Guidance on Tactile Human-System Interaction: Some Statements

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ABSTRACT

When compared to other kinds of perception, haptic perception has several special aspects. This paper presents a proposal for definitions of haptic perception and tactile interaction. These definitions are designed to support the process of developing interactive systems with haptic perception and tactile interfaces. To give an impression of the complexity of needed guidance, the difficulty of coding tactile information is further illustrated by example.

Tactile communication can be classified into three levels which are suggested as a useful structure of guidance for developers of interactive systems with tactile components. Some proposed general guidelines on designing tactile output should be the basis of further discussion on what guidance seems to be possible at the present stage of knowledge and what further investigation should be done. The summary contains an appeal to use system-oriented approaches. The aim of this paper is to give input for further discussion.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces—*standardization*

Keywords

Guidelines, haptic, interface, standards, tactile

1. INTRODUCTION

Human-system interaction is based on human activities as a mixture of multimodal perception, cognitive and intuitive mental processes, and motor actions.

Human capabilities to interact with systems are a result of basic resources, learning, and environmental influences. Design and development of interactive systems is based on well defined technologically and economically oriented knowledge and on ergonomic knowledge mostly presented as guidelines. Guidelines for developing computer supported systems have been concentrated on graphical user interfaces for a long time [8, 9, 10, 11, 12, 13].

With the growing impact of information technology in daily life there are at present good reasons for adding some guidance for other types of user interfaces, especially for those containing tactile interactions. Although haptic perception is a very basic human sense some serious reasons exist that the knowledge and methodology for describing tactile interactions is more complicated in comparison to visually dominated interactions. The most important reasons for this are:

- the haptic perception system is not concentrated on two organs like eyes or ears but are distributed — simply spoken — over the whole body,
- the transfer of thermal and mechanical energy from the environment into the human body has to be described not only in one dominating measure (e.g., radiation in the case of vision, pressure in the case of hearing), but in a multidimensional manner (i.e., force, pressure, distance, velocity, acceleration, strain, etc.), and
- there is practically no writing system, like grapheme- or phoneme-based systems, to describe haptic patterns.

The complexity of tactile interaction can be found in handbooks containing commonly accepted traditional knowledge on perception and human performance [1].

Guidelines are needed for tactile/haptic interactions.

Guidelines are needed for documenting and describing tactile/haptic patterns.

2. HAPTIC PERCEPTION AND TACTILE INTERACTION

For human-system interaction it seems to be helpful to distinguish clearly between "tactile" and "haptic". Although some definitions exist for these terms, e.g. [18, p. 204, 228, 229] the following point of view (new contextual definition) has some advantages:

- The term "haptic" should be used in cases of passive perception only. Passive perception means that no motor actions with the purpose of getting the haptic information are involved.
- The term "tactile" should be used in cases of human activities (interactions), based on haptic perception, in combination with purpose oriented (goal driven) motor actions.

Flux of mechanical and/or thermal energy is involved in both cases. That is the beginning of a very difficult matter: How can you describe, in terms and measures of energy flux, the haptic perception and the resulting haptic or (more complicated) tactile pattern recognition.

For some special conditions, well known methods exist for this problem. For example, at a very basic level, the interaction of key stroking can be described as a function $h = f(F, t, c_i)$, where h is distance (height), F is force, t is time, and c_i are other parameters, describing technological influences of interaction. Commonly, some special characteristics of this function are used as deputies for representing the whole function f.

Other functions, describing the transmission of signals via a system, are concentrated on dependencies of the interaction from signal parameters like frequency, nonlinearities, noise and other measures of system-signal-theory. This way of describing tactile interaction is applied in biomechanics frequently. The corresponding biomechanical knowledge can be useful for defining peak values of forces and other mechanical measures (e.g., level of mechanical vibrations) but it is not directly usable for guidance on designing tactile interactivity.

Guidance is needed in the definitions of common terms (e.g., haptic, tactile).

Guidelines are needed for documenting and describing pattern recognition of tactile/haptic patterns.

3. PHENOMENOLOGY (CLASSIFICATION) OF TACTILE COMMUNICATION

To distinguish between tactile interaction and tactile communication it can be helpful to define the purpose and context of guidance for tactile human-system interaction.

Tactile interaction can be defined as a transfer of haptically perceivable signals in a technological sense.

Tactile communication can be defined as tactile interaction including mental processes of understanding coded messages. Tactile communication can be classified into three levels:

Basic level:
Tactile communication at a basic level uses exchange of mechanical and / or thermal energy only.
Examples are: grasping a hammer, touching an object in the darkness, reading Braille text.

