A Lightweight and Efficient System for Tracking Handheld Objects in Virtual Reality

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ABSTRACT

While the content of virtual reality (VR) has grown explosively in recent years, the advance of designing user-friendly control interfaces in VR still remains a slow pace. The most commonly used device, such as gamepad or controller, has fixed shape and weight, and thus can not provide realistic haptic feedback when interacting with virtual objects in VR. In this work, we present a novel and lightweight tracking system in the context of manipulating handheld objects in VR. Specifically, our system can effortlessly synchronize the 3D pose of arbitrary handheld objects between the real world and VR in realtime performance. The tracking algorithm is simple, which delicately leverages the power of Leap Motion and IMU sensor to respectively track object's location and orientation. We demonstrate the effectiveness of our system with three VR applications use pencil, ping-pong paddle, and smartphone as control interfaces to provide users more immersive VR experience.

CCS CONCEPTS

• **Computing methodologies** → **Virtual reality**; • **Human-centered computing** → *Systems and tools for interaction design*;

KEYWORDS

virtual reality; object tracking; haptic feedback

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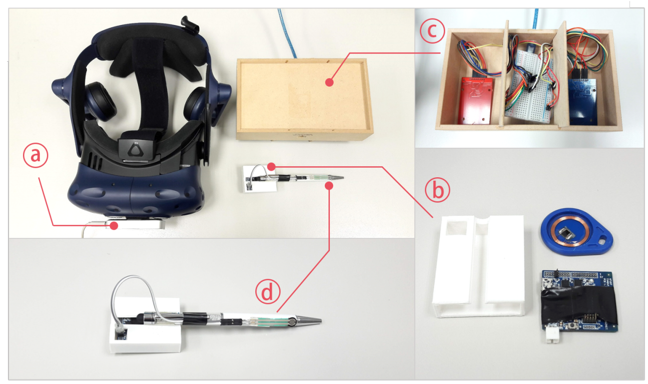

Figure 1: Hardware components. (a) A Leap Motion sensor. (b) An IMU sensor. (c) An inductive tray which is composed of a Vive tracker and a pair of RFID tag/sensor. (d) An optional touch sensor attached to the hand-held object for offering extra inputs.

1 INTRODUCTION

Realistic haptic feedback plays a crucial factor for obtaining immersive VR experience. However, most of existing VR applications still use conventional gamepad and controller as the interface for object manipulation in VR. Such a controller-based interface, constrained by its fixed shape and weight, can not provide the user physically correct haptic feedback. Although a haptic interface such as Grabity [1] offers an impressive solution, the mechanism therein might be too sophisticated to generalize to arbitrary objects.

In this work, we present a novel object tracking system that is lightweight, easy to setup, and is capable of achieving realistic haptic feedback when manipulating objects in VR. The key idea of our system is simple. In the context of the handheld object, the

Figure 2: Three VR applications implemented using our system. (a) 3D painting; (b) Photography using a smartphone; and (c) table tennis game.

object's 3D pose can be approximately represented by i) palm's location and ii) object's local orientation. Thus, an efficient object tracking performance is achieved by taking the advantage of Leap Motion and IMU sensor for hand tracking and deriving object's orientation, respectively. We demonstrate the effectiveness of our system with three VR applications where users can do 3D paintings by holding a real pencil, play with a ping-pong ball through a real paddle, and even take a photo in VR using a real smartphone.

2 SYSTEM DESIGN

2.1 Hardware components

Figure 1 shows the hardware components involved in our tracking system, which mainly includes:

- a *Leap Motion sensor* (see Figure 1(a)) used for a robust and accurate real-time hand tracking;
- an *IMU sensor* (see Figure 1(b)), which is attached to the target object for orientation tracking. Note that the transmission/receiving of sensor data is through a built-in bluetooth module;
- an *inductive tray* (see Figure 1(c)), which is composed of a Vive tracker and a pair of RFID tag/sensor, and is used to locate and calibrate the resting pose of target objects in VR; and
- an optional *touch sensor* (see Figure 1(d)) for offering extra inputs (e.g., click, double-click, etc).

2.2 Object tracking mechanism

The target object is initially placed on the inductive tray. Once the user picks up the object, the RFID sensor will notify the system to trigger the object tracking process. The tracking system then assigns the object to a particular hand, which is constantly tracked by Leap Motion, according to the proximity between the hand and inductive tray in VR. During the object tracking, the system constantly updates the object's 3D pose using the hand's location and accumulated orientation derived from the IMU sensor. The RFID mechanism allows our system to track multiple objects by installing different RFID tags to individual objects. Please refer to the supplementary video for the demonstration of object tracking.

3 DEMONSTRATION

We implemented three VR applications to demonstrate the power of our system. The applications include i) a VR 3D painting system, ii) a VR photography system, and iii) a VR table tennis game. Figure 2 shows snapshots of experiencing the applications in VR. We will next elaborate each application scenario.

VR 3D Painting. In this application, we develope a 3D painting environment, where users can freely draw in the VR space through a set of pre-defined functions, such changing different stroke brushes, choosing different colors from a color picker, and so on. A touch sensor is used to switch between painting/eraser modes. In the physical setting, the user only has to choose one of their favorite pens, attach our IMU sensor on it, link the sensor to the system and enjoy the immersive 3D painting experience (see Figure 2(a)).

VR Photography using a smartphone. After finishing the masterpiece, you might like to take a picture of it. In this application, we allow users to bring their daily used smartphone into VR, and exploit the multi-touch screen to perform intuitive camera operations (e.g., zoom in and zoom out) and click on the screen to take a photograph of the VR scene (see Figure 2(b)).

VR table tennis game. The last but not the least application is a VR table tennis game. In this application, we bring a real ping-pong paddle to VR, where the users will be asked to keep juggling a ball with the paddle to prevent it from falling to the ground. Each moment the user hits the ball, he/she will receive a coin as a reward. Figure 2(c) shows a snapshot of playing this game.

4 LIMITATIONS AND FUTURE WORK

Our system still has several limitations. i) Our system is unable to track the object's position when the user is not holding the object; ii) The working area of the tracking system is limited to the sensible range of Leap Motion controller; and iii) the user is unable to exchange holding hand after the object is being held. In the near future, we would like to explore other hand tracking techniques, such as wearable data glove, to expand the working area of the tracking system. We also plan to conduct a user study to validate the improvement of immersive experience in VR.

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