Dual-MR: Interaction with Mixed Reality Using Smartphones

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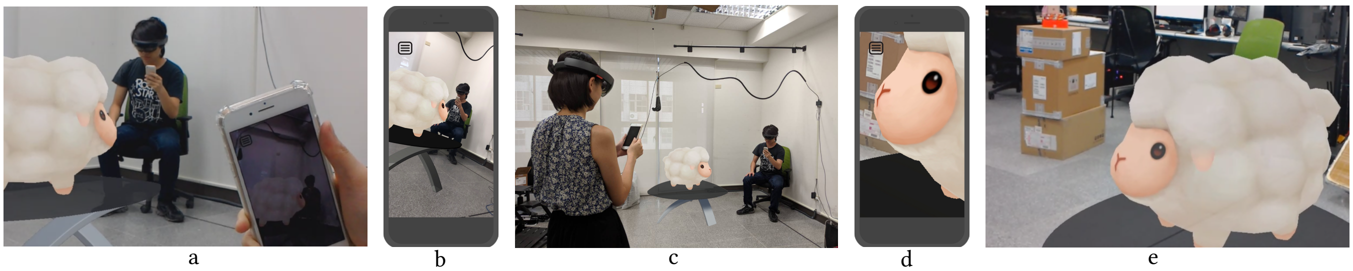

Figure 1: A typical *Dual-MR* system usage scenario. Our system is capable of synchronizing the MR viewpoints of HMD (a,e) and handheld smartphone (b,d) for indiviudal users as well as accross users (c). By placing users in the same MR coordinate system, they can colloaborate and manipulate with virtual objects (e.g., sheep and table) through the multi-touch input of smartphone. (Model courtesy: TurboSquid, Unity Asset Store)

ABSTRACT

Mixed reality (MR) has changed the perspective we see and interact with our world. While the current-generation of MR head-mounted devices (HMDs) are capable of generating high quality visual contents, interation in most MR applications typically relies on in-air hand gestures, gaze, or voice. These interfaces although are intuitive to learn, may easily lead to inaccurate operations due to fatigue or constrained by the environment. In this work, we present *Dual-MR*, a novel MR interation system that i) synchronizes the MR viewpoints of HMD and handheld smartphone, and ii) enables precise, tactile, immersive and user-friendly object-level manipulations throught the multi-touch input of smartphone. In addition, *Dual-MR* allows multiple users to join the same MR coordinate system to facilite the collaborate in the same physical space, which further broadens its usability. A preliminary user study shows that our system easily overwhelms the conventional interface, which combines in-air hand gesture and gaze, in the completion time for a series of 3D object manipulation tasks in MR.

CCS CONCEPTS

• **Computing methodologies → Mixed / augmented reality**;

KEYWORDS

Mixed reality, smartphone, multi-touch input, human computer interaction, 3D manipulation interface

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1 INTRODUCTION

Mixed reality (MR) has changed the perspective we see our world by blending the real and virtual world into a hybrid environment, where physical and virtual objects co-exist and interact. While the current-generation of MR head-mounted devices (HMDs) are capable of generating high quality visual contents, interation in most MR applications is primarily driven by in-air hand gestures, gaze, and voice, which allow natural and immersive interaction. However, there are some limitations, such as the inability to use the display-fixed user interface (UI) with gazing, the inconvenience of voice commands when it is too noisy or needs to keep quiet, and the fatigue caused by in-air hand gestures. Furthermore, none of them is suitable for a long-time usage.

In light of this, we present *Dual-MR*, a novel MR interation system that i) synchronizes the MR viewpoints of HMD and handheld smartphone, and ii) enables precise, tactile, immersive and user-friendly object-level manipulations throught the multi-touch input of smartphone. Specifically, our system leverages built-in motion tracking capability of individual devices (i.e., head tracking in Microsoft HoloLens [1] and ARKit [2] in iPhone) and aligns the coordinate systems of two devices through a marker-based 3D positioning technique [3]. By projecting the 3D MR scene to the 2D screen of smartphone, we implement a set of 3D object manipuations on the multi-touch input to support fast, accurate, and intuitive global and local object transformations. In addition, *Dual-MR* allows multiple users to join the same MR coordinate system to facilite the collaborate in the same physical space, which further broadens its usability. A preliminary user study shows that our system easily overwhelms

