One–Handed Control for Smartwatches Using Thumb Gestures to Ring

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ABSTRACT

Users operate smartwatches with touch gestures (e.g., tap, double–tap, swipe); however, the displayed target's small size causes tapping errors. Since the smartwatch's input space is covered by the user's finger, the user cannot verify the point to be tapped. In addition, users who wear smartwatches on their wrists must operate the smartwatch with the opposite hand, making it difficult to control the smartwatch when one hand is occupied. Therefore, we designed a one–handed control method that can execute operations by using the hand wearing a smartwatch and extending the input space. To detect thumb gestures, we designed a ring device equipped with photoreflectors. We implemented a system for detecting thumb gestures using time series data and the frequency power spectrum obtained by Fast Fourier Transformation of the time series data for Support Vector Machine. In a user study with five participants, the leave–one–participant–out cross–validation accuracy of the system to detect five thumb gestures was 87.33%.

CCS CONCEPTS

• **Human–centered computing → Gestural control**.

KEYWORDS

one–handed interaction, gesture detection, wearable device, distance sensor

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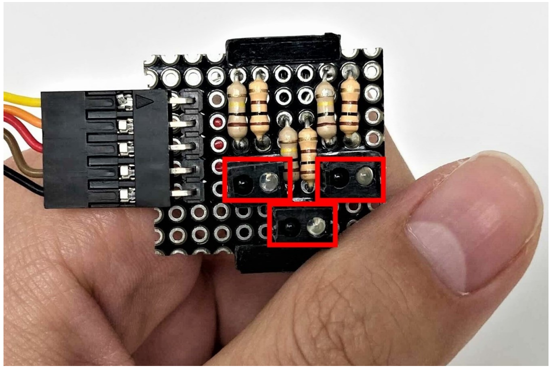

Figure 1: The ring device with three photoreflectors made to detect thumb gestures. The red frame indicates the photoreflector.

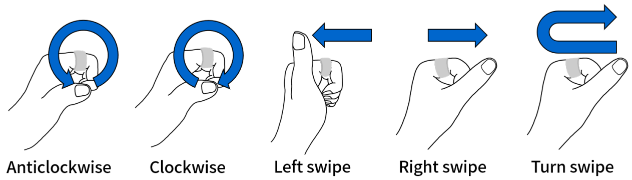

Figure 2: The posture of the hand at the start of each gesture and the gesture movement.

1 INTRODUCTION

Users operate smartwatches with touch gestures; however, since the input space displayed [8] is small, it causes tapping errors (fat finger problem) [6, 10]. In addition, the input space of the smartwatch is covered by the user's finger, so the user cannot see where to tap (occlusion problem) [6, 10, 12]. Furthermore, users who wear a smartwatch on their wrists must operate the smartwatch with the opposite wrist's hand, making the smartwatch operation more challenging when one hand is full and cannot be used [11]. We consider that this problem can be solved by allowing the user to operate the smartwatch with only one hand. The fat finger and occlusion problems are caused by the smartwatch's small screen and the user's touch interaction. Therefore, we designed a one–handed control method that can be operated by the hand wearing a smartwatch and extends the input space. To detect gestures, we implemented a ring device with three photoreflectors (Fig. 1). Our ring device detects thumb gestures using machine learning. The contributions of our work are as follows:

- We designed a ring with photoreflectors to capture the distance between the ring and the thumb.
- We used both the time series data of the gestures and the frequency power spectrum as features for machine learning, which enabled the system to detect five different thumb gesture movements.

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Figure 3: The confusion matrix about the average detection accuracy of leave–one–participant–out cross–validation with five participants.

