Smart choices for Deviceless and Device-based Manipulation in Immersive Virtual Reality

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ABSTRACT

The choice of a suitable method for object manipulation is one of the most critical aspects of virtual environment design. It has been shown that different environments or applications might benefit from direct manipulation approaches, while others might be more usable with indirect ones, exploiting, for example, three dimensional virtual widgets. When it comes to mid-air interactions, the success of a manipulation technique is not only defined by the kind of application but also by the hardware setup, especially when specific restrictions exist. In this paper we present an experimental evaluation of different techniques and hardware for mid-air object manipulation in immersive virtual environments (IVE). We compared task performances using both deviceless and device-based tracking solutions, combined with direct and widget-based approaches. We also tested, in the case of freehand manipulation, the effects of different visual feedback, comparing the use of a realistic virtual hand rendering with a simple cursor-like visualization.

Index Terms: Human-centered computing—Interaction techniques Human-centered computing—User studies Human-centered computing—HCI design and evaluation methods Human-centered computing—Virtual reality

1 INTRODUCTION

In IVEs, object manipulation is a quite difficult task due to the necessity of creating a natural [3] and effortless experience, relying on non necessarily accurate finger tracking and lack of haptic feedback. The most natural metaphor to perform translation and rotation is the so called "simple virtual hand" (SVH) [7], consisting of a selection procedure and the subsequent direct link of hand and object position and orientation until a release command is given.

The performances of this method, however, heavily rely on the selection method and on the accuracy of tracking. To overcome limitations of direct rotation and allow scaling, different options have been tested, like gestural metaphors, e.g. Virtual Handle [6] or crank handle [2], suggesting degrees of freedom (DOF) separation. Another solution is the use of bimanual metaphors like the handlebar [10] [1] allowing rotation translation and scaling, but requiring large gestures with both hands (and robust tracking).

To support indirect manipulation with DOF separation, widgets can be an effective solution. 3D widgets to help interaction in virtual environments were first proposed in [5], where a toolkit for developers is described. In [9] the authors presented a widget-based technique, 7-handle, and conducted an evaluation against the classic 6DOF direct manipulation. In [8] authors focused on the DOF separation that can be provided by widgets and were able to assess the advantages of DOF separation in terms of accuracy at the expense of execution time. Evaluation of the real advantages and disadvantages of the combinations of different HW/feedback solutions with different manipulation techniques could be extremely valuable for a smart application design.

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2 EXPERIMENTAL DESIGN

We designed an experiment to test the effects of different solutions for virtual object manipulation in terms of hand tracking and associated visual feedback in the IVE. We tested device and deviceless input by using respectively an Oculus Touch Controller and a Leap Motion Controller. In the deviceless condition we also tested two different types of visual feedback: the first showing a 3D hand model of an hand rigged on the joints tracked by the sensor and the second displaying a 3D cursor represented by a sphere with a diameter approximatively corresponding to the finger width. These different combinations generated three different experimental conditions: Leap Motion with 3D hand model visualized (L-H), Leap Motion with 3D cursor feedback (L-C) and Oculus Touch with 3D cursor (T-C). All these three conditions were examined in a user test consisting of a simple docking task to be performed with two different manipulation techniques: the Simple Virtual Hand [7] (SVH) to test a more direct method and the Smart Pin [4] (SPin) to test a widget-based method. Our intention with this choice was to verify if any possible emerging trend would show across both techniques based on a direct approach (i.e. SVH) and indirect ones (i.e. SPin). To obtain an IVE we used the Oculus Rift head mounted display as stereoscopic output device.

Our test group consisted of 18 people (12 males and 6 females), with no previous experience in VR contexts and with age ranging from 20 to 29 years (average 23.1). The group was divided in two sets: the first performed the docking task using the Smart Pin technique first while the second one started with Simple Virtual Hand version. For each technique, each user was asked to complete the task 3 times for each modality (L-H, L-C, T-C) with different order, following a latin square design. Each modality consisted of a learning session of fixed time (1 minute) with no docking involved and three runs of the actual task for a total of 18 runs per user. W collected the execution times for all the tasks and the number of actions taken to complete the docking. When all the required tasks were completed, each user had to fill a questionnaire to evaluate different aspects of their experience during the test.

