An Exploration of Representations to Aid Design of Haptic Behaviours

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ABSTRACT

Haptic representations need to support human goals, capabilities, and desires. Thus a challenge is to create usable and intuitive haptic representations of intangible real-world ideas. To support this challenge of designing better haptic interfaces, we need better abstract representations of haptic signals, and of the space the signals represent. These representations will (a) help designers explore the design space in a structured way; (b) facilitate communication among haptic practitioners – improving design practices more broadly; and, (c) potentially enlarge the design space, because exploration of alternatives can reveal gaps and areas for improvement. In this paper, we introduce a possible design space with the goal of raising questions about how to represent relationships between social & technical information and physical haptic signals.

Author Keywords

Haptics, Haptic representation, Haptic information design, Social computing guidelines

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous. H1.2. Models and principles: User/Machine Systems

MOTIVATING EXAMPLE

Suppose Wendy, a blind person, is standing at the corner of a busy street intersection. An audio 'chirping' sound changes in synchrony with the traffic lights. Distinguishing the change in 'chirping' sounds, she proceeds to safely cross the street.

Now suppose Wendy is at a similar street intersection without 'chirping' sound indicators; but, she has a haptic navigation aid (e.g., in her cane or embedded in her clothing) that gives her tactile cues to safely guide her across the street. To be effective, the haptic cues must be perceptually different to Wendy. In addition to functioning properly, the haptic navigation aid must fit into Wendy's lifestyle for her to purchase and regularly make use of it.

HIGH-LEVEL POSITION

The above example illustrates the importance of designing appropriate and desirable haptic behaviours for assistive devices. Designing such behaviours is important not only for assistive devices but for all tools. In this paper, we tackle the problem of developing haptic representations to support design activities. We explore two key challenges relating to haptic representation:

1. ***Meaning:*** What information (e.g., a fact, concept, or idea) is invoked and manipulated within people's minds during all aspects of performing a haptic task?[1]
2. ***Haptization:*** What haptic artifacts do people sense and exert while performing a task? We use the term haptization to mean the haptic equivalent of visualization or auralization for sight or sound, respectively. A haptization helps a person use and communicate meanings haptically.

OVERVIEW

In the *Background* section, we summarize example projects from our research group in an effort to describe a diverse range of haptic representations. We then propose a general design space that encompasses the haptic representations within these example projects. Next, we relate two more detailed examples to our preliminary design space – one to support each of the two primary design components *meaning* and *haptization*. We conclude with a list of questions that we would like to explore in the near future.

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[1] Note that we are *not* referring to the challenge of literal virtual haptic rendering of real world haptic sensations.

