Augmenting Real-world Social Networking with Vibrotactile Display

Nanda Khaorapapong
Media and Arts Technology
Doctoral Training Centre
School of Electronic Engineering
and Computer Science
Queen Mary University of
London, Mile End Road
London E1 4NS UK
n.khaorapapong@eecs.qmul.ac.uk

Matthew Purver
Interaction, Media and
Communication research group
School of Electronic Engineering
and Computer Science
Queen Mary University of
London, Mile End Road
London E1 4NS UK
m.purver@qmul.ac.uk

David Cox
Technical Partner
Lean Mean Fighting Machine
2nd Floor, 17 Ferdinand Street,
London NW1 8EU UK
dcox@leanmeanfightingmachine.co.uk

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Abstract
This paper discusses a design consideration and method in the early stage of development of Vibrosign: a wearable vibrotactile display used to facilitate social interaction in networking events. A pilot test was conducted to observe user's ability to perceive and interpret meanings conveyed by vibratory stimuli. The test result informs viable techniques that lead to modifications of prototype and required parameters needed in an upcoming informative experiment.

Keywords
Human-human interaction, Tactile interface, Social interaction, Wearable device, Wireless communication

ACM Classification Keywords
H.5.1 Multimedia Information Systems (augmented realities); H.5.3 Group and Organization Interfaces (synchronous interaction, collaborative computing).

Introduction
In social networking, the senses of sight and hearing are more used than the sense of touch; leaving the skin under-utilized and available for more targeted networking, that can support the other senses.

For this reason, we employ tactile communication methods in developing Vibrosign: a vibrotactile armband, designed to be worn in social networked events where visual and auditory senses of networkers are usually occupied by socialising routines. The armband is embedded with a Bluetooth technology, a microcontroller and a 2-deimensional gird of vibration actuators to generate tactile patterns giving the user information about other users with same interests. Our design considers the social weight that wearable technology may add to the wearer's physical and psychological presence. Thus, it is possible to embed in wearable items such as t-shirt and jacket. The technology serves two functions: 1) navigating the wearer to others who have interests and demography in common, 2) giving additional information about commonalities.

Technology for facilitating social interaction

Social interaction in real-world networked events can be a challenging task for poor socially skilled and introverted people. Similar interests and commonalities are often used among extroverts to open a conversation with strangers, ease the flow and lengthen the contents. Many mobile assistive technologies have been developed to facilitate social interaction: generally screen-based with text display i.e. Social Proximity Applications that alert the user when others who share commonalities are nearby [5, 7]. However, accessing information from such traditional interfaces (e.g. scrolling text up/down or pressing buttons) can create cognitive overload and interfere with social interaction by distracting visual/audio attention; therefore potentially limit the ability to keep him or herself alert and available for meeting new people.

Tactile display

Prior studies report feasibilities of tactile communication in transmission of different messaging types i.e. spatial orientation and guidance [8, 10], affective expression [3], and textual cues [11] – to our knowledge, none of this research focuses on augmenting face-to-face communication in social events. Our assumption is at the challenge of interpretation of message conveyed by vibratory patterns called *tactons*. The research questions we address are: 1) what information to display 2) what rules are used to translate real-world information into tactile display and then meaning 3) how complex the information (displayed as *tactons*) can be for the user to recognise and perceive their meaning. Interpretation of *tactons* with symbolic characteristics is much more problematic than directional so called deictic, which is often encoded with movement of pulses that are generated on different vibrational actuators in the display area. This issue is discussed more in detail in the design section.

Vibrosign: design rules

People have certain aims for participating in social events. High priority is given to appearing "normal" to some degree or "correct" in the event's context and to being perceived as sociable. Vibrosign is designed to avoid the interference of technology during the interaction between the user and the other he/she talks to. This concern is carefully applied to three factors described in [9] in which cognitive load, physical existence of the display and its apprehension potentials can degrade social interaction. However, at this early stage, our focus is on feasibilities of the technology to ease cognition of vibratory patterns and its messaging mechanism; the first prototype used in the pilot test is prepared to ease the setup of experiment and the measurement of required parameters. Thus, it is designed to be easily strapped to the subjects' upper arm in which one armband can fit any arm sizes and prompt the positional adjustment of vibration actuators' position when needed.

