p<0.001, η^2 = 0.01. A post-hoc test showed that the times for HIM (M= 385.76, SD= 238.74) were significantly higher than TCA (M= 344.75, SD= 188.38) and both were significantly higher than TC (M= 314.04, SD= 207.54). The results suggest that symmetric techniques allow the user to perform faster selection than asymmetric techniques. There were no differences for TLX Overall Workload, arm strain, ease of use, user comfort, or ease of learning.

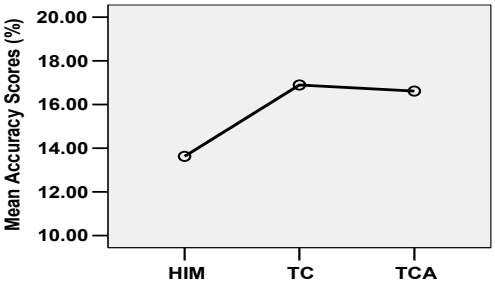

Figure 2: Mean accuracy scores for selection methods: Hand-in-Middle, Two-Corners, and Two-Corners Asynchronous.

The results of user preferences, of either asymmetric (HIM), symmetric (TC and TCA), or none, indicate significant differences, where symmetric techniques were preferred more than an asymmetric technique, for the following categories: overall use, χ^2 (2, 32) = 11.31, p= 0.003; comfort, χ^2 (2, 32) = 16.75, p< 0.001; best for long hours, χ^2 (2, 32) = 6.81, p= 0.016; best accuracy, χ^2 (2, 32) = 15.44, p< 0.001; most difficult to use, χ^2 (2, 32) = 19.00, p< 0.001; best focus, χ^2 (2, 32) = 15.44, p< 0.001; and most fun, χ^2 (2, 32) = 12.25, p= 0.002, and an asymmetric technique was preferred more in the recommended for other's category, χ^2 (2, 32) = 12.06, p= 0.002. There were no significant differences for type of symmetric technique for categories of hard task or reduced fatigue. There were no significant differences in any categories for the each method grouped by gender. The results suggest symmetric techniques are preferred above a asymmetric technique, though no difference in preference for type of symmetric technique. The main reasons reported in debriefing were they liked the symmetric techniques because they would rather use both hands or they did not like the asymmetric technique because they did not like using their non-dominant hand to control the box. This suggests that task division for the HIM technique was not optimal.

5 Summary and Future Work

In conclusion, we accept our hypothesis that participants prefer the symmetric techniques above the asymmetric technique, but no preference among type of symmetric technique. We accept our hypothesis that the symmetric asynchronous technique has an accuracy performance equivalent to the symmetric synchronous technique. We could not determine if the symmetric synchronous technique reduces fatigue, therefore more investigation is required. The symmetric techniques were significantly the fastest, but the symmetric synchronous technique was faster than the symmetric asynchronous technique. Our results suggest that when designing asymmetric selection techniques for volume selection, assigning gross manipulations to the non-dominant hand may be inappropriate. Further investigation will find if assigning these manipulations to the dominant hand will improve performance.

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