An Investigation of Micro- and Macro-Interaction for 3D Manipulation using Dual-Hand Controller in Virtual Reality Environments

Difeng Yu, Juntao Zhu, Wenge Xu, Hai-Ning Liang*, Charles Fleming, and Yong Yue

***Abstract*—In this research, we conduct a two-fold user study to investigate micro- and macro-interaction for 3D manipulation using dual-hand controllers in virtual environments. The chosen device is the HTC VIVE controller due to its richness and variety of features and similarity to other dual-hand devices for virtual reality systems. The first study evaluates whether the HTC VIVE Controller supports basic micro- and macro-interactions and the second study aims to find out whether micro- or macro-interactions are more frequently used to perform common manipulation tasks.**

***Index Terms*—Bimanual interaction, dual-hand controller, HTC VIVE, micro- and macro-interaction, user-elicitation study, virtual reality, 3D manipulation.**

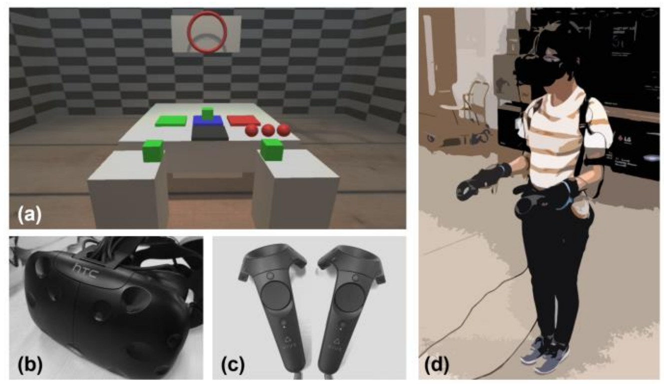

Fig. 1. (a) The VR environment setup for the study; (b) HTC VIVE Headset; (c) HTC VIVE Controller; and (d) a user is performing the task with HTC VIVE VR System and Noitom Perception Neuron.

I. Introduction

Virtual Reality (VR) is an emergent technology. It provides users the sense of immersion within virtual environments and enables the user to interact with the 3D objects inside them. For example, by using HTC VIVE (one of the most common VR systems), participants are able to grab, throw, rotate, and translate the objects in a predefined 3D virtual environment (see Fig. 1a).

This research investigates two types of interaction for manipulating 3D objects using the HTC VIVE Controller in VR environments: micro- and macro-interactions. Micro-interaction requires relatively subtle, small movements such as finger and wrist movements [1, 3], while macro-interaction usually requires large physical movement like full-arm movement [4]. Given the rapid introduction of commercial VR systems like the HTC VIVE and Oculus RIFT systems, it is important to know whether the system supports basic micro- and macro-interactions and how people tend to perform manipulations when interacting with 3D objects in virtual environments.

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In this paper, we present two users studies built on each other and provide our discussions based on the results.

II. User Study 1

Our main objective for this study is to evaluate whether users are able to perform some basic micro- and macro-interaction using HTC VIVE VR systems.

A. *Participants and Apparatus*

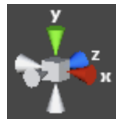
Thirty participants (11 females) between the ages of 18-22 were recruited from a local university campus to take part in this study. According to the results of a pre-experiment questionnaire, 2 participants were left-handed.

The experiment was conducted on an Intel Core i7 processor PC with an NVIDIA GTX 1070 graphics card. The program was developed in C#.NET and was run within the Unity3D platform. An HTC VIVE headset was used to immerse the user into the 3D virtual world and the HTC VIVE Controller was used as the input device for the user to interact with objects in the virtual environment (Figure 1a-c). We used the Noitom Perception Neuron, a body worn tracking device, to capture the body, head, and hand motions of the users (Figure 1d).

B. *Task, Procedure, and Experiment Design*

Participants were asked to perform a series of gestures via the HTC Vive Controller to manipulate 3D objects. Seven tasks (see Table 1) were predefined in this experiment [2]. For each

TABLE I
THE 3D TASKS GIVEN TO PARTICIPANTS IN THE USER STUDY 1

Manipulation	Animation Descriptions	Widget
Throwing	(1) Throw the Object forward	
Translation	(2) Move the Object along X-axis	
	(3) Move the Object along Y-axis	
	(4) Move the Object along Z-axis	
Rotation	(5) Rotate the Object along X-axis	
	(6) Rotate the Object along Y-axis	
	(7) Rotate the Object along Z-axis	

task, participants would first select the object and then perform three types of gestures: (1) Wrist Gesture: moving wrist to perform the task while keeping elbow and shoulder fixed; (2) Elbow Gesture: moving elbow to perform the task while keeping wrist and shoulder fixed; and (3) Shoulder Gesture: moving shoulder to perform the task while keeping wrist and elbow fixed. Note that the first type of movements was considered as micro-interaction while the second and third types of movements were counted as macro-interaction.

Before the experiment started, participants were asked to fill in a pre-experiment questionnaire with their demographic information and were given time to familiarize themselves with the virtual environment and the HTC VIVE Controller. Then, they would proceed to carry out the manipulation tasks one by one (with the order of presentation balanced). After the experiment, participants were instructed to provide some comments on three types of gestures they had performed. To assess whether users are able to perform these tasks, we record the whole movements using the Noitom Axis Neuron Software and analyze the completion rate result after.

C. *Results and Subjective Feedback*

Based on our analysis, nearly all 3D manipulation tasks defined can be completed by the participants (see Table 2). However, one exception was performing the rotation task along the Z-axis using Wrist and Shoulder. According to video recordings, we found that participants could actually finish the task if properly guided but they just could not figure out how to do it by themselves. This might indicate that rotation along the Z-axis using Wrist and Shoulder are unnatural interactions and sounds unfamiliar to users.

