Describing Haptic Phenomena

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ABSTRACT
This paper presents an overview of the tactile properties based on tactile languages, such as Braille and fingerspelling. The unique spatial and temporal properties of touch through use of exploratory procedures highlight the amount information available through touch. The authors make recommendations for haptic visualization to actively engage exploratory procedures and exploit context from other modalities.

The authors present a mobile device augmented with tactile UI feedback. General observations based on public awareness to the haptic phenomenon are described.

Author Keywords
Tangible interfaces, tactile communication, fingerspelling, deaf-blind, mobility aids, blindness, paging, telecommunications, multimodal sensory perception

ACM Classification Keywords
H.5.2 [Information Systems]: Information interfaces and presentation (H.5) (I.7)--User Interfaces (D.2.2, H.1.2. I. 3.6) Graphical User Interfaces (GUI); Haptic I/O

INTRODUCTION
The sense of touch can contribute much to enhance perception in other modalities. What follow are observations on the use of exploratory procedures, tactile languages, and current HCI research on touch.

Haptic Exploratory Procedures
The haptic exploratory procedures (EPs) demonstrate how touch can be both an active and passive way of interpreting information [13]. A series of lateral sliding motions made by the hands over an object give a vast quantity of unique information (identify texture, hardness, weight, volume, shape or contour). This subset of active EPs (lateral motion, pressure, static contact, unsupported holding, enclosure, and contour following) show that haptics is very powerful way to gain information on how an object might be manipulated.

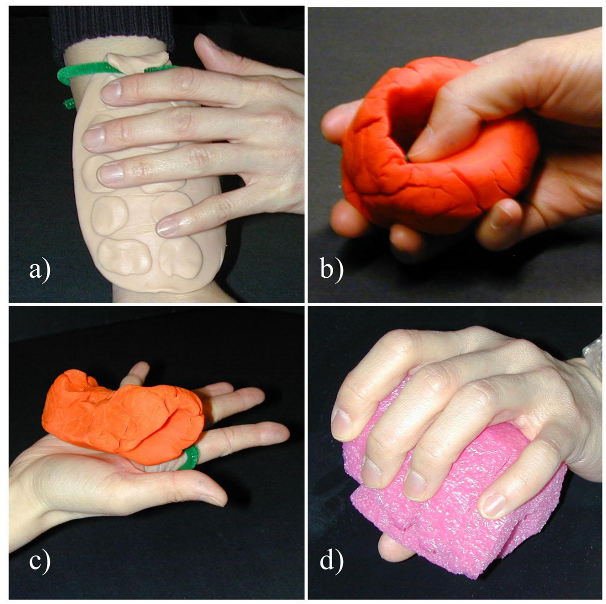

Figure 1. Subset of Exploratory Procedures (EP) depicting lateral motions for finding a)texture, b)pressure, c)unsupported holding, d) grasping.

The display of tactile information on the skin complements information perceived by other mediums (taste, sound, sight and smell) [1]. Furthermore, the sense of touch provides a means to act upon an object (e.g. by lifting, pushing or joining two parts together). Many interactions with the environment occur through touch. Even the toes in your shoes give you information about the ground, as you feet press down on the floor and make noise with your footsteps. Touch is used to manipulate interfaces, e.g. doorknobs, audio knobs, joysticks, mice, and keyboards [4].

Relative to the person, touch is useful for gathering information about details smaller than a person, within a person's immediate space. Normally, tactile interfaces rely on the hand as the input area and information is sensed and acted upon by the fingers, such as in the EPs. In contrast, audition and vision are useful for gauging spatial information relative to a person. Table 1 summarizes some qualities of haptics relevant to information gathering.

Spatial and Temporal Display Properties
As a display, touch can relay a lot of information: textures, temperature, force, shape and relative sizes. One of the problems with relaying this information to another person is

	Touch	Audition	Vision
Information given relative to person	Useful for details smaller than a person	Useful for gauging distance relative to a person	Useful for gauging size and distance relative to a person
Temporal aspects	Identification by parts. Information is gathered by sensing information over time.		Vision uses both part and whole images to identify whole things
Active and Passive Identification	Active and Passive methods for information gathering (e.g. applying pressure or echolocation)		Passive only
Spatial aspects	One-to-one only, a close proximity sensory experience	Can be close or remote, can be broadcast	
Illusory Possibilities	Touch is hard to fake	Easy to represent, replicate, reproduce digitally	

Table 1. Comparison of haptics attributes to audition and vision.

that there is a lack of vocabulary or common terms for expressing this information between people.

