ExtensionSticker: A Proposal for a Striped Pattern Sticker to Extend Touch Interfaces and its Assessment

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ABSTRACT
In this paper, we propose a striped pattern sticker called ExtensionSticker that allows a touch input to be transferred from an external source by simply attaching the sticker to a touch panel. This allows the user to input touches or continuous scrolling actions by touching a sticker printed with stripes of conductive ink, without directly touching the touch panel. This method could be applied to the sides or back of a touch panel, or even the surface upon which a device is located as a touch interface, allowing us to freely construct interfaces in shapes matching the demands of the user. This paper also reports the results of evaluation experiments conducted to assess the recognition accuracy of scroll and tap actions using the proposed method.

Author Keywords
Striped pattern sticker; continuous touch input; conductive ink; capacitive touch panel.

ACM Classification Keywords
H.5.2. Information Interfaces and Presentation : User Interfaces Input Devices and Strategies.

INTRODUCTION
In recent years, devices equipped with touch panels, such as smartphones and tablets, have spread widely. These devices allow users to have more direct control over the devices themselves by allowing them to touch the screen with a finger or a touch pen. In addition, since these devices allow for creating interfaces with input buttons in arbitrary positions on the display, it is possible to adapt interfaces for use in different applications. Many studies are already being performed in relation to touch interfaces, such as methods for extending input interfaces and tangible interfaces to be used with touch panel terminals like smartphones outside the display [5, 3, 10]. However, the interfaces used in these studies require specialized objects and are for use in specific applications. An environment that allows a user to create an interface for himself has not yet been realized. Thus, it is impossible to extend an interface over a more accomplished application's interface.

Today, conductive inks are gaining attention as a method that can be used in prototyping [9]. Conductive inks are inks that have electrically conductive properties. By using this type of ink in a ballpoint pen or a home inkjet printer, we can easily create electrical circuits on paper.

In this paper, we propose the ExtensionSticker, a sticker that allows us to extend touch interfaces by simply attaching it to a capacitive touch panel (Figure 1). Using conductive ink to print a striped pattern and attaching it to a portion of a touch panel, we can transfer a touch input from the sticker to the touch panel. This allows us to use the sides and backs of a smartphone, as well as desktop surfaces, walls, and any other surface as a touch interface. This method is not limited to receiving a touch input at a specific position, but it can also receive continuous inputs such as scroll commands within the area of the attached sticker. Since the ExtensionSticker can be easily created with home-use inkjet printers, users can freely extend touch devices by creating the interfaces they need.

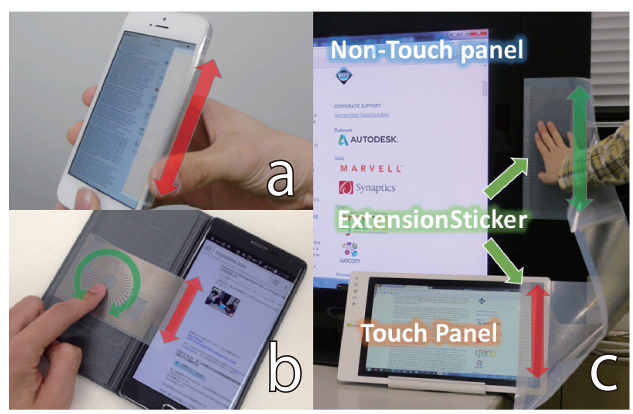

Figure 1. a) Smartphone side-input controls, b) rotation-scrolling control conversion, and c) touch controls for non-touch-panel displays.

RELATED WORK
Approaches to interfaces using capacitive touch panels include Rekimoto's SmartSkin [1]. Smartphones and tablets are also among the many interface studies that use capacitive touch panels [3, 7, 10]. Our proposed method can generate continuous touch inputs due to scrolling operations, for example, without moving interfaces that are arrayed with the conductive parts directly.

CHI 2015, April 18 - 23 2015, Seoul, Republic of Korea

http://dx.doi.org/10.1145/2702123.2702500

Studies employ a variety of approaches for extending smartphone input methods. With Clip-on Gadgets, clips with buttons or dials can be attached to the device and used as input interfaces [5]. In this system, a piece of conductive rubber is positioned on the clips attached to the device, making contact with the edge of the device's screen. When the user performs an action such as pressing a button, a touch input is recognized using changes in capacitance. It can also generate a continuous touch input by an outside attachment to the device. As compared with this study, our proposed method allows a user to create a variety of interfaces easily using an inkjet printer.

