Expanding One-Handed Touch Input Vocabulary Using Index Finger on and Above Back-of-Device

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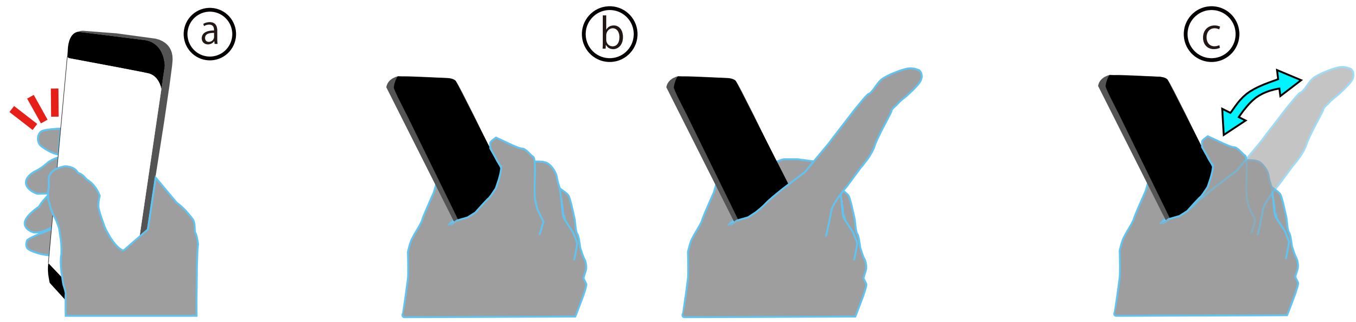

Figure 1: Overview of our method. a) One-handed touch input vocabulary using the index finger on and above back-of-device. b) Two postures of the index finger that expand tapping or swiping to two types of inputs; users can choose among two types of inputs by performing either of these postures: the posture with the index finger farther away from the smartphone and the posture with the index finger touched to the smartphone. c) The gesture of the index finger that expands long-tapping to a linear input; users can increase or decrease the value by bending/stretching the index finger.

ABSTRACT

This paper presents an input method to expand one-handed touch input vocabulary for smartphones using the index finger. To this end, our method combines thumb-based touch input and postures or gestures of the index finger on and above back-of-device. These postures and gestures are detected by three-dimensional directions or movements of the index finger. To enable this detection, users wear a ring-like device on the index finger. Moreover, our method includes a one-handed use detection system. Using this system, our method provides common input vocabulary for two-handed use and expands input vocabulary for one-handed use.

CCS CONCEPTS

• **Human-centered computing** → **Gestural input**; **Interactive systems and tools**.

KEYWORDS

mobile device, smartphone, touch-screen, single-handed interaction, ring-like device

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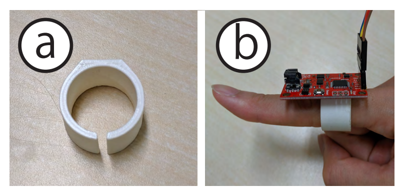

Figure 2: Our ring-like device. a) 3D printed ring model. b) The ring-like device worn on the index finger.

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1 INTRODUCTION

While multi-touch gestures such as a pinch gesture using two fingers expand the input vocabulary on touchscreen devices, they are difficult to perform with one hand. Moreover, multi-touch gestures on mobile devices require both hands [2]. In other words, touch input vocabulary is relatively limited for one-handed use of mobile devices.

To expand one-handed touch input vocabulary, we designed an input method using the index finger on and above the back-of-device (BoD) as shown in Figure 1. In our method, users use their smartphones with a combination of

1) three-dimensional direction or movement of the index finger on and above BoD and
2) thumb-based touch input on the touchscreen.

To track the three-dimensional direction and movement of the index finger, our method uses a ring-like device with an IMU sensor (Figure 2). In addition, our method includes a system that detects one-handed use by directions of the index finger and smartphone. With this system, the method provides common input vocabulary for two-handed use and expanded input vocabulary for one-handed use.

2 RELATED WORK

Our method relates closely to one-handed interaction techniques on mobile devices, finger tracking techniques for the detection of postures and gestures, and gripping postures detection techniques.

