Coupling Motion and Perception in Body Based UI

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ABSTRACT

In this essay I outline my current work on motion and haptic perception. I start from my perspective on Embodied Interaction, explaining why I chose to design interfaces focusing on the body in motion. I then describe how my research has moved from creating devices that are not negatively influenced by the moving body, to devices that take advantage of the moving body. This research path has led me to investigating how vibrotactile information and proprioceptive cues are integrated and together give rise to an experience of texture. I am searching for generalizable patterns in how we process haptic information, to apply it to other modalities. I believe that this will allow us to create new embodied experiences of sensations we previously only had indirect access to.

Author Keywords

Embodied Interaction Haptic Feedback; Sensory Substitution

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous

INTRODUCTION

Consumer interest in wearable devices is steadily increasing. Within the CHI and TEI research communities there is a trend of wanting to engage with the body in ever closer ways. This trend manifests in two slightly different streams. On the one hand projects are investigating how technologies can move ever closer to the body, for example interactive tattoos [22], makeup [5] and implantable devices [7,8]. On the other hand we are investigating the body itself: what constitutes the body, how can we design for the body, how can the body inform design, how does it mediate perception [10,12,20] etc.

I currently find myself exploring the second category of questions. For me one of the core properties of the body is that it is active agent; in my work I am exploring how the body acting in the world leads to an experience of perception. I am studying tactile perception in search of patterns generalizable to perceptual modalities that are beyond what we currently have access to.

In this essay I will outline the path that has led me to this topic, my current research, and my speculations and hopes for where this research might lead me in the future.

CONTEXT

Embodied Interaction

My interest in haptic perception was piqued by Taylor Carman's essay on the role of the body for Husserl and Merleau-Ponty [4]. Husserl suggests that tactile perception, or rather that we perceive tactile perception localized on our body, leads to bodily self-awareness. However, Husserl describes the Body as something inserted between the material world and the subjective experience of it. Carman contrasts this position with that of Merleau-Ponty, who suggests that the body is more than something inserted between the mental and physical world. Merleau-Ponty suggests that mental phenomena can only occur by the body engaging in the world; that perception is not something that happens through or to the body, but that perception is an activity of the body.

The concept of active perception was also used by Dag Svanæs to describes our perception of interactive artifacts [20]. He points out that interaction is perceived as a whole, rather than as a sum of user inputs and system outputs. For example, when operating a car with a manual clutch, we do not perceive the shifting as a composition of actions and reactions, but we perceive the whole process as one kinesthetic experience. Svanæs describes this as an *interaction gestalt*. When driving one car one day and then switching to another car the next, we perceive the differences in the clutching mechanism: the two different cars give rise to different *interaction gestalts*. Svanæs describes this as the *feel dimension*.

Technological Mediation

Rather than technology as a service that brings information to us, I would like to see technology that expands us, allows us to grasp at information far away in space and time.

A useful framework to discuss such design perspectives was introduced by Don Ihde. He points out different ways in which technology mediates our perception and makes a distinction between embodied mediation and hermeneutic mediation [9]: In embodied mediation, the technology itself does not become an object of perception, rather we perceive

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Figure 1 – Body and experience shape the affordances of objects [21]

the world through the technology. The prototypical example of such a technology is the blind person's cane. Ihde contrasts this with hermeneutic mediation, which also provides information of the world, but has an additional interpretive layer. An example of this is a thermometer, which shows us numbers that we interpret to infer temperature outside. Another example is a vibrotactile notification which we interpret based on context.

Affordances and Interface Design

While we often tend to focus on the virtual aspects of digital technologies, to me, an interface is most importantly a physical thing that we interact with by physical means. Like any other object, its shape, size and appearance are not inconsequential: The shape and size of an object acquires meaning relative to our experience and bodies. Jakob von Uexküll presented the charming example of a tree, describing how a gnarly tree might look scary to an imaginative young child, while a forester might asses it for its resource value. Simultaneously the tree might act as a shelter for a fox, a place to perch on for an owl or as an entire world for an ant (Figure 1) [21].

The idea of objects acquiring meaning relative to our bodies is related to Gibson's theory of affordances [6]. Gibson suggests that we understand objects in terms of what they enable us to do with them. For example, a tea-cup has the affordance of holding a fluid, and its handle suggests to us how we can pick it up.

