Non-Visual Information Display Using Tactons

Stephen A. Brewster and Lorna M. Brown
Glasgow Interactive Systems Group
Department of Computing Science, University of Glasgow, Glasgow, G12 8QQ, UK
{stephen, lorna}@dcs.gla.ac.uk www.dcs.gla.ac.uk/~stephen

Abstract
This paper describes a novel form of display using tactile output. Tactons, or tactile icons, are structured tactile messages that can be used to communicate message to users non-visually. A range of different parameters can be used to construct Tactons, e.g.: frequency, amplitude, waveform and duration of a tactile pulse, plus body location. Tactons have the potential to improve interaction in a range of different areas, particularly where the visual display is overloaded, limited in size or not available, such as interfaces for blind people or on mobile and wearable devices.

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INTRODUCTION

Force-feedback (movement/position-based) haptic interfaces are becoming common, with much research into their use in HCI. However, the cutaneous (skin-based) component is often ignored even though it is a key part of our experience of touch. As Tan [6] says "In the general area of human-computer interfaces … the tactual sense is still underutilised compared with vision and audition". One reason is that, until recently, the technology for tactile displays was limited or designed for very specific uses [4] which made it difficult to do general research into how best to design effective tactile cues. Devices are now available which allow researchers to investigate how taction should best be used and to establish some basic understanding to help interface designers create usable tactile user interfaces.

Tactons, or tactile icons, are a new communication method to complement graphical and auditory feedback. They are structured messages that can be used to communicate to users non-visually. Conveying structured messages through touch is useful in areas such as wearable computing where screens are limited or in interfaces for blind people where there is no visual display. This paper presents background in the perception and use of tactile stimuli and describes the design of Tactons and some potential applications.

Cutaneous perception is based on mechanoreceptors contained within the skin, and includes the sensations of vibration, temperature, pain and pressure. The skin is the largest organ in the body but little direct use is made of it for displaying information in user interfaces. As a receiving instrument the skin combines important aspects of the eye and the ear, with high acuity in both space and time [3] giving it good potential as a communication medium.

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Tactile displays present feedback to the cutaneous sense. One common form of tactile output is Braille, and dynamic Braille cells are available. A display is made up of a line of 'soft' cells (often 40 or 80), each with 6 or 8 pins that move up and down to represent the dots of a Braille cell. The user can read a line of Braille cells by touching the pins of each cell as they pop up. The focus of the work reported here is not on Braille as it is well understood and tends to be used mainly for representing text to the fingertip. We use vibrotactile pads (Audiological Engineering VBW32 transducers for use in tactile hearing aids) which evoke sensations using the vibration of a $1.5cm^2$ pad against the skin [4] and operate like small loudspeakers. These can be attached to different areas on the body. We connect the pads to the outputs of a PC sound card and play wav files through them to generate our Tactons. They are lower resolution than Braille but can be distributed over the body to communicate different types of information very effectively.

TACTONS

Shneiderman [5] defines an icon as "an image, picture or symbol representing a concept". In the visual domain there is text and its counterpart the icon, in sound there is speech and the Earcon [1]. In the tactile domain there is Braille but it has no 'iconic' counterpart. Tactons fill this gap. Icons/Earcons/Tactons form a simple, efficient language to represent concepts at the user interface. Tactons encode information by manipulating the parameters of cutaneous perception. The encoding is similar to that of earcons [1] where each of the sonic parameters is varied to encode information. Similar parameters can be used for Tactons (although their relative importance is different):

Frequency: Frequency can be used to differentiate Tactons. The range of 20 – 1000 Hz is perceivable but maximum sensitivity occurs around 250 Hz. Gill [2] suggests a maximum of nine different levels can be used. A change in amplitude leads to a change in the perception of frequency so this has an impact on the use of frequency as a cue. The number of levels that can be discriminated also depends on whether the cues are presented in a relative or absolute way.

Amplitude: Intensity of stimulation can be used to encode values. Perception deteriorates above 28 dB over threshold.