2.1 Techniques for Enriching One-Handed Interaction on Mobile Devices

Researchers have explored techniques to enrich one-handed interaction on mobile devices. For example, The Fat Thumb [2] is a thumb-based interaction technique that uses the thumb's contact size to switch a mode. Heo et al. [7] proposed Ta-tap, which utilizes consecutive distant taps to simulate multi-touch inputs. Unifone [9], a prototype mobile device equipped with pressure sensors on the side of a mobile device, enables squeezing gestures. Hinckley et al. [8] proposed interaction techniques that combine touch gestures with moving and tilting of the device. PalmTouch [11] is a touch input modality that uses the difference between touches by fingers and the palm. In contrast to these studies that used parts of hand touching or grasping the device, we focused on the feasibility of postures or gestures performed by the index finger gripping mobile devices. Our method combines postures or gestures of the index finger on or above the BoD with the thumb's touch interaction to enrich one-handed interaction on mobile devices.

BoD interactions that are available in one-handed use have been studied extensively. CamTrackPoint [18] is an interface that mounts a 3D-printed ring on cameras of mobile devices. Users can control this interface by BoD interactions using finger gestures. Hakoda et al. [6] placed a photoreflector to the BoD; they built a smartphone case with a hole to embed the photoreflector. Users can perform BoD interactions by covering the hole with their index finger. These BoD interactions with the device are performed in a two-dimensional space, whereas our method uses a three-dimensional space for tracking the direction and movement of the index finger.

2.2 Finger Tracking Techniques for the Detection of Postures and Gestures

Researchers have studied techniques to track postures and gestures of fingers for gestural interaction. Current techniques include those using the camera [3, 10, 15, 19], built-in sensors of a smartwatch [16, 17], or additional IMU sensors [1, 5, 13, 14]. Among these techniques, our method relates closely to Touch+Finger [13], a technique that uses finger tracking to recognize the gesture. This technique combines the touch input with multi-finger gestures to augment the interaction space. When touching with the index finger, a user performs variety of hand poses or in-air gestures using the remaining fingers. In this technique, the thumb and middle finger are tracked to recognize hand gestures. By contrast, our method tracks the index finger on and above the BoD when the thumb touches the device.

2.3 Gripping Postures Detection Techniques

Gripping postures detection techniques have been studied for use in an interaction context. iRotateGrasp [4] is a system that uses the device with 44 capacitive sensors attached to the back and side. In this system, a gripping posture is recognized by detecting the position of the hand that touches the device. HandSee [19] is a sensing technique that uses the front camera on which a right-angle prism mirror is placed. By capturing the user's hand gripping a smartphone, this technique provides fingers' 3D location, gripping posture, and finger identity. WhichHand [12] is a system that detects the hand that holds the smartphone. It provides interfaces adjusted to the holding hand. This system uses orientation data of a smartphone and a smartwatch for the detection. The detection system of one-handed use in our method is similar to WhichHand [12]. Our system detects one-handed use based on the directions of the index finger and smartphone.

3 OUR CONCEPT

When users use a smartphone with one hand, single-touch gestures such as tapping, swiping, and long-tapping using the thumb are available. Our method provides input vocabularies based on the combination of the touch gesture performed on the touchscreen and the posture or gesture of the index finger on and above the BoD. The postures of the index finger can be recognized based on the relationship between the directions of the index finger and smartphone. In addition, by acquiring the posture of the index finger continuously, we can track the index finger movement. Gestures of the index finger can be recognized from this movement.

3.1 Expansion Using Postures of the Index Finger

Our method allows users to select two types of inputs that are assigned to the same single-touch gesture by performing either of two postures of the index finger (Figure 1b). Tapping and swiping can be expanded in this approach. If the index finger is farther away from the smartphone, we define these gestures as different actions.

3.2 Expansion Using Gestures of the Index Finger

Our method provides a linear input, which can be performed by bending/stretching the index finger above the BoD during the thumb's touch gesture (Figure 1c). The value of this input is determined by the directions of the index finger and smartphone. It becomes smaller and larger as the index finger is far from and close to the smartphone.

