Taxtile Nerve Extensions

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ABSTRACT
A taxtile is a smart fabric that integrates tactile sensors and actuators in the same flexible material, inspired by human skin. Tactile illusions such as the 'shrinking waist' and the 'stretching nose' demonstrate that bodily awareness is dynamic and is not constrained to the physical body. The design sketch for Fauxy the Fake Fur Coat with Feelings has vibrotactile buttons sewn on the inside to connect the fabric sensor to skin sensations. We propose that bodily awareness could flow into the coat through these 'taxtile nerve extensions' to position the wearer's perceptual systems as the smarts in the Smart Fabric.

KEYWORDS
Textile, Tactile, Neuroscience, Animated Garment, Fashion

INTRODUCTION
The convergence of computing and textile technologies is marked by the inaugural conference on Smart Fabrics in 2005 [Smart Fabrics 2005]. Commercial products, such as the SensaTex Smart Shirt and the VivoMetrics Life Shirt are woven with sensors that register many of the same kinds of information that skin does. One day Smart Fabrics may even synthesise vitamins, repair DNA and heal physical cuts and bruises like skin does. However in current Smart Fabric designs there is a distinct gap between the sensors in the fabric and the senses in the skin. What if the sensors in the Smart Fabric were connected to the skin of the wearer to reposition the wearer from a source of 'data' to the 'smarts' in a wearable information system?

The ability of blind people to read Braille with their fingertips shows that skin provides a communication channel to the brain that can be used to understand abstract and symbolic information. There have been experiments on sensory substitution and the recognition of 2D images projected by electrical or vibro-tactile stimulation onto the skin since the 1960's. The Forehead Retina System consists of a miniature camera mounted in sunglasses that sends video to an array of 512 electrodes in the headband that transduce the image to nerves in the skin [Kajimoto et. al. 1999]. The Haptic Radar, modeled on cats whiskers, consists of a fibre that senses distance and transduces it to a vibro-tactile cue on the skin directly beneath it. The researchers suggest the whisker interface may be more efficient than visual-to-tactile systems for path finding and collision avoidance [Cassinelli et. al. 2006]. The e-Skin project has the ambitious aim to develop a textile modeled on the human skin. e-Skin is envisioned as a multilayered flexible textile that senses stimuli and has actuation mechanisms for tactile feedback on both inner and outer surfaces [Kirstein et. al. 2003]. The consortium in this project combines expertise from the fields of human computer interaction, wearable computing, bio-mimetic robotics and ergonomic design.

BODY IN THE BRAIN

The nerve connections between skin and brain are drawn on the neural cortex in Figure 1 [Penfield and Rasmussen 1950]. This 'body in the brain' with its outsized hands and lips that reflect the density of nerves and neurons dedicated to each part of the body, is known as the 'sensory homunculus'. The parts of the body are re-arranged, so that the hand is adjacent to the face in the middle. Some amputees feel the phantom sensation of their missing hand when their face is touched due to crosstalk between these adjacent regions in the homunculus [Ramachandran & Blakeslee 1999]. The homunculus is also used to explain the disappearance of body parts from conscious perception with certain types of brain damage, and distortions in the size of body parts during episodes of epilepsy or migraine.

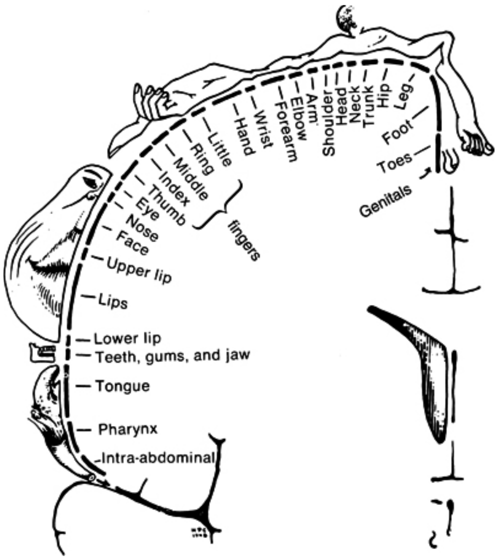


Figure 1. Mapping of nerves from the skin to the brain [Penfield and Rasmussen 1950]

