Augmenting a Wearable Display with Skin Surface as an Expanded Input Area

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Abstract. Wearable devices such as the wristwatch-type smart watch, are becoming smaller and easier to implement. However, user interaction using wearable displays is limited owing to the small display area. On larger displays such as tablet computers, the user has more space to interact with the device and present various inputs. A wearable device has a small display area, which clearly decreases its ability to read finger gestures. We propose an augmented wearable display to expand the user input area over the skin. A user can employ finger gestures on the skin to control a wearable display. The prototype device has been implemented using techniques that sense skin deformation by measuring the distance between the skin and the wearable (wristwatch-type) device. With this sensing technique, we show three types of input functions, and create input via the skin around the wearable display and the device.

Keywords: Skin Deformation, Wearable Display, Photo reflectivity.

1 Introduction

Owing to the recent miniaturization and performance improvement of handheld mobile devices, both users and suppliers have begun to focus on the possibilities of wearable devices that are smaller and more capable than those available a generation ago. Recent research and development has produced multiple watch-type wearable devices, including models that run on the Android OS. These devices have basic functions such as a clock, and other applications related to smartphones. In fact, wearable devices with small displays are suitable for obvious tasks such as checking time, reading news, or sending and receiving short text messages. However, when users want to control devices using familiar touch-based manipulation, and those devices have a limited ability to accept input, the convenience of being wearable is not useful for many users. Finger gestures have become familiar and acceptable for general interaction with mobile devices, and are suitable for providing users intuitive manipulation. However, if the display area is substantially smaller, the benefits of

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touch interaction with the display decrease. Further, small displays are obscured by fingers, and thus, they provide less visual feedback to the user.

A touch interface is advantageous for users, because they can receive tactile feedback, and it is easy to understand what users are operating on the display. Touch screens and software interfaces designed for touch interaction are proposed and used in currently available products. Wearable products that were previously controlled through a button interface are now more commonly controlled through touch gestures, because of improvements in touchscreen interfaces. In contrast, wearable devices provide the user with the convenience of operating the device through gestures made by the other hand. A touch interface is one of the best methods to provide feedback to users for display-based manipulation.

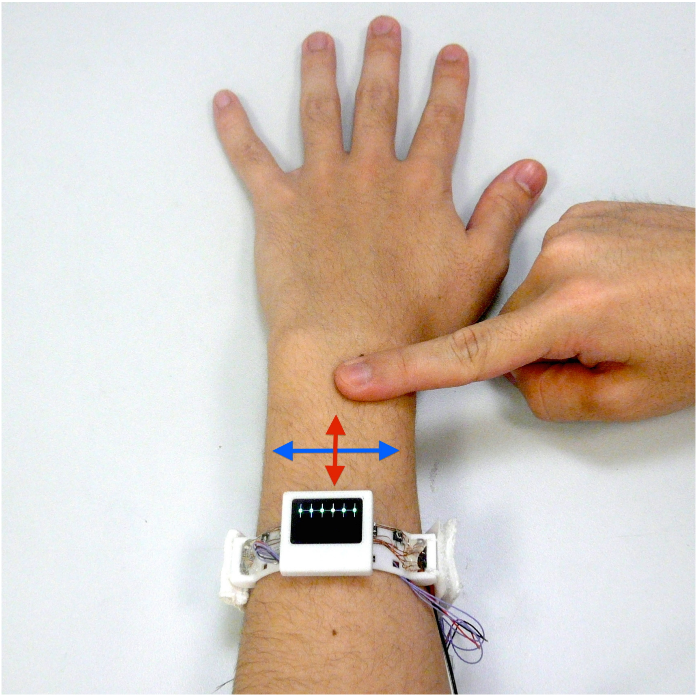

Fig. 1. Display and plastic arm band with six photo-reflective sensors. The display is placed at the center of the band and glued onto it. The opposite side of the band is made with a stretchable band to affix the band on the forearm. All wires are connected to a microcontroller. This device and sensor system accepts two-dimensional skin deformation input represented by the two lines in this picture. (The red and blue lines denote the vertical and horizontal deformation inputs, respectively.)

