Threads of Recognition: Using Touch As Input With Directionally Conductive Fabric

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Abstract

In this paper, we describe the design of a touch input system utilizing directionally conductive fabric for use as "smart fabric" in wearable computing garments. Our development is based on utilizing the fabric surface as a tactile interface. We have defined a set of qualitative gestures using heuristic algorithms. This model provides high-level interpretations for the tactile quality of the caress, which is used to derive parameters for the interaction model. The user (or wearer) uses this fabric as interface to select interaction modes that direct data between networked garments in a wearable art installation.

The fabric is composed of highly conductive fibers alternating with insulating materials, such that current can flow "along the grain" but not across. This design allows the fabric to become a passive conductor replacing conventional cables, and more significantly, an active device such as a touch sensor surface. The fabric is integrated into garments (in this example, a set of networked skirts), and is used to provide a source of tactile input.

The garment is used to explore the interpersonal exchange of physiological data, controlled and selected by the individual wearing the garment, using gestures sensed by the fabric, and contact between garments, as initiated by the wearer. These connections form the basis of ongoing studies of the dynamics of person-person and person-group interactions.

Categories & Subject Descriptors: J.5 [**ARTS AND HUMANITIES**]: *Performing Arts*; B.4.2 [Input/Output Devices]: *Tactile input*

General Terms: Design, Experimentation, Human Factors

Keywords: Tactile UIs, Input and Interaction Technologies, User Experience Design, Tangible UIs, gestural analysis, tactile input, Laban Effort-Shape analysis, whole hand input.

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INTRODUCTION

The input system is based on the blending of two primary techniques: Laban Effort-Shape Analysis and a generalized input library, called the Gestural Interface Toolkit. The Laban Effort-Shape Analysis provides a movement-based theoretical basis for the development and description of the system, while the toolkit supplies an abstraction layer for the realization of the system in hardware and software.

Effort-Shape Analysis is a system and a language for observing and describing effort qualities of movement, originally described by Rudolph Laban [8]. Effort/Shape Analysis describes: 1) movement qualities and dynamics defined as Weight, Space, Time and Flow, and 2) Shape qualities which are defined as interactions with the environment: Directional and Shaping. Our work extrapolates primarily Efforts. Effort quality is defined as a continuum between polarities — Weight varies between strength and lightness, Space varies between direct and indirect/flexible, Time varies between sudden and sustained and Flow varies between bound and free.

Combinations of the main qualities are described as "qualities" of Effort. There are eight Basic Effort Actions, corresponding to the eight possible combinations of Space, Time and Weight. Figure 1 shows these qualities organized as the vertices of a cube, superimposed on the Effort components.

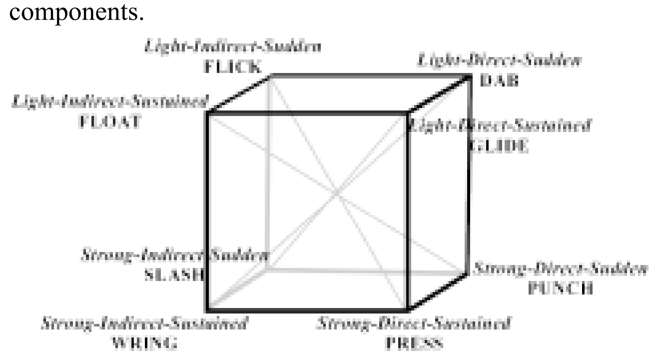

Figure 1. *Effort Qualities and Actions*

The Gestural Interface Toolkit (GIT) is an Application Programming Interface (API) for developing responsive wearable applications that require access to tactile input [19]. It incorporates gestural interpretation based on heuristic algorithms that represent Laban Effort Analysis. The objective of the toolkit is to provide uniform and consistent handling of several classes of tactile input.

The toolkit is parameter driven for tactile data [11]; in this application a two-dimensional model of signal sources from the fabric is used, in combination with thresholds and filters tuned for the range of the discrete attributes of Laban Effort qualities.

PRIOR WORK

The Laban movement notation is described in Laban [8]. Badler [1] presents a digital representation of the specific notation, Labanotation. Singh [18] describes a computer-based graphical tool for working with the similar Benesh Movement Notation.

