Assessing the Effects of Orientation and Device on 3D Positioning

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Abstract

We present two studies to assess which physical factors of various input devices influence 3D object movement tasks. In particular, we evaluate the factors that seem to make the mouse a good input device for constrained 3D movement tasks.

The first study examines the effect of a supporting surface across orientation of input device movement and display orientation. Surprisingly, no significant results were found for the effect of physical support for constrained movement techniques. Also, no significant difference was found between matching the orientation of the display to that of the input device movement. A second study found that the mouse outperformed all tracker conditions for speed, but the presence or absence of support had no significant effect when tracker movement is constrained to 2D.

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Additional Keywords: 3D manipulation, comparing devices

1 Introduction

Despite advances in 3D manipulation research, it is still far more difficult to perform certain tasks in a 3D environment compared to conceptually similar tasks in a 2D environment. Consider, for example, moving a desktop icon and then compare this to moving a 3D object in a virtual environment.

Although the bulk of VR research focuses on creating better user interfaces with 3D (6DOF) input devices, good 3D manipulation techniques exist also for 2D devices, in particular the mouse. The mouse provides several advantages including familiarity, physical support, and high precision. Also, when using direct manipulation interfaces, it is intuitively easier to accurately position an object in 2D space than in 3D space. This work examines several of these factors, to try to determine to what extent they can be utilized to create better 3D input devices for similar manipulation tasks.

1.1 Physical Support and Passive Haptic Feedback

The mouse requires a physical surface upon which to work. This not only prevents fatigue by allowing the user to rest their arm, but also steadies the hand, improving accuracy. However, this makes the mouse unsuitable for certain types of 3D environments such as a CAVE, since it constrains the input to locations where a tabletop or similar surface is present. Nevertheless, this feature has not gone unnoticed in the VR and AR communities; researchers have previously added physical support to VR systems with varying degrees of success [1, 3].

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1.2 Display & Device Movement Orientation

The mouse is essentially an indirect, relative manipulation device – no attempt is made to register the position of the device with that of objects on the screen. In contrast, many VR techniques register the position of a virtual hand with that of the user's real hand, in order to take advantage of proprioception. Furthermore, the mouse moves in a horizontal movement plane, which is mapped to a vertical movement plane on a typical desktop screen environment. We are interested in determining if a direct mapping (i.e., device movement *up* to cursor movement *up*) is more natural than the indirect mapping (i.e., device movement *forward* to cursor movement *up*) used by the mouse. These factors affect which muscle groups are used by the device, which can affect user performance [4].

2 Experiments

We conducted two experiments to evaluate the differences in input techniques and devices for 3D positioning tasks. Ray casting was used in all cases for object selection. Figure 1 depicts the experimental setup. Figure 2 depicts the task used in both experiments. The task involved moving several objects around a computer lab setting in the order depicted: object *1* to location *A*, object *2* to location *B*, etc.

Figure 1. (Left) The experimental setup. The table to the right of the system was used for the horizontal support condition, and the cupboard resting on top for the vertical support condition. The table was removed for the unsupported conditions. (Right) Hand tracker and mouse – fingers lifted to show mouse underneath.

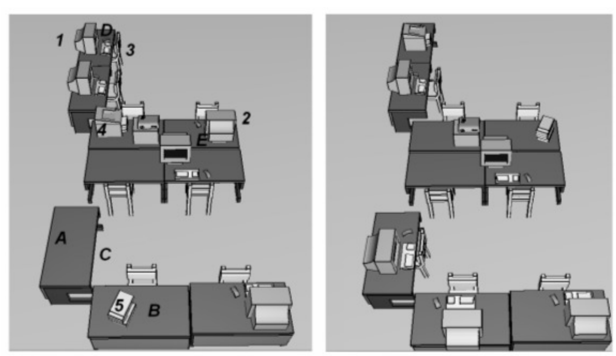

Figure 2. Experimental task used in both experiments. (Left) Overhead view of the starting condition. (Right) Completed task.

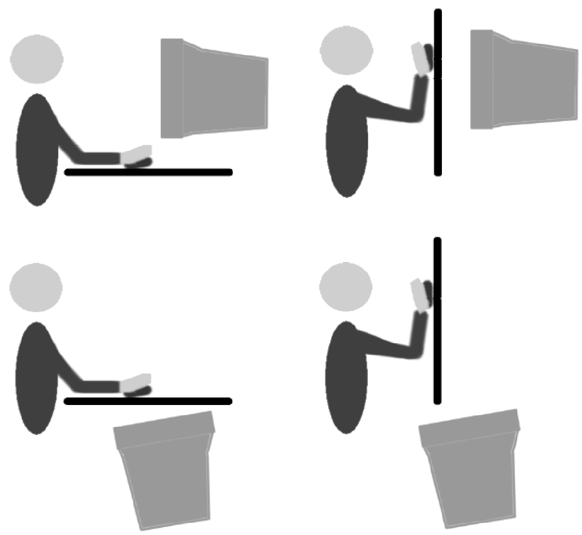

Figure 3. The experimental conditions, with physical support present. The unsupported conditions used the same four combinations of input and display orientation.

