Extending Cpacitive Sensing Ability of Touch Panel with ITO Sticker

*Abstract*—In this paper, we proposed a striped-based conductive sticker that is able to extend the capacitive sensing ability of various touch panels. By simply attaching our sticker to a touch panel, users are able to conduct many touch-based interactions such as scrolling, sliding and pressing on sides or back of smart devices. Technically, compared with previous work, our main achievement is that we design a method that could distinguish the inputs of touch-out from touch-on by measuring the difference of capacitive features of these two kinds of inputs, allowing touch devices to respond differently based on both the location and pattern of touch input source. To step further, this paper explored the possibility of recognizing arbitrary touch points on surface of our conductive sticker by analyzing the difference caused by different capacitive signals. Three applications were built on smartphones to demonstrate our method, and the experimental results indicated that our method was robust enough and had great potential to support various interaction patterns.

Keywords—extended capacitive sensing, 2D touch-out arbitrary location detection, interaction pattern

# Introduction

Capacitive-sensing-based smart devices such as smartphones, tablets and laptops is spreading widely, which offer a natural way of finger-touch interaction between human and computer. Recent years, some studies related to extending touch interfaces has been conducted, such as extending interaction area of touch panel terminals with specialized tangible interface outside the display [1,2,3]. While these interfaces were designed for special devices or applications and could not be generalized. After that, numerous conductive materials began to gain an increasing attention, which is frequently used in prototyping. As one of the representative among these materials, Indium Tin Oxide (ITO), which is also the most frequently used material in capacitive screens, stands out with its excellent conductivity and transparency. By using ITO-based conductive ink, individuals are able to design and print their own circuits on paper, which also release more space of creativity for interaction pattern design of capacitive panels.

Some research has been performed in extending the capacitive sensing ability of touch panel, such as ExtensionSticker [4], which is also a striped pattern sticker, enabling numbers of ordinary interaction outside the capacitive touch panel. While the major limitation of these work is that touch panel itself won’t be able to differentiate between outside and onside inputs, which sometimes can cause confusion. In this paper, we first successfully grabbed the capacity data of a smartphone’s screen. Then we proposed an algorithm that could distinguish the touch-out signal from normal touch signal. Based on that, we designed a striped pattern sticker that utilize this fundamental algorithm to locate arbitrary points outside the screen. Then we built several applications that deployed different interaction patterns like out-sliding, out-clicking and out-pressing to demonstrate the feasibility and usability of our designed pattern and algorithm.

# Related Work

The earliest work of using capacitive sensing in building input interfaces is Rekimoto’s SmartSkin [5]. It proposed a new sensor architecture for making interactive surfaces that are sensitive to human hand and finger gestures. In its architecture, sensor is able to recognize hand positions and calculate the distance between human hand and surface by analyzing the change of capacitance. In Steimle’s work, it proposed a versatile sensing technique called PrintSense[6], which is able to support multimodal flexible surface interaction based on capacitive sensing. PrintSense supports touch and proximity input and is capable of capturing different levels of pressure and flexing, offering more freedom for interaction. Moreover, with the help of conductive inkjet printing, it’s super simple for user to prototype and create their personalized input interfaces, including curved and deformable ones. To offer more freedom for individualized interaction design, Midas came out[7], which is a software and hardware toolkit which supports the design, fabrication, and programming of flexible capacitive touch sensors for interactive objects. Not limited to touch screen domain, Gong applied conductive ink to creating conductive image as input interface for audio controller [8]. In their proposed demo, they printed various conductive shapes such as circular slider, round button and touch-sensitive stripes to manipulate physical electric ukulele signals. A recent relevant work explored by Kato aims at recognizing user’s both discrete and continuous input in capacitance-sensitive devices from external input. They proposed a striped-based conductive sticker that allows transfer from external input source to touch panel. In this study, instead of building our own sensors and capacitive devices, we not only achieved the extension of touch panel’s sensing ability but also proposed an algorithm that is able to help distinguish external input from internal one. With our proposed method, we are able to maintain the existing capacitance-based interaction pattern while building personalized input interface for diverse touch sensitive devices like smartphone or tablet.

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# Touch-out Detection Method

In order to demonstrate our method, we first hacked a smartphone to grab the capacitance data from the touch screen. Then we attached a striped pattern conductive sticker as an input interface to the smartphone’s screen. Theoretically, by analyzing the difference of capacitance between touch-on-screen input and touch-out-screen input, we are able to recognize various external input pattern with no disturbance of existing interactions such as touch, click, slide, zoom in and zoom out.

## Threshold-based Differentiation

When hacking the smartphone’s screen, we found that the whole screen is interpreted as a matrix with a size of . Every element or pixels in the matrix holds a value of capacitance. Also through observation, we found that the value of capacitance signal of our hacked smartphone’s screen is between 0 and 2000. The capacitive value of a normal finger touch on screen will generally be in the range of 1600 to 2000. While an external touch on our sticker will generate a value roughly between 200 to 1400. So we here define three thresholds: . For value below , we recognize it as noise or no touch input; for value between and , we believe there comes a touch-out event; for value between and , we think it’s caused by the edge effect of a touch-on input, so it’s ignored; for value above , we interpret it as a normal finger touch input.

## Touch Position Refinement

From the first step of our threshold-based algorithm, while there always exist much noise that barrier us from figuring out the exact touch position. So our second step is noise reduction. Through our experiment, we found besides edge effect generated by normal touch-on input, there are still some elements whose value are below , consequently recognized as touch-out point. Fortunately, those points are always near to touch-on points, so we search every touch-on point whose value is above and examine whether there is any point whose value is between and , we then interpret these detected points as noise instead of touch-out signal. To further narrow the touch area, we only pick inner points that are not on the edge of each touch area as touch points. After these two steps, normally only two or three pixels remain for touch-out input of single finger, and three to four pixels remain for internal single finger touch input. Finally, we find the pixel with maximum value in every touch area, which is consisted of several adjacent pixels. So every touch area will be mapped to one element in the capacitance matrix.

Our method is quite robust during the test with finger touch, and could completely solve the problem generated by fat fingers. One limitation of our method is that it only supports finger touch interaction currently. When using touch pen, it encounter some problem to correctly recognize on-screen touch, because the capacitance value are partly or all below the threshold for internal touch.

# Application

In this section, we will introduce some applications we built based on our touch-out detection method. For each demo application, we are trying to prove the possibility of applying both touch-out and touch-on interaction on capacitance-sensitive devices.

## Touch-out Event Detection

First, we designed a striped ITO conductive sticker and cover it on the surface of the smartphone’s screen, as shown in Figure x. Our sticker contains 28 ITO-printed lines on each side. By delicately attach it to the screen, only a single column of the screen will be covered by ITO, remaining most part of its original touch sensing ability. While by sacrificing just a little portion of screen area which is not frequently reached by current common touch interactions, we offer a great amount of potential to extend the sensing area and create much more freedom for designing new interactions.

Then we defined two basic interactions: slide and click. As shown in Figure x+1, our event-detection method is able to recognize both click and slide event simultaneously.

## Hand Gesture Recognition

## Low-cost Interactive Toy

## VR-based Game

# Experiment and Evaluation

##### Acknowledgment

##### References