Multimodal Interaction Techniques for the Virtual Workbench

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ABSTRACT
The present study investigated the differential levels of effectiveness of various interaction techniques on a simple rotation and translation task on the virtual workbench. Manipulation time and number of collisions were measured for subjects using four device sets (unimanual glove, bimanual glove, unimanual stick, and bimanual stick). Participants were also asked to subjectively judge each device's effectiveness. Performance results indicated a main effect for device but not for number of hands. Subjective results supported these findings, as users expressed a preference for the stick(s).

Keywords
Virtual workbench, interaction techniques, pinch gloves, novel devices, 3-D object manipulation

INTRODUCTION
There has been relatively little research conducted addressing the evaluation of interaction techniques used in immersive and semi-immersive large display environments like the virtual workbench. [3] The present study set out to evaluate four separate interaction techniques, unimanual glove (UG), unimanual stick (US), bimanual glove (BG), and bimanual stick (BS). The authors were interested not only in the performance difference between unimanual and bimanual techniques, but also in any performance differences attributable to the devices themselves.

METHOD
Participants
24 undergraduate students volunteered to participate in this study for course credit. Participants were screened for experience with stereoscopic displays, immersive interfaces, and other virtual/augmented reality technologies in order to ensure that only novice users would be included in the experimental sample. Only one left handed individual participated in the study.

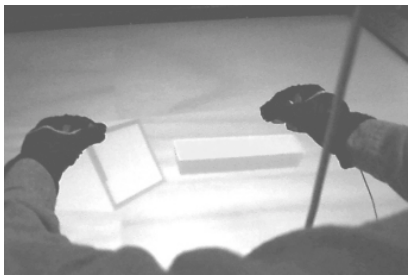
Apparatus
Display
A Fakespace Immersive Workbench was used in this study to display the stereoscopic images. It consisted of an Electrohome Marquee 8500 Projection system, Polhemus 3Space Fastrak tracking system, and a CrystalEyes emitter and glasses package. Head position was tracked by connecting a tracker to the CrystalEyes glasses. This display equipment was serviced by an SGI Onyx2 with 4 processors and IR graphics.

Pinch Gloves
Instead of utilizing a gestural grammar, Fakespace Pinch Gloves recognize 'pinches' or contacts made between the various contacts at the tip of each finger and in the palm. For the purposes of this experiment, the only 'pinch' recognized by the system was that of the thumb and forefinger contacts. This mimicked the normal grasping of an object between thumb and forefinger, providing a natural manipulatory motion. A tracker was connected to the back of each glove, at the base of the middle finger.

Fig. 1 The stick with attached tracker.

Sticks
Also called button chord devices [3], the sticks are PVC tubes with five buttons on them. The buttons are placed on the surface of the tube in such a way that each finger can access one corresponding button. For the purposes of this experiment, only the 'thumb' button (nearest the tip of the stick and set off from the other four buttons) was recognized by the system. Depending on the way the user chose to hold the stick, the thumb button could be depressed by the thumb (when the stick is grasped like the hilt of a sword) or by the index finger (when the stick is held like a pencil of stylus).

Fig. 2: The box and rod task performed with the bimanual glove device set.



Design and Procedure

During the experimental procedure, participants completed a simple object manipulation task on the virtual workbench. The task involved placing a rod into the open side of a five sided cube or 'box'. To begin each trial the box was presented at a random orientation and had to be manipulated so that the open side could be brought into view. After locating the open side of the box, the participant would proceed to place the rod into the opening. In the case of the two-handed techniques, these tasks could be performed in parallel (one hand manipulating the box and the other the rod) if the user chose to do so. In keeping with Guiard's framework for object manipulation [2], the box was always presented on the side of the users non-dominant hand, while the rod was always presented on the side of the dominant hand. If, at any time during the manipulation, the rod were to collide with the side or edge of the box, the box would turn red and the participant would have to remove the rod from the box and reinsert it. When the rod was inserted into the box without collision, the box would turn green and a new trial could be initiated. Rotation and translation of both the box and the rod were necessary in order to complete the task.

Following a brief introduction to the virtual workbench, each participant completed four blocks of 15 trials. These four blocks were comprised of one block for each of the four interaction techniques specified. Both subjective and objective performance measures were collected during the procedure. Objective measures included time of manipulation and number of collision errors. Subjective measures involved a Likert scale instrument designed to assess each participant's personal preferences and impressions with respect to the interaction techniques employed.

RESULTS

Objective Measures

Repeated measures ANOVA coupled with Tukey HSD post hoc analyses uncovered significant differences in the collision data ($F(3,69) = 5.637$, $p=.002$). Collisions per trial in the US condition ($\underline{M}=.40$) were significantly fewer than those in the UG and BG conditions ($\underline{M}=.66$ and $\underline{M}=.84$, respectively). There were also significantly fewer collisions in the BS ($\underline{M}=.48$) than in the BG ($\underline{M}=.84$) condition. Additional analysis indicated a significant main effect for device (stick vs. glove) but none for number of hands (bimanual vs. unimanual).

Repeated measures ANOVA coupled with Tukey HSD post hoc analyses also uncovered significant differences in the manipulation time data ($F(3,69) = 4.728$, $p=.005$). Pairwise comparison showed that the task was completed significantly faster in the each of the stick conditions ($\underline{M}=9.9$ and $\underline{M}=10.8$, for US and BS respectively), than in the glove conditions ($\underline{M}=13.5$ and $\underline{M}=13.0$, for UG and BG respectively). Here as well, additional analysis indicated a significant main effect for device (stick vs. glove) but none for number of hands (bimanual vs. unimanual).

Subjective Measures

When asked which device allowed them to perform the tasks most effectively, 20 of the 24 users chose the stick(s) (9 unimanual, 11 bimanual). When asked which device most hindered their performance of the task, 16 of the 22 users expressing a preference chose the glove(s) (6 unimanual, 10 bimanual). When asked which device was most appropriate for tasks requiring more precision, 17 of 23 users expressing a preference chose the stick(s) (12 unimanual, 5 bimanual). Finally, when asked which device was most appropriate for task requiring less precision, 18 of the 22 users expressing an opinion chose the glove(s) (7 unimanual, 11 bimanual).

CONCLUSION

The obtained results indicate no effect for the number of hands involved in performance of the task (unimanual vs. bimanual. However, both the subjective and objective results suggest that the sticks may be a more precise and efficient interaction device than pinch-gloves in object manipulation tasks requiring a degree of precision. As such, the stick should be considered in the design of 3-D interfaces involving object manipulation.

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