

# Palm Touch Panel: Providing Touch Sensation Through the Device

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## ABSTRACT

We present a novel touch sensitive handheld device, called Palm Touch Panel, which provides electro-tactile feedback on the back of the device thus simulating the sensation of being able to touch the user's palm directly through the device. Users hold the mobile device, which has an electro-tactile display attached at the back. When a finger touches the visual cues on the front screen panel, such as a button or an icon, the electro-tactile display at the back transmits the unique tactile sensation associated with this behavior of the cues to the palm of the hand. As a result, we speculate that the user can manipulate visual information with less visual attention, or even potentially in an eyes-free manner. In this paper we discuss the creation of this unique mobile device that allows the palm to be used for tactile feedback, thus enhancing the touch screen experience.

**ACM Classification:** H5.2 [Information interfaces and presentation]: User Interfaces. - Graphical user interfaces.

**General terms:** Design, Human Factors.

**Keywords:** Palm, tactile feedback, electro-tactile display, touch screen, on-body interaction, mobile computers.

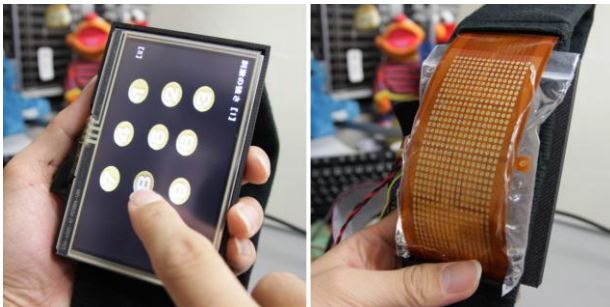


Figure 1: Front and back of the Palm Touch Panel.

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## INTRODUCTION

### Mobile touch screen and tactile feedback

A touch screen is commonly used in a variety of mobile devices, such as smart-phones, digital cameras, portable gaming devices, etc. Since the visual screen also works as an input surface, the touch screen simplifies the mechanical input components and enables direct touch interaction. These benefits contribute to expanding the design possibilities of mobile devices from an ordinary Front-Surface interaction to Behind-Surface interaction [2] and Dual-Surface interaction [3].

However, the touch screen loses fairly important and intuitive cues; that is, the tactile feeling provided by mechanical structures, such as a mechanical keyboard and mouse buttons. As a result, users have to rely heavily on rich visual cues and cannot divert their attention to other incidents. This is quite inconvenient especially for mobile devices, which may be used while the user is walking outdoors.

To deal with this problem, many tactile feedback methods for mobile device have been proposed, most of which utilize physical actuation of the touch screen. The touch screen is vibrated by electromechanical actuators such as a vibrating motor [4], piezoelectric bending motor [5], or a voice coil actuator [6]. There is also another proposal that uses electrostatic friction between the finger and touch screen with a charged conductive film [7]. These tactile devices improve the usability of portable touch screens, and enable users to manipulate visual images with a tactile feeling.

However, these tactile feedback systems have difficulty in presenting tactile sensations to multiple fingertips independently, and furthermore cannot present the distribution or movement of tactile cues, since they uniformly present tactile stimulation to either the front or back surface.

### Proposed Interaction on the Palm

The tactile solutions for touch screens described above represents an interface through which a user interacts with visual-tactile cues “on the screen” using a finger. By contrast, we propose the Palm Touch Panel, an interface through which the user interacts with visual-tactile cues “on the palm” using a finger. To achieve this goal, we used a mo-

bile touch screen with an electro-tactile display attached to the back. An electro-tactile display is a tactile interface that directly activates the sensory nerve under the skin [13]. When a user holds the device on the palm, a matrix of electrodes is placed on the palm. If the user touches the screen, a tactile sense is evoked in his/her palm corresponding to the position touched.

While not completely verified in this work, two speculate that the merits of Palm Touch Panel are as follows.

- Users can recognize the spatial positions of graphics without looking at the screen. This could ultimately reduce the errors and mental load required when operating a touch screen.
- We can create rich passive touch applications. To create tactile entertainment content, spatial and temporal resolution of the tactile device is important. One typical example is “Ants in the Pants” [8], which evokes an insect crawling sensation using a globe-type tactile display. In this system, the tactile device and visual display are separated. On the contrary, our method can present both visual information and a high resolution tactile sensation simultaneously, which is ideal for cross-modal interaction.

In this paper, we present the design and implementation of the Palm Touch Panel device.

## RELATED WORK

### On Body Interaction

The Palm Touch Panel can be regarded as one way of using the human body surface as a GUI interaction field. From this viewpoint, there has been some research that has proposed using the human body as a GUI interaction field. Harrison proposed Skinput [9] which uses the body as an interactive surface by incorporating an armband-type finger tap sensor and a pico-projector. However, this system relies heavily on visual cues projected on the body, and thus the user cannot recognize the existence of graphical icons with tactile cues. Sixth-sense [10] likewise projects visual images on the body, also without any tactile cues. These systems differ from our research in that we provide visual and tactile cues on the palm at the same time.

