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Gearbox Widget for Fine Adjustments by Hand Motion

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Abstract
Direct manipulation by hand is easy to understand and to use for approximate positioning. However, direct manipulation by hand is not suitable for making fine adjustments to virtual objects in an immersive environment because it is difficult to hold an unsupported hand in midair and then to release an object at a fixed point. Therefore we propose a virtual 3D gearbox widget. This gearbox widget enables the user to adjust a value precisely. A combination technique of this widget and hand manipulation can move virtual objects and place them in a target position quickly and precisely. For a comparison, we tested the usability of four techniques. Experiments showed that using the proposed gearbox in combination with direct manipulation was the best of the four techniques in terms of both performance data and subjective preference.

Keywords:
Gearbox, 3D widget, Direct manipulation by hand, Fine adjustments, Immersive environment

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

1. Introduction

Directly manipulating virtual objects by hand in immersive space to change their position is easy. Such direct manipulation is similar to the manipulation of objects in real life with the result that less specialized knowledge and skill is required. However, when manipulating by hand, fine adjustments are difficult without physically supporting the hand.

A slider is often used in GUIs to control the coordinates, but this is unsuitable for fine-tuning in an immersive environment since it is difficult to move the slider precisely with an unsupported hand. Constraint-based techniques such as those in ISAAC system [1] can be used to align virtual objects but it is difficult to arbitrarily adjust their positions.

Consequently, we propose a gearbox widget that enables us to make both large and fine adjustments to object positions. This widget can also easily be used to complement direct manipulation.

2. Gearbox widget

A gearbox widget imitates a physical gearbox virtually and abstractly. Rotating its gears changes a value. In this widget, multiple gears can be interconnected. Familiarity with gears in the real world means that users can easily understand how the gears change the value based on the gear ratio. The appearance of the gears matches the specified gear ratios although the interconnection between gears is not limited to physical structures.

We have developed a gearbox widget of the "it3d" class library[2], which is a Java class library for 3D applications. An example of a gearbox widget is shown in Figure 1. In the figure, the gearbox has four dials. A back gear (the larger gear) and a front gear (the smaller one), which are concentric, constitute one dial for rotational manipulation. The front gear at the leftmost dial is omitted. Any two adjacent dials are interconnected with an intermediate gear. The intermediate gear engages with the back gear of the dial at the left of it and with the front gear of the dial at the right of it. The intermediate gear is used to maintain the rotational direction of the dials for manipulation. If the intermediate gear is not used, the rotational directions of adjacent dials for increase are different. The intermediate gear does not prevent from rotating dials by hand. Rotating the dials changes the value. The leftmost dial is used for a large value change, and the rightmost dial is used for small changes. The value ratios of the dials in Figure 1 are 100:10:5:1 for one revolution. The programmer can specify the value ratio of a dial for one revolution. The sizes of back gears are all the same in this example. Thus the sizes of the front gears are appropriately determined by the gearbox widget according to the specified value ratios. For example, the value ratio of the second dial from the right to the rightmost dial is 5:1. Therefore the size ratio of its back gear to the front gear of the rightmost dial is 5:1.

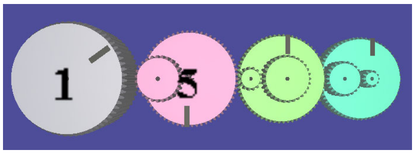

Figure 1 *An example of a gearbox widget.*

3. Experiment

We conducted an experiment to evaluate the use of the developed gearbox widget and other techniques. Eight subjects (5 male, 3 female) took part in the experiment. They were university students from 19 to 22 years of age (mean age = 20.8 years).

The subjects were asked to move a control point (a sphere) into a target (a translucent sphere) using each technique or a combination of techniques. We measured the time taken to move the control point from the initial position (10,10,10) into the target sphere at (0,0,0). The task required both large movements and fine adjustments. The radius of the control point was 1.5. The respective target spheres' radii were 4.5, 3.0, 2.0, and 1.7. We had a cut-off time of 3 minutes (180 seconds). Although the subjects were asked to complete the task as quickly and accurately as possible, some of them could not complete some tasks in the specified period.

We tested four techniques: (1) using only direct manipulation by hand, (2) gearbox only, (3) slider only, (4) hand manipulation and gearbox. Each subject performed the task using all four techniques. They performed the techniques in different order.

After they finished testing all the techniques, the subjects were asked to complete a questionnaire. The question was: "For the techniques tested just now, how do you rate their quality? Please answer on a scale of 0-to-9." In the scale, 0 = the lowest preference, and 9 = the highest preference. The quality evaluation consisted of six sub-questions related to speed, accuracy, ease of use, fatigue, satisfaction, and desire to use.

We performed an analysis of variance (ANOVA) with repeated measures on the within-subject factors. Manipulation time and subjective preferences were the dependent variables.

The mean time for each of the techniques is shown in Figure 2. The combination of direct manipulation and gearbox was faster than the other three techniques (mean = 33.2, SD=16.8), $F(3, 28) = 3.51$, $p < 0.05$.

The subjective ratings were based on the average value of the answers given by the subjects to the 6 questions. Significant differences were seen between the four techniques, $F(3,28) = 9.57$, $p < 0.001$. The combination of gearbox and direct manipulation had the highest preference (mean = 7.13).

The subjects reported that hand manipulation was easy for large movements and the gearbox was more suitable for fine adjustments. This matches our proposed purpose for gearbox widgets. We think that it is also possible to use the gearbox for large movements. We will further investigate manipulation techniques in an immersive virtual environment.

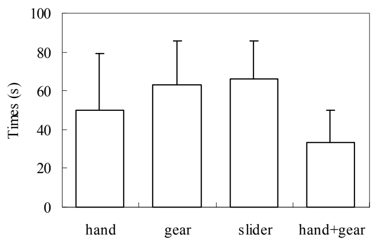

Figure 2 *Mean of manipulation time (with standard deviation error bars) for the four techniques.*

Acknowledgments

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