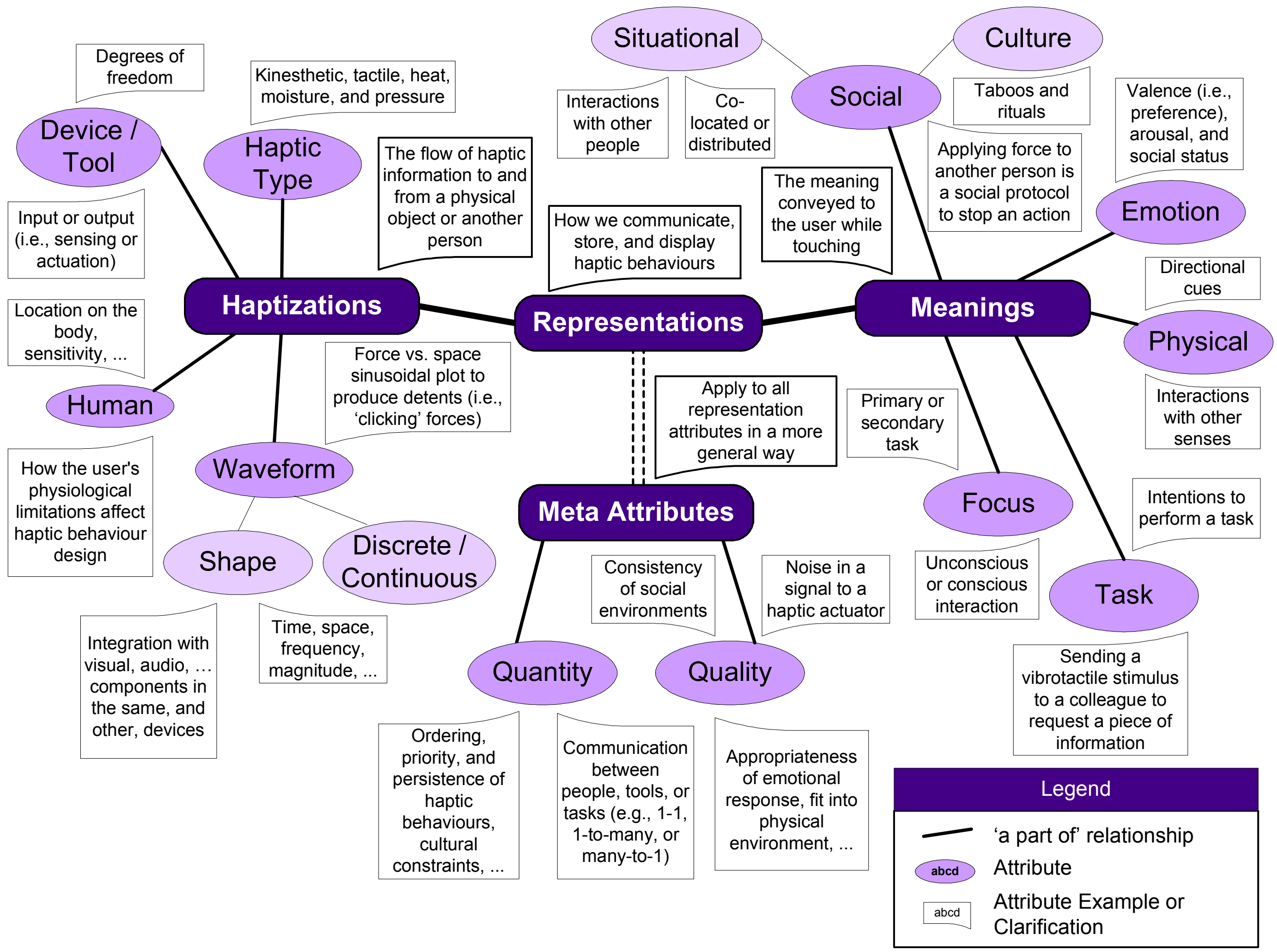

Figure 1: Possible Design Space of Haptic Components

BACKGROUND EXAMPLES

When focusing on perceptual and device characteristics, we are interested in the mechanics of touch. Good representations must be within the limits of human perception and they must be distinguishable from other haptic behaviours to be effective. Furthermore, users must be able to associate behaviours with appropriate meanings.

In order to create distinguishable haptic representations, designers need to know how much change is required for one behaviour to feel like a different behaviour, and to understand how haptic sensations are classified. For example, is frequency or amplitude more salient in determining the similarity of two signals? These issues are discussed with regards to haptic icons in MacLean & Enriquez [1].

Another important aspect of designing haptic representations is the ability to associate them with desired concrete or abstract meanings. For example, how should forces be applied to a user's hand to guide them along a safe path [4] (i.e., associate haptic stimuli with direction).

Social aspects of touch interaction are equally important. For example, haptic interfaces must be socially appropriate to gain long term acceptance. Forsyth [4] compared various haptic guides for aiding navigation along a predetermined path. For such guides to be successful the signal must be one that people will accept and use rather than fight.

Sometimes, older technologies have an advantage of providing a very hands-on-interaction compared to newer technologies designed to perform the same task. Haptic interfaces can potentially combine the advantages of hands-on-interaction with those of digital systems. But, to be successful, physical user interfaces such as the D-Groove DJ system [1] must provide an interaction that feels right.

Different haptic behaviours may elicit different emotional responses. Appropriate haptic representations are likely to consider these responses. Thus, an area of interest is in finding relationships between visceral preferences and physical characteristics of dynamic haptic behaviours.

Haptics can be used to facilitate more natural computer mediated human-to-human interaction. In this context, it is important that the haptic interaction be socially acceptable. One example of such a haptic interaction is using vibrotactile icons to facilitate turn-taking protocols in distributed real-time collaborative environments [2]. On a more intimate level, we are interested in exploring haptic representations through which people can convey and receive affective states. Such representations will need to be considered socially appropriate in order to be accepted

DESIGN SPACE OF HAPTIC COMPONENTS

The above examples present some aspects of haptic design. An ideal haptic representation would address how information is interpreted and remembered (i.e., *meanings*), as well as the development and use of physical haptic signals (i.e., *haptizations*). Figure 1 is our initial annotated organization of the primary components that we believe need to be addressed. We believe that a refined and expanded version of Figure 1 could be used as a the basis for organizing haptic design heuristics.