### Back-of-Mobile Device Tactile Feedback

Mobile devices with embedded tactile feedback systems on the back of the device have been proposed. Alexander presented Tactile TV [11], which has an ultrasonic tactile feedback system at the back of the device. This can present tactile stimuli with high spatial resolution. However the tactile intensities are weak and it allows no interaction via a finger. Semfeel [12] has five vibration motors on the back of the device and can create tactile sensations on the palm, but with limited movement patterns.

### Electro-tactile Displays

An electro-tactile display is a tactile device that directly activates nerve fibers below the skin at the location of the electrode by passing a local electric current through the skin.

The electro-tactile display can be made thin and flexible, since it only requires the electrodes as an end-effector. Owing to these merits, such displays have been extensively utilized for sensory substitution systems for the visually impaired [13, 15, 16], where visual information is converted to tactile patterns.

Electro-tactile displays have also been applied to touch screens, for example the Colorful Touch Palette [17]. However, since making transparent electrodes is technically quite difficult, a small electrode plate is attached to the finger.

Our proposal can be regarded as the optimal use of a “thin and flexible” (merit), but “non-transparent” (demerit) electro-tactile display for a touch panel, by attaching the display to the back of the device.

## PALM TOUCH PANEL: HARDWARE

### Overview

We used a 4.3inch TFT LCD (T43P00, TPO) with a resistive touch sensor, the electro-tactile display at the back of the LCD, and pressure sensors (FSR402, Interlink electronics) in between the two components (Figure 1). The four pressure sensors measure finger pressure, which is used to modulate electro-tactile stimulation (Figure 2). The electro-tactile display with 512 electrodes, each 2 mm in diameter and with 3 mm pitch, is made of flexible substrate and mounted on a deformable gel layer so that it deforms and fits into the palm. We also covered the electrodes with a hydrogel sheet to reduce the risk of any pain. Details of the electro-tactile display were given in our previous paper [13].

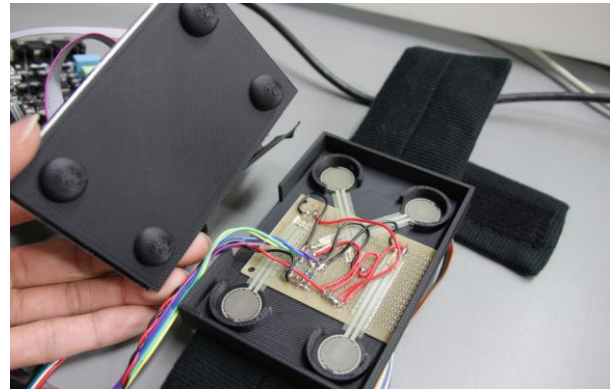


Figure 2: Four pressure sensors are embedded inside the case.

### System Structure

Figure 3 shows the system structure of the palm touch panel. A PC receives information from the touch sensor and pressure sensors and presents visual information to the LCD. It also sends a stimulation signal to the electro-tactile display unit via a serial interface, with the micro-processor (H8-3069, Renesas Electronics) controlling the electro-tactile stimuli.

The positions and intensities of the stimuli are sent to the microprocessor. According to this signal, a stimulating

pulse is generated by a D/A converter, and converted to a current pulse by a voltage current converter, driven by a high-voltage source (350 V). The electrical current of the stimulating pulse ranges from 0 to 10.0 mA, and can be controlled by the PC. The current pulse width is fixed to 50  $\mu$ s. The pulse is sent to a switching IC (HV507, Supertex), which selects a stimulation electrode and applies the current pulse to the palm. Although the switching IC selects only one electrode to stimulate the skin at a time, we can excite multi point tactile cues by time division control of the high speed microprocessor.

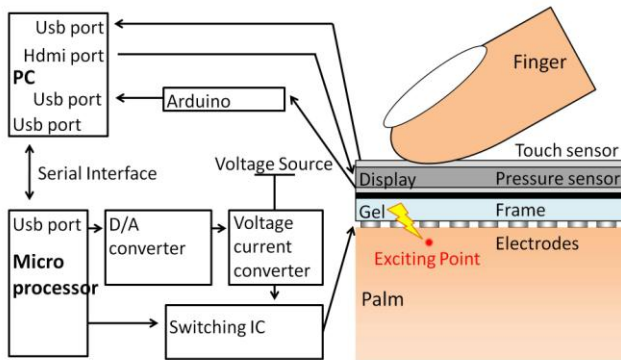


Figure 3: System structure of Palm Touch Panel

### ELECTRO-TACTILE STIMULUS DESIGN

To realize palm touch interaction, we need to design electro-tactile stimuli. In this section, we explain how to implement actual finger and palm interaction for our device through electrical stimuli patterns.

#### Reproducing the Palm Sensation of being Touched by a Finger

When one's palm is touched by a finger, the size of the palm tactile perception is altered by the pressing force of the finger. To implement this in the Palm Touch Panel, we vary the electro-tactile stimuli patterns according to the pressure sensor.