3 EXPERIMENTAL RESULTS

Figure 1 shows box plots representing the distribution of the average task completion times of the 18 users with the three different implementations of the SVH technique. It is evident using the Touch performances are significantly better, while different feedback solutions for the Leap Motion mode does not create statistically significant differences. Touch based interaction was ranked as the preferred method by 15 subjects (Figure 2), while there is no clear preference between the two visual feedback choices with Leap Motion.

In the Smart Pin case the task required also a scaling of the object before docking, however, this did not create large increase of the completion time with Leap Motion interaction. Device based interaction is still significantly faster (see Figure 3), but the difference with

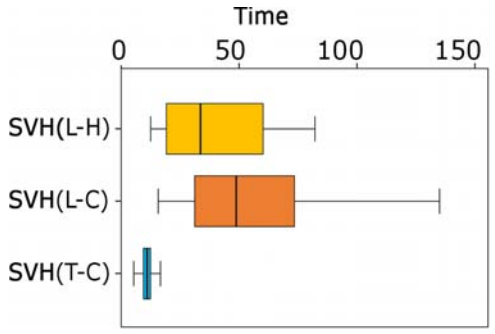

Figure 1: Box plot showing task's completion time, in seconds, using the SVH technique in the different conditions. The chart presents the median, 1st and 3rd interquartile ranges (boxes) and 95% confidence interval (whiskers).

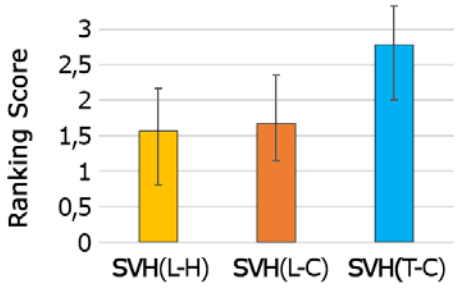

Figure 2: Average ranking scores (higher is better) given by users sorting by preference the different combinations of Controller/Feedback options in the Simple Virtual Hand task.

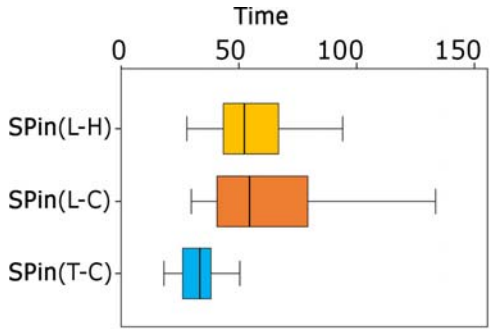

Figure 3: Box plot showing task's completion time, in seconds, using the Smart Pin technique in the different conditions. Times are not comparable with those in Figure 1 as the task included scaling.

the hand tracking based methods is decreased. No significant differences between the visual feedback choices are measured. Touch based interaction was ranked as the preferred method by 15 subjects (Figure 4), while there is no clear preference between the two visual feedback choices with Leap Motion.

4 Conclusions

In this paper we presented an initial effort aimed at evaluating different choices related to tracking devices, methods/metaphors and feedback in manipulation tasks. Despite the limited number of comparisons and users, with the data collected during the test, we can suggest at least one smart design guideline and confirm the

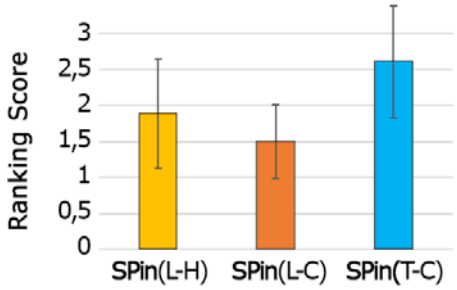

Figure 4: Average ranking scores (higher is better) given by users sorting the different combinations of Controller/Feedback options in the Smart Pin.

tight interaction between all the different design aspects investigated (hardware, method/metaphor, visual feedback).

Handheld devices, that guarantee shorter manipulation tasks' completion times, should be preferred if available in the planned setup and if the efficiency is critical. Direct manipulation (VH) guarantees shorter execution times with the devices, but are not necessarily preferred to a widget based method by users.

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