Haptics is spatially constrained to what can be felt over the skin. Touch conveys a wealth of information, and is our most intimate sense [3]. One of the features of haptic stimuli is that they are confined to our skin. With the exception of remote communication devices used in research or the use of tactile languages, tactile perceptions are not usually transferred between people across space.

Haptics is temporally dissipative. When a haptic sensation occurs, our haptic receptors generally begin to tune the sensations out. Thus, relative changes in haptic stimuli are perceived more easily. Our haptic sense relies on the perceptive ability to piece together haptic information from different spatial regions of our bodies and relate the change of haptic sensation over time. This makes haptics an ideal medium for transmitting information.

Tactile language displays

A brief look at existing tactile languages gives insight on how well touch conveys information. Tactile languages are subdivided into two classes of languages, alphabetic and symbolic. The first class, alphabetic language uses the representation of the alphanumeric letters to form words. Examples are chording keyboards, Braille, Moon, and telegraphs.

Conversely, symbolic language represents higher-level concepts that are not mapped directly to words, but rather, abstract ideas and expressive emotions. Examples of symbolic language are facial expressions, hand gestures and body language for expressing interest and emotional state.

Symbolic and alphabetic language can be combined in a language. For example, Morse code is one example of such a combination of methods. In one study of Morse code, users started out by learning individual letters. As the time of usage increased, a symbolic language emerged and it then became hard to distinguish individual letters in transmission. After a while, expert users were able to recognize whole sentences using shorthand and perform simultaneous encoding of messages in addition to decoding Morse messages.

Fingerspelling, a tactile language where the pressure and movement of one hand is received on another hand, is another example of a tactile language that has capabilities for both symbolic and alphabetic language [15]. It is interesting to note that fingerspelling makes full use of the EPs, particularly reliant on relative lateral motions between the hands of the receiver and sender, and has faster transmission rates than Morse code.

Tadoma is a method of speech reading using touch, where the receiver places his thumbs on the lips of the speaker, with fingers on the throat [16]. Intonation information was available from the vibrotactile stimuli at levels reliably about 70% [2]. Touch combined with other modalities (such as the use of touch and vision in Tadoma), seems to offer greater depth in communication.

Research on vibrotactile devices such as the Tactaid, show that speech recognition increases dramatically when audio and touch input are combined in speech reading [16]. By coupling the audio channel with the private sense of touch, sensory redundancy can allow for faster and more accurate transmission of information.

Various researchers have also been able to synthesize textures by combining haptics with vision [12, 14]. An equally vast amount of research has also focused on simulating forces (by using force feedback devices like the Phantom). These displays have been developed to provide navigational and geographical information [11] and also for entertainment [9].

RECOMMENDATIONS FOR HAPTIC VISUALIZATIONS

Given the breadth of additional information haptics can provide, it seems very likely that haptic visualization techniques should take advantage of exploiting differences from vision and audition. General principles for the haptic visualizations are suggested:

1. Use of EPs to interact with display information. By enabling a user to directly manipulate information, the resulting deformations can provide unique tactile information. By affording EPs into an interface, a closed feedback between the user and the display can give the user a more intuitive grasp on the information.

2. Incorporate other modalities to support the interface. Context is highly reliant on an integrated sensory experience, and the perception of context is more accurate when there is redundant sensory information

Tangible haptic visualizations and evaluations

Figure 2. Tangible Media Group's metaDesk allows how users manipulate and display information simultaneously.

There are many examples of haptic visualizations within the HCI community. For brevity, only one example of haptic visualization projects that incorporate active EPs is mentioned. The visualization projects from Ishii's Tangible Media Group, such as metaDesk in figure 2 [10], use haptics as both an input and output for information display. The spatial coincidence enables abstract information to be represented and manipulated, for example, how altering the position of building affects shadows and wind flow. The reinforcement of haptic input (and physical display) with visual cues from the work surface gives users a way to intuitively visualize information not readily apparent. Note that in communication devices, however, this spatial coincidence might also confuse users who are looking to distinguish their manipulation from the output signal [3, 6].

The evaluations for haptic visualization interfaces have been comparable with evaluations for visual interfaces. Indeed, leveraging known interfaces (such as desktop metaphors) seems to enable users to learn new interfaces quickly. Many psychophysical evaluations have been done on the cognition of haptic phenomena [13], for example, Geldard's experiments on ability of people to learn body english [8]. Other evaluations have focused on understanding the thresholds of haptic control and perception (e.g. perceiving information from spatial haptics [7], finding the detectable resolution of vibration) in order recreate haptic displays to match the resolution of human perception. Many HCI studies also seek to identify interaction techniques that can be designed into the affordances of next generation interfaces.