Midas proposes an environment that allows the user to create touch interfaces for applications that can be controlled by those interfaces [8]. The method for making touch interfaces using conductive ink is also proposed by [4, 6]. In this study, we propose a method for extending touch interfaces without any software interposition.

EXTENSIONSTICKER

Our method uses a sticker with a striped pattern printed using conductive ink and attached to a touch panel (Figure 2). The ExtensionSticker comprises three portions: the input portion, which the user touches directly; the output portion, which is attached to the area that generates touch events; and the connecting portion, which connects the other two portions. The user can transfer a touch input to the portion attached to the sticker (output portion) by touching part of the sticker (input portion). Multiple thin lines less than 1 mm thick each are tightly grouped. When a portion of these lines is touched with a finger simultaneously, it generates a change in capacitance sufficient for touch recognition.

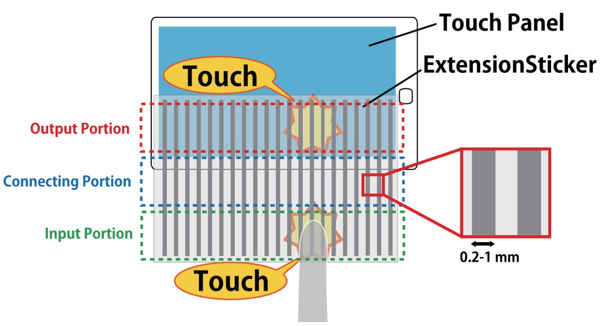

Figure 2. A Striped Pattern Printed Using a Conductive Ink.

The ExtensionSticker can be applied not only for receiving touch inputs at specific locations, but also at points that allow for continuous inputs, such as scroll operations. Then, the quality of the touch input can be controlled, so to obtain "finer accuracy through stripe pattern thickness or spacing", as the input to a capacitive touch panel is determined by the input position in the contact region.

Thus, when the finger is tilted while held down, the contact surface shifts and the touch input changes subtly. Figure 3 shows how this is being done, comparing the amount of movement on the x-axis as the finger moved left and right on the touch panel and sticker, so to generate a touch input.

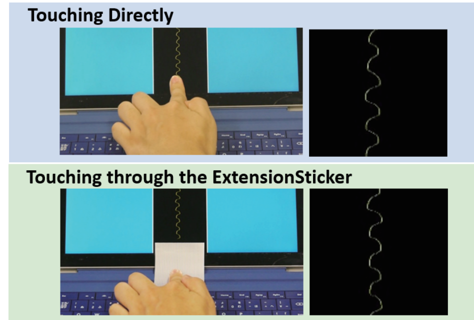

Figure 3. An example of tilting with a finger held down.

APPLICATIONS

Changing the form of the touch input area of the ExtensionSticker allows a user to create a variety of touch interfaces. Here, we describe three extension possibilities: touch input position extension, input operation extension, and input method extension. Figure 4 shows an overview of each method.

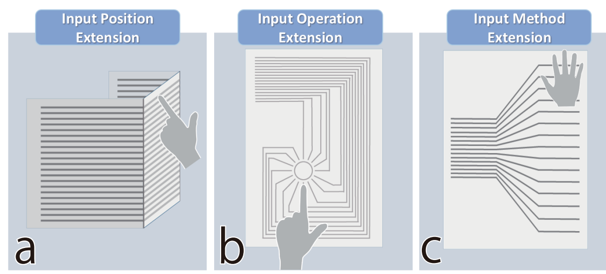

Figure 4. Extension methods for the input interface: a) input position extension, b) input operation extension, c) input method extension.

First, we attach the output portion of a sticker to a touch panel and then curve the sticker such that the input portion is on a side surface of the device (Figure 1 a). This allows us to use the side (or back) of a smartphone as a touch interface. Users can scroll through content on a web browser without blocking the screen with a finger. This method is also effective for a variety of other devices. For example, this could be applied to devices with small displays, such as smart watches, so to extend the input interface to the band portion.

Second, by changing the position of the input portion and connection portion of the printed sticker, we can extend the user's input operations (Figure 1 b). For example, as in the figure, the input area can be placed in a circular shape at a constant interval, and then connected to the output portion. As the user performs a circular operation by tracing the input portion with a finger, continuous up and down touch inputs can be generated.