##### Experimental overview

The aim of this experiment is to obtain the relation between pressure and contact dimensions. We recruited 4 participants (2 female, 2 male) with ages ranging from 24 to 26 (mean 25). The participants pressed their fingers onto white paper on an electronic scale with the fingertips painted with red ink. The participants continued pressing their fingers onto the paper until the scale monitor of the electronic balance reached a certain pressure value. Then the participants released their fingers from the paper. In this way, we recorded the dimensions of the fingertips. Each participant repeated this procedure for 9 specific pressure values (0.33, 0.66, 1 ... 3N), and repeated the procedure 3 times for each specific pressure value. To obtain the dimensions, we scanned the papers, and measured them by image processing.

### Results

Figure 4 shows the relationship between contact pressure and contact dimensions. The changes in the finger contact dimensions can be approximated by a logarithm function. Ikeda et al. obtained similar results [14].

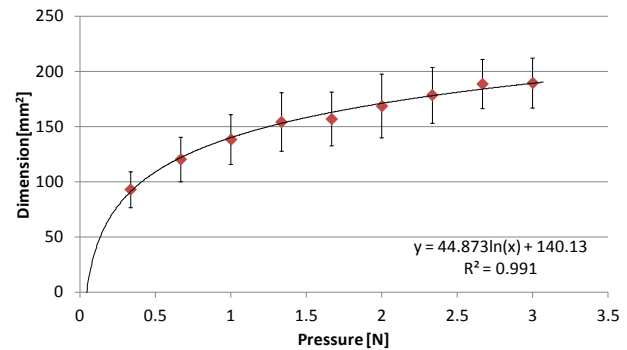


Figure 4: Relationship between contact pressure and contact dimensions

### Implementation

From the fitted curve given above, we designed electrode stimuli patterns as shown in Figure 6. Each electrode pattern has a corresponding pressure range.

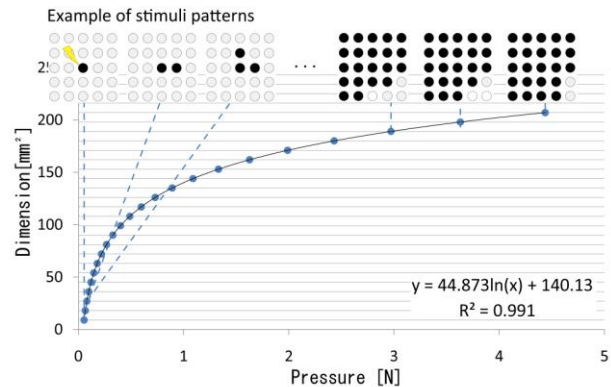


Figure 5: Relationship between contact pressure and stimuli patterns

### Reproducing the Sense of Pressing a Button on a Palm

If a light object such as a coin or button is placed on one's palm, a tactile sensation caused by the weight is felt. However, the tactile sensation is not obvious because of its light weight. If a force is applied to the object, the tactile sensation is unmistakable owing to the added force. We recreated this clarity change in the Palm Touch Panel.

### Implementation

We reproduced the contact sensation through density changes in the stimuli electrodes. Figure 6 shows an example of a contact sensation. Since the diameter of the button graphic is 9 mm, we used 9 electrodes underneath the graphic. Without finger contact, 4 electrodes stayed active (44% density). On the other hand, with a finger touching the graphic, all 9 electrodes became active (100% density).

We speculate that this density change causes the contact sensation on the palm.

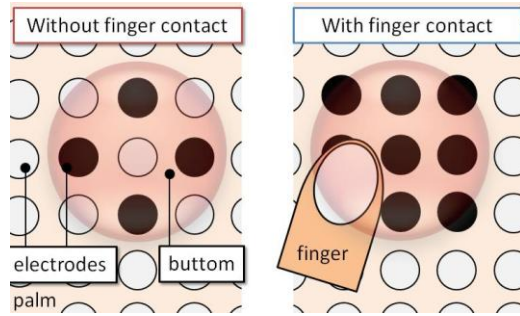


Figure 6: Method to reproduce palm tactile sensation when a finger touches the button.

## DISCUSSION AND FUTURE WORK

We evaluated our prototype device by means of an informal usability study with 5 colleagues. All participants commented that the feeling was as if they were touching their own palm. On the other hand, a shortcoming of the current implementation was revealed. The resistive touch sensor was not sensitive to subtle touch, and thus participants had to press the touch panel intentionally, rather than just touching the palm. Accordingly, we intend using a capacitive or infrared touch screen in the future.

As future work, we will first carry out a formal perceptual study to investigate how accurately this device can feed back tactile cues to the user, by letting the user trace the position and movement of a randomly presented tactile cue. Second, we will evaluate how realistic the finger pressure feedback and density changes algorithms proposed in this paper can present, by comparing to the actual touches. Furthermore, under the same conditions as the first experiment, we will verify whether the proposed algorithms in this paper improve precision and speed of the user's answer. Third, we will create the various multi touch and passive touch applications mentioned in the introduction.

## CONCLUSION

This paper reported the design and implementation of the Palm Touch Panel, an interface for interacting "on the palm" using a finger and a palm. In an informal user study, the participants confirmed that this implementation realized our concept of palm touch interaction. We believe that palm touch interaction opens many new possibilities for mobile touch screen interfaces.

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