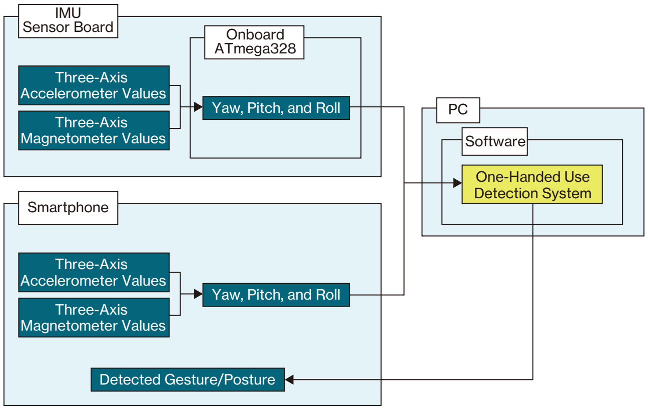

Figure 3: Block diagram of the prototype system.

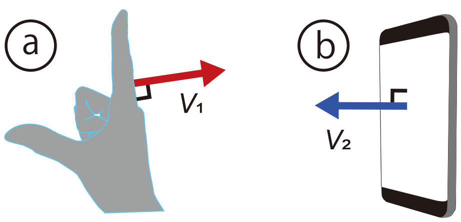

Figure 4: Two vectors used for the detection of one-handed use: a) V_1 is a normal vector to the back of index finger and b) V_2 is a normal vector to the touchscreen of the smartphone.

4 PROTOTYPE

We built a prototype system using a smartphone and ring-like device to demonstrate our method. Figure 3 summarizes our prototype system.

4.1 Hardware

The system consists of a smartphone, a ring-like device for tracking the motion of the index finger, and a PC. We used a Samsung Galaxy S7 edge as the smartphone in our prototype system. It collects built-in sensor values (i.e., three-axis accelerometer and three-axis magnetometer) and then calculates yaw, pitch, and roll from the sensor values. These data are sent to the PC via Bluetooth. The ring-like device is composed of a 3D printed ring model (Figure 2a) and an IMU sensor board (SparkFun SEN-10736), which includes a nine-axis inertial motion sensor (i.e., an accelerometer, gyroscope, and magnetometer) and an onboard ATmega328. The IMU sensor board is attached to the ring model and the ring-like device is worn on the index finger (Figure 2b). This ring-like device sends sensor values from the IMU sensor board, yaw, pitch, and roll calculated from the sensor values using the onboard ATmega328 to the PC via USB at a sampling rate of 50 Hz.

4.2 Detection of One-Handed Use

To detect if the smartphone is used with one hand, we use the direction of the index finger with respect to the smartphone. When the smartphone is used with one hand, the index finger is located on or above the BoD. In this case, the angle between the vector V_1 (Figure 4a), which is a normal vector to the back of the index finger and the vector V_2 (Figure 4b), which is a normal vector to the touchscreen of the smartphone, is over 90 degrees. Thus, we implemented the software on the PC that detects one-handed use by the angle between V_1 and V_2 (Figure 5). V_1 and V_2 are calculated from yaw, pitch, and roll data provided by the IMU sensor board and smartphone. This software detects one-handed use when the angle is over 90 degrees.

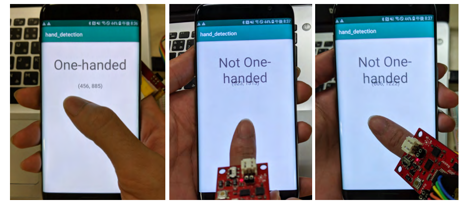

Figure 5: Detection of one-handed use using the prototype system.

4.3 Detection of Expanded One-Handed Touch Input

The detection of one-handed touch input, which is expanded by postures or gestures of the index finger on and above the BoD, is performed as follows. When the touchscreen of the smartphone detects a touch action, the software that detects one-handed use starts; when the software detects one-handed use, our prototype system recognizes index finger postures by the angle between V_1 and V_2 or gestures by the change in the angle between V_1 and V_2. The system provides the touch input vocabulary according to the index finger posture or gesture. If the software does not detect the one-handed use, the system provides the common input vocabulary.

5 APPLICATIONS

In this section, we demonstrate sample applications of expanded one-handed touch input vocabulary.

