Pinstripe: Eyes-free Continuous Input Anywhere on Interactive Clothing

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ABSTRACT

We present Pinstripe, a textile user interface element for eyes-free, continuous value input on smart garments that uses pinching and rolling a piece of cloth between your fingers. Input granularity can be controlled by the amount of cloth pinched. Pinstripe input elements are invisible, and can be included across large areas of a garment. Pinstripe thus addresses several problems previously identified in the placement and operation of textile UI elements on smart clothing.

ACM Classification: H5.2 [Information interfaces and presentation]: User Interfaces. - Haptic I/O.

General terms: Design, Human Factors

Keywords: smart textiles, wearable computing, eyes-free interaction, continuous input.

INTRODUCTION

Smart clothing incorporates electronic circuits in garments, whether to control devices, to take measurements, or to output information. Designing user interface elements for such e-textiles is hard: They need to be wearable, durable and fashion compatible, they should not activate involuntarily, and since their surface area is delimited, they need to be easy to detect on the clothing through visual or haptic cues. Their position on the body frequently shifts with body posture and movement, and users on the move often require eyes-free, one-handed operation. Finally, existing textile controls mostly resemble buttons supporting discrete input only. Pinstripe addresses all of these challenges.

RELATED WORK

Holleis et al. [1] identify many of the above challenges, emphasizing the need for eyes-free, one-handed interaction, and fashion acceptance problems. Schwarz et al. [3] use the headphone cord of an MP3 player as input device that can be twisted and tugged. The interaction gesture is related to Pinstripe, although its location is constrained to the length of the cable. Their system is not textile-based or designed as an invisible part of a garment. Komor et al. [2] propose a chording button interface to reduce involuntary activations of textile controls. While effective, it required a higher mental effort and was slower to use than standard textile buttons.

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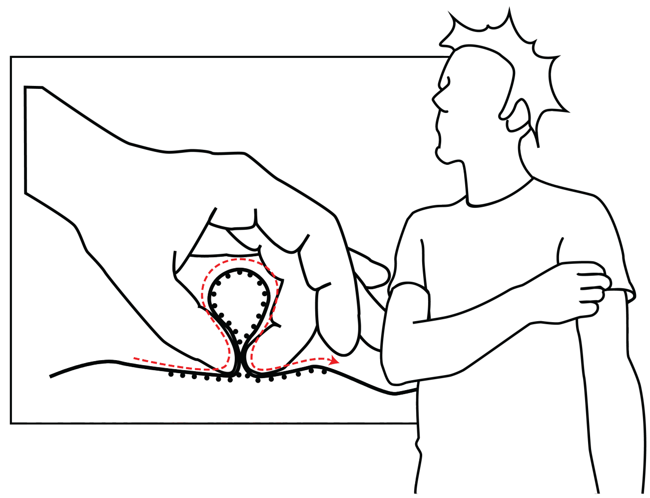

Figure 1: To use Pinstripe, you pinch and roll a fold of your garment between your fingers.

INTERACTION DESIGN

The key idea of Pinstripe is to build upon two affordances of textiles: grasping and deforming. Most clothes exhibit loose folds in different areas when worn, and Pinstripe makes use of this fact: It lets wearers provide input by pinching a part of their clothing between their thumb and another finger, creating a fold in the garment, and then rolling this fold between their fingers (Fig. 1). This rolling movement changes the relative displacement of the two sides of the fold, which is measured by conductive threads sewn into the fabric, and interpreted as a continuous change in value. Since it is not necessary to create the fold at an exact location on the garment (control is *non-local*), Pinstripe is particularly well-suited for eyes-free operation. The active areas thus do not need to be highlighted on the garment, and since the conductive threads only run along the inside of the textile, their impact on fashion or wearing comfort is minimal—both important considerations in the design of smart textiles [1].

These non-local controls also make Pinstripe highly robust against the garment shifting relative to the body during movement. While a button implemented as a local capacitive touch sensor, for example, may change its position from the back of the wrist to its side when the sleeve of the garment twists, Pinstripe works equally well no matter which part of the general wrist area the input gesture is applied to.