Objects have affordances based on their shape, and are understood relative to our bodies and experiences. If an objects shape fits the human body, like the grip of a skiing pole or an ergonomic mouse, it suggests how it might be used. By explicitly addressing the body's shape and function, well designed objects need no further instruction manual to be used.

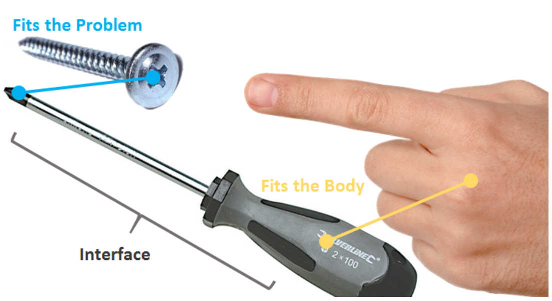

Figure 2 – Tool as interface between the body and an object poorly suited for interaction with the body

Sometimes however a device does not fit the body. For example, a screw has the affordance to hold two pieces of wood together, but its shape does not conform to our body in such a way that we can easily use it: The screw does not have the affordance to be rotated by us. That is where tools come in.

A tool (in this case a screwdriver) has two parts: one that fits the problem (the screw) and one that fits the body. The screwdriver extends the screw and the body, so that as a system we can drive the screw into the wood (Figure 2). The screwdriver can be seen as something corresponding to a computer interface: The CPUs in our everyday devices have affordances that are important to us, they conduct calculations we are not capable of. However, the CPU itself is difficult for us to interact with. Much like the screwdriver mediated between the body and the screw, we need a tool that fits both the CPU and the human body. In practice this tool consists of a chain of tools, the user facing side of this chain is what we refer to as the interface (These ideas are inspired by Bret Victor [2]).

Based on this perspective, interfaces should be designed to have the best possible fit to the human body. Based on the embodied perspective of the body discussed above, the interface must not only fit the body as one objects shape might compliment another, it must also fit the body as an active agent in the world.

PAST WORK

Respecting the body in motion

As pointed out by Marshall and Tennant, there are few interactive systems which allow and facilitate the body to move freely. Gestural input typically constrains body movement to a predefined subset, while 'mobile' systems usually assume that the user will intermittently interrupt their primary activity and stop to use them [13].

Together with Jesse Burstyn I designed DisplaySkin to address this issue [3] (Figure 3). DisplaySkin is a wrist-worn device with a cylindrical display that wraps around the wearer's arm. We designed DisplaySkin to be 'pose-aware': using a kinematic model of the user, we adjusted content on the device to the user's perspective, so that the wearer could glance at the devices content independently of body pose.

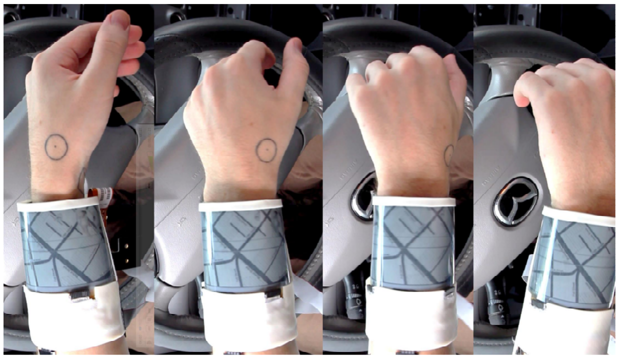

Figure 3 – DisplaySkin: Note that the image remains stable while the hand rotates [3]

While DisplaySkin did not constrain the user's motions, I was hoping to go beyond that. In addition to accommodating motion, I was interested in designing a device that becomes better through human motion or that takes advantage of human motion.

Working with the body in motion

We use motion and actions to understand the material world around us. We might rub fabric between index finger and thumb to feel its texture better, or sit down on a bed to feel if it is soft or hard. The next project I worked on, ReFlex [17], explored this concept: Using a strain gauge, we measured how much pressure was being exerted on a flexible smartphone prototype (Figure 4). We used this to infer the extent to which it was bent.

The smartphone prototype had an embedded recoil-style haptic actuator [23]. With this actuator we generated vibrotactile feedback based on bending of the phone. We compared generating feedback relative to the extent of the bend (High frequency when the phone is strongly bent, low frequency when it is only slightly bent) to feedback based on the actions of the user (High frequency while the shape of the phone is being changed fast, low frequency while the shape is changed slowly, and no vibration when the phone is resting in any given shape). We found that if we provided pulse trains relative to the rate with which the users changed the shape of the device (so relative to the users motion), these pulse trains were not experienced as vibration, but instead changed how the material was experienced. The haptic impulses made users feel as if the material was more complex and was often described as being either less or more flexible than without feedback.

