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Using Real Objects for Interaction in Virtual Reality

Ryota Yoshimoto*, and Mariko Sasakura†
* *Department of Information Technology, Okayama University*
† *Department of Computer Science, Okayama University,*
Okayama, Japan
Email: sasakura@momo.cs.okayama-u.ac.jp

***Abstract*—Output devices to view Virtual Reality (VR), like Head Mount Displays, are getting common lately. However, there is no standard input devices to tell computers user's intention in VR yet. According to the naive intuition, using real objects that has similar shapes as in VR is the better way than using controllers like mouses or game controllers to manipulate objects showed in VR. But is it true? To make it clear, we develop an game system like tower defense. Users played the game in two ways, one is using real objects, the other is using mouse to place "Towers". As the result of questionnaire after game plays, "easy to use" factor was lower for the real objects operation mainly because of the technical difficulties like object detection failure. But the "fun to use" factor was still higher for the real objects than the controllers. It show that using real objects has high potential for interaction between users and the VR system.**

***Keywords*-Virtual reality, Real objects operation, Tactile feedback**

I. Introduction

The history of Virtual Reality (VR) has started over 40 years ago. It is one of dreams of computer engineers that makes virtual space look like the real world. Now, such VR is coming true.

The major device for providing virtual space is a head mount display (HMD) which is a kind of "glasses" that cover whole view of a user. It costs cheaper than before it did so that a casual user can buy it and enjoy VR space. It contributes to realizing VR space like the real world for users.

On the other hand, unlike the output device such as HMD, there is no standard input device for VR yet. The early time, data globes were the most commonly used, but they costs high and they are not natural to use. Nowadays, simpler devices are used to operate in VR space.

The input devices for VR space that are recently used are categorized in two types. One type is to operate VR space by hand and/or body gestures without any devices on hand/body. The other type is to operate VR space by devices on hands.

In the first case that is using gestures, a system recognizes gestures by sensors and/or cameras. In the second case of using devices on hands, a system know the input from users by buttons, sticks and/or sensors in the devices. Some devices have haptic feedback, which make feeling of reaction force. For example, if a user makes an operation for moving a wall, the haptic device make feeling of friction from the wall. We can have the experience by Nintendo switch easily.

In VR space, intuitively, we would like to have physical feedback to grab or touch for operating things. It would make us feel the VR space more natural. One way to implement physical feedback is, for example, haptic feedback on a controller. The other way, and the most natural way for it is using real objects that can be grabbed and touched in the real world. But, is it true? Really do we need physical feedback in VR? Is the interaction with physical feedback more efficient? Is it more attractive?

This research tries to clarify the importance of physical feedback in VR space. We made a sample game system and compare the usability between a case with physical feedback using real objects and a case with a controller without any physical feedback.

II. Related Works

The traditional approach of input to VR environment is to use a special device, such as data globes or haptic devices. However, recent years, some researchers have proposed interaction methods using real objects in VR environment.

Augmented Reality (AR) is one of major field. However, in AR, the real world plays a major role and VR plays a supporting role.

There are new researches to put VR as a major role and the real world as a supported role. One of them is [2] which shows the real ball can be caught in VR even if a user does not see the ball itself but see the position where the ball will come.

[1] is more interesting. A user who touch a straight wall in VR, think that she/he walk straight even though the wall she/he touched is curved. Tactile sensing can make illusion.

This research is classified to the field in which VR as a major role and the real world as a supported role. We try to know the role of tactile sensing in the field.

III. Concept

Every object in VR should be touchable ideally, but there is a limit of computing power. So, we assume the world consists of two kind of things; virtual objects that cannot be touched, and imitate objects that can be touched.

