A Raycast Approach to Hybrid Touch / Motion Capture Virtual Reality User Experience

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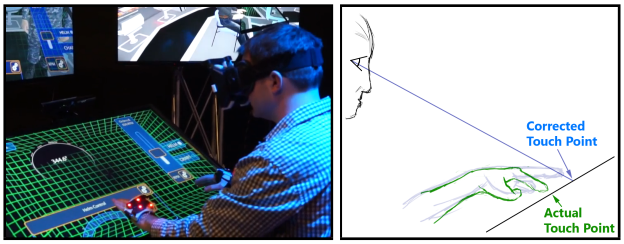

Figure 1: *Left:* Our virtual environment uses a tracked HMD and a touch screen. *Right:* Our approach, illustrated in a one-dimensional case. The physical user is indicated in green; the self-avatar as seen in the HMD in blue.

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ACM Classification Keywords
H.5.2 User Interfaces: Interaction Styles; I.3.7 Three-Dimensional Graphics and Realism: Virtual Reality

INTRODUCTION
We present a novel approach to integrating a touch screen device into the experience of a user wearing a Head Mounted Display (HMD) in an immersive virtual reality (VR) environment with tracked head and hands. In our system, the user's hands are tracked by a plastic rigid body with motion capture markers. This rigid body straps to the back of the user's hand. This design is convenient, but lacks fingertip tracking.

Our interaction uses an infrared multitouch overlay on a LCD display. This overlay is used for user input both inside and outside of the HMD experience (Figure 1, *left*).

Since the user's fingertips are not tracked, they may not align with the self-avatar's fingertips. This error is amplified because users may have different length fingertips, and the hand rigid bodies may not be placed identically on all users.

As a result of these errors, the user's self-avatar fingertip, as viewed through the HMD, does not consistently align with the real-world user's fingertip as sensed by the touch surface. This causes the user to perceive frustrating, inaccurate responses from the user interface.

APPROACH
We developed a raycast-based approach to determine corrected touch locations accurate to the user's perspective in the virtual environment. When the a touch event is reported, we determine the closest self-avatar pointer finger to the touch point, based on the rigid body attached to each hand. We then check if the touchpoint is within some threshold distance, experimentally set at 10cm, of the self-avatar fingertip.

If the fingertip is within the threshold, we raycast from the user's eye point through the index finger of the user's self avatar hand. We use the intersection of this ray with the virtual screen to compute a perspective-correct touch point.

If neither self-avatar finger is nearby, we assume that the user is interacting without the HMD and hand trackers, and use the original touch point. These corrected touch points are positioned relative to the self-avatar fingertip as seen by the HMD user. Differences in hand size or finger length do not impact the results because the corrected touch point is computed relative to the self-avatar fingertip as viewed through the HMD. Likewise, differences in hand tracker position are reflected in the position and orientation of the self-avatar fingertip (Figure 1, *right*).

This approach does not require an active touch screen. We have used the system to create interactive surfaces in midair, or on blank wood and glass surfaces for haptic feedback. In this use case, we detect a touch based on the self-avatar fingertip colliding with an object in the virtual environment that represents the screen.

LIMITATIONS AND FUTURE WORK
This approach has several limitations that may be addressed in the future. The system does not afford multi-touch gestures. Since the fingertips are fixed in the user's self-avatar, the same approach is not useful for multi-finger gestures. This challenge could be addressed by e.g. determining the transforms of other touchpoints relative to the index finger touchpoint, as determined based on the orientation of the hand.

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