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Title	Sensor Sleeve: Sensing Affective Gestures
Type	Article
URL	http://ualresearchonline.arts.ac.uk/1066/
Date	2005
Citation	Randell, Cliff and Andersen, Ian and Moore, Henk and Baurley, Sharon (2005) Sensor Sleeve: Sensing Affective Gestures. Ninth International Symposium on Wearable Computers – Workshop on On-Body Sensing. pp. 117-123.
Creators	Randell, Cliff and Andersen, Ian and Moore, Henk and Baurley, Sharon

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The Sensor Sleeve: Sensing Affective Gestures*

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Abstract

We describe the use of textile sensors mounted in a garment sleeve to detect affective gestures. The ' Sensor Sleeve' is part of a larger project to explore the role of affect in communications. Pressure activated, capacitive and elasto-resistive sensors are investigated and their relative merits reported on. An implemented application is outlined in which a cellphone receives messages derived from the sleeve's sensors using a Bluetooth interface, and relays the signals as text messages to the user's nominated partner.

1 Introduction

In this paper we describe research into textile sensors that are integrated into clothing and used for the explicit recognition of affective gestures. This research is part of a project to explore a clothing concept that enables expressive or inferred emotional messages to be exchanged remotely between people who are relationally close, by conveying a sense of touch and presence. New emotively-rich forms of remote communication and interaction that are repressed by current technology can be enabled by embedding communications technologies and smart textile sensors into clothing. The project is multi-disciplinary drawing on expertise from fashion and textile design, electronics, wearable computing, human-computer interaction design and psychology.

The importance of nonverbal communication through body movement and touch in human communication has been studied by the psychologists Ekman and Friesen, and Jones and Yarborough, the anthropologist Desmond Morris, and the naturalist, Charles Darwin, who have all identified links between human emotion and behaviour [1, 2, 3, 4]. There are key types of bodily movements and touch actions that are recognised as having emotional meaning. *Affect displays* are movements of the body and face to show emotion; *illustrators* help to reinforce verbal messages; and *auto-contact behaviour* or *self-intimacies*, are "touching actions we direct towards ourselves ... that provide comfort because they are ... unconsciously mimed acts of being touched by someone else" [3]. Our design framework is based on these key types of behaviour. We aim to detect embrace, squeeze/press and stroke actions centred around the arm as this is one of the principal areas of interpersonal touch actions. A smart textile system comprising of textile circuits with gesture and touch/pressure sensors, together with micro-controller and Bluetooth devices, is integrated into the sleeve of a garment. Therefore the embrace, squeeze/press and stroke gestures can all be recognised by the smart textile system to comprise a menu of expressions.

Potential benefits and applications of affective interfaces for computers were addressed by Rosalind Picard in her book 'Affective Computing' [5]. Picard underlines the importance of taking the risk of providing emotive interfaces to computers to maintain balance in the user's emotional and rational abilities. Research has already been carried out into the sensing of emotion using deductive techniques such as measuring heart rate, respiration, skin resistance, blood pressure and muscle activity [6]; and by sensing stress patterns in speech [7]. Tangible interfaces, such as the Voodoo Doll [8], can provide explicit measurements. We explore the explicit sensing of affective gestures by using sleeve mounted sensors for human-human communication or for human-computer interface.

In the following section we report on four sensor technologies. These use conductive fibres to sense pressure; capacitance and electrical skin resistance to sense proximity; and conductive threads to determine stretch. We also outline an example application in which the sensors are connected via Bluetooth to a cell phone enabling affective text messages to be sent to a nominated recipient.

*Funding for this work is received from the U.K. Engineering and Physical Sciences Research Council, Grant No. 15986, as part of the Equator IRC; and from the U.K. Arts and Humanities Research Council as part of a Fellowship Grant in the Creative and Performing Arts.

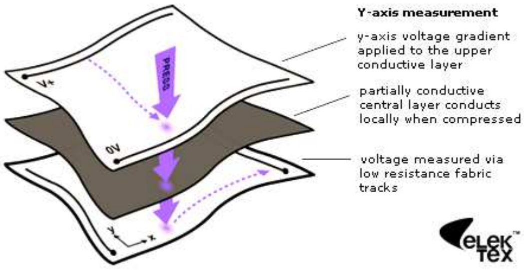

Figure 1. Pressure and position sensor.

Figure 2. Striped fabric touch sensor.