Gill states that that no more than four different amplitudes should be used [2]. Due to the interactions between this and frequency several researchers have suggested that they be combined into a single parameter.

Duration and rhythm: Pulses of different durations can encode information. Gunther [3] investigated a range of subjective responses to pulses of different durations. He found that stimuli lasting less than 0.1 sec. were perceived as taps or jabs whereas stimuli of longer duration were perceived as smoothly flowing tactile phrases. Groups of pulses of different durations can be composed into rhythmic units. Differences in duration can be used to group events when multiple events occur on the same area of skin. The tempo at which the pulses are played can also be varied.

Waveform: The perception of wave shape is much more limited than with the perception of timbre in sound. Users can differentiate sine waves and square waves but more subtle differences are difficult [3]. This drastically limits the number of different values that can be encoded.

Body location: Spatially distributed transducers can encode information in the position of stimulation across the body. The choice of body location is important, as different locations have different levels of sensitivity and spatial acuity. A display may make use of several body locations to group tactile stimuli. Spatial patterns can also be "drawn" on the user's body. Patterns can move about the body, varying in time and location to encode information.

We have developed two main methods for Tacton design (based on simple earcon design): *Compound Tactons:* A set of simple Tacton 'phrases' has been created**.** A high-frequency pulse that increases in intensity represents, for example, 'Create', a lower frequency pulse that decreases in intensity represents 'Delete'. A two note falling Tacton represents 'File' and two rising notes 'Directory' (the mapping is abstract; there is no intuitive link between what the user feels and what it represents). These Tactons can then be combined to create compound messages, e.g. 'Create File' or 'Delete Directory'. This set of elements can be extended and a simple language of tactile elements created to provide the building blocks for creating feedback for non-visual displays.

Hierarchical Tactons: Tactons can also be structured in a hierarchical way. Each Tacton can represent a node in a tree and inherits properties from the levels above it. The top of the tree uses a Tacton which has a basic rhythm played using a sinewave (a different tree would use a different rhythm so it is not confused). The rhythmic structure of Level 2 inherits the Tacton from Level 1 and adds to it. In this case a second, higher frequency, Tacton played with a squarewave. At Level 3 the tempo of the two Tactons is changed. The other parameters above are used to add further levels. A hierarchical structure can thus be presented non-visually. This is useful when navigating around hierarchical data or menu structures without the need for sight.

There is much potential for the tactile enhancement of desktop interfaces, but our main focus is on situations where vision is limited or unavailable. Text can be rendered simply via speech or Braille, but graphics are more problematic. One area of interest is the accessibility of visualisations for blind people. For example, with multidimensional data one dimension might be mapped to the frequency of a pulse in a Tacton, another might map to body location and another to rhythm. As the user moves about the data he/she would feel the different parameters. As long as this is done in a comprehensible manner users can gain access to their data in a much more effective way than with current tools.

The other main application area is mobile and wearable devices (for both sighted and blind people). Mobile telephones commonly have a very simple stimulator built-in that can alert the user to a call. These are often only able to produce pulses of different durations. More sophisticated tactile displays could do much more. For example, in a wearable device users could have body-mounted transducers so that information can be displayed over their body. In the simplest case this could be used to give directional information by vibrating one side of the body or other to indicate which way to turn (e.g. Tan *et al.* [6]). A belt of transducers around the waist could give a compass-like display of direction; a compound Tacton could be pulsed continuously at north so the user can maintain orientation after turning (useful when navigating in the dark) or at the position around the waist corresponding to the direction in which to head. A more sophisticated display might give information about the user's context, presenting compound Tactons describing information such as the type of building the user is close to, or information more related to the concerns of visually impaired people, such as the number of stairs leading up to the entrance. For fire-fighters, whose vision is impaired due to smoke and flames, a tactile display could provide the location of rooms and exits in a building. Such tactile displays can also work alongside auditory or visual ones for a fully multimodal display.

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