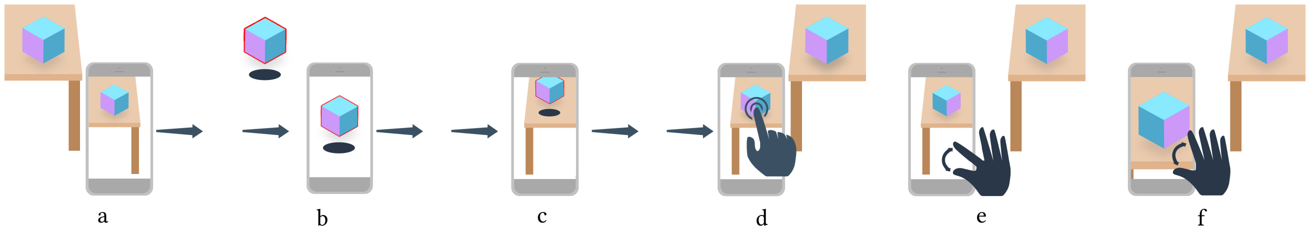

Figure 2: Illustration of global placement and camera control (a) The user double-clicks on a virtual object to select it. (b) The selected object will be attached to the smartphone. (c-d) The user can move the object around the world simply by moving the handheld smartphone. (e,f) The user can zoom in or zoom out the smartphone camera to interact with distant objects. (Image courtesy: Freepik)

the conventional interface, which combines in-air hand gesture and gaze, in the completion time for a series of 3D object manipulation tasks in MR. Figure 1 shows a typical usage scenario of *Dual-MR*.

2 SYSTEM DESIGN

Hardware setting. Our system mainly includes HMDs and smartphones, and we implement it on Microsoft HoloLens and iPhone. HoloLens and iPhone are connected through Wi-Fi, while iPhone served as the master, sending the transformation of the virtual objects and other commands. Besides, because of a variety of sensors on HoloLens, it can provide a more precise representation of real-world surfaces around the user. Therefore, the data of spatial mapping will be sent to the iPhone by HoloLens through Wi-Fi for further applications.

2.1 Coordinate system synchronization

While HoloLens and iPhone have their own coordinate system which is based on themselves in the same environment, it is important to synchronize their coordinate system in our system. The synchronization is mainly based on Vuforia[3], which uses computer vision to recognize and track planar images (Image Targets). During the initialization, the Image Target will be shown on iPhone, so HoloLens can get the relative positioning of iPhone via Vuforia, and set a world anchor where iPhone is to position and orient the coordinate system. After the initialization, HoloLens and iPhone will track the movement of themselves through head tracking and ARKit respectively.

2.2 Interaction design

We implemented a set of 3D object manipuations on the multi-touch input to achieve both global and local object transformations, including global placement of objects, local transformation on objects, and camera control.

Global placement. Our system allows the user to move virtual objects around the world through smartphone. The user first double-clicks on a virtual object to select it and the selected object will be attached to the smartphone. The user can then move the object around the world simply by moving the handheld smartphone, or move the object closer or further by pinching fingers. Figure 2 (a-d) illustrates the above manipulations.

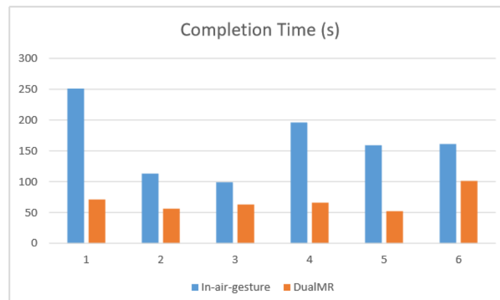

Figure 3: Statistics of user study.

Local trasnformation. We borrow the same design from Tseng el. al [4] to support local translation, rotation, and scaling through one- or two-finger gestures.

Camera control. Our system allows the user to zoom in or out the camera of smartphone through an intuitive pinching gesture to facilitate select and manipulate distant virtual objects (see Figure 2 (e-f)).

3 EVALUATION

An experimental study is conducted to evaluate the performance of *Dual-MR*. In the experiment, we compared our system with the built-in in-air-gesture of HoloLens, including *Gaze* as the targeting mechanism, and *Air Tap* as a mouse click or select, by measuring the completion time for a series of 3D manipulation tasks executed by the participants. We recruited six novice users, including five males and one female with a mean age of 21. No novice user had prior experience of using HoloLens, but all of them are well-trained smartphone users. Results are shown in Figure 3, which indicates that *Dual-MR* is much more efficient than the built-in in-air-gesture of HoloLens.

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