2 Sensors

The objective is to design and build sensors to detect embracing, squeezing/pressing and stroking actions. We have chosen to detect these actions on the arm, however our sensors could equally be deployed on other parts of the body. We have selected four technologies for our experiments. Firstly a commercial multilayer fabric which uses conductive fibres; secondly a capacitive sensor which uses a touch sensor integrated circuit in conjunction with a fashion textile with conductive stripes; thirdly an electrical skin resistance (ESR) version of the capacitive sensor; and lastly, a mechanical stretch sensor using conductive threads developed, and kindly provided, by Philips Research. Alternative technology which may be useful for explicit gesture measurement include piezo-resistive sensors [9], however these were not available to us. The Sony Interaction Lab has also researched implicit gesture measurement using accelerometers, and fabric based capacitive sensing with a wrist-worn transmitter [10].

2.1 Multilayer Resistive Fabric

This sensor uses a multi-layer fabric, ElekTex [11], in which contact is made between the layers by pressing on the fabric (see Figure 1). By using two conductive layers which are separated by a layer with conductive fibres which conduct when compressed, it is possible to determine the X/Y position of the pressure on the fabric, as well as measuring the amount of pressure (Z). The fabric has two outer insulating layers which result in a total five layer construction less than 1mm thick. The fabric is flexible and can be shaped to become part of a piece of clothing whilst retaining its measuring properties. Using this fabric we successfully carried out experiments sensing touching, discriminating between squeezing and pressing; and stroking by measuring contact moving across the sensor fabric in a line.

We have used four I/O pins of a PIC microcontroller to measure the X/Y location on the ElekTex fabric. Two pins are connected to the top and bottom contacts of the top layer, and the other two pins are connected to the left and right contacts of the bottom layer. In order to measure the Y location, we dedicate the top and bottom pins to be outputs, and output a 1 and 0 respectively. We dedicate the left and right pins as a common input and measure the voltage. The X location is measured by outputting a 0 and 1 over left and right, and by measuring on the top/bottom pins. The pressure is gauged by measuring the resistance value between the layers. The three value measurement cycle takes around 100ms. These X/Y/Z sensing properties make it practical to use this material as a fabric QWERTY keyboard.

The disadvantages of this fabric arose from its bulk, making it difficult to conform with the drape of the lightweight garment structure; and its colour. The black colouring arising from the composition of conductive fabrics is a common aesthetic limitation for fashion clothes designers, often resolved by containing the sensor in a sealed pocket, further adding to the bulk.

2.2 Capacitive

The use of changes in capacitance created by proximity of the human body is a commonly used technique for electrical control. In our sleeve design we have experimented with an integrated circuit touch sensor, the QProx QT240 by the Quantum Research Group [12], connected to Heathcoat F6354/A [13], a plain ripstop weave scoured and finished with 5mm silver heatset stripes 14mm apart (see Figure 2). The sensor IC has 4 channels with spread-spectrum and discrete outputs. The sensor fabric was positioned on the upper part of the lower arm, and was threaded through to the outside of the garment shell making it possible to touch the conductive strips with the opposing hand. This arrangement was preferred to the multi-layer sensor because of its reduced bulk, and for the aesthetic reasons outlined previously.

The reliable detection of capacitance changes proved to be challenging as the user's arm gave a capacitive effect in addition to the user's hand. This problem was solved by Rekimoto by using a wrist-worn transmitter [10].

Figure 3. Stretch sensor with fabric bus.

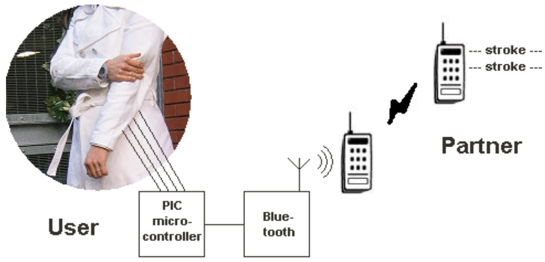

Figure 4. Application architecture.

We did not wish to use additional devices for our gesture sensing and thus explored the potential of tuning the QProx IC, however we were unable to achieve satisfactory results in the time available and thus turned to electrical skin resistance measurement as an alternative approach.