Finally, by changing the printed spacing of the input portion and output portion of the sticker, we can extend the touch input method (Figure 1 c). Even if the conductors positioned on the input portion are separated, they can be combined into a single touch input on the output portion, meaning that if the user touches the necessary lines simultaneously, this action can generate a touch event. We can use this to transform a touch operation performed with the palm of the user's hand into a fingertip touch operation. For example, we can display the smartphone screen on a large display and connect the two displays with a sticker to transform large horizontal touches on the display to simulated scrolling. In the figure, an input is transferred from a sticker attached to a large non-touch panel display to a tablet device.

EVALUATION

It is necessary to ensure that each conductive line is thin enough to not generate a touch input through touching a stand-alone line, and the spacing between every two lines is tight enough to generate a touch input through touching multiple lines. So, we conducted an experiment to evaluate recognition accuracy of tap and scroll operations using the ExtensionSticker.

The experiment involved 10 participants, all of them were university undergraduate and graduate students with an experience in using smartphones. Assuming the size of a human finger, we attached the portion of a sticker that is 10.0 mm thick to the touch panel as the output portion. The experiment was conducted for stickers with striped patterns having different combinations of line thickness (0.2, 0.4, 0.6, 0.8, and 1.0 mm) and line spacing (0.5, 1.0, 1.5, and 2.0 mm). We limit the line thickness to 0.2 mm, because of the risk of disconnection when lines of conductive ink are printed with thickness of less than 0.1 mm; we limit the line length to 60.0 mm. The ExtensionStickers were printed on PET transparencies using silver nanoparticle ink (Mitsubishi Paper Mill, part number NBSIJ-MU01), and were attached to the display using a 10.0 mm wide double-sided tape.

In the tap operations, the participants tapped on specific locations on each sticker. Recognition mistakes are recognized as errors, and the recognition rate was recorded. Each participant performed the tap operations 20 times for each sticker. In all the experiments, line thickness and spacing patterns were given in random order (Figure 5 left).

In the scroll operations, a bar that moves at a constant speed from the left edge to the right edge of the display was demonstrated. The participants performed scroll operations on the sticker using the bar's location as a guide. Interruptions in a touch input task when the moving bar was between the start and end positions were recognized as errors, and the recognition rate was recorded. Scroll operations were performed 10 times for each sticker (Figure 5 right). Each experiment was performed using MS SurfacePro 3.

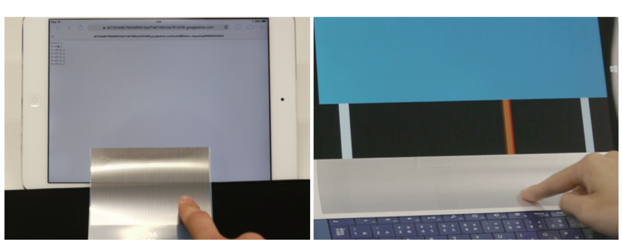

Figure 5. Experiments: tap operation experiment (left), scroll operation experiment (right).

Results

The results of the experiments are shown in Figure 6 (top). In the tap operations, the 0.5 mm spacing achieved over 97% accuracy for line thicknesses of 0.2, 0.6, and 1.0 mm. 1.0 mm line spacing also achieved recognition with accuracy above 90% for line thicknesses 0.4 and 0.6 mm, with significant variance in the results.

In the scroll operations, recognition was high for the 0.5 mm spacing (95%) and 1.0 mm spacing (90%) regardless of line thickness. Of these, all striped patterns with line thickness of 0.4-1.0 mm achieved high recognition accuracy of close to 99%.

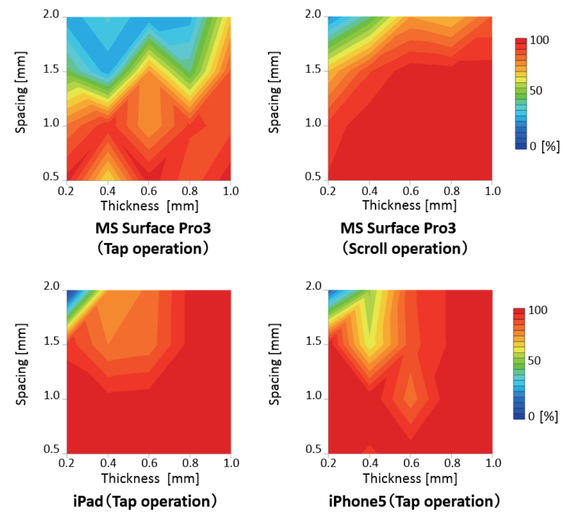

Figure 6. Results: tap operation experiment using MS SurfacePro 3 (upper left), scroll operation experiment using MS SurfacePro 3 (upper right), tap operation experiment using iPad mini & iPhone (bottom).

