Exploring Indirect Touch Gestures for Smartphone Interaction within VR Environments

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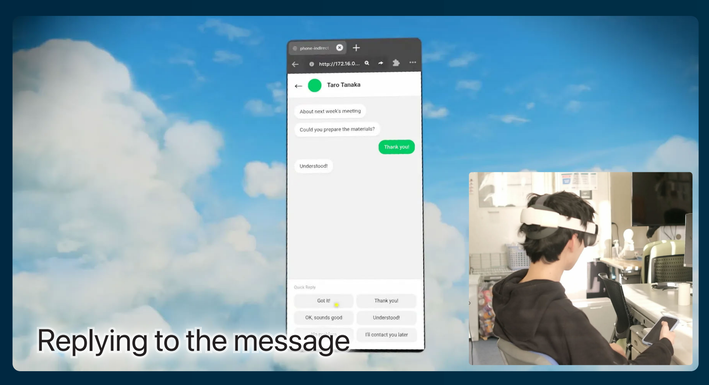
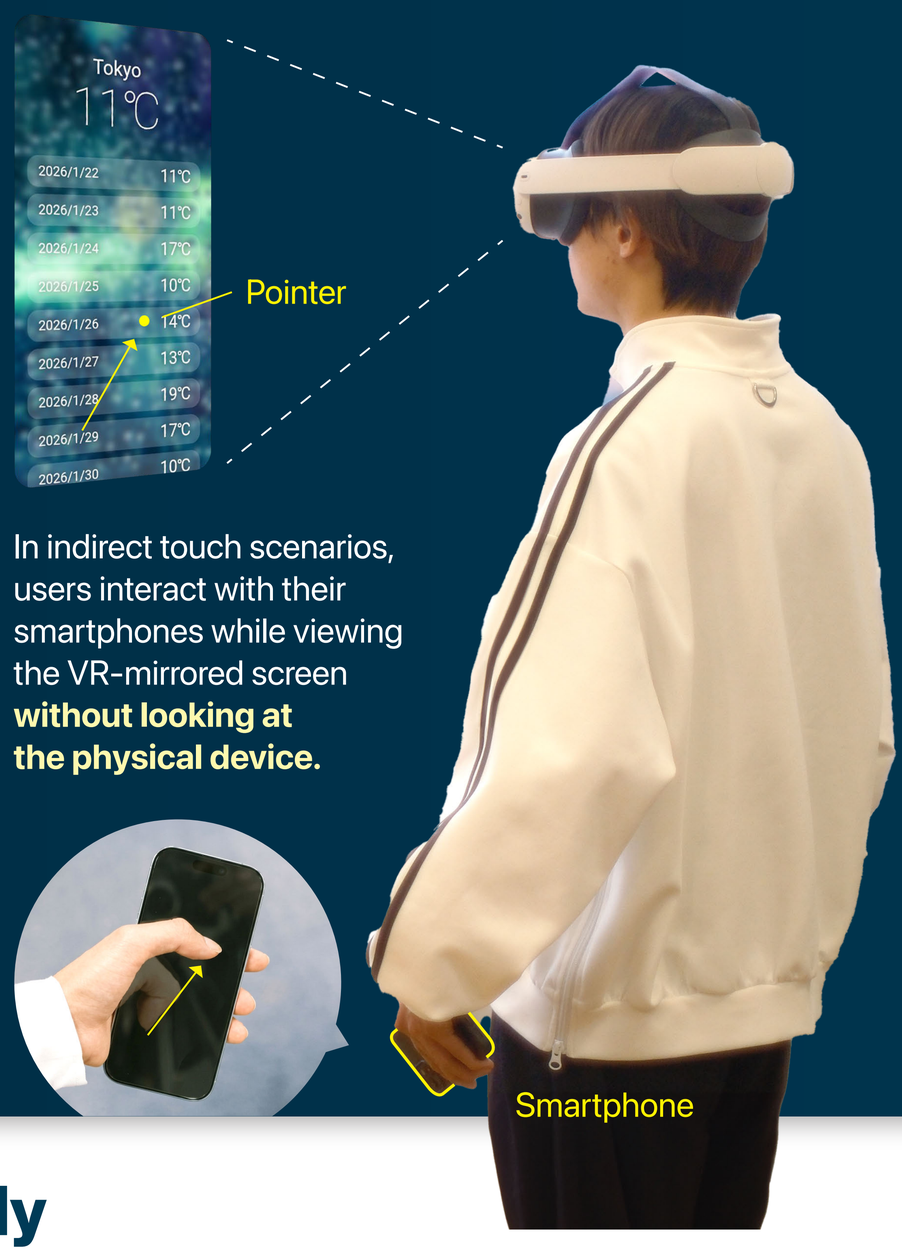
We present a set of indirect touch gestures that enable smartphone interaction in VR environments.

