Developing an efficient technique of Selection and Manipulation in Immersive V.E.

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ABSTRACT
An Interaction Task in Virtual Reality is such that a user can modify a computer generated virtual world using various techniques. But current interaction techniques cannot be applicable for most virtual environments due to their inefficiency and inconvenience. In this paper, we propose a selection and manipulation technique called the Finger-gesture. We evaluate its usefulness by conducting quantitative and qualitative experiments within a specific environment. Results indicate our new technique is more efficient in selection and modification tasks than other existing techniques including Go-Go and Ray-casting in terms of the task completion time and accuracy.

Keywords
Virtual Reality, 3D interaction technique, Finger-Gesture, Go-Go, Ray-casting.

1. INTRODUCTION
As the technology of display and graphics systems has developed, virtual environments (VEs) applications have come into common use outside the research laboratory [3]. Most VE applications require more high-level tasks in object manipulation. Currently, there are a great variety of existing human-computer interaction tasks, which attempt to solve the problem of grabbing and manipulating objects in Virtual Environments (VEs). But the proposed and developed interaction tasks are not applicable for general-purpose application; most of them are domain- and application-specific. In general, interaction tasks in virtual environment (VEs) fall into four task categories: viewpoint motion control, selection, manipulation and system control [2]. Viewpoint motion control refers to a task in which the user interactively positions and orients his viewpoint within the environment. Since head tracking affects viewpoint orientation, mainly concerned part is a viewpoint translation like navigation. Selection is a task which involves picking a virtual object in VEs. Manipulation is a positioning and orienting task to manipulate one or more virtual objects using translation and rotation. Generally selection and manipulation tasks are used altogether, although the selection task can be used solely. Lastly system control is a task, which deletes the selected object, saves the position of objects and loads VEs with objects (new models). But at a low level, system control can be characterized as selection and manipulation tasks.

To evaluate performances with other various techniques, we need to develop or use formal measurements like the testbed evaluation method. Many testbed evaluation measurements have been proposed. The VEPAB project [6] was a research effort aimed at producing a testbed for VEs. And VRMAT [10] is a tool aimed at the evaluation of 3D manipulation technique. In this paper, we have concentrated on the evaluation of selection and manipulation tasks. Task completion time (speed) is natural for evaluating performance and accuracy is widely used for quantitative experimental analyses. But from a point of view of human-computer interaction, it is essential to consider usability, acquisition and comfort (e.g. user-centric performance measures [10]). Especially immersion is the most important aspect. Therefore qualitative experimental analyses may be necessary for evaluating various techniques.

In this paper, we propos a new technique called finger-gesture, which was designed using the designing and evaluating methods used in selection and manipulation tasks.

2. RELATED WORKS
2.1 Natural Mapping
Selection refers to the act of specifying or choosing one or more objects for some purpose. Manipulation is the task of setting the position and orientation of selected virtual objects. Manipulation requires a selection technique, but the opposite is not always true. Selection techniques can be used alone for tasks such as choosing a menu item or deleting an object. The user can rotate or translate an object by using virtual hand or mouse.

In VEs, most of the current techniques use the natural metaphor because of its affordance [8]. Therefore selections and manipulations in various VEs use natural mapping. Natural mapping is a technique in which the user's hand maps with the virtual hand in size and position. The user selects an object by

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touching it with a virtual hand, and thereby manipulates the object. Natural mapping is afforded naturally because it is from the user's actual motions. However it is not practical for most of the VE applications.

One is that the user can select a virtual object only when it is in arm's reach (extent). Therefore he can select and manipulate the object in the narrow space of VEs. To select and manipulate an object at a distance, we need to apply or design another technique such as travel technique (navigation) and arm-extension techniques.

The other is that the natural mapping cannot be applicable for selecting and manipulating a large virtual object. The extent (virtual cubit) and the size are restricted in selection and manipulation. For example, when the user wants to relocate a building (virtual object) in city-planning applications, he might have difficulty resulting from the "lever-arm" problem [1]. Manipulation of large objects is difficult, since they obscure the user's view during positioning tasks and the user must be within an arm's length of the object to pick it up. Therefore we need a different interaction technique, one that has the general view of a natural metaphor and the flexibility of extended natural mapping.