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Figure 1. Piece Holding

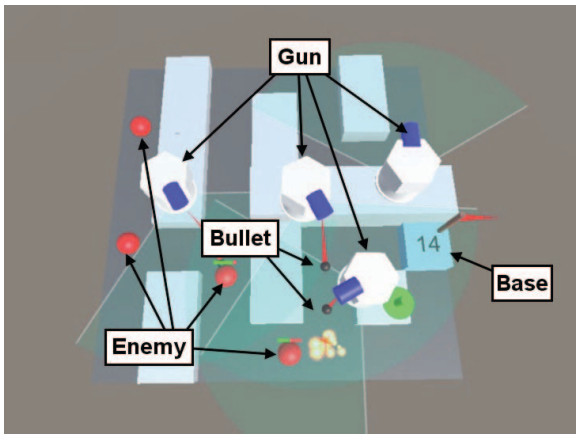

Figure 2. Game Label

Virtual objects are consists only of graphic and cannot be touched. Virtual objects can be used to express things that cannot be touched also in the real world, like light and shadow. Another application of virtual objects is to express something that is not necessary to be touched, or things that cannot be touched because it is located far away, like mountains or stars. Imitate objects can be touched by real objects. The shape, colour and size of imitate objects may be the same as real objects. Sometimes they may not be the same shape, colour or size, like unlimited corridor [1]. Imitate objects are made by graphic and displayed in HMD, but there are real objects in real world corresponding to the imitate objects.

We cannot build totally VR space using imitate objects. Because imitate objects must have the corresponding real objects, and the real objects must be affected the real world. For example, real objects fall down if there is no stay under the real objects. We need some power to lift real objects. We cannot clear away real object in a moment.

We are not sure that imitate objects with real objects are useful or not. We would like to make clear what do users feel by using imitate and real objects.

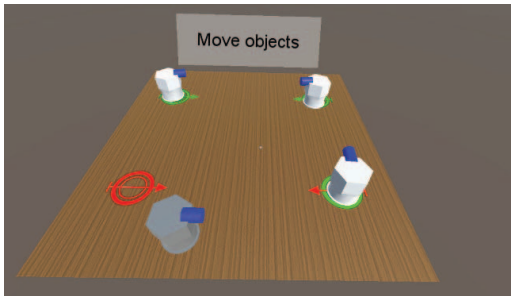

Figure 3. Experiment 1

IV. Test Environment

We develop a system for an experiment to make clear whether tactile sensing is needed for VR environment. In this section, we explain the system. The system runs on Gear VR by Samsung Electronics.

A. Virtual Reality Tower Defense

Virtual Reality Tower Defense (VRTD) is a developed game system for our experiment. A player of the game defense her/his base from enemies who come and attack to the base. A player shoots enemies by guns as “Towers”. If a player defend the base in defined period of time, the player wins. If the base is broken by enemies, a player loses. A gun has a direction so that can shoot a given direction. A player can move guns and change the direction of guns.

The game field has differences in height. Enemies go to the lowest height area. Guns put on high area and shoot the enemies. We compare the result of this game by using real objects to operate guns with the operating by mouse. We make two experiments. In experiment 1, we measure the time of moving a gun. In experiment 2, we ask subjective impression to players who play VRTD.

B. Real Object

Figure 1 shows a real object for a gun. The upper half of the real object is hexagonal cylinder. We put markers on top and side of the real object. The lower half is cylinder so that a player easily holds it in a hand.

We recommend a player to hold a real object as Figure 1. Since there are markers on the upper half of a real object, a player is expected to hold the lower half of a real object. The shape and size of a real object are fixed by preliminary experiment which measure the recognition rate of real objects. The real objects we use are created by 3D printer.

C. The Specification of VRTD

VRTD consists of a base, guns, enemies and a field. The game can be played in VR environment. Figure 2 shows 2D

image of the game which are displayed during a play, for monitoring by the experimenter.

The base is a sky-blue cube in which a number is displayed. The number is the remaining hit points. 15 is full. If the point becomes 0, a player loses. When an enemy comes to the base, the point decreases 1, and the enemy is disappeared. Enemies are shown as red cubes.