Zhao [21] has applied Laban Movement Analysis (LMA) to studies of communication gestures. In this work, we focus on interpretation of the gestures as control actions for selecting communication pathways, as opposed to the gestures expressing the communication.

Schiphorst et al [13,14] describes the use of kinematic models to represent movements and Calvert et al [4] describes the further development of the composition tool into the product Life Forms, which uses Laban notation as the representation language. The current work was influenced by the choreographic approach to motion description and presentation of these studies.

Buxton et al [2] provides early descriptions of the unique characteristics of touch tablets relative to other input devices such as mice and trackballs. In particular they explore multiple-touch and pressure-sensitive tablets. The fabric used in our work can be multiple-touch, although our initial focus has been on single-touch gestures, as well as a more symbolic, high-level, treatment of the data.

Chen et al [5][6] describe the use of a touch-sensitive tablet to control a dynamic particle simulation using finger strokes and whole-hand gestures, where the gestures are interpreted as a form of command language for direct manipulation. In this work, we extend the concept of a direct manipulation language to incorporate some emotional expression in the observed gestures.

IMPLEMENTATION – HARDWARE

Our exploration with conductive fabric is based on the following needs from our prior work:

1) The conventional cables for the electronics used with sensors and personal digital assistants (PDAs) in our first prototype garments were too bulky and too rigid, so that the natural movement of the wearers became constrained and awkward, due to concern with the physical interconnects, such as cables and attachment points.
2) The interaction model that we wished to explore required a more robust connection mechanism between garments than we had experienced with earlier prototypes; it focuses on affective and expressive non-verbal communication based on touch, gesture, and movement, integrating these missing modes of communication into computer-assisted human-human networked systems as well as human-computer interfaces. Mechanical connections (such as fabric snaps) were hard to connect and required significant visual attention from the garment wearer to work; we want to connect more by feel, based on more associative and intuitive, touch-based gestures.

The implementation of our touch-based interface uses directionally conductive fabric, silk organza [12], forming layers of a garment. The prototype garment is a skirt that has integrated embedded cables that use the conductive fabric (as shown in Figure 2) to power transducers and to route data signals from sensors to a small wearable computer. The transducers are clusters of vibrator motors and fans embedded in the skirt lining to provide localized feedback for the wearer of the garment. Thanks to the physical characteristics of the fabric (nearly transparent and very lightweight), the cabling can be easily adjusted to accommodate different garment configurations, activities or wearers.

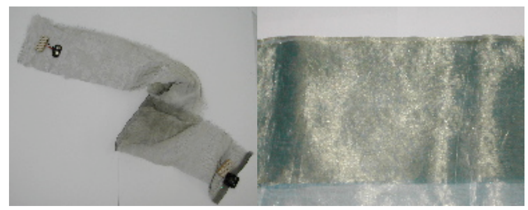

Figure 2. ***Conductive Fabric Strip***

Connections can be made directly to the fabric, with a high degree of isolation between signals. This can be accomplished without interfering with the flexibility or appearance of the conductive fabric. Large pockets in the garment are used to house the wearable computer, the power supplies and the associated electronics.

Figure 3. ***The Garments***

In addition, the conductive fabric is easily added to the garment to form response areas [7]. The fabric is layered with non-conductive fabric to form a simple grid that can be interrogated with a small amount of electronics [13] to identify a point of contact or applied pressure [17]. The information obtained from the fabric is sent to a small, lightweight, wearable computer, which communicates wirelessly with a central server. The server integrates the information from the garments with physiological data (such as heart and breath rates), gathered using a commercially available medical-grade sensor system that utilizes low-noise electronics and very reliable biosensors.

Figure 4. ***Sensor Electronics***

IMPLEMENTATION – SOFTWARE

Early versions of the garment used a very ad hoc approach to touch and contact recognition, primarily due to limitations imposed by the hardware architecture. The software model has been refocused to emphasize the dynamics of connection and contact, which are key to our studies of non-verbal interpersonal communication.