EXAMPLE CASES WITHIN THE HAPTIC DESIGN SPACE

To support the components shown in Figure 1, we explore more detailed, concrete examples for each of our two key challenges, *meaning* and *haptization*.

Meaning Example

We receive many messages through our sense of touch from facts (that burner is hot) to complex emotional messages (I care about you). Given the ability to physically actuate IO devices, we are interested in the kinds of haptic representations that can be created to deliver information to computer users. We explore one way haptic representations can be used in computer mediated collaboration.

Work has been done on creating short haptic signals that can be used as distinguishable units of meaning (i.e., haptic icons). From a haptization perspective we are concerned with how these icons can be represented and created. Here we look at an example of the messages that these haptic icons can represent and how they can be utilized.

The vast majority of software is designed to be manipulated by a single user. Tools exist to support collaborative work by allowing multiple people to view a single instance of an application. These tools provide varying facilities for the viewers to assume control over the application, with the limitation that only one person can control the application at a time. A haptic protocol for turn taking was developed by Chan & MacLean [2]. Below we discuss this protocol in the context of the meaning region of our design space.

This protocol is situated in a distributed collaborative work environment and thus should fit within the social norms of this situation. For example, a protocol that only supported users grabbing control from one-another violates the cultural norm that in collaborative situations the person in control generally has some control over releasing it. At the same time, the protocol may give the users the option of grabbing control relying on cultural norms and taboos to regulate use of this control mechanism.

The emotional involvement among users of such a protocol is likely to be that of colleagues and so the representations used should not be overly intimate. For example, the

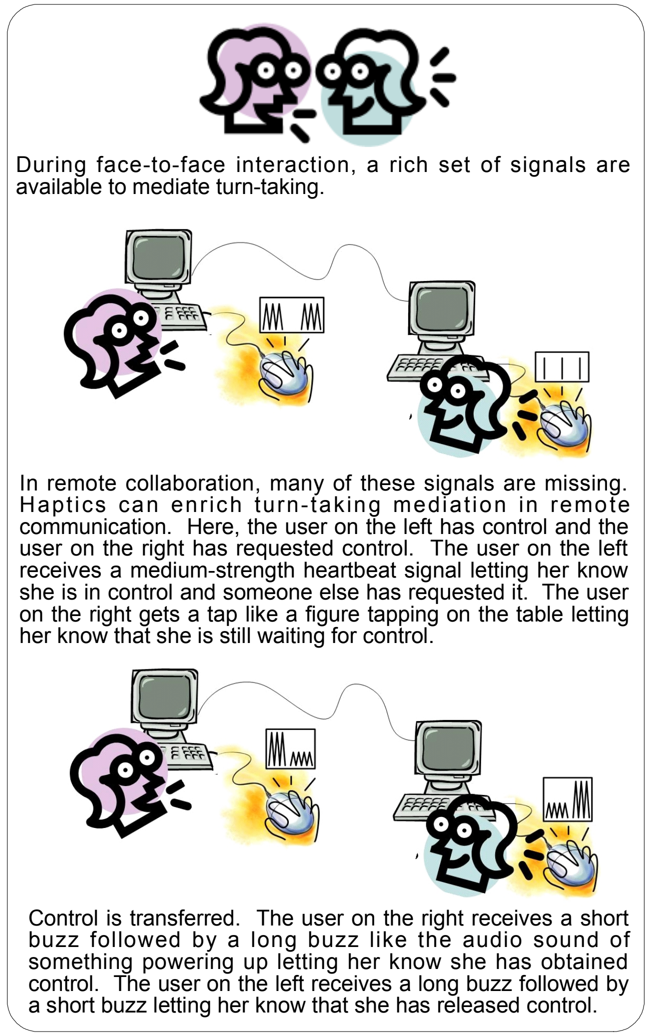

Figure 2: Example social turn-taking protocol between two people concurrently collaborating on the same document

metaphor of tapping on a table used to convey waiting for control is appropriate but the metaphor of tapping the person in control is probably too intimate for the situation.

