Tactile Presentation to the Back of a Smartphone with Simultaneous Screen Operation

Sugarragchaa Khurelbaatar
The University of Electro-Communications
1-5-1 Chofugaoka, Chofu, Tokyo, Japan
sura@kaji-lab.jp

Vibol Yem
The University of Electro-Communications
1-5-1 Chofugaoka, Chofu, Tokyo, Japan
yem@kaji-lab.jp

Yuriko Nakai
The University of Electro-Communications
1-5-1 Chofugaoka, Chofu, Tokyo, Japan
yuriko@kaji-lab.jp

Hiroyuki Kajimoto
The University of Electro-Communications
1-5-1 Chofugaoka, Chofu, Tokyo, Japan
kajimoto@kaji-lab.jp

Ryuta Okazaki
The University of Electro-Communications
1-5-1 Chofugaoka, Chofu, Tokyo, Japan
okazaki@kaji-lab.jp

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Figure 1. Appearance of the device with a user. The electro-tactile display on the back of the smartphone presents a shape-touching sensation to the index finger of user.

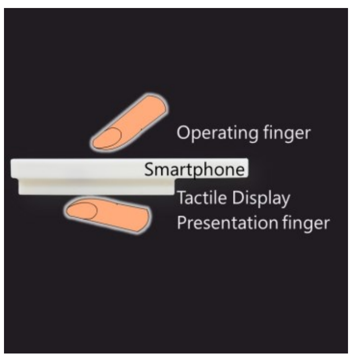

Figure 2. Tactile sensation of shape touched by a finger at front side is presented to a finger on the back.

Abstract
In most common methods of tactile presentation on touch screen, the tactile display was directly attached or contacted onto the screens. Therefore, the tactile display must be transparent so that it does not obstruct the view of the screen. On the other hand, if the tactile sensation is presented at the back of the device, the tactile display does not need to be transparent. However, tactile presentation to the whole palm of hand is not appropriate while a shape on the screen is touched by only one finger. To overcome these limitations, we propose a new method to present tactile feedback to a single finger on the back. We used an electro-tactile display because it is small and dense (Figure 1). The tactile display presents touch sensation as a mirror images of the shape on the touch screen. This paper reports the ability of shape discrimination, by comparing two cases where the device is operated by one hand and two hands.

Author Keywords
Electro-tactile display; Smartphone; Tactile feedback.

ACM Classification Keywords
H.5.2. [Information interfaces and presentation]: User Interfaces-Haptic I/O.

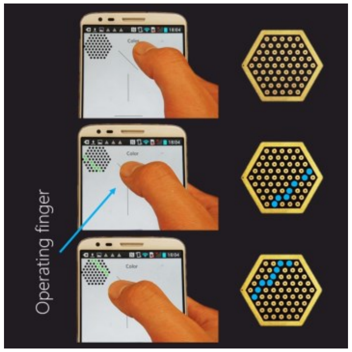

Figure 3. Sample shape on the screen and electro-tactile presenting algorithm. (1) Operating finger approaches to "\" shape. (2) The finger is on the upper part of "\" shape. (3) The finger is on the lower part of "\" shape.

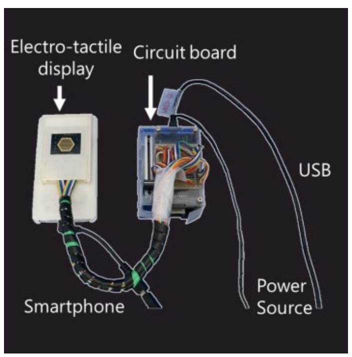

Figure 4. Overall view of the prototype.

Introduction

With the spread of mobile touch-screen devices, improving comfort and accuracy of operation has become an important issue. Even though the device can be intuitively operated by directly touching icons or buttons on the screen, the lack of clear tactile feedback such as click feeling causes degradation of performance (operating errors) [1, 2].