We propose and discuss the use of skin as a gesture surface for expanding the operational area for gesture interaction with display-based wearable devices. We designed skin deformation sensing techniques for manipulating wearable devices with a display. An infrared reflective sensor installed behind the watch band recognizes skin deformation by sensing the distance between the skin and the sensors. The distance changes according to the direction and force of push applied on the skin. Because of the skin's structure and softness, the skin is pushed out from the pressed area. Using the sensor array present under the device, the system recognizes the point where the user pushed and the direction in which the finger is moved. By expanding the gesture interaction area, the user can control devices without feeling discomfort from the finger occlusion over the display.

2 Related Works

2.1 Interface and Interaction Using Infrared Reflection

There are many related works describing techniques that leverage photo reflection for measuring material condition. The most familiar example is a technique used for testing water quality by measuring the transparency of visible or invisible rays. Another example would be detecting a small movable component inside peripheral equipment such as an optical disk drive tray. [11] applied this sensor technique for an interactive system that detects the touching and pushing of a soft object by reading the transparency change of a photo-reflective sensor. [12] describes another technique to accept user input via elastic fabrics as a soft interface. This is accomplished by placing a photo-reflective sensor to measure the density of the fabric that changes based on the level of stretch.

To the best of our knowledge, the first case for adopting infrared sensing to an embodied interface is iRing [9], which utilizes four photo-reflective sensor arrays inside the ring device to detect the push and rotation input applied to the ring. This was achieved by estimating ring rotation with an absolute angle by analyzing reflectivity based on melanin content, which is distributed on the surface of fingers.

Makino et al. [5] proposed a method to detect the one-dimensional tangential force applied to the skin without covering the skin with any sensors. They employed a distance sensor that uses infrared reflection to measure the distance between the skin and sensor that changes when the skin is deformed. This is a novel method to measure the applied force between the skin and the sensor compared to previous ideas such as using the silicon finger model with a force sensor to measure the force between the skin and the sensor, and the skin model. Recently, Ogata et al. [8] improved this method to two-dimensions by placing sensor arrays around the area to be used for touch interaction. We adopted this method to detect and receive user input via skin deformation.

2.2 Manipulating System on the Body

In addition to familiar screen-based display interaction, the body surface can also be utilized to project input impulses, and can therefore be used as an input surface. Skinput [3] is used to turn the body, particularly the arm, into a touch input surface that allows the user to input commands by tapping the arm. Sensing is performed using acoustic sensors that detect the tapping point by analyzing the sound transmitted by the body. They also performed a demonstration where the user taps the projected command on the arm and selects an expected function.

For implanted user interfaces [4], researchers are investigating the interactive capability of implanting a controller under the skin. They device was surgically implanted into a specimen arm. OmniTouch [2] provides a method to turn any surface into a touchable interface by combining projection and depth sensors. They demonstrated a hand-based interface; therefore, their idea can be used for on-body interaction such as using the arm as an interface and manipulating it using the other hand. AugmentedForarm [7] has the same motivation for extending the display of wearable devices; however, its implementation is different. They explored enhancing the forearm with wearable displays without affecting the human motor system. They showed several applications and situations by describing the augmented displays as private and public property.

2.3 Wristwatch Type Interfaces

In addition, there are many types of wearable devices and various sensing or input methods for these devices. GestureWrist [10] reads user gestures by using capacitive sensing via an electrode implanted behind the arm band. Fukui et al. [1] developed an arm band-like sensor array and recognition system to detect the depth information on the wrist to estimate hand gestures. Makino et al. [6] had the same motivation to expand the wearable device's input area onto the back of the user's hand. They used an infrared distance sensor array to detect the finger that touches the palm. However, their methods and interactions are different from our approach, because their technique detects finger position, whereas our approach recognizes skin deformation and skin input.

3 Designing the Augmented Wearable Display

Wearable displays tend to be smaller than handheld mobile devices, owing to the importance of weight and compact appearance. However, the user will want to manipulate the wearable display, and not simply view it to obtain information from the device. We propose a solution that will employ the skin surface for user input, in conjunction with the device's display screen. The proposed solution monitors the skin in the area that surrounds the wearable display. This solves the problem of finger occlusion under the wearable display by adopting the skin deformation sensing technique. The overall idea is to augment the wearable display by turning the skin around the display into a gesture surface.