The sensory-homunculus has a twin, known as the motor-homunculus, that maps the afferent nerves in the other direction, from the brain to the muscles and skin. The homunculus twins, shown together in Figure 2, share many features, such as the enlarged hands and lips. However the motor homunculus differs more from one person to the next and over time, so that, for example, the motor homunculus hands of a surgeon increase in size with surgical training.

Figure 2. The Sensory and motor homunculus twins

The fluidity of body awareness is demonstrated by the Pinocchio Illusion in which the nose is felt to extend up to an arms-length out from the face. The illusion can be produced by having someone hold their nose while at the same time touching a vibrator to the biceps tendon of that arm. The nerves from the fingers and nose signal contact, while the vibrator stimulates nerves that signal that the bicep is extending [Lackner 1988]. The person feels their nose stretch as the brain resolves the sensations by extending the neural image of the nose along with the extending arm. Physically, of course, the nose and arm are not moving at all. When the opposing triceps tendon is vibrated the nose feels like it is shrinking. The related 'shrinking-waist' illusion is produced by having someone place their hands on their hips, and then vibrating the tendons of their wrist. This illusion was repeatedly used in a brain-imaging experiment using fMRI to investigate the neural correlates of changes in the self-perception of the size of body parts [Ehrsson et. al. 2005].

TAXTILE NERVE EXTENSIONS

The data from sensors in Smart Fabrics is usually transmitted to a computer for analysis of aspects of the wearer's movement, or location or health. In the other direction, wearable information systems communicate data to the wearer through a head-mounted display with visual and audio interfaces. We propose that an actively tactile textile, or taxtile, can be used to create a unified sensing and communication system tightly integrated with the users body. To demonstrate this possibility we constructed a Smart Fabric that can sense a hand stroking it using the 'tribo-electric effect' that occurs when electrons move between materials that rub together [Barrass 2007]. Most people will be familiar with this effect from science demonstrations where a glass rod is rubbed with silk cloth so it becomes charged and can be used to pick up small pieces of paper. Skin is at the extreme positive end of the tribo-electric scale, whilst polyester, vinyl, and plastics are at the negative end. This means that when skin rubs against synthetic fabrics there is a transfer of charge, which is why polyester shirts are 'sticky'. In tropical climates polyester can be worn more comfortably because water vapor in the humid air allows the charges that build up to dissipate. Cold air holds less water and static sparks can become frequent and irritating if you wear polyester in sub-zero temperatures.

A prototype taxtile, shown in Figure 3., consists of a square of fake fur with a 'nervous system' sewn from conductive thread connected to a microprocessor 'brain'. A level of excitement is computed from static charge generated by stroking the fabric, and sent through the efferent nerve to actuate fluffy vibrating appendages. The result is the highly-strung strangely-geometric run-over poodle-like object we called Scruffy. Stroking Scruffy causes the tail-like appendages to wag in spasmodic frenzy so he quivers all over with what looks like joyful excitement. In colder climates or dryer weather that cause static charges to build up, Scruffy can be excited by people walking over carpet several metres away without any direct physical contact.

Figure 3. Scruffy – a prototype Taxtile

Based on the neuroscience of body image and our experiments with Scruffy we hypothesise that a taxtile could close the gap between sensors in a smart fabric and the perceptual system of the wearer. These 'taxtile nerve extensions' would allow the wearer to perceive information conveyed from the sensors to the brain through the skin. These augmented perceptions would position the wearer, rather than a computer, as the 'smarts' in a wearable information and communications system. In the design sketch for Fauxy the Fake Fur with Feelings, shown in Figure 4. modular 'taxtile buttons' with independent static sensing nerves are sewn in any arrangement, doing away with the need to custom sew efferent and afferent nerves through the fabric to each one.