2.2 The extent of Natural Mapping

In Figure 1 we can see a simple classification of current VE manipulation techniques [11]. From the summarization and the classification of the proposed techniques, we can find a clue of designing new technique.

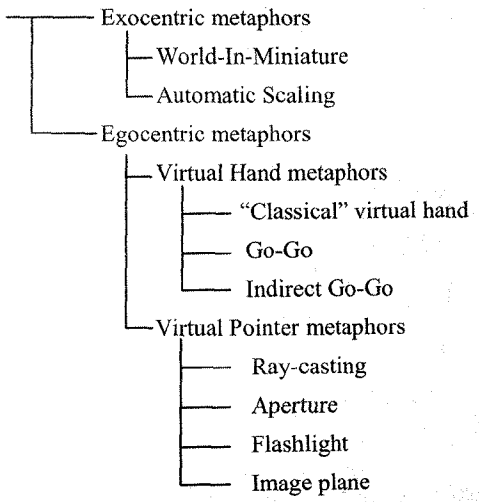

Figure 1. Classification of VE Selection and Manipulation

The exocentric metaphor is sometimes called God's eyes viewpoint and users interact with VEs from the outside. On the other hand, with the egocentric metaphor, which is the most common for immersive VEs, users interact from inside the environment. Currently there are two basic metaphors for egocentric manipulation: the virtual hand metaphor and the virtual pointer metaphor. Go-go [9] is one of the virtual hand metaphors while ray-casting [4] is one of the virtual pointer metaphors.

In [1], Bowman and Hodges have researched and evaluated the characteristics of go-go, ray-casting and modified techniques. In that experiment, they have tested in the same environment and made some questions to evaluate what people think. In [5], Kwak, et al. have done similar experiments. They have found that users quickly become fatigued from holding input devices steady and rotating an object in the go-go technique. Also it was more inaccurate for selecting objects than the ray-casting technique. But most people answered that the go-go technique was more efficient than ray-casting when users manipulated one or more objects. In addition, most techniques were not suitable for rotation.

3. THE FINGER-GESTURE TECHNIQUE

We know that the go-go technique is easy for manipulating, but difficulty occurs when an existing object located out of arm's reach (virtual cubit [11]). Although the ray-casting technique is useful for selecting objects, it has a "lever-arm" problem - objects are attached to the end of the ray. Therefore there is no simple method for rotating an object. Thus, only 1 degree of freedom may be controlled. But since the virtual object is attached to the virtual hand, the go-go technique give users control over all 6 degrees of freedom for an object, therefore it may be suitable for manipulating objects. As mentioned above, two different techniques have problems for rotation control. Therefore dividing the manipulation operation into two subtasks such as translation and rotation is more effective to evaluate performances [1].

We have designed the new technique called Finger-Gesture with efficient translation and rotation methods. The finger-gesture technique uses data-gloves in right hand. And most of the hand's motions are mapped to a virtual hand to select and manipulate objects. To select an object, the user can use an index finger as Ray-casting does. But the difference is that objects are attached to the center of the virtual hand rather than to the end of the ray. Also manipulation task of rotation can be done by bending a thumb and an index finger.

4. THE EXPERIMENTS

We attempted to evaluate and compare several types of techniques including the finger-gesture technique under the same experimental settings.

4.1 Systems

I-Glasses (HMD) were used, along with Polhemus Insidetrack trackers on the head, a 3-button mouse and Data glove (5th glove). The VE was built using the Simple Virtual Environment (SVE) toolkit, and rendered on a desktop computer (dual CPU) with graphic accelerator. SVE was developed by GVU lab in Georgia Tech. [13]

4.2 Method

Twenty student volunteers participated in the experiments. Although they all had basic knowledge about computer technology, they had never experienced human-computer interaction tasks such as selection and manipulation in VEs. Five selection and manipulation techniques (e.g. Go-Go, Indirect Go-Go, Ray-casting, Ray-casting with reeling [1] and Finger-gesture) were compared for evaluating performances.

