Co-location and Tactile Feedback for 2D Widget Manipulation

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Abstract

This study investigated the effect of co-location and tactile feedback on 2D widget manipulation tasks in virtual environments. Task completion time and positioning accuracy during each task were measured for subjects under 4 situations (co-located vs no co-located and tactile feedback vs no tactile feedback). Performance results indicate that co-location and tactile feedback both significantly improve the performance of 2D widget manipulation in 3D virtual environments. Subjective results support these findings.

1 Introduction

Several researchers have evaluated the benefits of 2D widget manipulation using hand held props in immersive and semi-immersive environments, [1, 2, 3]. It has been shown that the use of physical props for manipulating these widgets can provide effective feedback to aid the user. This study evaluates the effect of co-location (having the hands physically in the same location as where the virtual object is displayed) and tactile feedback for various selection and steering tasks.

2 Method

Apparatus The Personal Space Station, a mirror based VR system was used to display stereoscopic images [4]. The user reaches under the mirror to directly interact with virtual objects by using input props, see figure 1. An acoustic tracker was used for head tracking, and an optical tracker for tracking the pose of input props. The perception and interaction spaces are co-located.

The 2D widget-interface system consists of a virtual cube and a virtual pen. Each side of the virtual cube is equipped standard widgets, such as buttons, pop-up menus, sliders, labels, message boxes, etc. A virtual pen is used as selection device. Visual feedback is provided when widgets are manipulated. Widgets on the cube are displayed as 3D objects whose appearance changes when selected. The tip of the virtual pen changes color when a widget is selected.

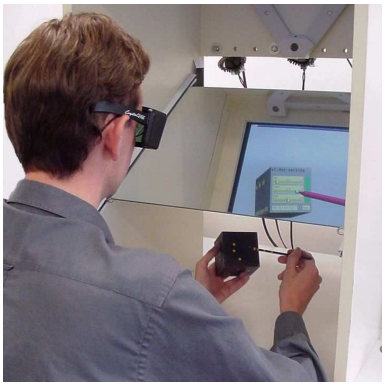

Figure 1. The Personal Space Station and the cube-widget interface

A wooden cube and stick are used to control the placement of the widget-interface system. In the co-located case, the virtual objects are drawn with the pose of the props. In the non co-located case, virtual objects are drawn with a positional offset of 48 centimeters from the props position. Tactile feedback is provided when the stick 'brushes' the surface of the wooden cube. In the non-tactile case, the virtual pen was assigned a lengthwise offset of 4 centimeters to the position of the wooden stick.

Subjects Twenty subjects participated in the experiment. 17 subjects were right-handed, 3 of them left-handed. 4 subjects had previous experience using the apparatus.

Procedure Subjects were required to complete three widget manipulation tasks: a button pressing task, a pull-down menu task, and a slider dragging task. Each task was per-

formed in 4 situations: co-location and tactile feedback, no co-location and tactile feedback, co-location and no tactile feedback, no co-location and no tactile feedback.

For the button task, subjects were required to select a particular button from a set of 16 buttons. The entire task consists of 20 button selections. The menu task consists of selecting an item in a pull down menu. An entire task consists of 12 menu selections. For the slider task, subjects were required to set the values of three sliders to values displayed in a dialog box. The entire slider task is repeated 5 times.

Both objective and subjective performance measures were collected. Objective measures included task completion time and the number of times a widget was incorrectly selected. 1520 timings for button selections, 768 timings for menu selections, and 340 timings for slider manipulations were collected. Subjective measures were collected through a questionnaire.

3 Results

Objective measures A linear regression model was used to model the effect of co-location and tactile feedback on the performance time. More specifically, the model

$$t = a + (1 - T)l_T + (1 - C)l_C$$

is used, where a is the average time needed in the co-location and tactile feedback situation, l_T is the average extra time needed when there is no tactile feedback, l_C is the average extra time needed when there is no co-location, T is 1 when tactile feedback is enabled, 0 if not, C is 1 when co-location is enabled, 0 if not. Applying the regression model to the collected data shows that lack of co-location and lack of tactile feedback both have a negative effect on the performance of manipulation.

Table 1 summarizes the results of applying the regression model. The table tabulates the relative contributions of l_T and l_C with respect to the average task completion time a. For example, in the slider task, the lack of tactile feedback results in a 37% increase in task completion time. The lack of co-location results in a 23% increase.

An ANOVA analysis performed on the results of the regression shows that the results are significant and that the relative contributions are independent.

Subjective measures Many subjects commented that they disliked the situations without tactile feedback, especially for slider tasks. Subjects noted that is was very difficult to keep the virtual pen on the virtual cube to manipulate the slider. Moreover, some of the subjects complained that it was more strenuous.

	a	l_T		l_C	
button	1.09	0.13	(12%)	0.11	(10%)
menu	3.24	0.61	(19%)	0.56	(17%)
slider	12.95	4.83	(37%)	2.93	(23%)

Table 1. Results of linear regression model: average task completion time (in seconds) and relative contributions in the no tactile feedback and no co-location cases.

Subjects did not regard lack of co-location as more difficult. Many did not even notice the difference, others said they felt that there was something strange happening but could not explain what it was. Those who did notice the displacement said that it did not make the tasks more difficult. This is in contrast with the results of the experiment. The lack of co-location does not reduce user appreciation, but subconsciously users have more difficulties manipulating the widgets.

4 Conclusion

This study investigated the effect of co-location and tactile feedback on 2D widget manipulation tasks in near field virtual environments. Analysis shows that both aspects contribute significantly to widget manipulation performance and that the contributions are independent. The lack of co-location increases the times to perform the tasks. The lack of tactile feedback increases these times even more. This is especially true for steering tasks, such as dragging a slider.

Subjective results support these findings as users expressed a preference for the co-located with tactile feedback situation.

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