With a Flick of the Wrist: Stretch Sensors as Lightweight Input for Mobile Devices

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ABSTRACT
With WristFlicker, we detect wrist movement through sets of stretch sensors embedded in clothing. Our system supports wrist rotation (pronation/supination), and both wrist tilts (flexion/extension and ulnar/radial deviation). Each wrist movement is measured by two opposing stretch sensors, mimicking the counteracting movement of muscles. We discuss interaction techniques that allow a user to control a music player through this lightweight input.

Author Keywords
Wrist input, hands-free interaction, wearable computing.

ACM Classification Keywords
H.5.2. [User Interfaces]: Input devices and strategies.

General Terms
Design, Human Factors, Measurement

INTRODUCTION
While the human arm offers many degrees of freedom, traditional human-computer interaction inputs only make use of a limited subset of possible movements: mice only move in one plane; keyboards and touchpad's use limited arm movement to enable finger input. Recent research attempts to leverage the user's wider range of motion by using forearm muscle activity [7] and wrist rotation and flexion [1,6]. They show particular promise in mobile contexts, to access devices in an eye-free or hands-free manner.

Previous work has focused on the use of accelerometers to measure detailed wrist tilt and rotation, with a clear advantage of creating small sensors that are easily wearable [1]. However, accelerometer-based sensors introduce noise: when the user changes position, e.g. start walking, the device moves on their body, requiring recalibration. To avoid this noise, we focused on creating a system that would allow the user to move location without the need to recalibrate. Additional design goals included a discreet and non-intrusive device, with lightweight components, easily mounted in everyday clothing.

TEI 2012, Feb 19-22, 2012, Kingston, Ontario, Canada.

In this paper, we present WristFlicker, a system detecting both wrist flexion and rotation through stretch sensors embedded in a wrist warmer, comfortable to wear and unobtrusive. Our contribution focuses on the use of opposing stretch sensors to measure wrist movement (Figure 1). We present some basic interaction technique with WristFlicker.

WRIST ANATOMY
The human wrist can perform both rotational and angular movement. The wrist rotates when the palm's direction changes, with no variation in the palm-to-arm or thumb-to-arm angles. This movement is divided into pronation (right arm counterclockwise motion) and supination (right arm clockwise motion) [2]. There are two types of angular, tilting movements [6]: vertically or horizontally, given a downwards facing palm. The vertical tilt occurs when the wrist is flexed (upwards) or extended (downwards), which is defined by a change in the palm-to-arm angle. The horizontal tilt, or ulnar (left) and radial (right) deviation, occurs when the thumb-to-arm angle changes.

RELATED WORK
Few designs have considered some of the general limitations and possibilities of using tilt input with the wrist. We focus on two recent studies that evaluated wrist-based interaction for mobile devices. Crossan et al. [1] assessed wrist rotation while the user was standing, walking, or seated, using a 3 axis accelerometer. Their results show that selecting targets while walking was significantly harder, and point out that accelerometers introduce noise. Rahman et al. [6] investigated the design space of wrist-based interaction by systematically analyzing the three axes of movement (rotation and two types of tilt). They used a TiltControl sensor, which measures two angular movements at once using a 2D accelerometer. The authors recommend up to 12 levels for pronation/supination, and 8 levels for flexion/extension. Finally, other studies have shown that position mapping of tilt to a virtual cursor is more controllable than rate based mapping of tilt [4].

WRISTFLICKER
To mimic the flexion and relaxation of muscles to produce body movements, we select a resistive sensing solution to

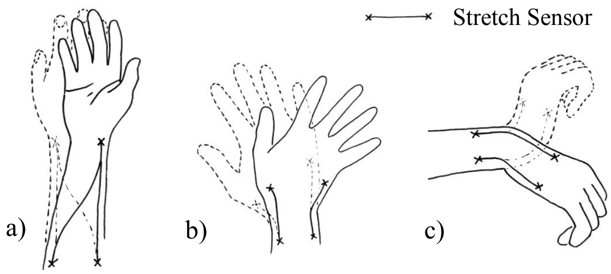

Figure 1. WristFlicker stretch sensors placement: a) pronation/supination; b) ulnar/radial deviation; c) flexion/extension.

measure three types of wrist movements simultaneously. This also allows us to avoid the use of accelerometers and their limitations in sensing wrist movement [1]. We use a conductive polymer as stretch sensors to measure each movement. The polymer cable is approximately 2mm in diameter and can be stretched up to 175%. The sensor's resistance changes according to the amount of stretch, an indicator of movement. However, once the sensor is relaxed, the signal does not return directly to its baseline, but rather decays in an approximately exponential manner. To solve this issue, we use two counteracting sensors to measure each set of movement – while one sensor is stretched, the other is relaxed. Combining the readings from both sensors allows us to ignore the slower decay time, as we can access the precise reading from the stretched sensor. Having access to both sensor values is also used for increased precision and noise reduction.

We measure the rotational motion of the forearm by assessing the distance between three mounting points, as indicated in Figure 1. This method is analogue to the movement of the pronator teres and supinator muscles in the lower arm, which by flexing or relaxing dictate the rotation of the wrist. To measure the two types of angular wrist movement, we use two sets of opposing stretch sensors (Figure 1).

Sensor values are digitally sampled by an Arduino prototyping board. We use a low pass filter for noise reduction and a threshold value for selecting which of the counteracting sensors to use as input. The Arduino connects to an Android phone using a Bluetooth module and Amarino [3].

INTERACTION TECHNIQUES

WristFlicker can produce both discrete and continuous values for each movement. While Rahman et al. segments input for wrist flicks [6], we mapped angular movements to binary input, selecting a quick, imprecise movement with limited possibilities over a slow, precise movement with numerous values. Wrist rotation, however, can be used as either binary or continuous input, depending on application.

To avoid accidental activation, we use a double flick of the ulnar/radial deviation as an on/off trigger to enable and disable the wrist input. This command was selected as it is unlikely to be performed accidentally, and because Rahman et al. recommended minimal use of that command [6].

We use WristFlicker to control a music player application. When browsing music, we map continuous rotation to scrolling in a playlist, and binary flexion to selecting a specific piece, which is played with a second flick. When music is playing, wrist rotation is mapped to the volume and a wrist flexion allows you to continue browsing music. Finally, a wrist extension stops the music.

DISCUSSION

WristFlicker is an innovative method to measure wrist rotation and tilt through two opposing stretch sensors, mimicking the counteracting movement of muscles. As the sensors are currently located under clothing, we imagine the stretch sensors to be part of the clothing itself in a next iteration, by taking advantage of the properties if resistive fabric [5]. In addition, we believe the integration of an E Ink segmented display with WristFlicker will allow for more direct coupling between the input and the output, similarly to Snaplet [8], an E Ink screen mounted on the wrist.

The input sensors could be expanded beyond wrist motion capture: WristFlicker technology can mimic almost any type of body movement. Such an embodied motion capturing system could track body language for use with gesture recognition systems, or find application in the field of telerobotics. Contrary to current input for such applications, the technology presented with WristFlicker does not require an external frame of reference and is thus not only more lightweight, but also allows for mobile use.

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