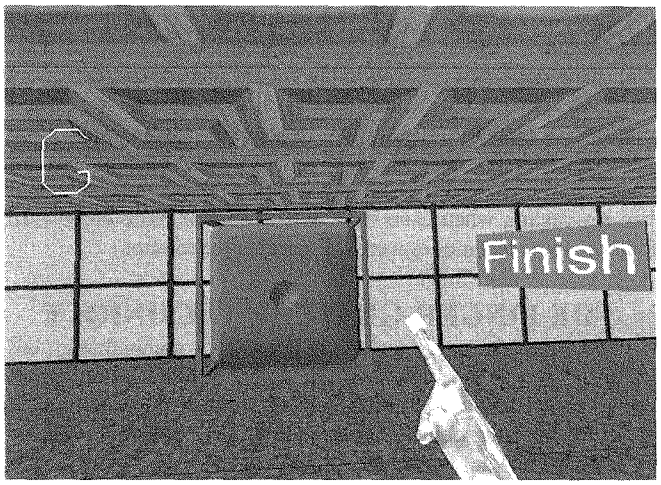

Figure 2. Target status: An object in the wire rectangle

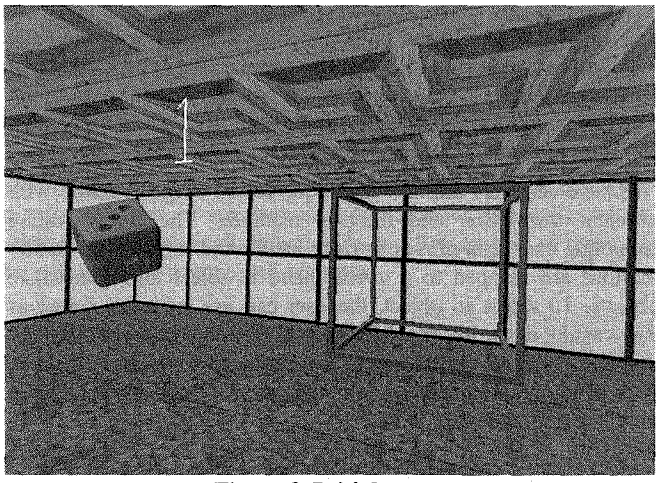

Figure 3. Initial status

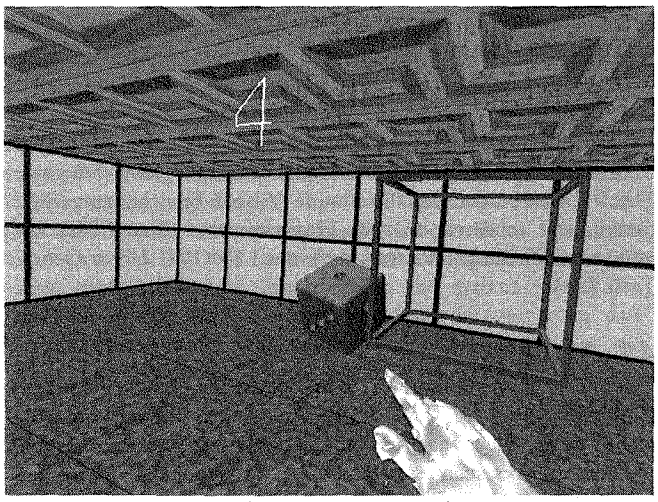

Figure 4. The Go-Go technique

We performed the experiments to evaluate techniques in the same experimental setting. The experiments had a scenario which was designed to include selection and manipulation tasks. Users select a die (virtual object) and position it inside a wire rectangle frame with the digit on the die facing the front. Figure 3 shows the target status in order to finish the task. Figure 4 shows the initial status when the experiment begins.

In the go-go technique, the physical hand movement is mapped to virtual hand movement with non-linear mapping. While the physical hand is within a distance D from the body, the motion is one-to-one. Beyond D, the virtual hand follows a non-linear function as the physical hand is stretched. The middle mouse button picks up a selected object. Figure 4 and 5 shows how go-go works. Indirect go-go technique uses a 3D mouse and the virtual hand is moved in and out by using the mouse buttons. The right button extends the virtual hand, and the left button brings it back. The middle mouse button picks up a selected object.