Skin is a soft material, and the deformation of skin could not be measured using previously available sensors. In addition, there are potential ethical problems and general user resistance when implanting sensors for receiving device input, especially if a better solution that uses wearable items is available. Therefore, we designed a new method to measure touch interaction in a non-invasive manner. For example, the method to stick a sensor pad on the skin, such as a strain gauge, can obtain reliable signals from the sensor, but if the sensor is difficult to remove, it is unsuitable for wearable use. In this paper, we adopted a sensor that is attached to the human body but can be easily removed. The infrared distance sensor proved to be effective in measuring skin deformation.

The original technology to detect skin deformation was proposed in previous works [5, 8]. In this paper, we focus on designing the augmented display by leveraging the skin deformation sensing technique. The combination of a wearable display and skin deformation input provides an intuitive and enhanced interaction for the user.

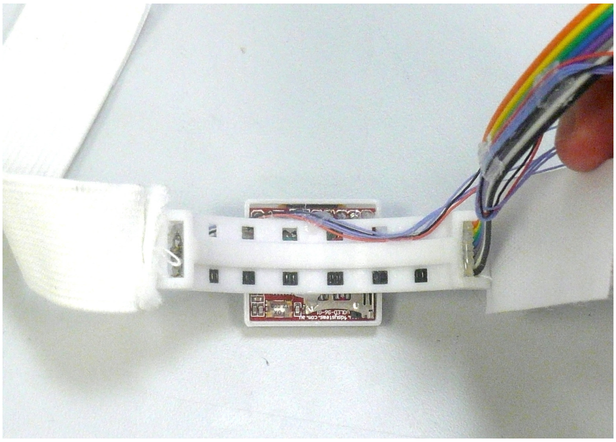

Fig. 2. Back side of the arm band and the six photo-reflective sensors that are installed. The display and six sensors are connected to a microcontroller so that the microcontroller functions as an A/D converter and samples the analog voltage value of six sensors to a digital value. The plastic arm band has a ridge on the center that measures the distance between the sensor and the skin even when skin deformation has not occurred.

3.1 Device Design

The proposed device consists of a small OLED 0.96-inch display, a plastic arm band constructed using a 3D printer, and six infrared reflective sensors, which are positioned to face the skin surface. By placing the display on the arm band, the display can show the results and operations interactively. Figures 1 and 2 shows the device and sensor components.

3.2 Measurement

For measuring the distance between the sensor and the skin, we selected an infrared reflective sensor. A reflective sensor is the combination of an infrared LED that emits infrared rays on the object, and a photo diode that measures the reflected rays from the object. This sensor detects the precise distance changes within 0.1 mm without touching the target, if the power of the LED and the sensitivity of the photo diode are adjusted properly. Figure * shows the circuit of the sensor that is connected to the A/D converter. The A/D converter reads analog voltages and converts them into a digital 10-bit signal before sending it to the computer. We used 75 Ω and 30 kΩ resistors for adjusting LED emission and photo diode sensitivity, respectively.

When users moves their finger on the skin near the device, the sensors under the device read the changes in skin distance. Distance changes are caused by touching the skin, because skin is a soft and elastic material. Thus, the sensors and system recognizes skin deformation, even if it is not near the sensor array. In addition, the sensor array has a two-dimensional resolution. The vertical force can be determined by comparing the skin to its non-touched status, and the horizontal force can be determined by comparing the right and left sensor values. This description is illustrated in Figure *. We treated the two-dimensional input as the relative value from the sensor value of the non-touched state.

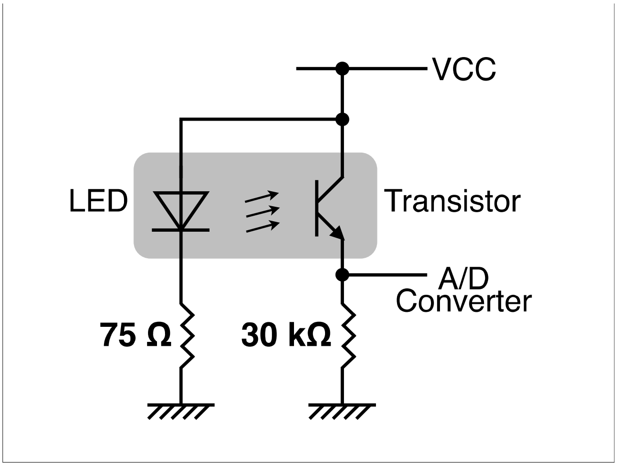

Fig. 3. Circuit and configuration of experiment apparatus. We used 95 Ω and 76 kΩ resistors on the LED side and the photo diode side, respectively, to accurately control the infrared rays.