There are 4 guns in the field. They are displayed as white hexagonal cylinders with blue cylinder which is a firing port. A light green sector indicates the area which a gun shoot bullets. Bullets are displayed as small blue cubes. When a bullet hits an enemy, the hit point of the enemy decreases. The enemy is disappeared if its hit point become 0.

The field of the game consists of three type of height, 0mm, 20mm, and 40mm from a table. If guns are put on 0mm height area, they cannot shoot bullets. They must be put on 20mm or 40mm height area for shooting enemies. Enemies appear at a corner of the field and go to the base through 0mm height area.

The base and enemies are virtual objects. Guns and the field are real objects. Guns are operated by players, but the field is not.

The player will win when she/he defend the base during 196 seconds. If the hit point of the base become 0 before 196 seconds, the player will lose.

V. Results

We perform two experiments using the environment mentioned in section IV-A. Subjects are eleven, who are students of graduate and under graduate. Each experiment is performed by using a mouse and real objects.

1) **Experiment 1:** An experiment of putting guns on specified place and specified direction to compare the time of operation.
2) **Experiment 2:** An experiment of playing VRTD to compare remaining hit points of the base and ask subjects impression of the game by a questionnaire.

A. Result of Experiment 1

To compare the time of operating guns, we perform experiment 1 which put guns from initial position to specified position as specified direction. At first, a subject try to move one gun twice and try to move four guns twice. Figure 3 shows the screen-shot of moving 4 guns. Red circle indicates the specified position and direction. When a gun is moved to the correct position and direction, the circle is changed green.

The time is shown in Table I. Subjects A to F performed mouse operation first, and subjects G to K performed real object operation first.

The average of mouse operation is better than real object operation. Variant of real object operation is mush larger than mouse operation. The difference of variant suggests that if subjects would be used to use real object operation the result of real object operation may become better.

In fact, the shortest time of moving one gun and four guns are recorded by real object operation. The shortest time of moving one gun by mouse operation is 2.78 seconds by subject D on the second try, and the time by real object operation is 1.87 seconds by subject J on the first try. The shortest time of moving four guns by mouse operation is 11.79 seconds by subject C on the second try and the time of real object is 10.45 seconds by subject K on the first try.

B. Result of Experiment 2

After performing experiment 1, subjects perform VRTD as experiment 2. Subjects A to F performed mouse operation first, and subjects G to K performed real object operation first.

The result is shown in Table II. The table shows the remaining hit points of the base. The high point and average of mouse operation is better than real objects operation. Subjects A, F and I record better score by real object operation than mouse operation. A and F perform mouse operation at first, I performs real objects operation at first.

After performing experiment 2, we ask subjects to answer questionnaire. Table III shows the result. In Q5 and Q6, if a subject answers “Yes”,we ask she/he to write comments freely.

All subjects have not experience of using VR. Only one subject answers real object operation is easier to use than mouse operation. Three subjects have troubles in mouse operation and ten subjects have trouble in real objects operation. Six objects answer real objects operation is fun than mouse operation.

VI. Discussion

The result of experiments of real object operation is not so good as we expected. The major reasons we know from the comments of subjects are:

- the system often fail to recognize real objects, and
- we don’t show the position of player’s hands in VR, so player often fail to hold real objects.

The problem of false recognition of real objects is mainly occurred by the position of camera. We use the camera on Gear VR to recognize real objects. But by only one camera, occlusion must be occurred. Although we recommend subjects to hold real objects from the side, many subjects hold real objects from the top. It may be natural for human. But it is one of the major reason of the failures of recognition. This problem may be solved to use several cameras to recognition and/or change the shape of real objects.

The problem of the position of hands may be solved. It is a little bit difficult to recognize the position of hands by a camera, but if we put markers on hands, it is possible to recognize the position of hands and display it in VR.