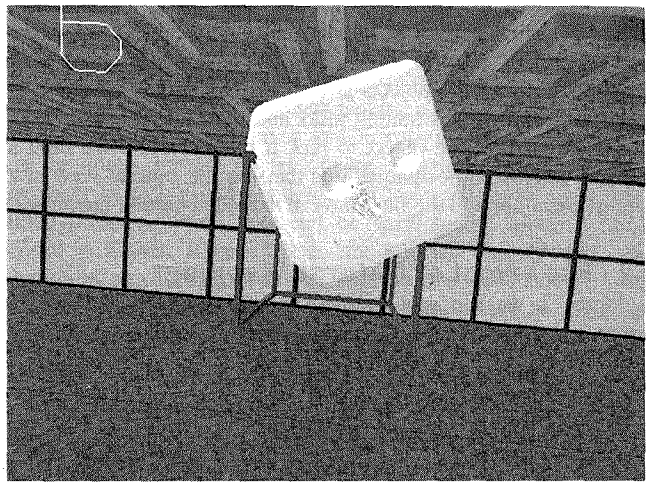

Figure 5. Grabbing an object with a virtual hand using Go-Go and moving it

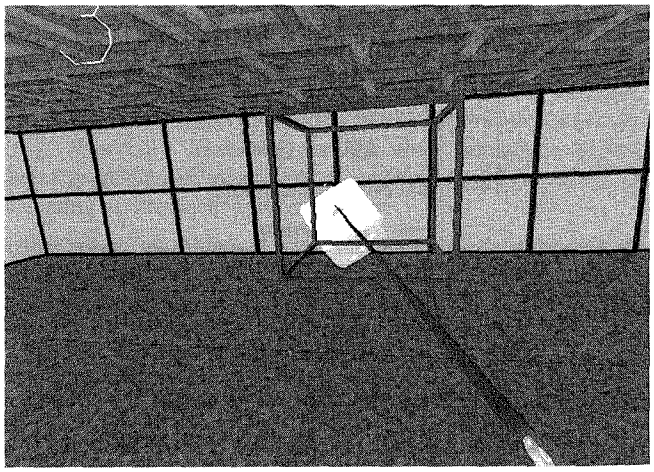

Figure 6. Moving an object via Ray-casting

In ray-casting, the user selects an object by intersecting it with a virtual light ray. The ray is activated by holding down the middle mouse button. When an object is intersected, it can be picked up by releasing the button. The object then attaches itself to the light ray. Figure 6 illustrates the ray-casting technique. Ray-casting with reeling technique uses a 3D mouse to control range between the virtual hand and objects. Selection and grabbing are done the same way as in ray casting, but the user can also bring the object

nearer to him or put it farther away using the same button. Subjects participate in the experiment after hearing some explanation and were surveyed after finishing it to evaluate the performance. The results are saved automatically into a data file. Frame rate was maintained above 10FPS(Frame Per Second).

4.3 Evaluation Methods

Each technique is evaluated with speed (time) and accuracy for quantitative experimental analyses. And the time was evaluated in three parts: selection time, completion time and manipulation time. Selection time is the elapsed time from the initial status to the time to pick up the object. Completion time is the total elapsed time to finish the given task. Finally, the manipulation time is the difference between completion time and selection time.

One question is related to the sense of presence. The question of primary interest is: a rating question on overall presence where 100 signified highest presence and 1 signified no sense of presence. We ask the participants that which one is the most convenient or inconvenient and write down reason, which one is most natural, and which one is easiest to learn. The answers to these questions become the basic data for qualitative analysis.

4.4 Result and Discussion

4.4.1 Evaluation

Table 1 presents a summary of timing results. Selecting an object via ray-casting with reeling is faster than go-go and indirect go-go technique. But the ray-casting technique takes much longer during manipulation because it requires grabbing and releasing an object in order to manipulate it continuously. Although finger-gesture technique is slower for selecting an object using data glove, it make a great progress in rotation. Therefore the manipulation and completion time was reduced. We know from Figure 7 that in terms of overall performance, our new Figure-gesture technique is superior to any other techniques.