Advanced level:
Tactile communication at an advanced level includes feedback of additional perception channels (like visual or auditory perception) to basic level tactile communication.
Examples are: using pointing devices for positioning the cursor at a computer screen, using a gun, reducing the loudness of a radio.

Complex level:
Tactile communication at a complex level includes body language (like gesture and mimic) and emotionally controlled motor actions to transfer messages which cannot be expressed alphanumerically.
Examples are: dancing, hand shaking, playing piano

The existing knowledge of all kinds of tactile communication is very limited in comparison to the human capabilities. Nevertheless this knowledge should be more and more encapsulated into guidance on designing tactile human-system interaction. Therefore a need exists to systematically summarize existing knowledge into categories of artefacts to be designed for tactile input and tactile output (e.g., designing input devices for graphics [19, p. 188], effective text input devices [23], or touch screen interfaces [17]).

Guidance is needed in the definition of the differences between tactile interaction and tactile communication.

Guidelines are needed to organize and summarize existing knowledge of input/output device design.

4. EMPIRICAL KNOWLEDGE AND THE NEED OF GUIDANCE

Guidance on designing tactile human-system interaction should be established as much as possible on commonly accepted models and empirically formulated functions. Some of these would appear obvious, for example, the human movements required of tactile interaction would suggest the need to consider guidance reflecting the Law of Practice which, simply put, states that practice improves performance [7]. Others are not as clear. For instance, scientific publications in human-system interaction often refer to Fitts' Law [5] and Card and Moran's Keystroke-Level Model [2], but can traditional models fit into tactile interaction? How these models can fit into a purely tactile domain and what other models might also be appropriate need to be determined.

To fill the gap between existing models and the challenges of designing a specific tactile interaction process, additional guidance on how to proceed is necessary. Even to develop such guidance, an efficient methodology has to be defined. This may require a model specific to tactile interaction. The question remains, how to encapsulate this experience and knowledge into some guidance or a few guidelines.

Guidance is needed regarding how to apply commonly accepted human-system interaction models and empirically formulated functions in the tactile/haptic interaction domain.

Guidelines are needed to describe how to identify and resolve gaps between existing interaction models and the tactile/haptic interaction process.

5. CODING OF TACTILE INFORMATION

As mentioned in Section 3, tactile communication needs understanding of coded messages. To draw some attention on the challenge behind this statement, consider the following brief example:

A blind student is dealing with modelling in bioinformatics. Typically such modelling needs some experimental investigations, in this case some electrophoretic measurements. The results of agarose gel electrophoresis is usually presented as a grey-level image (see Figure 1). The question is: How to design a tactile representation providing the equivalent information in the sense of web content accessibility guidelines such as WCAG [4].

Guidance relating this this problem has been historically lacking. ISO/TS 16071 [14] provides guidance on software accessibility, but lacks guidance on haptic access [3]. Specific guidance requiring haptic equivalents to information has been added to ISO 9241-171 [15], however no guidance on how to map abstract visual information into a tactile medium is provided. Much knowledge exists about designing tactile information if the referent is spatial (e.g., city maps) or is based on a hierarchical sequence (e.g., train time tables), but higher levels of abstraction need higher levels of guidance (and education).

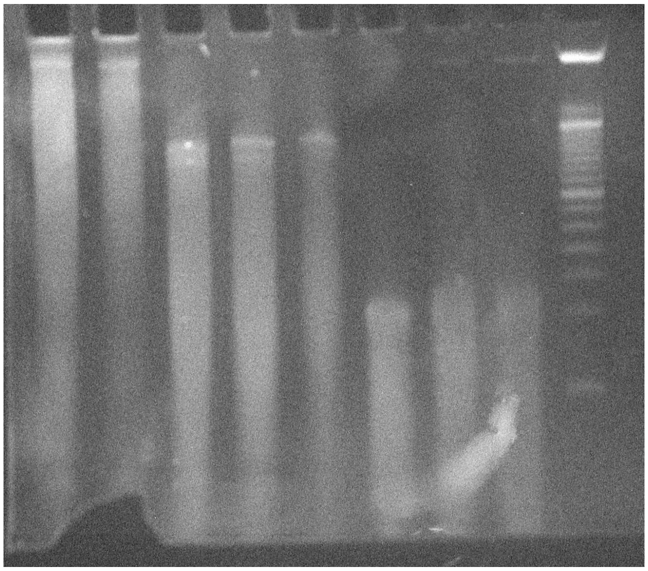

Figure 1: Example of a grey-level image as a result of electrophoretic measurements to be transformed into an equivalent with tactile components for blind users.