- It is common for users to access information on smartphones when engaging in VR experiences using HMDs. In this context, operating a **VR-mirrored smartphone with indirect touch** enables comfortable interaction without additional setup, allowing users to maintain a relaxed posture.
- Although previous studies have proposed a precise tap gesture for indirect touch, **other essential gestures for smartphone interaction remain unexplored**.
- By designing other essential smartphone gestures, we aim to enable smartphone interaction in VR environments without requiring users to look at their hands or relying on smartphone tracking.



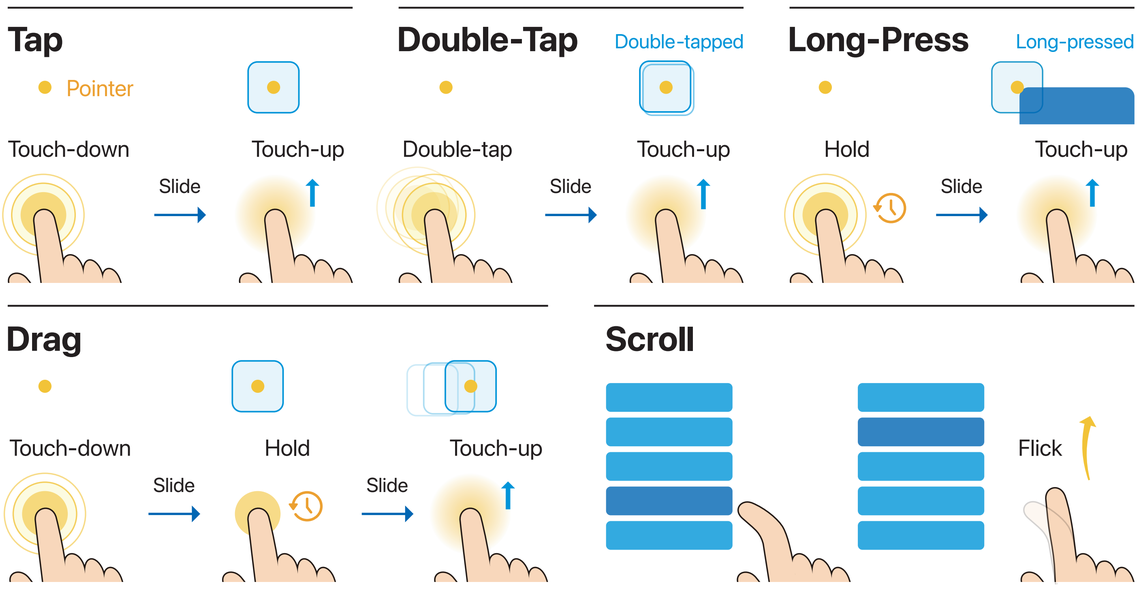


Indirect Touch Gestures

We implemented indirect touch gestures for smartphone interaction, which include tap, double-tap, long-press, drag, and scroll gestures.