Table 1. Quantitative Evaluation

	Go-Go	Indirect Go-Go	Ray-casting	Ray-casting with reeling	Finger-gesture
Seletion time	18.0 sd=6.9	20.3 sd=6.3	5.0 sd=9.5	4.0 sd=2.0	4.3 sd=1.7
Comple-tion time	62.0 sd=20.2	59.2 sd=17.3	62.0 sd=12.6	21.5 sd=31.8	18.6 sd=10.1
Distance of error	0.3 sd=0.15	0.3 sd=0.13	0.2 sd=0.06	0.2 sd=0.12	0.15 sd=0.05
Manipu-lation time	44.0 sd=27.4	38.9 sd=18.9	57.0 sd=22.4	13.8 sd=23.7	13.8 sd=10.5

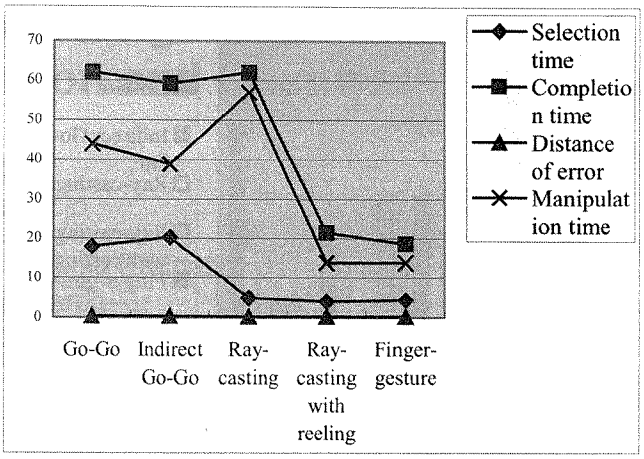

Figure 7. Graph representation of Quantitative evaluation

4.4.2 Characteristics of the Technique

Immersion rate for experimental environment was about 64.7 percent. Table 2 represents the results of qualitative analysis. Subjects noted difficulties with go-go and ray-casting. Finger-gesture is the best in terms of naturalness, convenience and easiness of learning. On the other hand, almost every user commented that grabbing an object via ray-casting is easier than when using other techniques.

Table 2. Qualitative Evaluation

	Natural	Convenient	Inconvenient	Easy of learning
Go-Go	1	2	8	2
Indirect Go-Go	1	4	1	2
Ray-casting	0	1	4	0
Ray-casting with reeling	2	5	2	4
Finger-gesture	16	8	5	12

Only five of our users commented on the inconvenience of finger-gesture. Those people have small hands not enough to handle data glove. Natural technique tends to be easy to use and learn.

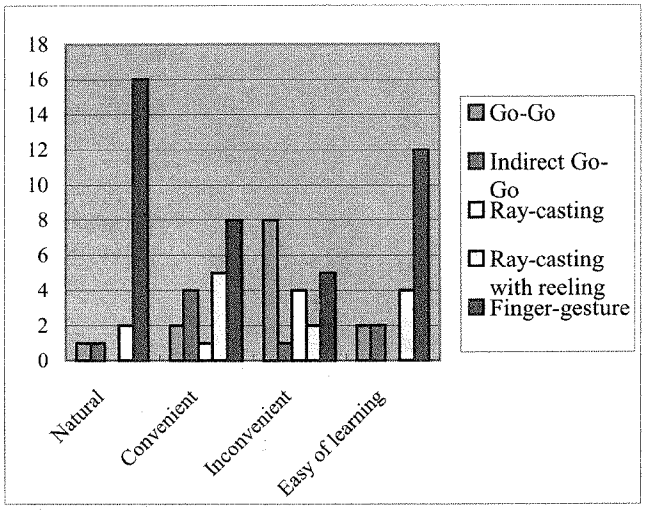

Figure 8. Graphical representation of Qualitative Evaluation

5. CONCLUSIONS

As we noted, implementing general interaction techniques are necessary because most selecting and manipulating techniques are application-specific. In this paper, we propose a systematic interaction method for implementing, and designed a new technique called Finger-gesture. Also we evaluated the performance with current techniques and compared them with the proposed one in the same experimental setting. The proposed technique, Finger-gesture, adapted some efficient characteristics from another techniques. It gives a natural selection and manipulation using a natural mapped virtual hand.

In the future, it will be useful to develop a more generic evaluation testbed and compare Finger-gesture with other more techniques such as HOMER [1], WIM [12] and Autoscaling [7], which are excluded in this work. Also another generic technique should be designed. Therefore users can select and manipulate a paired object, a huge object and a long-distance object more easily.

6. REFERENCES

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