Sprout I/O: A Texturally Rich Interface

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ABSTRACT
In this paper we describe *Sprout I/O*, a novel haptic interface for tactile and visual communication. *Sprout I/O* combines textiles and shape-memory alloys to create a soft and kinetic membrane with truly co-located input and output. We describe implementation details, the affordances made possible by the use of smart materials in human computer interaction and possible applications for this technology.

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Haptics, Kinetic Interface, Shape-Memory Alloy, Smart Materials, Co-located I/O.

ACM Classification Keywords
H.5.2 [Information Interface]: User Interface—Haptic I/O.

INTRODUCTION
Our perception of the world is highly informed by the textures and material qualities of the physical objects we interact with. Variations in pressure, shape and temperature are responsible for adding dimension, weight and material composition to the surrounding environment, and most importantly, they limit how we communicate through our physical interfaces. In order to engage users at a high expressive and emotional level, computer interfaces must attempt to support a wider set of material affordances, while creating denser mappings between digital information and its material representation.

Inspired by the rich textures of carpet and fur, we are developing *Sprout I/O*: an array of soft and kinetic textile strands which can sense touch and move to display images and animations (see Figure 1). *Sprout I/O* is built from a seamless shape-memory alloy (SMA) and felt composite, which is jointly responsible for textile actuation and touch sensing. By developing a composite material that co-locates

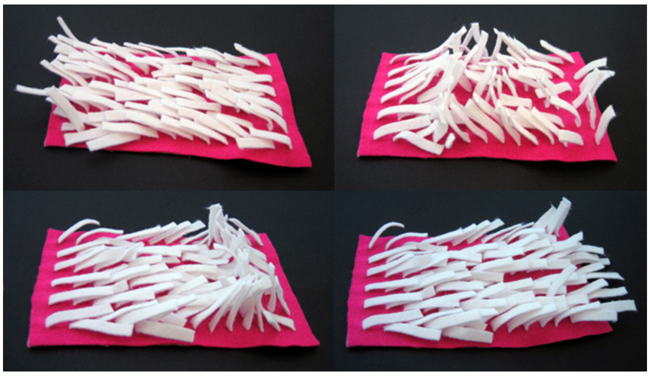

Figure 1. Sprout I/O conceptual design

kinetic I/O while preserving the tactile qualities of soft materials, we created a multipurpose substrate which can seamlessly embed dense computation and interactivity into our surrounding environment to support expressively richer and potentially more meaningful interactive experiences.

BACKGROUND AND MOTIVATION
Sprout I/O's design has been influenced by a series of technologies and natural phenomena. Its primary inspiration is drawn from the footprints we leave on a carpet by reorienting its fibers and their light reflectance. In the research realm, sources of inspiration are *Super Cilia Skin* [3] and *Lumen* [2], two table top interfaces that couple tactile input with tactile and visual output. While both of these systems enable a rich set of interaction scenarios, their level of kinesis is limited, since they rely on the use of rigid actuators and surfaces. *Sprout I/O* builds upon previous research by embedding a soft actuator within the pliable strand, creating a soft and malleable surface that looks and feels like a textile, but behaves like a kinetic display.

SPROUT I/O
Sprout I/O's core innovation is the use of a seamless composite made of shape-memory alloy and felt. While the SMA is responsible for sensing touch and giving two-directional movement to the fur strands, the felt provides structure, as well as visual and textural quality. A shape-memory alloy is an alloy, made of nickel and titanium, that once treated to acquire a specific shape, has the ability to indefinitely remember its geometry. After undergoing a physical deformation, an SMA wire can be heated to its final transformation temperature (A_f) and regain its original

shape. Through resistive heating, it is possible to electronically control the temperature of an SMA strand and generate enough force to control the shape and movement of a textile [1]. Since SMAs are conductive and heated through a controlled pulse width modulation, it is possible to measure the capacitive coupling between every SMA wire and a person's hand, creating a dense, soft and texturally rich matrix that truly co-locates input and output.

Textile Composites

Our primary design goal was to create a soft interface that could sense, mediate and communicate touch in a subtle and non-intrusive manner, taking advantage of textural and surface changes, rather than light emitting techniques. To develop a material that could preserve its soft properties, while being continuously actuated, we experimented with several SMA and textile techniques.

Figure 2. Teflon and SMA spun yarn

For our first prototype, we developed a Teflon and SMA spun yarn in which the SMA is actuated to curl the fur strand down, while the yarn's internal structure forces the strand back up to its original shape. In spite of being electrically insulated and fire retardant, the Teflon yarn is affected by increasing hysterisis and over time it starts to 'learn' and retain the shape of the SMA, losing strength to counteract the actuation force of the alloy. In an attempt to address this problem, we also experimented with different knitting techniques and a composite consisting of SMA, Teflon-wool yarn and polyurethane. The polyurethane in this case was chosen because of its tensile strength and capacity to return to its original shape after deformation. However, this technique proved to be impractical, since the balance between the materials' strength was hard to control and could not account for variations in fabrication and use.

Figure 3. Two-way actuation

Finally, we opted for a bi-state actuation method by sewing a three dimensional SMA strand onto both sides of a rectangular piece of felt. By controlling the current applied to each side of the SMA strand and localizing heat, it is possible to cause an orthogonal bend on the felt, as well as control its angle, speed and direction (see Figure 3). This process proved to be the most reliable, since the SMA's actuation is independent of the felt's capacity to return to its shape. Moreover, this technique is more energy efficient, since the kinetic display only needs power to change the state of a strand, which remains in the same position until it is actuated again.

TEXTURALLY RICH INTERFACES

Most interfaces strive to capture and convey the subtleties of human communication, but usually fail at supporting the textural affordances we encounter in the physical world. Part of the problem resides in the difficult electromechanical coupling between sensors, actuators and the materials they control. Smart materials have the potential to circumvent these interface and construction problems by physically approximating input and output and simplifying their electrical connections. This flexibility can support the design of interactive surfaces that do not need to be dissociated from their electronic control, but can become integral aesthetic and structural elements, which are texturally richer and capable of sustaining multi-sensory experiences that fully engage our senses.

EXAMPLE APPLICATIONS

We envision a series of future applications for this technology: carpets for public spaces that can guide people to their destination or display information about a game or event taking place; a robotic skin that can sense the fine subtleties of touch and respond with goose bumps to create tighter emotional bonds with their owners; interactive clothing that can record its history of interaction or simply animate to display the mood or personality of its wearer; and, a tactile display and sensing surface for the visually impaired.

CONCLUSION AND FUTURE WORK

Sprout I/O is still at an early stage and, as such, there are many future challenges to address. Our next step will be to develop a full *Sprout I/O* matrix and explore some of the kinds of communication this interface can foster when scaled, and more specifically how variations in the size and shape of fur strands, as well as their location, kinetic speed and feel can affect *Sprout I/O*'s use.

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