Evaluation of Direct Physics-Inspired Interaction for Mixed Reality Based on Optical See-Through Head-Mounted Displays

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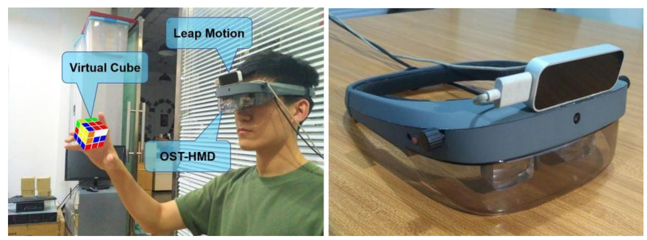
***Abstract*—In this paper, we propose a mixed reality system consisting of a binocular optical see-through head-mounted display(OST-HMD) and a depth sensor. Based on the proposed system, participants perform manipulation tasks to experience the direct physics-inspired interaction mode. Moreover, we design an active selection rule for accurate detailed manipulation. The result indicates that although direct physics-inspired interaction mode is not sufficiently efficient, it shows an advantage regarding the humanization and attraction.**

***Keywords*-mixed reality; physics-inspired interaction; OST-HMD; active selection**

I. Introduction

Mixed reality applications build a visual environment combined with the virtual world and the real world, where users can interact with virtual elements in real time. For mixed reality technology, human-computer interaction is a rather significant part. Based on depth sensors, such as Leap Motion controller and Intel RealSense, different kinds of interaction modes were developed. Gesture recognition and hand shape detection are the most widely-used hand-based interaction modes. In gesture recognition, different gestures mean different commands. While in hand shape detection, the space information of palms and fingers is detected to build virtual hands which share the same physical attributes with physical hands. In this paper, some experiments were conducted to study the operational efficiency and amenity of the direct interaction based on the hand detection of the hand shape. Fig. 1 (a) shows the system overview.

Since the single point active alignment method (SPAAM) was proposed by Tuceryan et al. [1] for calibrating OST-HMDs, it has been widely spread and commonly used. To evaluate this method, Moser et al. [2] constructed an experimental apparatus to obtain the baseline accuracy and precision values of OST-HMDs, which contributed to future studies. The direct interaction has also been a hot research point for a long time. Harrison et al. [3] presented a system named OmniTouch including a depth camera and a mini projector, which allowed users to use their hands, arms and legs as graphical and interactive surfaces. Lee et al. [4] proposed an interaction system that created such an environment



(a) (b)

Figure 1. System overview. (a) is the manipulation using direct interaction. (b) is the hardware of the system.

where users had a feeling that they can manipulate the virtual objects in space. Hilliges et al. [5] proposed the HoloDesk, which was an interactive system based on an optical see-through display and the Kinect camera, creating the illusion that users were directly interacting with 3D graphics.

II. Method

A. Calibration

In mixed reality applications, virtual objects are controlled by users. In our study, the interaction between the real world and the virtual world is performed by hand. Users interact with real objects directly by physical hands. To simulate similar operations in a mixed reality environment, virtual hands are established based on the detection of physical hands. When a physical hand is captured by sensors, its corresponding virtual hand would repeat the same movement in the virtual world. In order to accurately register the virtual hands with the physical hands, a mixed reality system must be properly calibrated. SPAAM is implemented, in which the Leap Motion controller is regraded as a tracking camera.

B. Physics-Inspired Interaction

For any mixed reality application, it's important to enhance the user experience by introducing an novel interaction mode. In our system, the physics-inspired interaction mode is implemented. When a physical hand is detected by the depth sensor, the corresponding hand model will be

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mapped into the virtual world. The physical properties of virtual hands can be set in the software. Ordinarily, a hand should be a rigid body with a collider. When the hand in the real world moves, the hand model in the virtual world also has a corresponding movement. If the virtual hand collides with some three-dimensional objects, those objects will act as if touched by a real hand. Experiments in this paper were performed, which can detect palms and fingers of hands.

Considering that the project requires more detailed interactive manipulation, we design a rule for the physics-inspired interaction named active selection. According to this rule, only the nearest part of virtual objects to the virtual hand is activated. For example, the experiment consists of the translation and rotation of a virtual magic cube. In general, rotating a magic cube is a relatively detailed task for a mixed reality application in view of limited hardware and software at present. When a hand is identified, the nearest part to the center of the hand can be computed in real time, then this part is activated and it can be directly rotated by the hand. Meanwhile, if both hands are detected by the depth sensor, we can move and rotate the whole magic cube by physics-driven collision.

III. Experiment

A. System Setup

As shown in Fig. 1 (b), the system consists of a binocular OST-HMD and a Leap Motion controller firmly attached to it. The resolution of micro projector in the OST-HMD is 800×600 pixels. The system is connected to a computer.

B. Tasks

Ten participants were required to wear the binocular OST-HMD and finish a small task. After the experiment began, a deliberately disrupted third-order virtual magic cube appeared in the view of the participant. Then the participant needed to use the hands to restore it. The user can use two hands to move and rotate the magic cube. However, if he wants to rotate a certain side of the virtual cube, he can only use one hand (either left or right) to get near to the target. Before the experiment, we inform all participants of the operation order (four steps) to restore the magic cube.

The program for this experiment was developed by Unity3D in desktop computer. We recorded the finish time of all participants. Each participant was invited to complete a questionnaire survey after the task. We used the Likert scale and set up five questions as follows:

- Q1: The system runs smoothly.
- Q2: I manipulate the magic cube with low system delay.
- Q3: The magic cube is played as a real one.
- Q4: The interaction with the magic cube is comfortable and intuitive.
- Q5: I would like to play the game about magic cube as a means of leisure.

Finally, we asked the participants whether they had experienced virtual reality or mixed reality games and what the equipment was. Moreover, they evaluated various interaction modes if they had experienced other modes.

IV. Discussion and Conclusion

According to the results, the average finish time of ten participants is 2 minutes and 23 seconds. The whole task only requires rotating the cube four times. The fastest participant, who has done similar experiments, spent only about a minute and a half. But the slowest participant spent more than five minutes and reported that this task made him feel uncomfortable mentally, which resulted in his frequently mistakes in manipulation. From this it appears that not all people are suitable for use of mixed reality systems without the further development of hardware. Moreover, the efficiency of manipulation could be increased after more practice. The results of latter surveys indicate that the whole system runs smoothly basically. The humanization and attraction of physics-inspired interaction are rather prominent. As mentioned by some participants, this mode is more interesting than the 'tap' method in Microsoft HoloLens. Most participants acknowledged that they are willing to try a complete game. As a result, the physics-inspired interaction mode has huge potential in mixed reality applications. Meanwhile the active selection rule proves to be helpful to increase the accuracy of manipulation.

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