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Comparison of 3 Different Methods to Grab Virtual 3D Objects in Distance Using Hand Gesture

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1. Introduction

In recent years, numerous virtual reality (VR) applications and games are available in the market. In those applications and games, the user can interact with a virtual environment using hand-hold control devices or hand gestures. Methods to grab virtual 3D objects in distance using hand gesture has been studied since the last century [1,2,3]. Bowman et al. [1] proposed a method to grab objects using a virtual ray and a virtual button. Recently, Lu et al. [3] developed a virtual shop in which objects can be grabbed using a virtual ray and a hand gesture. Another recent system [2] also uses ray and gesture in a virtual space. These systems employ different hand gestures to rotate the ray and move the target object to the hand. However, there are few VR applications that adopt hand gestures to grab distant objects. In this study, 3 different methods to grab virtual objects in distance are compare in an experiment.

2. Methods of Grab Virtual Objects

All three methods use a virtual stick extended from the virtual right hand of a VR user, who can select a virtual 3D object in distance by rotating the stick to hit the target object. When the object is selected, the stick turns yellow, and a mark appears near the object. The user can move the selected object to the right hand by using a pinch gesture.

In Method A, the user rotates the stick by turning the head. The orientation of the stick is aways equal to the orientation of the head of the user:

$$q_{Stick} = q_{Head}, \tag{1}$$

where q_{Stick} and q_{Head} are quaternions.

In Method B, the user rotates the stick by changing the position of the right hand. For instance, the stick turns left when the user moves the hand to the left. The orientation of the stick is a product of three quaternions:

$$q_{Stick} = q_{\alpha} q_{\gamma} q_{\theta}. \tag{2}$$

The user can tilt the stick by moving the hand vertically. The tilt angle θ is calculated using the following equation:

$$\theta = a\big((y_{Head} - b) - y_{Hand}\big). \tag{3}$$

The tilt angle determines the third quaternion q_{θ}:

$$q_{\theta} = \cos\frac{\theta}{2} + i\sin\frac{\theta}{2}. \tag{4}$$

The stick rotates to the left and right when the user moves the hand in a horizontal direction. The rotational angle γ is calculated as follows:

$$\gamma = c\Big((v_{Hand} - v_{Head}) \cdot v_{Right} - d\Big), \tag{5}$$

where v_{Hand}, v_{Head}, and v_{Right} are 3D vectors representing hand position, head position, and a direction, respectively. The second quaternion q_{γ} is calculated using γ:

$$q_{\gamma} = \cos\frac{\gamma}{2} + j\sin\frac{\gamma}{2}. \tag{6}$$

The quaternion q_{α} represents another rotation around the vertical y-axis:

$$q_{\alpha} = \cos\frac{\alpha}{2} + j\sin\frac{\alpha}{2}. \tag{7}$$

The rotational angle α is determined by the orientation of the head as follows:

$$\alpha = atan2(v_{Forward} \cdot e_x, v_{Forward} \cdot e_z). \tag{8}$$

In Method C, the user selects the target object by rotating the right hand:

$$q_{Stick} = q_{Hand}, \tag{9}$$

where q_{Hand} is a quaternion that represents the orientation of the right hand.

3. Experiment

We invited 15 people as experimental subjects and divided them into three groups in

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different order of the methods: A-B-C, B-C-A, and C-A-B. All subjects went through a tutorial to get familiar with the methods and the position of the objects. Then, they completed a task to grab 6 objects: a pen, 3 books in different positions, a cup, and a photo in a virtual room. Finally, the subjects answered a questionnaire included the following questions:

(1) 5-point evaluation questions about the ease of grabbing each of the 6 objects by using 3 methods described in the previous section.

(2) Questions to ask which was the hardest and which was the most error-prone.

(3) A question to ask which the subject preferred to use for grabbing virtual objects in the future.

4. Results

Table 1 compares the number of objects grabbed and time required by each subject using the different methods. It can be seen that most subjects grabbed significantly more non-target objects and took more time when using Method C than when using Method A. The results of the 5-point evaluation questions showed statistically significant differences of ease score to grab objects between Methods A and C from 3 objects (see Figure 2) and between Methods B and C from 2 objects (see Figure 3). Eleven subjects thought Method C was the hardest, and thirteen preferred Method A for future use (see Figure 4).

Table 1. The Number of Objects Grabbed and Time Required

	Object Grabbed			Time (seconds)		
	A	B	C	A	B	C
Mean	7.6	8.1	9.1	50	52	61
SD	0.34	0.31	0.54	6.1	3.7	6.4
Median	7	8	9	41	50	50

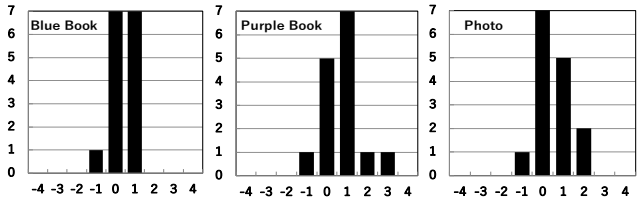

Figure 2. Comparison of Ease to Grab Objects between Methods A and C

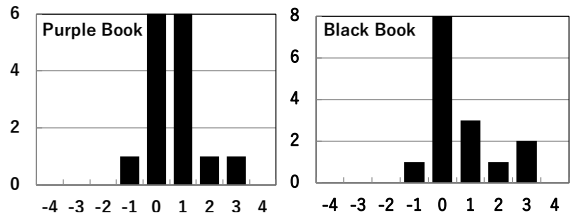

Figure 3. Comparison of Ease to Grab Objects between Methods B and C

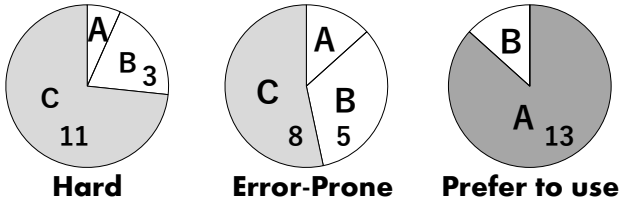

Figure 4. Single-choice Questions Results

5. Conclusion

(1) All the methods are useful for grabbing a virtual object unless it is too far away or there are many other objects nearby. However, novices will occasionally grab a non-target object.

(2) Method A is the easiest for the most novices, and they will choose it among the 3 methods. It is more effective and less error-prone than Method C.

(3) Method B is almost as effective as Method A. However, for some novices, Method B might be slightly more difficult to use than method A.

(4) Method C is more error-prone and less efficient than the other methods. It is the least likely to be chosen by novices.

6. References

[1] Doug A. Bowman, Larry F Hodges (1997), “An Evaluation of Techniques for Grabbing and Manipulating Remote Objects in Immersive Virtual Environments”, In Proceedings of the 1997 Symposium on Interactive 3D Graphics (I3D ‘97).

[2] Barrett Fox, Martin Schubert (2018), “Exclusive: Summoning & Superpowers - Designing VR Interactions at a Distance”, Road to VR, Accessed 29 Dec 2021.

[3] Chunmeng Lu, Boyang Liu, Jiro Tanaka (2019), “Implementing Hand Gestures for a Room-scale Virtual Reality Shopping System”, International Journal on Advances in Software, vol. 12, no.3 & 4.