A Hybrid 2D-3D Tangible Interface for Virtual Reality

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ABSTRACT

Virtual Reality (VR) controllers are widely used for easy object selection and manipulation as a primary 3D input method in the virtual environment. Mobile devices with touchscreens like smartphones or tablets provide precise 2D tangible inputs. This research combines a VR controller and a touch-based smartphone to create a novel hybrid 2D-3D interface for enhanced VR interaction. We present the interface design and its implementation and also demonstrate four featured scenarios with the hybrid interface.

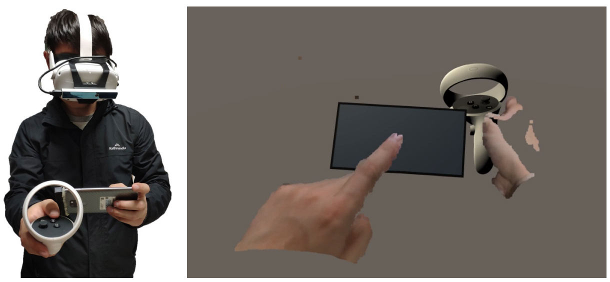

Figure 1: Left) A 3D printing structure connects a smartphone and a VR controller for 3D alignment, and a depth camera is mounted on the front panel of a VR headset to capture the hands. Right) Users are enabled to operate the VR controller and the smartphone for hybrid 2D-3D tangible interaction.

CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**; **Interaction design theory, concepts and paradigms**; **Smartphones**.

KEYWORDS

Smartphone, VR controller, hybrid interface, Virtual Reality

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1 INTRODUCTION

The smartphone with a built-in touchscreen for control input and multimedia output has become an essential daily-used mobile device. Some research work explored bringing the mobile phone into Virtual Reality (VR) and operating the corresponding virtual screen of the phone in VR [Takashina et al. 2018]. With an additional camera mounted in front of the head-mounted display (HMD), the user can see a 2D hand image from a live window [Alaee et al. 2018] or a 3D hand point cloud [Desai et al. 2017].

Most recent research attached a customized VR controller to a smartphone for its 3D tracking, and also mounted an RGB-Depth camera on the headset to capture a dense 3D hand point cloud [Bai et al. 2021; Zhang et al. 2020]. This type of setup provides stable and robust phone localization and enables a natural and full-featured operation experience in VR. However, the disassembled controller was only used for tracking purpose, and was not integrated with the smartphone-based interaction yet.

In this research, we develop a novel input method combining the controller and the full-featured smartphone to create a hybrid 2D-3D tangible interface in VR for virtual object manipulation. We design a phone case-like structure to firmly connect a smartphone with a controller without a bulky configuration. The controller not only provides 3D registration but also performs as an input device. The user can operate the hybrid interface with both hands to provide 2D precise touch input and 3D spatial input simultaneously, as shown in Figure 1. We present a few VR interaction scenarios that could take advantage of our hybrid interface to support rich interactions within the virtual environment.

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2 DESIGN AND IMPLEMENTATION

The VR controller has real-time spatial tracking with a high refresh rate. They could provide finger-based physical inputs with embedded triggers, buttons, and joysticks. The smartphone has a significant advantage on multimedia display and rich graphical user

(a) Asymmetric operation **(b) Spatial tangible input** **(c) Second virtual perspective** **(d) Augmented Virtuality**

Figure 2: Featured application scenarios based on the hybrid 2D-3D tangible interface.

inputs with virtual buttons. Its high-definition screen and multi-touch recognition support efficient and precise tangible 2D input. Based on these facts, we present our hybrid interface design principles as below: 1) The smartphone is used for precise and detailed 2D input, while the VR controller is used for spatial and coarse 3D interaction. The hybrid interface should preserve the legacy interaction patterns of both the smartphone and the VR controller; 2) The touch input on the smartphone and the VR controller input can be directly mapped to each other. The touchscreen content can be seamlessly transited from the 2D space to fully spatial and vice versa; 3) The user can choose to use a single device or the hybrid interface according to the circumstances. Any operation with one device can be dynamically swapped and completed by another device, or the hybrid interface.

The hybrid VR interface is built upon bringing the smartphone into VR and links the screen-touch with the controller-based input. The interface consists of three main components.

1) *Hardware calibration* As shown in Figure 1, a smartphone is connected to a VR controller with a 3D printing structure to secure its relative position to the controller. The calibration step calculates the transformation matrix from the controller's local coordinate system to the phone's local coordinate system. An extra calibration is conducted between an RGB-Depth camera and the VR headset. The two calibration tasks can be done with visual tracing and Iterative Closest Point (ICP) method.

2) *Smartphone registration and screen mirroring* The VR controller provides off-the-shelf tracking for the hybrid interface in real time. A collocated 3D virtual phone model is rendered in VR to provide consistent visual and tactile feedback, and moves correspondingly with the real phone in VR. Instead of directly capturing the phone screen, the smartphone screen is sampled and transmitted to VR as a live texture, which is then augmented on the top surface of the virtual phone. This design brings full-featured smartphone touch interaction into VR.

3)*Hand segmentation and rendering* An RGB-Depth camera is mounted in front of the headset to capture the physical environment in a colored dense point cloud. With a color-based detector, only the hand region is preserved in the scenario, and its point cloud is well aligned with the actual hands based on the extrinsic parameter obtained from the calibration procedure. The user wearing the VR headset can see the realistic 3D hands and accurately operate with the interface.

3 APPLICATIONS

The hybrid interface features both 2D screen-touch and 3D spatial interaction. We provide four potential application scenarios to show the value of our design.

1)*Asymmetric operation* The right hand operates the controller for coarse input, and the left hand touches the screen for precise synchronous operation (Figure 2a).

2) *Spatial tangible input* The controller moves in 3D space, while the smartphone provides tangible touch input (Figure 2b).

3) *Second virtual perspective* The smartphone can provide a virtual camera view or a specular view from another perspective beyond the main viewpoint (Figure 2c).

4) *Augmented Virtuality* The smartphone camera can be used as a bridge between reality and the virtual world by capturing and visualizing the physical surroundings in VR (Figure 2d).

4 CONCLUSION AND FUTURE WORK

This research presents a novel hybrid 2D-3D tangible VR interface by combining a smartphone and a VR controller with a customized 3D printing structure. Through this interface, touchscreen-based precise 2D input and 3D spatial input can be well integrated and supported. Users can see their virtual hands and operate the controller and the smartphone in VR simultaneously, which provides a broad design scope for VR users. Four sample applications have shown the potential of our hybrid interface. We plan to investigate the comprehensive design space for the hybrid interface, and evaluate the usability of using the hybrid VR interface for object manipulation by comparing it with common solutions.

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