3D Printed Physical Interfaces that can Extend Touch Devices

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ABSTRACT
We propose a method to create a physical interface that allows touch input to be transferred from an external surface attached to a touch panel. Our technique prints a grid having multiple conductive points using an FDM-based 3D printer. When the user touches the conductive points, touch input is generated. This allows the user to control the touch input at arbitrary locations on an XY plane. By arranging the structure of the conductive wiring inside a physical object, a variety of interfaces can be realized.

Author Keywords
Physical interface; 3D printer; Capacitive touch panel.

ACM Classification Keywords
H.5.2. Information Interfaces and Presentation (e.g. HCI): User Interfaces Input Devices and Strategies.

INTRODUCTION
In recent years, the variety of devices with a capacitive touch panel, such as smartphones and tablets, has increased significantly. These devices allow users to perform more instinctive operations by touching the display with their finger. Previous studies have employed a variety of approaches relation to the touch interfaces, such as a tangible user interface using on the touch panel [1, 3] and a method for extend touch interface with physical devices [2, 5]. A method to realize these interfaces using on a capacitive touch panel with conductive materials, is one of the popular methodology. The user also fabricates a prototype interface using this method very easy and low-cost. However, the most of the interfaces using this method can generate touch inputs at specific locations contiguous with conductive surface.

In this study, we propose a touch extension physical interface that can generate touch input at an arbitrary location on a surface. Our technique generates touch input by activating a grid-layout of multiple conductive points (Figure 1a). When the user touches these conductive points, touch input is generated. This allows the user to control the touch input at arbitrary locations on an XY plane. The user can input not only tap and scroll operations but also a variety of gestures using our interface simply by connecting it to the touch panel. In addition, our technique can be fabricated using an FDM-based 3D printer with conductive and non-conductive PLA materials. This allows the user to easily prototype touch extension interfaces.

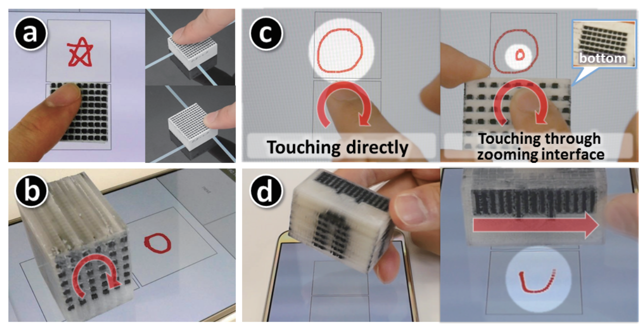

Figure 1. Applications. (a) Generating touch input using conductive points; (b) Side touch interface; (c) The touch zoom interface; (d) Transforming the touch movement.

PROPOSED METHOD
The proposed physical interface comprises two portions: the input portion that the user directly touches and the output portion, which is attached to the area that generates touch events. Each portion has a grid layout having multiple conductive points; these points are connected to either side portion's points via an inside physical interface. When a portion of the conductive points is simultaneously touched by a finger, it generates a change in the capacitance sufficient to trigger touch recognition. This also allows the user to input continuous touch input, such as scroll operations. When the user slides their finger, a portion of the conductive points will be activated in a given order. This allows the touch panel to recognize the uninterrupted touch input. The fundamental approach for this method is based on the technique proposed by ZebraWidgets and ExtensionSticker [1, 2]. Our method can recognize touch interactions at arbitrary locations on an XY plane using a grid layout of multiple conductive points.

We fabricated a physical interface that has a grid layout of multiple conductive parts using an FDM-based 3D printer with dual print-extruders (BS01 Dual ABS/PLA Model1, Bonsai Lab.Inc.). Grid layout of multiple conductive parts are exposed on the top and bottom face of the interface.

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Thus, this physical interface has implanted multiple conductive poles implanted structure. Our interfaces were printed using grapheme-based conductive PLA (Graphene 3D Lab., volume resistance: 0.6 Ω-cm) and non-conductive PLA materials. At this time, it is necessary for each conductive part to be independent and to not contact other conductive parts. CleanColor reported that the printing quality can be decayed when using an FDM-based 3D printer having dual print-extruders [4]. Due to material smears from the unilateral print head in the idle process, it is possible for conductive parts to come into contact with each other. Therefore, it is necessary to further develop the printing of a physical interface to improve the printing quality.