Figure 4 – ReFlex: Flexible Smartphone Prototype [17]

This suggests to us that the vibrotactile actuation and the motion is integrated, leading to a new sensation. Using Svanæs terminology, the interaction was not perceived in distinct action/feedback pairings, but gave rise to an *interaction gestalt*, which was experienced as a change in the *feel dimension* of the device.

CURRENT WORK

Perception Through Motion

Similar studies have also shown that if vibrotactile feedback is coupled closely with motion or pressure, these are perceived as variations in the physical properties of the vibrated material [11,16]. This is not surprising if one considers haptic perception as a closed perceptive loop [1].

I am currently exploring this closed loop of perception. Using a similar haptic actuator as used in ReFlex, I am exploring how material perception is influenced by individual parameters of haptic feedback. In an initial study, using a low friction slider augmented with the actuator, I have explored how granularity, amplitude and timbre influence how a material is experienced, if vibrated relative to how it is being moved. Results show that this method and the parameters chosen can be used to generate virtual textures. However, results also hint towards a more complex relationship between motion and actuation than initially assumed, especially the role of timbre in vibrotactile feedback should be explored further in future work [19].

FUTURE WORK

Concepts

Technology has the potential to provide us with access to sensory dimensions beyond those that we are familiar with. Moon Ribas uses technology to 'feel' earthquakes, while Neil Harbisson uses sound to perceive color [14]. We might imagine technologies that enable us to perceive ultra violet, or bat echo-location, wireless communication, or stock market activity. To perceive these in the *feel dimension,* or in what Don Ihde refers to as *embodied mediation*, rather than as symbols we need to interpret, we must design interfaces that present the information suiting the body. This means considering the active nature of perception and designing kinesthetic experiences that we can actively explore.

In my previous work I have demonstrated how the body integrates perceptive stimuli and actions, giving rise to an *interactive gestalt.* In my current work I am exploring how this resulting haptic experience can be manipulated. In future work I plan to explore applying these observations of haptic perception of materials to in air interaction: By providing the three-dimensional space around us with structured textures, different spatial directions can be given a different *feel.* This can be used to provide gestural interfaces with affordances to help users understand what gestures are possible, or how to perform them.

In an additional step, such virtual textures could provide us with sensory experience we typically do not have access to. For example, the north-south dimension could be given a different feel than the east-west dimension. Light with strong ultra-violet content might be made to feel 'harder' than light less harmful to our skin. These extra-sensory dimensions could also communicate information not typically linked to sensory experiences, for example, the space around a credit card could provide a varying haptic experience based on the current account balance. Doorways and entrances could provide the people crossing through them with a tactile experience of what to expect beyond them etc. For all these examples, the intent is to limit interpretive steps required to understand this information, designing what Don Ihde would refer to as *embodied mediation.*

Possible Implementations

Such *feel dimensions* could be presented to users with wearable haptic devices. A simple implementation might be a wristband with an IMU and a haptic actuator. This device might create a physical experience of time by generating its *feel dimension* using the motion and orientation of the hand as input and modulating it based on events and scheduled activities of the user.

An alternate approach could use an implanted device [18]. Such a device would have the benefit of being always present, which may lead to it being better integrated with the user's body-schema. Fully encapsulated devices with a haptic actuator are currently feasible, and various non-academic groups have started experimentation with implanted devices. The fidelity of such devices could further be increased with direct nerve communication, though such devices are still highly experimental [15].

CONCLUSION

In this essay I have outlined some concepts that guide my work. I have described how wanting to design devices that consider body pose eventually lead me to studying perception. In studying haptic perception I have found that we integrate vibrotactile feedback and motion: if the coupling between action and haptic feedback has a sufficiently high temporal resolution, vibrotactile feedback is no longer perceived as vibration but gives rise to a new experience, a new *feel dimension.* This provides us with a new set of tools for the design of interfaces and experiences that are explicitly based on the user's body and the active nature of perception. In the future I wish to apply what I have learned about haptic experiences to other modalities, with the intent to create embodied experiences of sensations which we usually only have symbolic access to.

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