We propose a high density tactile feedback method using an electro-tactile display on the back of a mobile device that stimulates the finger touching the back (in this paper, referred to as "presentation finger") with a mirror image of the shape being touched by the operating finger (Figure 2 and Figure 3).

In this paper, we present our system using an electro-tactile display attached to a smartphone, and report the integration ability of the user during operating the device.

Related works

While various tactile presentation methods for touch panel have been proposed, for most of them the tactile feedback is presented to a finger that is touching the screen (in this paper, referred to as "operating finger"). ActiveClick [3] realized a click feeling by vibrating the entire touch panel. Teslatouch [4] created a texture feeling by controlling electrostatic friction on the touch panel. Winfield et al. [5] modified surface texture by modulating the presence or absence of ultrasonic vibration. However, most of these methods have a limitation of spatial resolution; i.e., the sensation is presented to the whole fingertip and the resolution is limited to the finger size when the finger stands still. There are some studies aiming to realize higher resolution tactile presentation. Skeletouch [6] enabled electrical stimulation on the screen using a transparent electrode. Tactus Technology's Tactile Layer [7] created tactile cues for button position by physically deforming the touch panel surface. Fundamental limitation of all these works is that, the tactile sensation is presented to the operating finger, so that the necessity of transparent tactile display that does not visually obstruct the screen dramatically limits the ways to present tactile sensation on touch panel, and high density tactile feedback becomes difficult.

One way to cope with these issues is presenting tactile stimulation on the back of the screen. The tactile display is placed on the back of the device, so it does not need to be transparent. SemFeel [8] used vibration motors to present tactile stimulation to the back area of a mobile device. Fukushima et al. [9] presented tactile feedback to hand by placing an electro-tactile display on the back of the touch panel. However, these methods present tactile feedback to entire palm of the hand holding the device, which would not be an appropriate way because the shape is touched by only one finger.

Our idea is to present tactile stimulation to a finger on the back of mobile device as if it is touching a shape on the screen. Because the presentation finger is stationary, we present the tactile pattern by dynamically moving it according to the motion of the operating finger. The key question of this method is that, whether the tactile perception of the finger and the movement of the operating finger can be integrated and interpreted accurately. We assumed integration is possible, because Optacon [10], which is widely used as a visual-tactile conversion device for the visually

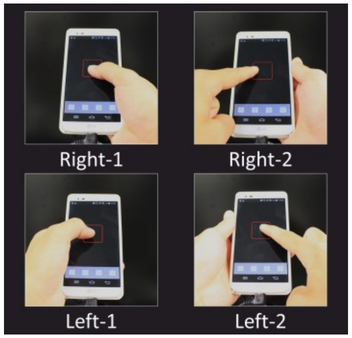

Figure 5. Experimental conditions. “Right” or “Left” represents a right or left hand holding the device. “1” or “2” represents, the case where only one hand is used for holding and operating the device or both of two hands are used, one is for holding and the other is for operating the device. For one hand case, the thumb of device holding hand is used as an operating finger.

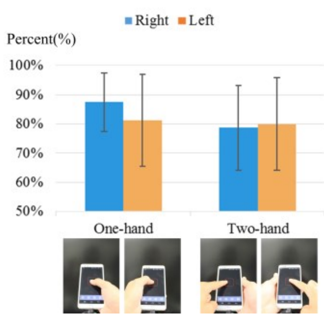

Figure 6. The comparison of the mean correct answer rate.

impaired, works in a similar way (i.e., a finger of one hand touches the tactile display while the other hand holds the camera). The main difference between Optacon and our system is that the tactile display is on the back of the screen.

Device

Figure 4 shows the prototype of our device. The device is composed of an electro-tactile display that was developed in our lab and a smartphone (LG G2, 138.5×70.9×8.9[mm^3], Android 4.2.2). The electro-tactile display comprises 61 electrodes with 1.2mm diameter. The distance between the centers of two adjacent electrodes is 2mm. The entire display becomes a regular hexagon of 10mm. The tactile display is connected directly to the smartphone by a USB serial communication.