In this situation, the work being done on the document is the primary task and turn-taking is a secondary task. Thus the haptic representations must not require the user's full attention and should be delivered through a device that does not require them to entirely disengage their focus from the primary task. Therefore, the protocol used haptic icons to indicate the current turn taking state through a Logitech iFeel mouse. The mouse is already part of the user's interaction and does not require additional overhead to use. An additional study with the haptic icons verified that users could use the icons while concentrating on another task.

Design of this protocol required determining the states that needed to be represented (based on the situational context) and then designing appropriate representations (with the considerations above). It was also important to consider perceptual constraints and develop representations for related states that were similar but distinguishable. Finally, representations were used that could be easily related to the state. Figure 2 illustrates an example of control transfer.

Haptization Example

We have experimented with several waveform editors to design kinesthetic behaviours for haptic knobs (i.e., the positional and temporal input attributes of the user's hand on the knob determines the output torques supplied by the knob). We group these editors into two major categories:

- *Static Editors:* Haptic behaviour is conveyed to the hand *without* taking into consideration input from the user (i.e., a haptic icon).
- *Dynamic Editors:* The user's interactive hand motion on the knob changes the resulting haptic behaviour conveyed to the user in realtime.

Figure 3 illustrates very simple static and dynamic representations via independent axes A) and B), respectively. A sine wave over time will apply an oscillatory torque to the knob, regardless of user response. A sine wave over space will create the feeling of detents as the user actively rotates the knob.

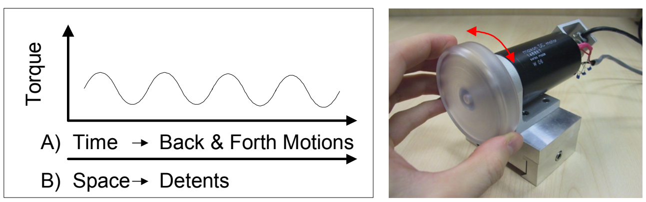

Figure 3: Example waveforms for creating simple rotational behaviours with a haptic knob

We have and are experimenting with composition of more complex behaviours (e.g., see Enriquez & MacLean [3]). Additional editor features include the following:

- Interactive line editors with a mouse.
- Development of haptic primitives that can be merged and superimposed into more sophisticated behaviours.
- Inclusion of angular velocity, acceleration, and state changes (e.g., input from additional humans or devices) to enhance interactivity.
- Recording of knob motions by the user.
- Changing the waveform noise level, discretization accuracy, and timing synchronization to simulate behaviours for inexpensive, mass produced devices.

'Haptic tiles' and 'Prioritized graphs' are two examples of more sophisticated haptic behaviour design tools that we are beginning to develop. 'Haptic tiles' is a concept similar to many video editors. Primitive tiles can be concatenated and merged into more complex tiles. These more complex tile representations can then be classified as a custom primitive tile for future use in even more sophisticated behaviour designs. Tiles could also produce conceptual effects such as 'harden', 'more squishy', or 'springy'.

'Prioritized graphs' is an interactive editor concept for rapidly exploring the effects of multiple variables including time, rotary position, velocity, and acceleration. Interacting with one line graph will automatically change the lines on adjacent graphs.

GUIDING QUESTIONS FOR WORKSHOP

We would like to directly explore the two previously mentioned key challenges relating to kinesthetic representation, *meaning* and *haptization*. We propose the following activities for the workshop:

- Brainstorm and sketch ways to represent the haptic attributes in Figure 1. This should include choosing a small number of concrete haptic behaviours and example applications of interest to the workshop group. We could collectively discuss ways to represent behaviours for these examples. Afterwards, we could use these concrete examples as a springboard for discussion of more abstract, general representation concepts such as the strengths and weaknesses of the attributes in Figure 1.
- Develop rapid prototypes of some the ideas resulting from the above brainstorming session including:
  - Graphical user interface mockups using Flash (e.g., interaction sequences of turn-taking protocols, emotion communication devices, representation editors).
  - Exploration of haptic knob and/or vibrotactile behaviours using custom software and hardware supplied by our laboratory.
  - Physical mockups using materials such as acetate sheets, tape, paper, foam core, and cardboard.

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