In this study, we print a physical interface sideways as conductive poles inside the object are lain on a layer (Figure 2 Right). Therefore, conductive material is added only at the specific conductive points to stand in a low. In addition, a non-conductive material layer is printed after conductive parts for one line have been printed. Thus, this approach can reduce printing errors, such as those reported by CleanColor. Based on these techniques, we conducted a reliability experiment to evaluate the print quality. We printed a number of striped patterned plates (Figure 2 Left). This plate is comparable with conductive points placed in a row of conductive points with grid-layout. As mentioned above, the probability of connecting the conductive materials along the vertical direction is very low. Therefore, here we focused on the contact of the each conductive part along the side-by-side direction.

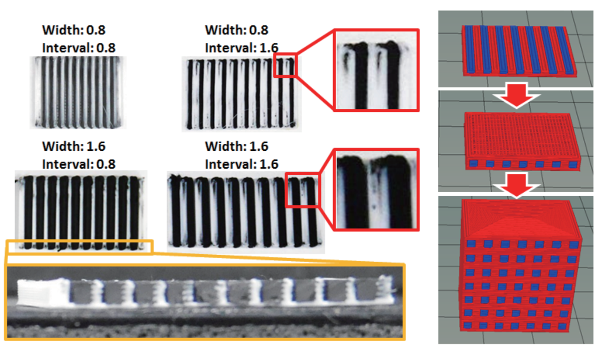

Figure 2. Left: Striped pattern plates. This plate is comparable with conductive points to stand in a row of grid-layout conductive points; Right: Printing Process.

We measured the resistance between successive conductive parts by using a multimeter that can measure resistances up to 20 MΩ. A number of multimeter measurements were recognized as errors, and the authenticity rate was recorded. The experiment was conducted for conductive striped pattern plates having different combinations of point width (0.8 mm and 1.6 mm) and point interval (0.8 mm and 1.6 mm).

We printed 10 striped pattern plates with 10 conductive parts each with various combinations of width and interval. Based on the experimental results, the 0.8 mm interval conductive parts achieved over 75 % for 0.8 mm and 1.6 mm width, and the 1.6 mm width conductive parts achieved over 96 % for 0.8 mm and 1.6 mm width. The experimental results show that the authenticity rate dropped as the interval grew narrower.

We observed that the edge of the conductive part had spread laterally. This was attributed to the filament smears caused by over extruded materials from the print head. It is presumably the cause of the contact between adjacent conductive parts. Then, we measured the resistance between the conductive parts after cutting 1.0 mm from both edges of the plate. As the result, the 0.8 mm interval conductive parts achieved over 98 % for 0.8 mm and 1.6 mm width, and the 1.6 mm width conductive parts achieved 100 % for 0.8 mm and 1.6 mm width. Therefore, by rasping the face grid-layout conductive points, and laundering the filament smears, the user can print the physical interface with considerable reliability. In addition, it is necessary that the grid-layout conductive points remain in complete contact with the touch panel. Moreover, rasping the face of the proposed physical interfaces is also an acceptable approach.

APPLICATIONS

Our interface can implement a variety of touch interfaces that can extend touch devices by shaping the structure of the conductive wiring inside a physical object. As shown in Figure 1b, bending the direction of a wire by 90 $^{\circ}$ allows the user to install touch interfaces on the sides of devices. This allows the user to input a variety of touch operations, such as tap, scroll, and swipe in all directions, as well as rotation operations, using only a single object. This example can also be applied to a cardboard head-mounted display (HMD). Our method can make a cardboard HMD with a trackpad, such as the Samsung GearVR, possible at a low cost.

As shown in Figure 1c, by changing the printed interval of the input and output portions of the conductive points, we can create a touch zooming interface that can change the speed of the touch controls between the user's touch operation and touch event generated on the touch panel. This means the touch zooming interface can allow touch devices to generate finer movement touch inputs than the user's touch operations. In general, pinch operations are performed when the user draws small figures on touch-panel devices, such as smartphones. Our method will allow touch operations on smaller touch-panel devices, such as smartwatches.

In general, touch input can be generated at the output portion with the same movement as the user's touch operations on the input portion, as shown in previous sections. Breaking certain portions allows the interface to generate touch input at certain areas of the output portion. In addition, arranging the location of the input portion in a straight line and changing the form of the wiring inside the physical interface allows the user to input a unique pattern of touch operations using a simple straight-line scroll operation (Figure 1d). We can record the user's touch operation and fabricate a physical interface that can generate the same movement touch operations in the output portion. Applying this to a pattern lock, such as the Android OS, the user can fabricate an interface that can unlock the smartphone by scrolling or swiping on the face of a physical object.

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