As mentioned above, the presentation finger is stationary and the user is able to sense the information on the smartphone by integrating the tactile feedback sensation from the presentation finger with the movement of operating finger. The tactile stimulation pattern corresponds to the shape on the screen and the motion of the operating finger. As shown in Figure 3, when the operating finger approaches and then touches the shapes on the touchscreen, the tactile display presents tactile stimulation that mirrors them (left/right inversion). The movement of tactile pattern is reversed to the movement of the operating finger so that the user can perceive the shape as if he/she is moving his/her presentation finger on the shape.

Shape Recognition

We recruited eight subjects to participate the preliminary experiment. The purpose of the experiment was to validate the shape recognition ability of users without showing visual information on the screen but only tactile sensation of a shape was presented to the back of device. The shapes were square “□”, circle “O”, equilateral triangle “Δ”, and cross-shape “×”. One pattern of shape was presented five times. The order of pattern presenting was random. In addition, subjects conducted the experiment with four conditions of device holding and operating as shown in Figure 5. The order of four conditions was counterbalanced across subjects.

Overall, the mean correct answer rate was 82.5% (Figure 6), and the mean reaction time was 6.94s (Figure 7). The results indicated that when the presentation finger and operating finger were both in the same hand, the correct answer rate became slightly higher (85.6% and 79.4%, respectively) and reaction time became faster (6.7s and 7.2s, respectively).

Applications

We developed two applications to demonstrate the potential and feasibility of our device: “guitar application”, and “worm application”.

"Guitar application"

Figure 8 (left) shows the guitar application. In this application, the user is able to sense string vibration on his presentation finger while playing the guitar with his operating finger. The dots array in hexagon on screen represent the electrodes array of electro-tactile display. User can touch any string by moving this dots array onto the string.

"Worm application"

Figure 8 (right) shows the worm application, which provides weird feeling of the worm crawling on the skin.

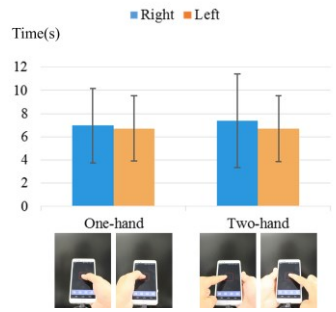

Figure 7. The comparison of the mean reaction time.

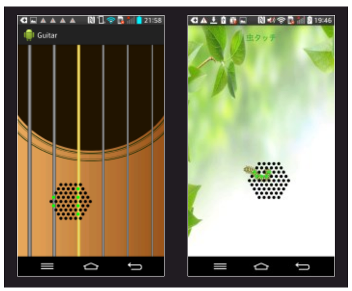

Figure 8. Sample applications of playing a guitar (left) and touching a worm (right). Tactile sensation of touch are presented on the back.

In this application, the worm is moving freely on the screen. User can touch the moving worm by moving the dots array onto the worm with the operation finger.

We asked eight subjects above to try these two applications and they mentioned that, the system was very realistic. Particularly, in the case of worm.

Conclusion and Future work

We proposed a new method for presenting tactile information to one finger based on the shape touched by another finger. We used a small and dense electro-tactile display, as it is suitable for smartphone. In our method, the electro-tactile display is located on the back of a smartphone, produces tactile stimulation that is a mirror image of what an operating finger touches and delivers it to the presentation finger. An experiment using shapes confirmed that users could stably identify different shape types.

We did observe that when the presentation finger and operating finger were both from the same hand, the performance became slightly better. It may be that to understand the relationship between the shape on the screen and tactile mirror image, the relative position of the operating finger and the presentation finger is important.

We also showed that our method can be used to add tactile sensation to entertainment. We envision using the device for people with visual impairments, perhaps as a character presentation system. Although a visual display is not necessary in that case, the coexistence of input (touch panel) and output (tactile display) in a small mobile device will be a practical help for visually impaired people.

Acknowledgements

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