2.3 ESR

As an alternative to the QProx IC we have developed a sensor which detects electrical skin resistance (ESR) between the tracks of the Heathcoat fabric. This design used darlington pair transistors to detect current flowing through the hand between the tracks. Alternate tracks connected to a current source and the bases of the darlington pairs. When the user moves their hand over two of the tracks they will provide enough current to activate the transistors. From our tests we found this to be a more robust arrangement than capacitive sensing. We can determine touch, and by looking at the order and duration of the signals from the sense lines, discriminate between an upwards stroke or a downwards stroke as long as the bearing hand straddles the conductive strips.

2.4 Mechanical Resistive Knit

The final sensor we evaluated uses an mechanical resistive knitted strip developed by Philips Research [14]. This was intended to assist with measuring gestures in which the clothing was stretched, in particular by mounting it on the elbow it should be possible to sense embraces (see Figure 3). The sensor detects strain by measuring resistance change in a strip of stretched fabric by interweaving carbon fibres with elastomeric yarn using a knitting process. In an unstretched state loops of carbon yarn protrude from the fabric surface decreasing resistance by reducing the conductive path. Stretching the sensor causes an increase in measured resistance due to an increase in the length of the conductive paths. The sensor was connected as part of a potential divider and the output voltage monitored as the resistance changed.

Originally designed to be used in strips along parts of the body, for our application it was mounted in such a way so as to straddle the elbow joint on the outside of the elbow. The mounting technique maintained stretch enabling the elbow joint movements to be accurately monitored and the sharp angle created by embracing oneself to be detected reliably. The stretch sensor performed well in discerning a single gesture, the arm bend associated with an embrace, and was especially effective with sensors mounted on both elbows to reliably detect when both arms are bent in a self-embrace action.

3 Application

The properties of the Heathcoat striped fabric were also appropriate for use as a low power and signal bus [15]. We were thus able to integrate the fabric into the sleeve construction (see Figure 3) with the sensors placed on the arm. The textile conductive tracks from both sensors, two from the stretch sensor and four from the touch sensor, were stitched onto an outer lining layer, and travelled up the sleeve towards the rear of the garment. The same number of conductive tracks were stitched onto the rear of the garment body; the conductive tracks in the sleeve and those in the main body of the garment were connected when the sleeve was stitched onto the main body. The conductive tracks carrying both power and data signals travelled to the hem of the garment, to which wires were attached using metal poppers. The wires were connected to the printed circuit board with a microcontroller and Bluetooth device to provide control and transmission of the affective gestures to a cell phone.

To test, and to demonstrate, the functioning of our design we built an application in which the user performs an affective gesture that is relayed to a nominated partner using a combination of Bluetooth and Short Message Service (SMS) communication channels. Users were equipped with lightweight jackets fitted with the gesture sensing sleeve and Bluetooth-enabled cell phones (see Figure 4). To provide support for the Bluetooth and SMS communication, a software program was installed on the user's cell phone.

The process of communicating an affective gesture from one user to the nominated party is as follows:

- The user performs the desired gesture;
- The micro-controller in the garment processes input signals from the sensors, and outputs signals to the Bluetooth device;
- The signal is then transmitted to the users Bluetooth-enabled cell phone where the signal is examined to see the type of gesture that has been sensed;
- A text message with a predefined prefix is then constructed with a message body indicating the gesture type. This text message is then automatically sent to the nominated party's (partner's) cell phone;
- The partner's cell phone notifies the user of the received message.

This application provided a way for users to transmit nonverbal communication through body movement and touch despite being separated. Aside from this application, the use of the SMS emerged as a useful alternative to the General Packet Radio Service (GPRS) for the communication of events.

4 Conclusion and Future Work

We have investigated the potential of commercial off-the-shelf textiles, and a special weave from Philips Research, for use as sensors to recognise explicit gesture recognition on the body. The most appropriate sensors for a fashion garment have been selected, and integrated with a textile power and communications bus into a sleeve structure. A demonstration application has been successfully tested by triggering pre-formatted SMS messages sent to the user's partner.

Further work to develop this concept is being carried out by investigating a range of actuators to be fitted to the partner's garment. These include vibrators, heat pads and muscle wires selectively activated when the partner's cell phone with a complementary application intercepts the text message, identifies the gesture and generates events.

User tests are underway to elicit views on the value of this technology, including functional testing to observe what people communicate, how they communicate, and to determine if and how people appropriate the technology. In this way we expect to be able to evaluate the effectiveness of these sensors as interface tools, as well as assessing the potential value of building emotive communications capabilities into clothing.

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