3.3 Skin Deforming Input

We designed an input method for a wearable display device. There are three types of skin deforming inputs described below. Each input is distinguished using the support vector machine. Sensor values from six photo-reflective sensors show different signal patterns for each input type. We tested using vertical and horizontal flip and pinching gestures. Each sensor value from the skin input is visualized on the display on the armband. If a command is recognized, the display shows an arrow that identifies the command executed by the finger gesture on the skin.

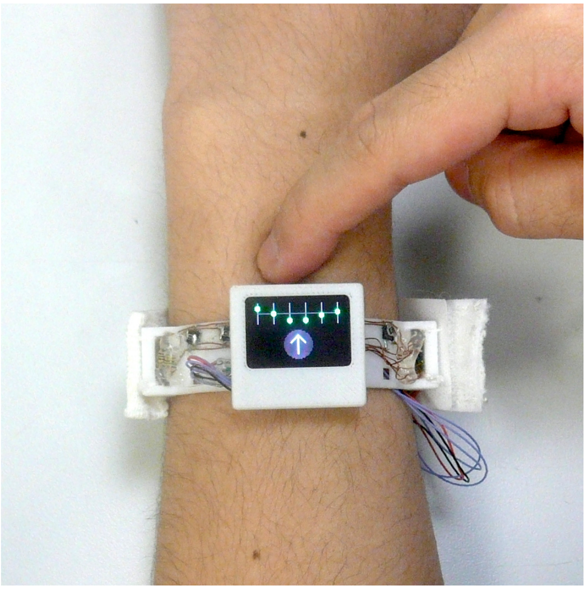

Fig. 4. Finger pushes the skin in the vertical direction

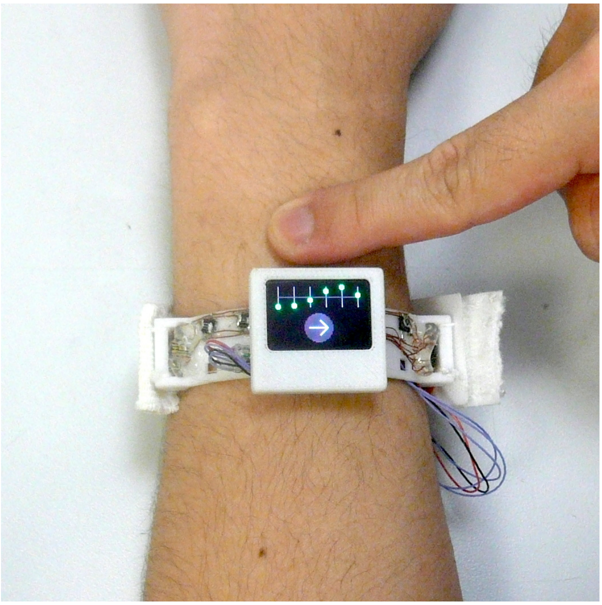

Fig. 5. Finger pushes the skin in the horizontal direction

Figure 4 shows vertical pushing. Several sensors under the center part of the arm band react to the deformation. Six sensors allow the user to select various choices from the display, because the sensors recognize finger position and action if the finger is on an area covered by the six sensor array. Figure 5 shows horizontal pushing. Each side of the sensors that is separated at the center part of arm band shows a different reaction. In this case, the finger moves the skin to the left, and therefore, the values of the three left sensors increase, and the values of the three right sensors decrease. Figure 6 shows a pinching gesture. This function requires several sensor values to be recognized when the gesture is executed in the center of the arm band. This gesture increases the center sensor value and decreases the value of other sensors. Thus, this gesture is distinguished from vertical pushing.

