TactileTape: Low-Cost Touch Sensing on Curved Surfaces

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ABSTRACT
TactileTape is a one-dimensional touch sensor that looks and behaves like regular tape. It can be constructed from everyday materials (a pencil, tin foil, and shelf liner) and senses single-touch input on curved and deformable surfaces. It is used as a roll of *touch sensitive material* from which designers cut pieces to quickly add touch sensitive strips to physical prototypes. TactileTape is low-cost, easy to interface, and, unlike current non-planar touch solutions [2,7,11], it is better adapted for the rapid exploration and iteration in the early design stage.

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General terms: Design, Human Factors.

Keywords: Flexible Interfaces, Curved Touch Input.

INTRODUCTION

The emergence of thin, flexible display materials expands the design space for computing devices by requiring designers to contextualize input and feedback within an object's physical three-dimensional space. [8]. Instead of being constrained to the flat surfaces of tablet PCs, mobile phones, or desktop screens, displays will be wrapped around non-planar objects and, potentially, envelop the everyday things people use with a seamless multi-touch interactive skin [8].

Recent advances showcase the breadth taken to sense touch on non-planar surfaces: Mouse 2.0's [10] FTIR-based sensing, the UnMousePad's [6] flexible force-resistive sensor, and Sung et al.'s [7] cylindrical capacitive sensor. Although highly novel and robust, operating these new touch sensors typically requires a technical expertise that makes it difficult for designers to quickly *try out an idea* [3]. During ideation, designers often sacrifice high-fidelity materials to produce non-interactive or semi-interactive prototypes that provide proof of concept. TactileTape addresses this by seamlessly embedding touch sensing within the material of a familiar prototyping tool; in this case, tape. Even though prototyping platforms like d.tools [5] already help designers explore lightweight interaction via hardware sensors, it is a challenging and time-consuming task to retrofit off-the-shelf sensors to a physical prototype that has curved surfaces.

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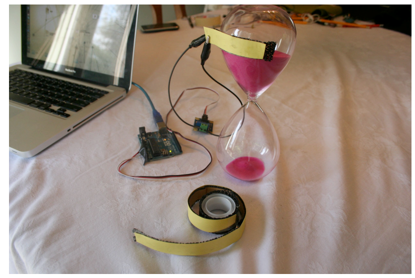

Figure 1. TactileTape is cut from a roll (foreground) and attached to an hourglass. An Arduino relays the touch data to a desktop computer.

To better support touch input on non-planar surfaces in the early design stage, we present TactileTape, a one-dimensional pliable touch sensor that looks and behaves like regular tape. TactileTape can be built from everyday supplies: an H2 pencil (resistive surface), tin foil (conductive surface), and a shelf liner (spacing material). We envision it as a readily available material in the design studio. When a designer wishes to add touch sensitivity to an industrial prototype, they grab a roll of TactileTape, cut off a piece, and attach it to the surface (see Figure 1). To sense touch input, the designer only needs to connect two wires: one to each of the resistive and conductive surfaces. As a hardware sensor, its electrical behavior is similar to common sensors used with Phidgets, Arduino, and rapid prototyping platforms [5,9]. Using TactileTape, the designer can explore touch input on a variety of curved and deformable surfaces: spheres, coffee cups, bracelets, paper, credit cards [1], interactive coke cans [1], and so on.

NON-PLANAR TOUCH INPUT FOR DESIGNING

TactileTape's pliable shape is closely positioned to Grossman et al.'s ShapeTape [4]. However, ShapeTape's fiber optics based bend and twist sensor does not sense direct touch. Wilson's [11] use of depth sensing to sense touch affords lightweight multi-touch input on non-planar camera-facing surfaces. However, its reliance on a static background model inhibits sensing touch on moving objects. Although DisplayObjects [1] senses touch on moving objects in a 360° field of view, it requires the designer to provide the Vicon motion capturing system with a model of the prototype and then carefully instrument it with infrared sensors.

DESIGN CONCEPT & IMPLEMENTATION

TactileTape is a flexible potentiometer that relies on graphite to express a linearly resistive electrical signal. There are three surfaces (see Figure 2) that form an open circuit when

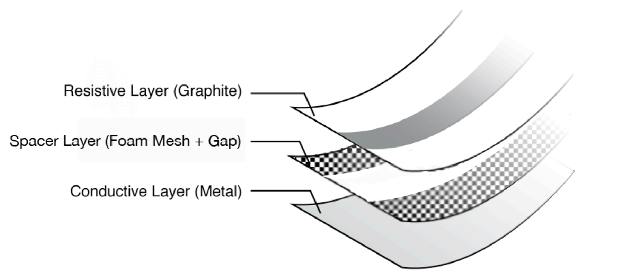

Figure 2. The combination of these three layers forms a linear potentiometer that acts as a flexible 1D single-point touch sensor.

touch is not present. When a finger deflects the surface, the circuit closes and the electrical signal is sampled. The graphite in an H2 pencil (resistance of 6 ohms/m) produces a one-dimensional input value that represents the position of a single touch event. At a width between one and two centimeters, the graphite has uniform resistance across the length of its surface and supports sensors up to 30cm long with an input resolution of 3mm. However, this upper bound on length increases when supplying a higher voltage or current (Arduino supplies 5V and 40mA to TactileTape).

The spacer layer is the enabling material for wrapping TactileTape around curved surfaces. It is made up of two tracks of cushioned material adhered to the edges of the tape, with a gap in between. This layer absorbs the forces generated when curving TactileTape and supports bends up to 85 degrees. In general, TactileTape is best at being shaped to Bezier curves, similar to the non-twisted shapes described by Grossman et al. [4]. In general, a suitable spacing material is any thin porous material that distributes force evenly: shelf liner, double-sided foam tape, thin tracks of silicone rubber, and so on.

Interfacing a piece of TactileTape requires a *one-time* calibration. A designer slightly exposes the tape's layers at both ends and affixes an alligator clip to the resistive surface (at the right most end) and another clip to the conductive surface (at the left most end). Both wires are connected to a Phidgets voltage divider (commonly used when prototyping with potentiometers and bend sensors), which is then wired to the Arduino's 5V, ground, and analog input. Initially, any touch point on the TactileTape will register a slight offset in its resistive value and, to calibrate the tape, the designer must adjust this to absolute zero. In our work, we use Arduino to sample the touch sensor, subtract the offset, and send these values over a serial connection to Quartz Composer, a tool used to quickly prototype interactive visualizations.

FUTURE WORK

We have observed a number of ways to extend TactileTape. First, it is possible to physical overlay multiple pieces of tape and sense touch input in two-dimensions. Second, it is possible to re-engineer TactileTape as *TactileString* so that it is easier to wrap around objects with complex surface geometry. Third, it is possible to altogether inverse TactileTape's sensing: instead of using tape, the designer could draw circuits *directly* on a physical prototype. Like before, the graphite acts as a linear resistor and the current travels through the designer's body to the hardware input device (eg. Arduino). This, however, requires a persistent physical connection to a conductive surface.

Although these extensions each have their unique affordances, they introduce complexities in the sensing (e.g. attaching more wires) or inconsistent behavior in the electrical signal (e.g. drawing circuits of different lengths and widths varies resistivity). TactileTape is a first step in developing and manufacturing a cheap touch sensor that offers a simple and usable experience to designers when sensing touch on curved surfaces.

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