Discussion

In the tap operation experiment, our results show that the recognition accuracy dropped as the spacing grew wider for each device. Even of the combinations of spacing and thickness that resulted in high recognition in the scroll operation experiment, some patterns resulted in lower accuracy in the tap operation experiment, leading to wide variation in results. Since touching multiple thin lines generates a single touch input, we can assume that there is variation in touch recognition accuracy due to changes in the areas of the contact region caused by the finger of different finger sizes and at different tap locations.

When a touch input is performed on a capacitance touch panel through a conducting material such as a metallic foil, if the contacting surface is approximately the size of the finger, this may be recognized as a touch. However, as the contact surface becomes wider, the touch position is not constrained to a single point and therefore cannot be controlled. In the ExtensionSticker, we allowed the control of the touch position on the x-axis (the vertical direction of the striped pattern) by positioning the conducting material in a striped formation. However, we cannot currently control the y-axis of the striped pattern (the horizontal direction of the striped pattern), so the input position on the y-axis can change based on the width of the portion where the sticker is attached.

We then performed comparison of a scrolling operation using a sticker of 0.6 mm line thickness and 0.5mm spacing, which had the highest recognition rate, and performing it by touching the touch panel directly. The results show that the average movement on the y-axis per frame for the sticker was 0.35 px (approximately 0.04 mm), and the average of the largest deviations was 2.25 px (approximately 0.27 mm). When performing a scroll operation through touching the touch panel directly, the average movement on the y-axis per frame was 0.43 px (approximately 0.05 mm), and the average of the largest deviations was 3.11 px (approximately 0.37 mm). Little difference was observed between the two. This shows that by setting the width of the portion for attaching the sticker to 10.0 mm, we can perform scroll operations with operation accuracy similar to that of the performance when directly touching the touch panel. We also performed the scroll experiment with the same tasks for the settings of 0.4, 0.6, and 0.8 mm, but in these cases, the deviation width was approximately 1.0 mm. However, when the width of the attached portion was 0.4 mm, the recognition accuracy dropped, so the width between 0.6 and 1.0 mm is considered suitable.

Generalization

In addition, we conducted the same evaluation experiment for the tap operations with five participants using iPad and iPhone (Figure 6 bottom). The results show that each device's recognition accuracy dropped as the spacing grew wider and thickness grew thinner. As the following results show, the proposed method also allows the user to operate other devices in high recognition accuracy.

We tested the scroll operations on the ExtensionSticker attached to a variety of touch devices (iPad1 &2 &mini, iPhone5, Samsung Galaxy note edge & Gear Fit, ASUS Nexus7, Sony VAIO Pro11 &Type T, MS Surface1 &3) using some high recognition accuracy parameters. We attached the ExtensionSticker with the spacing of 0.5 and 1.0 mm, and thickness of 0.2-1.0 mm. While for all the parameters, ExtensionSticker allow us to control scrolling operations on all these devices, recognition accuracy occasionally dropped for certain thickness and spacing combinations. Thus, it is necessary to set the right condition parameters for each device. In this study, a successful touch input occurs on the ExtensionSticker even if there is a distance of several dozen centimeters between the input and the ExtensionSticker's output. However, the touch input is not transferred properly if the distance is longer. Furthermore, a touch input can occur unintentionally in the wiring area. This problem could be resolved by covering the exposed area with a relatively thick insulating material.

CONCLUSION

We gave a demonstration of the proposed application at UIST 2014, and in this study, we also presented results of recognition accuracy assessment in scrolling and tapping operations using a sticker. While we showed a number of application examples, this method can also be applied to a variety of other devices with capacitive touch panels [2].

This method could be used to freely create interactions for a variety of devices in our daily lives based on our needs. The ExtensionSticker reported in this paper used silver nanoparticle ink as the conductive ink for printing the striped pattern. This made it difficult to see the portion of the display attached with the striped pattern. However, this problem could be solved using transparent conductive inks. Furthermore, the printed surface degraded during use, necessitating the need for finding more suitable materials. Currently, this method only allows control of the touch input in one direction. Future improvements also include investigating how to control the touch input at arbitrary locations in an x-y plane.

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