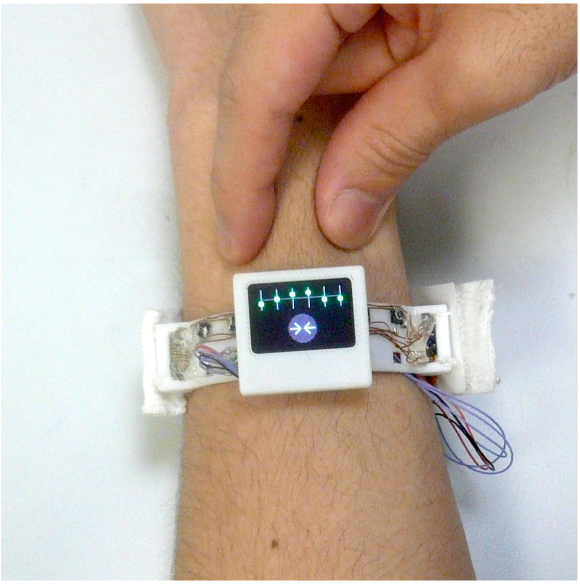

Fig. 6. Fingers pinch the skin at the center position

4 Conclusion

We proposed the expansion and augmentation of wearable displays by using sensing techniques for measuring skin deformation. A prototype of a wearable display device with a six-sensor array recognized three types of input methods on the skin. The sensor and system distinguished each of these three inputs and displayed the command by providing visual feedback. We have demonstrated the concept of connecting a wearable display and its input method by using skin deformation, which enables the user to manipulate the device by finger gestures on their skin.

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References

1. Fukui, R., Watanabe, M., Gyota, T., Shimosaka, M., Sato, T.: Hand shape classification with a wrist contour sensor: development of a prototype device. In: Proc. UbiComp 2011, pp. 311–314 (2011)
2. Harrison, C., Benko, H., Wilson, A.D.: OmniTouch: wearable multitouch interaction everywhere. In: Proceedings of the 24th Annual ACM Symposium on User Interface Software and Technology, pp. 441–450. ACM (2011)
3. Harrison, C., Tan, D., Morris, D.: Skinput: appropriating the body as an input surface. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 453–462. ACM (2010)
4. Holz, C., Grossman, T., Fitzmaurice, G., Agur, A.: Implanted user interfaces. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 503–512. ACM (2012)
5. Makino, Y., Sugiura, Y., Ogata, M., Inami, M.: Tangential force sensing system on forearm. In: Proceedings of the 4th Augmented Human International Conference, pp. 29–34. ACM (2013)
6. Nakatsuma, K., Shinoda, H., Makino, Y., Sato, K., Maeno, T.: Touch interface on back of the hand. In: ACM SIGGRAPH 2011 Emerging Technologies, p. 19. ACM (2011)
7. Olberding, S., Yeo, K.P., Nanayakkara, S., Steimle, J.: AugmentedForearm: exploring the design space of a display-enhanced forearm. In: Proceedings of the 4th Augmented Human International Conference, pp. 9–12. ACM (2013)
8. Ogata, M., Sugiura, Y., Makino, Y., Inami, M., Imai, M.: SenSkin: adapting skin as a soft interface. In: Proceedings of the 26th Annual ACM Symposium on User Interface Software and Technology, pp. 539–544. ACM (2013)
9. Ogata, M., Sugiura, Y., Osawa, H., Imai, M.: iRing: intelligent ring using infrared reflection. In: Proceedings of the 25th Annual ACM symposium on User Interface Software and Technology, pp. 131–136. ACM (2012)
10. Rekimoto, J.: Gesturewrist and gesturepad: Unobtrusive wearable interaction devices. In: Proceedings of the Fifth International Symposium on Wearable Computers 2001, pp. 21–27. IEEE (2001)
11. Sugiura, Y., Kakehi, G., Withana, A., Lee, C., Sakamoto, D., Sugimoto, M., Inami, M., Igarashi, T.: Detecting shape deformation of soft objects using directional photoreflectivity measurement. In: Proceedings of the 24th Annual ACM Symposium on User Interface Software and Technology, pp. 509–516. ACM (2011)
12. Sugiura, Y., Inami, M., Igarashi, T.: A thin stretchable interface for tangential force measurement. In: Proceedings of the 25th Annual ACM Symposium on User Interface Software and Technology, pp. 529–536. ACM (2012)