5.1 Zoom In/Out

By applying our method to the swipe gesture, the input, which is generally provided by pinch gesture, is available for one-handed use (Figure 6). On a map application, users can zoom in/out the map by performing the swipe gesture with the index finger farther away from the smartphone; users can scroll the map by performing the swipe gesture with the index finger touched to the smartphone. This input vocabulary allows users to perform zoom in/out operation for one-handed use without changing the grasping posture.

5.2 Volume Control

Our method enables a linear input by expanding the long-tap gesture. This expanded input vocabulary provides an alternative to the one-dimensional slider input used to control volume or display brightness (Figure 7). Users can perform this input by bending/stretching the index finger above the BoD during a long-tap. In contrast to a traditional GUI where one-dimensional slider input

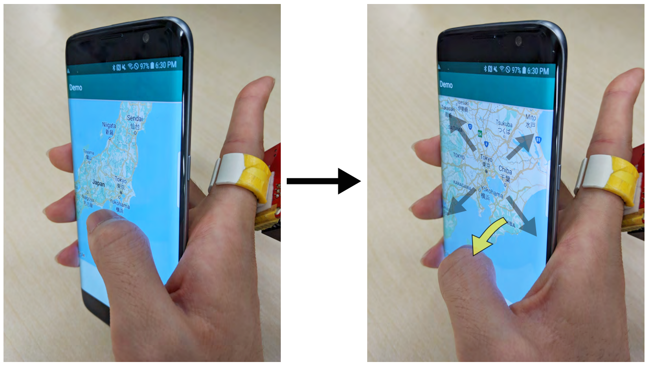

Figure 6: Expanding the swipe gesture using the posture of the index finger. Users can perform zooming by swiping with the index finger sufficiently away from the smartphone; users can perform scrolling by swiping with the index finger touched to the smartphone.

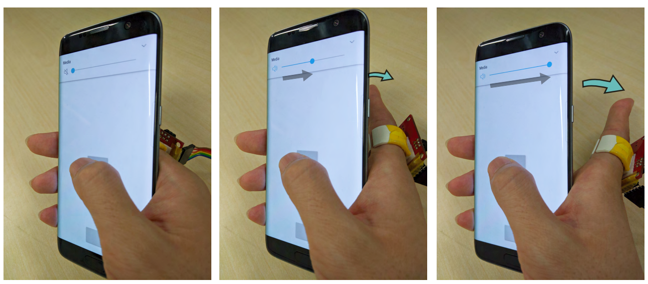

Figure 7: Expanding the long-tap gesture using the gesture of the index finger. Users can perform this input by bending/stretching the index finger above the BoD when long-tapping with the thumb.

requires a large UI element, our method allows users to perform equivalent input by designing a small area for the long-tap gesture.

6 LIMITATIONS

Our prototype utilizes the three-axis magnetometer on the IMU sensor board to track the index finger. When the index finger approaches the smartphone, the magnetometer cannot function properly owing to the magnetism of smartphones. Moreover, the accelerometer of the smartphone cannot function properly while moving or tapping the smartphone harder. Therefore, yaw, pitch, and roll of the smartphone cannot be calculated accurately in this kind of situation. To solve these problems, it is necessary to revise these values.

We demonstrated a prototype system at an academic workshop. When our system was used by several users, we found that the size of the user's hand or the thickness of the user's index finger could affect usability. This is because 1) the range of the index finger's movement depends on the size of the hand and 2) the fitting of the ring model depends on the thickness of the index finger. Users with relatively small hands seemingly struggled with the movement of the index finger. Some users commented that "the index finger is difficult to move because the ring model does not fit". To solve them, we are considering making the ring-like device adjustable for each user using Velcro tape.

7 CONCLUSIONS AND FUTURE WORK

In this paper, we explored the input method to expand one-handed touch input vocabulary using the index finger on and above the BoD. To this end, we built a prototype system that uses a ring-like device with the IMU sensor board and the smartphone and demonstrated two applications of our method.

In the future, gyroscopes or additional sensors will be used to correct the yaw, pitch, and roll of the ring-like device and the smartphone. Moreover, we will explore additionally available index finger postures or gestures (e.g., tapping and swiping) and implement their applications. In addition, we will conduct user studies to investigate the accuracy of the system for detection of one-handed use, the recognition accuracy for postures and gestures of the index finger, and the performance of our method in various postures of users, such as standing, sitting, or lying. We will also evaluate the usability of our system in these studies.

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