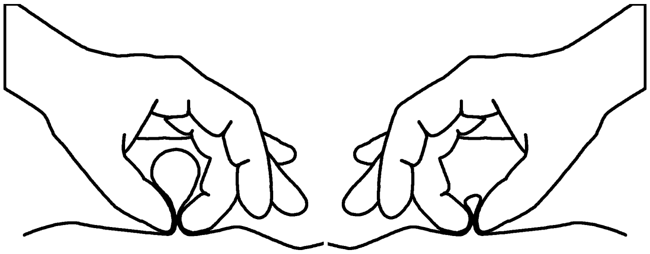

Figure 2: Pinching and rolling deeper or smaller folds of the textile provides different granularities of control.

Continuous value input elements usually exhibit an inherent problem of domain scaling. A GUI slider, e.g., can only produce as many distinct values as it occupies pixels on the screen. Zooming sliders, such as in the Apple iPhone video player, are often used to mitigate that problem. Pinstripe implements a similar approach: pinching a large fold in the textile allows coarse control over a wide range of values. Pinching a smaller fold yields more fine-grained control (Fig. 2).

SYSTEM DESIGN

For our Pinstripe prototype, we sewed 18 lines of *SparkFun 117/17* 2-ply conductive thread to the inside of a T-shirt sleeve (Fig. 3). For the outer (visible) counterthread, we used standard black cotton. Each line was connected to a digital I/O pin of a LilyPad[1] Arduino microcontroller board.

To determine the binary matrix of which lines are connected to each other, the microcontroller connects one line at a time to 0V, connects all other lines to 5V via internal pull-up resistors, and then checks their voltage level. If any of those lines report a level near 0V, they are recorded as having a connection to the current line at this time. Even though the inside conductive thread directly touches the skin, skin conductance is low enough to not impede our sensor readings. The process is then repeated using the next line as the ground line, thus yielding the next row of the connection matrix (Fig. 4).

The complete matrix is sent via a serial connection to a computer running Mac OS X, where it is filtered to remove noise before being searched for a connected area of positive entries. The location and size of this 'blob' along the secondary diagonal of the matrix indicates the size of the fold the user has pinched. When the user rolls the fold, the blob changes its position along the main diagonal (Fig. 4).

This information can now be used, e.g., to change the volume of a mobile MP3 player, to adjust the temperature of a garment with built-in heating, or to navigate through graphical or auditory menus on a device. For this prototype, we implemented part of the processing chain on a desktop computer to facilitate rapid prototyping. Industrial microcontrollers are already powerful enough to perform these computations directly, so that future versions of Pinstripe can run untethered.

FUTURE WORK

We are now creating an untethered, self-contained wearable prototype, which we will use to test our interaction concept with users wearing our technology under real-world conditions. By covering multiple areas across different locations of the body, we hope to learn more about which regions and gestures work best for various garments, postures, and tasks.

[1] http://www.arduino.cc/en/Main/ArduinoBoardLilyPad

Figure 3: Lines of conductive thread sewn into the sleeve of a T-shirt and connected to a microcontroller board (left: outside, right: inside). Lines are spaced approx. 2mm apart. On the outside, the lines are also painted on for demonstration purposes—normally the black outer cotton thread would be invisible.

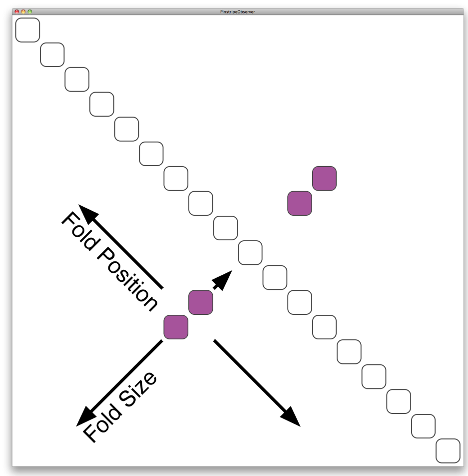

Figure 4: The connection matrix shows which lines are currently connected through pinching. The 'blob' of connection entries indicates the size and placement of the fold across the conductive threads. Here, the user has formed a small fold for fine-grained control.

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