Most participants suggested that some gestures made them feel uncomfortable when performing although they were able to complete the tasks. This motivated us to conduct the second user study—to explore natural, intuitive micro- and macro-interactions when performing 3D manipulation tasks.

TABLE 2
THE COMPLETION RATE FOR THE TASKS.

Manipulation	Axis	Wrist	Elbow	Shoulder
Throwing	-	30/30	30/30	30/30
Translation	X-axis	30/30	30/30	30/30
	Y-axis	30/30	30/30	30/30
	Z-axis	30/30	30/30	30/30
Rotation	X-axis	30/30	30/30	30/30
	Y-axis	30/30	30/30	30/30
	Z-axis	19/30*	30/30	17/30*

III. USER STUDY 2

This study aimed to find out whether micro- or macro-interactions were more frequently used by users when performing common manipulation tasks with the HTC VIVE Controller.

A. *Participants and Apparatus*

Fifteen participants (7 females) between the ages of 18-22 were recruited for this experiment. They all had some VR experience before. This experiment employed the same apparatus and materials as the previous experiment.

B. *Task, Procedure, and Experiment Design*

We used similar task design and experimental procedure as the previous experiment. However, instead of instructing the participants to finish the task by Wrist, Elbow, and Shoulder successively, we let them use the gestures which they felt most comfortable with to complete the tasks.

C. *Task, Procedure, and Experiment Design*

Fig. 2 shows the frequency distribution of participants performing the 3D manipulation tasks using Wrist, Elbow, or Shoulder Gestures. For both throwing tasks and rotation tasks, participants favored using Elbow Gestures the most, followed by Wrist Gestures. Few used Shoulder Gestures in these two types of tasks. Participants tended to avoid large macro-motion in these cases. On the other hand, for translating tasks, most participants favor macro-interactions (Elbow Gestures and Shoulder Gestures) than micro-interactions (Wrist Gestures). All participants used Shoulder Gestures when translating the object along Z-axis. This was probably intuitive to understand since the Wrist Gestures were not able to move the object for a long distance and may rarely be used to translate an object in normal life. We noticed that micro-gestures would always cooperate with macro-gestures to complete a translation task.

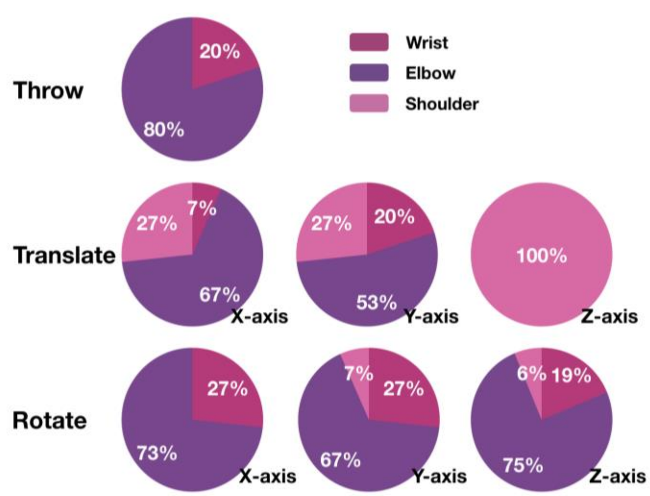


Fig. 2. The frequency distribution of participants performing Task (1)-(7) using Wrist, Elbow, or Shoulder.

IV. Discussion and Future Work

According to our user studies, we summarize the following lessons we learned:

1) The HTC VIVE Controller supports most basic micro- and macro-interactions. However, some interaction gestures seem to be unnatural for users and should be carefully considered when designing VR applications.
2) VR environments should minimize requiring users to carry out large full-arm movements with the HTC VIVE Controller, and similar devices, to finish throwing and rotation tasks.
3) Users tend to favor macro-interaction when translating an object using dual hand controllers like the HTC VIVE Controller.

In the future, we can either conduct elicitation studies on more complex 3D manipulation tasks which include multiple basic gestures or explore how we can transfer large macro movements (for example, Shoulder movement) to fine-level middle-range interactions (like Elbow movement).

V. Conclusion

This research focuses on investigating micro- and macro-interactions for manipulating objects using dual hand controllers like the HTC VIVE Controller in 3D virtual environments. We have conducted two studies that are built on each other to explore if the HTC VIVE Controller supports basic micro- and macro-interactions and whether micro- or macro-interactions are more frequently used by users to perform 3D manipulation tasks.

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References

[1] Edwin Chan, Teddy Seyed, Wolfgang Stuerzlinger, Xing-Dong Yang, and Frank Maurer. "User elicitation on single-hand microgestures." In *Proc. CHI* pp. 3403-3414. ACM, 2016.

[2] Joseph J. LaViola Jr, Ernst Kruijff, Ryan P. McMahan, Doug Bowman, and Ivan P. Poupyrev. *3D user interfaces: theory and practice*. Addison-Wesley Professional, 2017.

[3] Katrin Wolf. "Microinteractions for supporting grasp tasks through usage of spare attentional and motor resources." In *Proc. ECCE*, pp. 221-224. ACM, 2011.

[4] Richard Tang, Xing-Dong Yang, Scott Bateman, Joaquim Jorge, and Anthony Tang. "Physio@ Home: Exploring visual guidance and feedback techniques for physiotherapy exercises." In *Proc. CHI*, pp. 4123-4132. ACM, 2015.

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