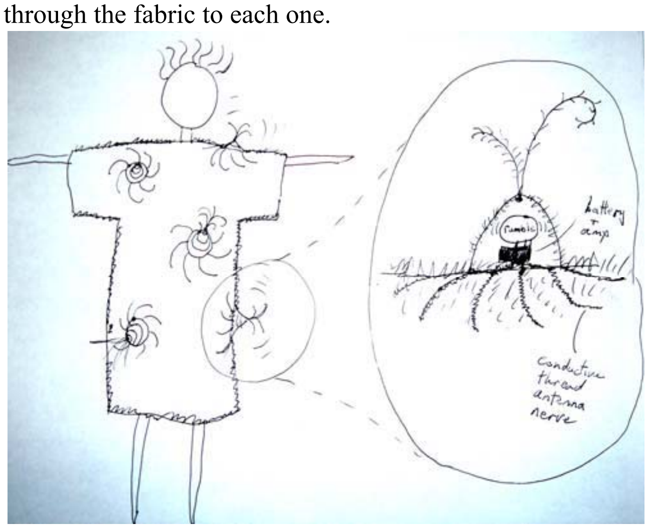
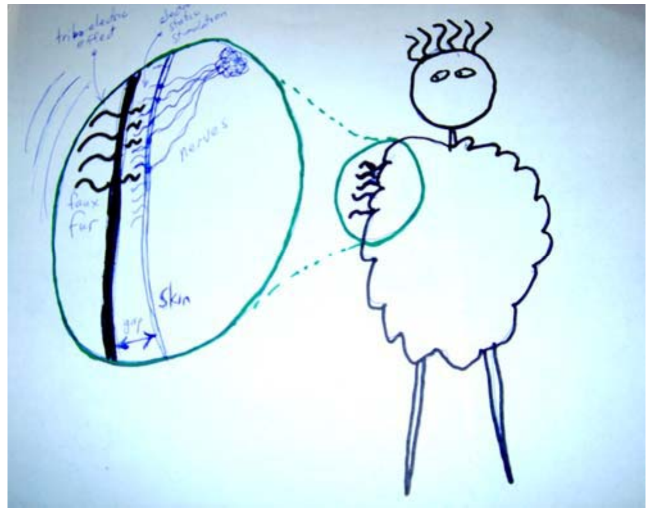


Figure 4. Sketch for Fauxy the Fur Coat with Feelings

The taxtile buttons on the inside of the coat, shown in Figure 5, are prototype 'taxtile nerve extensions' that bridge the gap between the cloth and the skin. These buttons are designed to extend the perceptions of the wearer into the coat, augmenting their skin with the capability to feel static electricity all around. The buttons on the outside have feathery extensions that visually amplify the vibrations for the purposes of external expression and communication. In further work we aim to develop the concept of an animated 'pet' garment that has its own persona and moods independent of the wearer. We envisage Fauxy will become excited when she is taken out of the wardrobe for an outing, and will raise her hackles if someone passes wearing real fur.

Figure 5. Concept sketch for tactile nerve extension buttons



CONCLUSION

We are exploring the concept of 'taxtile nerve extensions' that connect sensors in a Smart Fabric to the 'body in the brain' of the wearer. Based on the neuroscience of body image we hypothesise that these taxtile nerve extensions may allow bodily awareness to flow into the garment, and enable augmented perceptions. The design sketch for Fauxy the Fake Fur with Feelings develops the Scruffy taxtile into an immersive wearable information system. We are currently developing a modular 'taxtile button' that can be sewn on the inside of Fauxy, as prototype taxtile nerve extensions. In future work we will explore the effects Fauxy has on the behaviour, sensations and body image of the wearer. Rather than using a smart fabric to project information about the wearer to the outside world, we aim to project the outside world into the mind of the wearer.

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