GENERAL KNOWLEDGE OF HAPTICS

The combination of temporal and spatial information provided by haptics to reinforce perception and communication is ubiquitous. For many years, vibration in mobile devices, such as pagers and cellphones, alerted people of calls or messages. The ubiquity of vibrating alerts in mobile devices has also misled many consumers to believe haptics is equivalent to vibration, which some haptics researchers may find interesting.

Workshop presentation

At the workshop, the authors will demonstrate a mobile phone with enhanced tactile resolution and haptic user interface feedback. This augmented mobile phone was demonstrated at Designing Interactive Systems Conference 2004, and the resulting evaluations have been submitted for a paper at the current CHI [5]. While these evaluations were very basic, general comments received about haptics provide an illustrative example of the public knowledge about haptics.

There appears to be a large vocabulary gap between the scientific and HCI community and haptics understanding in the common usage. Quality in consumer products often relates directly to touch (weight, surface finish, and contours). However, there is little vocabulary to describe haptic sensations. When asked to describe haptic quality, a surprising number of people would relate haptic vibrations to audio [5]. Figure 3 displays the spectrograms of two audio files used for comparison. Many people simply said "it feels different", but were unable to say why.

This lack of expressiveness about haptics is surprisingly minimal in contrast with that of the sense of smell. Before the days of aromatherapy, there was little conscious awareness of the cause and effect of smell. In fact, until marketing began to become popular, body odor was not considered a problem [17]. People did not typically describe smells, nor did they obsess about altering them. Nowadays, people can identify common scents in products (cinnamon, vanilla, bayberry, cologne scents) and they can also understand smells can be controlled and distinguish differences between smells. The common vocabulary for smells has increased from merely "strong or noxious" to a myriad of descriptive phrases "lavender, rosemary, spearmint, bergamot, etc". Furthermore, there is a vast amount of consumer interest in creating scents (one can easily find recipes online for air fresheners, relaxation, and medical therapy). The large perfume market gives evidence to the fact that "smell is a commodity" [17, p. 62].

Raise Haptic Consciousness

One way to raise consciousness is to create objects that stimulate the haptic senses more directly. Various force-feedback and vibration gaming joysticks have incorporated haptics sensations for years. Certain phones include haptics as a feature inherent in audio quality. Digitally controlled haptics is subtly integrating into consumer products, but it is still very hard for consumers to distinguish and disseminate haptic sensations. Could this lack of definition be due to the dearth of vocabulary to describe haptic qualities in our culture?

The visualization of haptics might be a challenge because of the lack of awareness of haptic phenomenon in popular culture. It is rare to find language for distinguishing the roughness of textures from one another (e.g. dotted pattern versus serrated rows). There are few common ways to describe a vibration profile (sawtooth vibrations versus sine waves). For example, try to describe the difference in tremors in the floor due to heating systems "oscillations", traffic "rumblings" and earthquakes "shockwaves". Even

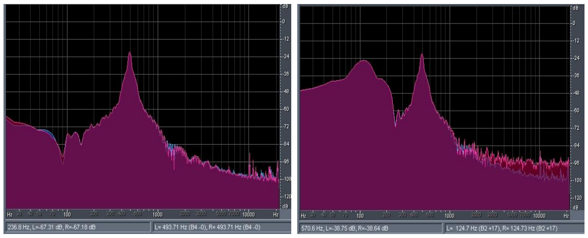

Figure 3. Spectrograms describe the difference between a) audio sound and b) vibration-enhanced audio. People were only able to describe the vibrations very generally.

among researchers in haptics, there are few generalized terms to describe force profiles or vibration envelopes.

A quick survey of the consumer marketplace finds that many haptic experiences are targeted to the high-end of consumer product lines. Force feedback joysticks are high-priced and geared toward the gaming public. Devices touted for their tactile qualities, such as high-end audio equipment, are more expensive than offerings for the general public. In most cases, devices displaying greater vibration control are targeted to special-needs users. The target market for haptic devices seems to be very specialized and narrow.

Perhaps social consciousness will be raised when product literature incorporates descriptive expressions for haptic information that can be repeated and discussed by the general population. Once the public can express the value of haptic sensations, haptic visualization may be more common.

CONCLUSION

The sense of touch can contribute much to enhance perception in other modalities. Haptic visualizations should utilize active exploratory procedures and integrate context information from other modalities. By making use of active EPs, haptics stimuli can add information not available to other senses.

A general issue for haptic visualization is that there is currently little consumer understanding of haptic phenomenon. Further work will have to be done to raise the public consciousness and educate the world about understanding and describing the sense of touch.

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