Guidance is needed on how to map abstract visual information into tactile patterns.

6. METHODS FOR TACTILE OUTPUT

Devices specifically designed for tactle/haptic output address the somatic senses of the human operator. As such, they should concern more than just touch. Somatic senses, the “senses of the skin”, include the sense of pressure, cold, warmth, touch, and vibration [6]. In addition, two more senses, both related to the proprioceptors, are the “sense of position” and the “sense of force” [6].

Proprioceptors are sensory receptors found in muscles, tendons, joints, and the inner ear that detect the motion or position of the body or a limb. They measure the activity of muscles, the stressing of tendons, and the angle position of joints. This sense of proprioception, the ability to feel movements of the limbs and body, is also called kinesthesis [20].

Guidance on haptic and tactile interaction needs to provide coverage across all tactle/haptic output methods available across the somatic senses. Shimoga categorizes these devices by stimulus [21]:

Pneumatic stimulation involves using air jets, air pockets, or air rings. Pneumatic devices tend to have low bandwidth. Users may eventually experience muscular fatigue reducing their ability to sense.

Vibrotactile stimulation involves using blunt pins, voice coils, or piezoelectric crystals to generate vibration. Vibrotactile devices can be very small and have a high bandwidth. They are often the best way to address the user’s somatic senses.

Electrotactile stimulation involves using electrical impulses provided via small electrodes attached to the user’s fingers.

Functional neuromuscular stimulation involves stimulation provided directly to the neuromuscular system of the user. Although this approach has been used to activate paralysed limbs, it has not caught the imagination of most tactile/haptic interaction researchers. This approach is highly invasive and not appropriate for the casual user. The possibility of surgery and the potential liability in case of damage to the neuromuscular system further removes this approach as an attractive alternative method of tactile/haptic interaction.

Haptic interfaces using **heat stimulation** also exist. Thermal stimulation of the skin can be provided using radiation (IR and microwave), convection (air and liquid), conduction (thermo-electric heat pumps), or some combination of these. There is ongoing research into the question of which temperature ranges offer the best resolution [16].

Guidelines need to provide coverage over the full human somatic sensory range.

Guidelines are needed to categorize input/output devices by communication style (as per Section 3) and/or method of stimulus (as per Section 6).

7. BASIC GUIDANCE ON DESIGNING TACTILE OUTPUT

Independent of the existing detailed knowledge of haptic perception, like haptic thresholds and other characteristics, and the theoretical questions of proprioception [22, p. A84], some guidance on a more general level seems to be helpful for developers of interactive systems with tactile components especially with tactile output.

The following subsections contain example draft guidelines.

7.1 Clearly document tactile patterns

Provide electronic text explaining the pattern used for tactile output presentation.

NOTE In contrast to visual and acoustic output for tactile output only a few sets of symbols are standardised (e.g., Braille-code in several versions).

EXAMPLE 1 Bursts of tactile vibrations are verbally described as acting in analogy to a ringing bell.

EXAMPLE 2 The vibration pattern of a pointing device with tactile feedback is explained according to the functionality of the selected object.

EXAMPLE 3 The adjusted maximum level of pressure output of a force feedback system is presented as an alphanumerical value via a visual display.

7.2 Do not rely on tactile output alone

The system should provide an alternative modality (description) for tactile output signals.

EXAMPLE An end user with a haptic disability can understand the tactile presented message if this message can be presented additional as a verbalized message.

7.3 Do not cause injury

The system should enable users to adjust tactile output parameters to avoid injury or pain.

EXAMPLE A user with reduced haptic perception can individually adjust an upper limit for the tactile output of a force feedback system.

8. SUMMARY

There is a need to summarize the knowledge on haptic and tactile interaction, beginning with defining a clear vocabulary and ending with guidance on developing and using interactive systems with tactile components. This guidance should be structured analogously to the purposes and context scenarios of the systems in question. For this task a system-oriented approach should be used. The dominating part of such guidance should support the process of designing dialogues based on haptic perception of objects and of tactilely usable functionality.

Such guidance (and the included guidelines and conformance procedures) should not strongly distinguish between those concentrated on software and those concentrated on hardware. The reason for this demand comes from the high complexity of tactile communication — the fact that the most important part of tactile interaction of the human being is not clearly divided into hard- and soft- ware.

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