IPT & EGVE Workshop (2005)
R. Blach, E. Kjems (Editors)

Enhanced Hand Manipulation for Efficient and Precise Positioning and Release

N. Osawa

National Institute of Multimedia Education, Japan

Abstract

Direct manipulation by hand is important in that it allows users to manipulate 3D virtual objects easily in an immersive virtual reality environment. Although direct hand manipulation is easy to understand and easy to use for approximate positioning, it has been considered unsuitable for making precise adjustments to virtual objects in an immersive environment because it is difficult to hold an unsupported hand in midair and then release an object at a fixed point. This paper therefore proposes automatic methods of adjustment to position and release virtual objects precisely. These methods are position adjustment, virtual hand size adjustment, viewpoint adjustment, and release adjustment. Combinations of these adjustments enable users to accurately manipulate virtual objects. Experimental evaluation revealed that release adjustment significantly increased the completion ratio for tasks and subjective preference for small targets.

Categories and Subject Descriptors (according to ACM CSS): H.5.2 [User Interfaces]: Interaction styles; I.3.7 [Computer Graphics]: Virtual Reality

1. Automatic adjustments

Two difficulties arise with direct hand manipulation. The first is the difficulty of moving a virtual object to an exact position (precise positioning), and the second is the difficulty of releasing it accurately at a position (precise release). However, these difficulties have not been sufficiently studied; the release problem especially has not received full attention. To overcome these difficulties, we propose position adjustment, virtual hand size adjustment, viewpoint adjustment, and release adjustment. The assumption underlying these adjustments is that the user's hand moves slowly when he or she wants to manipulate a virtual object precisely. Our proposed adjustments are based on speed.

Position adjustment (referred to as *pos* or case 1) is designed to enable precise positioning. This technique adjusts the position of the virtual hand on the basis of hand speed. Log records from our previous study show that about 95% of movements during a precise positioning task were done more slowly than 0.5 cm/s. We therefore selected 0.5 cm/s as the threshold for determining slow and precise movements. Our position adjustment method is similar to PRISM [FK05]. However, the threshold speeds in our experiment were much slower than the PRISM parameters.

Virtual hand size adjustment (referred to as *size* or case 2) is proposed to enable precise release. With this technique, the size of the virtual hand is shrunk while the hand grasping the virtual object is moving slowly. When the hand is small, the releasing action only has a slight effect on the finger position. The size of the virtual hand can be changed according to a linear relationship with speed. However, the subjects in our pilot experiments disliked linear change because the size was constantly changing, which was a distraction during the manipulation. We therefore used a two-stage model in the simplest case. When the hand moved slowly, the virtual hand shrunk to one third the normal size. We also introduced a form of hysteresis to avoid rapid fluctuations in hand size.

Viewpoint adjustment (referred to as *view* or case 4) is mainly used for precise positioning. When the hand grasping the virtual object is moving slowly, the viewpoint approaches the point where the virtual object was grasped (grabbing point). This movement in the viewpoint enlarges the scene, including the virtual object, and enables it to be inspected in detail. We expect this viewpoint adjustment will usually be used with hand size adjustment. When both hand size and viewpoint adjustments were used in the experiment, we kept the apparent hand size constant.

Release adjustment (referred to as *rel* or case 8) was designed to enable more accurate release. When a virtual object is quickly released –i.e., when the thumb and fingers (forefinger in the experiment) are opened quickly – the position of the virtual object is moved back to what seems to be the intended release position.

Release adjustment is based on the reaction time needed to respond to a stimulus. On the basis of the information processing model by Card et al., 300 ms was chosen as the stimulus-response reaction time. When a virtual object is released from the hand, the most appropriate release position is searched for. Let T_s be the time when the relative speed of the thumb and finger becomes faster than 1 cm/s. A candidate data sample is searched for from the time of (T_s -300 ms) towards past. The search for an appropriate release position is limited to 1000 ms before release. This restricts the buffer size for the data sample history. Fig. 1 plots the relationship between the estimated release timing and release action.

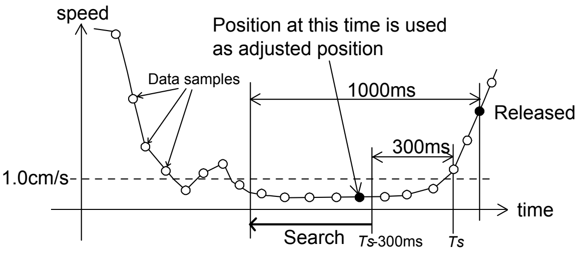

Fig. 1: Release adjustment

2. Experiments

We conducted an experiment to evaluate the usefulness of combinations of automatic adjustments for manipulating virtual objects in an immersive virtual environment with immersive projection using circular polarization.

Twelve participants (seven males, five females) took part in the experiment. The subjects were asked to move a control sphere into a translucent target sphere in an immersive virtual environment, which was the same as the one we used in our previous study [OR04]. The control sphere was initially centered at (5, 5, 5) (unit: cm) and the target position was at (0, 0, 0). The radius of the control sphere was 1.5 cm. The target spheres had a radius of either 2.0 or 1.7 cm. Because orientation was not considered, we selected a sphere as the shape of the control for the experiment.

When a combination of proposed adjustments was used, there were 16 possible combinations of adjustments. We designed the system so that *view* worked with *size*. We therefore omitted four combinations using *view* without *size*. As each of the 12 subjects tried each task twice, there was a total of 24 trials for each task.

We had a cut-off time of one minute because it would have been inefficient to have taken longer than this for a precise manipulation. Fig. 2 plots the ratio of completed trials for the methods and target sizes. Some methods resulted in incomplete trials, especially with small targets (1.7-cm radius). An incomplete trail meant that the subject did not complete the task within the time limit.

Release adjustment significantly improved the completion ratio when the targets were 1.7 cm in radius. There was a significant difference for each method with and without the release adjustment (all $p<0.05$ with a two-tailed Fisher's exact test).

Moreover, in a questionnaire conducted after the experiment, significant differences were also found between subjective preferences for the *direct* (without automatic adjustment) and *rel* methods.

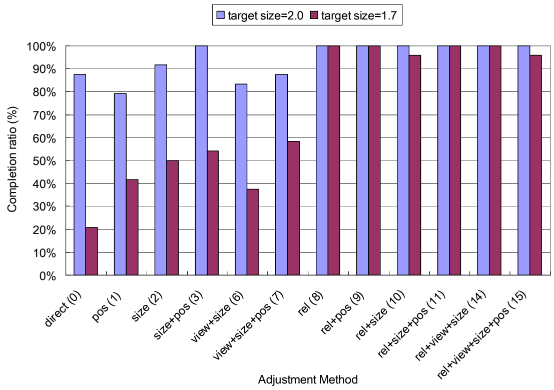

Fig. 2: Completion ratio of trials

Although improvement due to adjustment methods other than release adjustment was not as obvious from the experiment, we intend to investigate how useful they are for smaller error tolerances and also to enhance them.

References

[FK05] Frees, S. and Kessler, G. D.: Precise and Rapid Interaction through Scaled Manipulation in Immersive Virtual Environments, In *Proc. of IEEE Virtual Reality 2005* (2005), pp. 99-106.

[OR04] Osawa, N. and Ren, X.: Virtual 3D Gearbox Widget Technique for Precise Adjustment by Hand Motion in Immersive VR," *IEICE Trans. on Information and Systems*, *Vol. E87-D*, *No. 10*, (Oct. 2004), pp. 2408-2414.