2.1 Orientation vs. Support Study

The first study was a 2×2×2×4 design comparing display orientation (horizontal or vertical) to device movement orientation (horizontal or vertical) to physical support (present or absent) over 4 repetitions. Figure 3 depicts the four supported conditions. An Intersense IS900 3D tracker was used in all conditions for input. Sixteen paid volunteers participated. A previously presented 3D movement algorithm, which maps 2D input to 3D motion and constrains objects to slide over other objects in the scene [2], was used in all conditions. This algorithm effectively reduces the complexity of 3D movement to a 2D problem.

No significant difference was found in speed between horizontal and vertical display ($F_{1,511}$=0.25, ns), horizontal and vertical device movement ($F_{1,511}$=0.48, ns) and most surprisingly, supported and unsupported motion ($F_{1,511}$=0.05, ns). For accuracy, no significant difference was found between the three conditions: display orientation ($F_{1,510}$=0.95, ns), device orientation ($F_{1,510}$=1.44, $p > .05$) and support ($F_{1,510}$=0.17, ns).

2.2 Supported 2D vs. 3D Movement Study

The second study was a 5×6 design comparing 5 input techniques across 6 repetitions each. The input techniques were mouse input, 2D constrained tracker input, both with and without a supporting surface, a supported tracker mode with a larger area for movement and full 3DOF movement. The 2D constrained tracker with support effectively emulates a mouse. Collision avoidance was used in the 3DOF movement condition. With the exception of the mouse condition, the IS900 was used in each condition for object movement. The purpose of this study was to directly compare 2D and 3D object movement techniques, and to further assess the value of support. Tracking precision was also examined via the larger movement area. Finally, as the mouse and tracker were directly compared via the 2D supported conditions, we hoped to also determine how well 3D object movement techniques designed for use with a mouse translate to 3D input devices.

A significant difference was found between the five conditions for speed ($F_{4,295}$=61.19, $p<.001$) and accuracy ($F_{4,290}$=4.65, $p<.005$). Tukey-Kramer post hoc analysis indicated that the mouse was significantly faster than all other conditions. The 2D tracker conditions were not significantly different from one another. The 3DOF tracker was significantly slower than all other conditions. The mouse condition was also found to be significantly more accurate than the 3DOF tracker condition. No other significant differences were found.

3 Discussion

We were unable to determine if input device orientation and display orientation affects performance in constrained 3D movement tasks in our first study. Furthermore, both studies failed to show a significant difference for the effect of support. Although this is not in line with previous findings [1, 3], a key difference in our study was that the input space was disjoint from the display area. Previous studies registered the working space with the input device, which may account for the difference in our results. We hypothesize that a different input strategy, which registered the display with the input device (e.g., a stylus/touch-screen), may benefit more from support. Future studies are needed to confirm this.

The results of the second study suggest that the mouse is well-suited to constrained 3D movement tasks. One possible explanation for the lower performance of "mouse emulation" with a tracker could be the higher tracking resolution of the mouse. The large area tracker condition was intended to provide more spatial resolution to the tracker, but it was not found to be significantly better than the other tracker conditions. Another explanation could be user familiarity with the mouse. However, although users learned initially quickly in 3DOF tracker mode, after the third repetition no significant improvements were observed between individual trials. Consequently, we believe that in the short-term at least, 3DOF input devices cannot reach the performance levels of the mouse for constraint-based manipulation. Finally, another possible explanation is the differences in muscle group usage between the devices [4]. We attempted to compensate for this by requiring the users to hold the mouse in a top-down grip in all conditions. However, fine motor control via fingers was still possible with the mouse, but not with the tracker.

4 Conclusions

Two experiments were conducted to assess various physical features which can affect choice of input device for 3D user interfaces. The first compared input device movement orientation to display orientation and physical support. The second directly compared different input devices. The results suggest that constraining 3D devices to 2D can yield better performance compared to 3D operation. None of the 2D-constrained 3D tracker modes were significantly different from each other in speed, yet were comparable in accuracy to the mouse. This bodes well for designers of VR systems that use indirect 3D input devices, as constraining the operation of these devices to 2D may improve the immediate usability of such systems.

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