I am near my navel: learning mappings between location and skin

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ABSTRACT
We describe a hypothetical device which observes and clusters location patterns, performs Principle Component Analysis, and maps the resulting eigenvectors to haptic sensations along the limbs. In doing so, we suggest machine learning methods to generate artificial sensory motor contingencies in a predictable and meaningful way. Instead of performing simple sensor-to-stimulus mappings, we believe transformations of sensed information can be more purposeful.

Author Keywords
augmented reality, haptics, sensory substitution, hearing aids, augmented cognition, pattern recognition

ACM Classification Keywords
F.2.2.d Pattern Matching
I.2.6.g Machine Learning
H.5.2 Haptic I/O
B.4.2 Input/Output Devices

WEARING LEARNING
We take the view that artificial sensorimotor contingencies can be mappings of sensor signal patterns onto a vocabulary of palpable symbols. Many existing sensory substitution systems make a one-to-one mapping between input sensor signals and actuated output. Furthermore many wearable pattern recognition devices detect complex patterns and classify them. In fusing these two technologies one arrives at wearable devices that recognize patterns but provide a large vocabulary of haptic or audio cues to the wearer. As an illustrating example, we describe the Skinwalker Suit.

SKINWALKER SUIT
Imagine a suit that produces a haptic sensation depending on the person's location. So suppose that the person's home is represented as their navel or belly-button. When the person is at home, they feel a buzz or warm sensation at their belly button. At first the suit represents deviations from the home location where most time is spent as haptic random walks across the skin proportional to the distance from home.

As they wander about their day, the person moves to other locations in their daily ritual: train station, supermarket, workplace, gym, favorite eatery. They also visit some unexpected, infrequently visited locations: police station, dentist's office, government bureau, or concert hall.

The Skinwalker Suit monitors the person's location (perhaps through GPS or electronic markers). The two-dimensional tracks of the person's comings and goings form a rather complex pattern which has previously been modeled as a Lévy flight [6]. However, a person with a daily ritual (even with random deviations) will still expose to analysis obvious patterns which can be extracted using elementary machine learning methods.

Suppose the latitude-longitude pairs of the person's location throughout the day are recorded. These form a cloud of two dimensional points which are oriented on a North-South coordinate system. However, it is possible to perform an orthogonal linear transformation onto the coordinate system that defines the axes along the greatest variance. Principle component analysis (PCA) provides a mathematical procedure for exactly this sort of transformation [7].

So, the Skinwalker Suit records the person's comings and goings. It learns something from patterns in the person's comings and goings. Lastly, it presents what it has learned to the user. This takes the form of haptic stimulus along the limbs. Let's suppose the person's path between work and home produces the greatest variance in the location point cloud. Suppose that movements which correspond to this dimension are then linked to haptic stimulation ranging from the navel to the right hand. So as I leave my home for work it is as if I feel fingers walking from my navel towards my right hand. Likewise, movement along the second eigenvector following PCA might be correspond to haptic stimulus between the navel and left hand.

Such a system might be a novel travel aid or memory aid. It would furthermore be interesting to wear another person's Skinwalker Suit as one could gradually discover their daily rituals.

RELATED WORK
A large variety of work anticipate the still imaginary skinwalker suit. Gault's work in the 1930s demonstrated through psychological experiment that participants could locate the source of an audio stimulus from haptic stimulus [4]. A good number of electronic navigation aids have experimented with haptic cues. For instance, Ertan, et al. discussed a wearable computing system to provide haptic cues for navigation [3]. Wächter's feelSpace belt demonstrated mapping

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of magnetic north to a set of haptic actuators. Wearers of the device would feel haptic stimulus on the part of their body closest to north, even as they rotated [9]. Lindemann, et al. have described directional vibrotactile cuing to speed up the process of exploring and clearing a virtual building [8]. We have studied a system that transforms distance to haptic cues and thus extends the body scheme beyond the reach of one's limbs [1]. Yet other researchers have developed assistive technologies based on a different modality of cuing; for instance, Nemirovsky and Davenport's GuideShoes provide musical patterns as a way to provide guidance from a wearable system [11]. Traylor and Tan created a wearable device that uses directional cues to impart situational awareness [13].

Concurrently, there has been a lot of research on context aware wearable systems. Clarkson describes a wearable sensor systems which perform unsupervised machine learning to recognize context [2]. Many location tracking, classification, and tagging systems have been proposed, including systems capable of automatic classification of the wearer's activity [10].

However, none of these systems explore the combination of high-level location classification with linked sensorial stimulation (in particular not relying in GUI displays or alphanumeric information of any sort).

THE SKINWALKER APPROACH

The Skinwalker Suit is an attempt to merge these two themes in wearable system to provide a learning system which provides wearers with a predictable sensory-motor stimulus to aid them. Our previous Haptic Radar system took the much simpler approach of mapping distance to haptic intensity. The Skinwalker Suit would diverge by learning a meaningful mapping for users; moreover, if it works, the body schema would be extended dramatically in comparison with the Haptic Radar approach. Indeed, the user would be (unconsciously) aware of relative distances between places very far away (and why not also about relevant information about these places - such as local weather, traffic, etc - all conveyed through appropriate and subtle skin stimulation). To which degree such extension is possible is still to be understood; however, a cell-phone or the now extinct pager are evidence that this kind of extension is in a way possible and desirable.

What we are proposing here is to design a system that will help generate a haptic and cortical correlate of the space: the equivalent of the cortical homunculus for the user's location - or *cortical loculus*. One can argue that such a representation of location already exists in a more or less efficient form in our brains; however, (1) its updating requires cognitive effort (and sometimes skill) - and (2) its accuracy may vary widely from person to person as suggested recently [12]. It is perhaps the lack of frequent updating and the very subjective nature of this representation that makes very difficult for us to form (least to master) any coherent sensorimotor map between our wandering and the perceived, multi-sensorial Aura [5] of the place). Our perception of location is not yet concrete and tangible.

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