For this, earlier work [16] on adapting Laban Effort-Shape Analysis to recognizing gestures on a touch-sensitive tablet were adapted to the problem of identifying similar gestures on a response area. Some simplifications were necessary, as the fabric doesn't provide fine variation in detectable pressure. It does, however, have good isolation between the conductive fibers, so that determining the bounds of the contact region is both easier and repeatable. It is assumed that, at any given moment, there is only one touch-effort intended by the user [10]. For example, the wearer is not tapping with one finger and jabbing with another.

Data from the response area is input into an image-processing environment, with some filtering performed using the wearable computer. The image is then processed as a visual representation, to extract parameters that we have identified as representing physical values that can be extracted or calculated from the information that the response area provides over time. These parameters are described in Table 1.

To simplify the decision process used to determine what quality of touch is used, we take a fuzzy approach and use some techniques borrowed from Laban. The rationale for this is that parameters generally aren't represented linguistically by gradations of numbers, but are described in more dualistic terms such as "soft" or "hard. By categorizing each parameter into two or three qualitative values, the number of possible touch-efforts is reduced to a manageable quantity, which is more representative of the actual types of touches that we have identified. These values are then quantized to provide a standard representation that can be further analyzed and mapped to gestures, such as "stroke", "pat" or "touch". These gestures are combined with inter-garment connection information to generate a model of the actions being requested by the garment wearer — she can indicate which physiological signals she wishes to share or observe, and how the signals are to be mapped to the feedback devices on the garment.

Parameter:		Description
pressure	soft-hard	The intensity of the touch.
time	short-long	The length of time a gesture takes.
size	small-medium-big	The size of the affected region in the response area.
number	one-many	The distinction between one finger or object and many fingers.
speed	none, slow-fast	The speed of a touch-effort. This is the overall velocity of movement.
direction	none, left, right, up, down, and diagonals	The direction of movement.
Secondary:		
space (speed)	stationary-traveling	A function of speed. If speed is zero then the gesture is stationary.
path (direction)	straight-wandering	If the speed is not zero, and there is only one direction registered, the gesture is straight.
disposition (pressure)	constant-varying	If the pressure maintains a single value after an initial acceleration the gesture is constant.
pattern (gesture)	continuous-repetitive	If a gesture is unique in relation to the gesture immediately before and after, it is continuous.

Table 1. Parameters That Can be Extracted or Derived

At the same time, the connection information provides a representation of the groupings of the garments into clusters; each cluster can, at the discretion of the participants, provide aggregated physiological signals that can be used to modify aspects of the environment, in the form of visual imagery projected on suspended reflective sheets.

RESULTS

The response areas on the garments allow us to explore a touch-based interaction model that supports wearer-controlled sharing of physiological data from multiple sensors as self-to-self, self-to-other and self-to-group communication. The use of lightweight electronics and a wireless network allow the garment wearer essentially unrestricted movement within the installation. The response areas can be adjusted for each wearer, so that differences in "reach" or applied pressure can be accommodated.

The vibrator motors and fans that are embedded in the skirt lining provide sensual, non-verbal representations of the recognized gestures and allow the wearers to experience the contact and sharing aspects of the system, which is our primary exploratory focus.

FUTURE WORK

We are interested in applying the parameterized model of effort qualities to expressing and inferring meaning from caress and other forms of touch, such as holding and hugging [8]. The current system uses a single fabric insertion area as a response area, which limits the range of movements that can be expressed. By incorporating multiple response areas, it should be possible to create multiple active regions on the body, so that interpersonal touch can be represented and qualified [19]. Alternatively, the same fabric could be used to form an active area within a device or object, by embedding it within the floors and/or walls of a room, or by applying it to surfaces such as furniture.

Wearable computers in the form of PDA's provide localized processing; we are porting the platform to the cell-phone Symbian environment. This will enable peer-to-peer exchange of interpretation of gestures and the formation of ad-hoc communities, which will provide opportunities for higher-level analysis and exploration of other applications where quality, intention and meaning, rather than quantitative position-based interaction is required [3]. Moving to a more decentralized organization, where servers in multiple locations exchange gesture information through the internet, will also allow us to explore how gesture exchange might work when there is no visual contact between participants, let alone direct touch.

This work raises some interesting questions: Can we integrate such visceral information with conventional communication mechanisms, in such a way that the sensual nature of a gesture is not lost? How does one store, access, communicate and elicit such communications, as we do with a telephone call? Can we e-mail a hug?

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