2 RELATED WORK

Several studies [1, 3, 5, 9, 11, 13] have been conducted to solve the fat finger and occlusion problems in smartwatches and the need for two–handed operation. The following studies that extend the input space have been conducted to solve these problems. Schneegass et al. [9] proposed a method to detect the gesture of tracing a finger over touch sensitive fabrics attached to the forearm. Zhang et al. [13] proposed a method to detect multiple types of taps on the surrounding skin using the inertial sensors and microphone of a smartwatch. The following methods have been proposed for one–handed operation and extended input space. Laput et al. [5] proposed a method to detect vibrations during a gesture by collecting them from smartwatch accelerometers. Hamdan et al. [3] proposed a method to detect the body part tapped by a user using motion capture. Aoyama et al. [1] proposed a method to detect left–right sliding controls by estimating the amount of thumb movement on the side of the index finger using a wrist–worn device. This method is similar to ours in that they perform thumb gestures. Our method is superior in that it can detect five gesture types.

One–handed operation methods using ring devices [2, 4, 7, 14] have been proposed. Ogata et al. [7] proposed a method to detect finger flexion and rotation by acquiring changes in the finger's skin shape using infrared distance sensors attached to a ring. This method requires appropriate rings for users' fingers, which vary widely in size and shape. Nonetheless, our method does not acquire information on the inside of the ring, there is no need to prepare a ring that fits each user's finger closely.

3 IMPLEMENTATION

We set five thumb gestures—anticlockwise, clockwise, left swipe, right swipe, and turn swipe (Fig. 2); because they are easy to control and correspond to a smartwatch's scrolling control. Therefore, we designed a ring device to detect five thumb gestures (Fig. 1). The ring device consists of a ring and three photoreflectors. The body of the device was fabricated on a 3D printer (Ultimaker3 Extended) using PLA filament. RPR–220 was used as the photoreflector. Three photoreflectors were arranged in a triangle shape to distinguish between vertical and horizontal thumb movements. Each of the three photoreflectors acquires the sensor value of the distance to the thumb. The photoreflectors are connected to a microcontroller (Arduino Nano), and the sensor data are sent to the computer. When we collected sensor data during gestures using our ring device, we acquired data at approximately 88 Hz. In this study, we used both the time series data of the gestures and the frequency power spectrum obtained by Fast Fourier Transformation (FFT) of the time series data as features to verify the detection accuracy using Support Vector Machine (SVM).

4 USER STUDY

We conducted a study to investigate the accuracy of gesture detection. This section provides an overview, followed by data processing, the results, and a discussion of the study.

In this study, five people (23–26 years old, M=24.6 years old, SD=1.36 years old, all male, all right–handed) in our laboratory including the author, participated as volunteers. Participants wore the ring device on their left hand and performed five gestures. We asked the participants to perform each gesture within three seconds. We collected sensor data for 375 repetitions (5 gestures $\times$ 15 repetitions $\times$ 5 participants).

4.1 Results

The sensor data collected from each participant were formatted into a total of 80 feature points: 20 feature points before the threshold and 60 feature points after the threshold. In addition, this time series data was transformed into a power spectrum by FFT, and 41 feature points were obtained. Finally, the combined data of these features (121 feature points) were used for SVM. Incidentally, there were three missing gestures in the data collected this time, and they were not used for SVM. The average detection accuracy was 87.33% about leave–one–participant–out cross–validation (Fig. 3).

4.2 Discussion

Fig. 3 shows many false positives for anticlockwise and left swipe combinations and for clockwise and right swipe combinations. The sensor data showed that the shape of the graphs for anticlockwise and left swipe combinations, and for clockwise and right swipe combinations were similar for some participants. In addition, when the clockwise or anticlockwise gesture duration was extremely short, it could be falsely detected as a left or right swipe. When we compared and analyzed the sensor data, we observed that the behavior of each sensor value at the beginning of the gesture was similar, possibly affecting gesture detection accuracy. Therefore, we will try to improve accuracy by changing the arrangement of the three sensors.

5 CONCLUSION

We proposed a one–handed control method for smartwatches. In this method, a ring device was designed, and SVM was used to detect thumb gestures. A user study with five participants demonstrated that our system could detect five thumb gestures with an average accuracy of 87.33%. Since there were only five participants in this study, we plan to conduct the study with more participants in the future, expanding participant demographics to include women and left–handed people. Furthermore, we will attempt to add new features to the system to make detection more robust and to verify the system's accuracy.

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