Operation

- **Tap**: Move the finger to position the pointer on the target.
- **Double-Tap**: Perform a double-tap immediately after a touch-down.
- **Long-Press**: Perform a hold, a slide, and a touch-up.
- **Drag**: Perform a touch-down, a slide, a hold, a slide, and a touch-up.
- **Scroll**: Flick the finger.



Gesture Classification Procedure

Our system classifies a gesture using the holding threshold and the gesture classification model optimized through the pilot study.

1. If a double-tap is performed after touch-down
   → **Double-Tap gesture**
2. If the finger remains pressed beyond the holding threshold after touch-down
   → **Long-Press gesture**
3. If the tap/scroll gesture classification model identifies a scroll gesture
   → **Scroll gesture**
4. If it is held beyond the holding threshold after the finger has moved
   → **Drag gesture**
5. Otherwise → **Tap gesture**

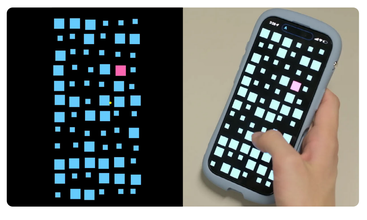
Our gesture recognition system and the teaser movie are available on GitHub!
https://github.com/inaniwaudon/smartphone-indirect-touch-gestures

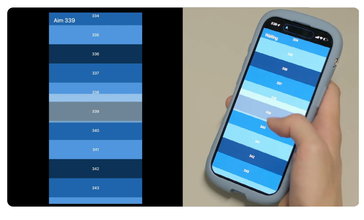
Pilot Study

We conducted a pilot study to investigate the optimal parameters for our indirect touch gestures and to develop a classification model for tap and scroll gestures.

- The study involved 8 participants recruited from our laboratory (8 males; mean = 22.75 years, *SD* = 1.09 years).
- The pilot study consisted of two subtasks, a **pointing task** and **scrolling task**, conducted in an indirect touch scenario within a VR environment.
- Participants operated the smartphone without looking at it directly while viewing a VR-mirrored smartphone display.


Scene of the pilot study


Pointing task


Scrolling task

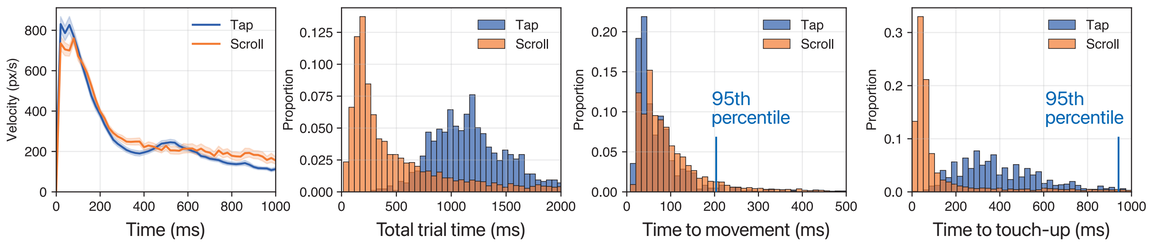
Optimal Parameters

We defined the holding threshold as follows:

- The threshold distinguishing tap and long-press gestures is **210 ms**.
- The threshold distinguishing tap and drag gestures is **950 ms**.

These values were determined based on the following results:

- The 95th percentile of the time to movement was 207.45 ms.
- The 95th percentile of the time to touch-up was 941.00 ms.



Gesture Classification Model

We developed a classification model for tap and scroll gestures.

- We used LightGBM as a classification model with the finger trajectory data from the first 50, 100, 200, 300, 400, and 500 ms after touch-down.
- We evaluated the model accuracy and AUC-ROC using 5-fold cross-validation.
- The model achieves **the highest accuracy of 97.8%** (*SD* = 0.6%) with an **AUC-ROC of 0.997 using 200 ms window size**.