Table I
THE TIME TO MOVE GUNS (SECONDS)

subjects	mouse, 1 gun		mouse, 4 guns		real object, 1 gun		real object, 4 guns	
	first	second	first	second	first	second	first	second
A	3.30	5.41	15.12	15.93	2.50	6.69	17.36	16.83
B	5.98	3.85	13.56	12.37	3.17	8.01	19.17	17.54
C	3.30	3.40	15.32	11.79	3.75	6.48	15.79	15.83
D	3.27	2.78	15.44	15.23	5.77	5.79	18.29	20.14
E	3.77	4.35	14.36	11.84	4.39	5.62	19.54	19.02
F	3.04	3.65	12.15	12.74	19.57	12.67	33.68	22.24
G	4.99	3.90	16.26	16.83	6.86	7.61	24.78	25.26
H	3.39	6.93	18.18	13.79	11.29	4.17	37.57	104.83
I	4.77	5.12	18.59	16.96	2.17	2.38	29.15	33.71
J	4.64	3.22	14.76	13.49	1.87	7.27	33.85	31.83
K	3.65	3.80	17.13	12.86	3.46	3.15	10.45	11.22
Average	4.11		14.76		6.12		28.26	
Variant	1.10		4.17		17.00		367.82	

Table II
THE REMAIN HIT POINTS OF THE BASE OF EXPERIMENT 2 (VRTD)

Subjects	mouse	real objects
A	7	12
B	9	7
C	9	6
D	2	2
E	10	7
F	5	12
G	10	3
H	5	0 (135.37 seconds)
I	12	0 (132.27 seconds)
J	5	8
K	13	6
Average	7.9	5.7
Variant	11.49	17.42

By real object operation, subject H and I lose. The time of the end of the game is recorded (subject H is 135.37 seconds, and I is 132.27 seconds).

Table III
RESULT OF QUESTIONNAIRE

Subject	Q1	Q2	Q3	Q4	Q5	Q6
A	a	b	a	b	b	b
B	a	d	a	b	a	b
C	a	c	a	a	a	b
D	a	a	b	b	a	a
E	a	c	a	b	b	b
F	a	b	a	a	a	b
G	a	a	a	a	a	b
H	a	d	a	a	a	b
I	a	d	a	a	a	b
J	a	d	a	b	b	b
K	a	d	a	b	a	b

Q1 How often do you use VR? (a:not use, b:some times in a month, c:some times in a week, d:every day)
Q2 How often do you play video games? (a:not play, b:some times in a month, c:some times in a week, d:every day)
Q3 Which operation is easy to use? (a:mouse operation b: real objects operation)
Q4 Which operation is fun for you? (a:mouse operation b: real objects operation)
Q5 Do you have any trouble in mouse operation? (a:No, b:Yes)
Q6 Do you have any trouble in real object operation? (a:No, b:Yes)

From the questionnaire, almost subjects have troubles in real objects operation, but the majority prefer real objects operation than mouse. This result is interesting. We think this result supposes that tactile sensing is necessary in VR.

The real objects operation in VR we propose has two features which existing any input device has not. The first feature is that a user can lose hold of real objects. We think it is very important for tactile feedback. The second feature is that a user can use two hands to operate two real objects simultaneously. In fact, in our experiences, subject K uses two hands to operate real objects, who has the fastest record to move 4 guns in experiment 1. The real objects operation can be easily expand to plural users in principle.

In future work, we must know more about tactile sensing, especially from the view of human cognition. Some researches show tactile sensing can give different cognition from the real world [1]. If we have more knowledge about this topic, the interaction of VR will be more fruitful.

VII. CONCLUSION

We propose real object operation as one of the interaction methods for VR. We also perform two experiments to make clear that tactile sensing is needed as VR interaction or not. The answer is "maybe yes". Our experimental system has many trouble, but major part of subjects feel real object operation is more fun than mouse operation.

We would like to develop an interaction design for VR to use real objects operation.

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