Hardware overview

The armband is configured with 9 of 3.3V vibration DC motors that are arranged in a 3 by 3 grid allowing for generation of two-dimensional display, which can be driven by a 5V Atmel328 microcontroller. While there is a wide selection of motors that have the same specifications to those used in prior studies, we have chosen the 8mm pancake-type (smallest in the current market), for which it is difficult to find testing results in the previous studies. However, this provides a small dimension of the display area (94mm by 94mm) that fits the subjects' upper arm.

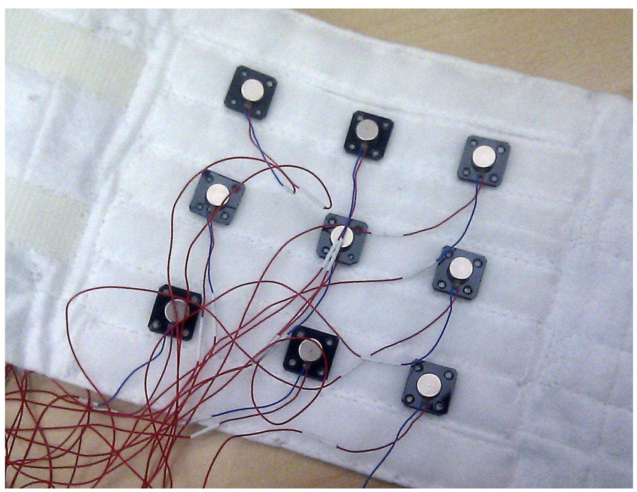

figure 1. An image of Vibrosign prototype with 9 DC 3.3.V vibration motors embedded.

The choice of 8mm motors was made for two reasons: one is an attempt to improve acuity; smaller contacted area of stimuli causes greater vibratory strain at the skin's receptor than larger [4]. Another is to override the vibrotactile acuity reported in two highly cited experiments in this area of research: Weinstein (1968) report ~45mm as an average two-point discrimination distance for static stimuli tested on volar upper arm [13]; and Cholewiak and Collins (2003) advise 50mm for vibratory stimuli tested on the same body area [2]. We use 35mm discrimination distance in combination with a fixed 60 Hz frequency rate. This rate is considered much lower than that used in Cholewiak and Collins but close to the range that is reported in Verrillo et al. (1969) to better improve subjects' sensitive level than higher frequencies i.e. 100Hz (lower sensitive level) and 250Hz (lowest sensitive level) [12].

Relation between parameters and perceived intensity of vibration

The parameters used for pulsing vibration are significant to form and distinguish one pattern from another. Amplitude of motors is perceived as intensity of vibration. In DC motor, amplitude is directly controlled by its specified voltage, not the frequency; that is why we set the frequency rate constant and alter the intensity of vibration. The Pulse Width Modulation technique, reported as an effective method [1] for controlling the amount of voltages supplied to motors is used to alter the intensity of vibration in the experiment.

Method for messaging

To translate message contents into tactile language, alterations of hardware capacities as defined by parameters i.e. amplitude, pulse durations, and positions and number of vibrating motors are used to form tactile "words" that are translated from sets of messages in which the device is given to convey [6]. For the armband, there are two types of message required by each function explained with examples of *tacton*'s forming steps:

- Function 1 – use deictic messaging to direct the user along a route towards another user with similar interests. Navigating cues i.e. turn left, turn right, go forward, go backward is directly mapped into left, right, up and down message of vibrating mechanism without translation. This is because this type of message has geographical and movement characteristics that inherit their meaning and metaphor from the user's intuitive perception. A sequence of continuous stimuli (e.g. vibrating one motor next to another without inter-pulse duration) together with directions of movement can represent directional cues. For instance, a short pulse of vibration that starts from the motor on the far right, then move on to the one in the middle and end at the one on the far left can be used to convey a message of "turn left" whereas the same steps in a reversed order suggests "turn right".

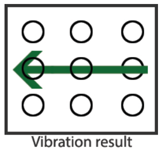

figure 2. A diagram of 3 by 3 grid motors with a vibration result of "turn left" sign that is formed with a sequence of 3-step stimuli (shown in figure 3).

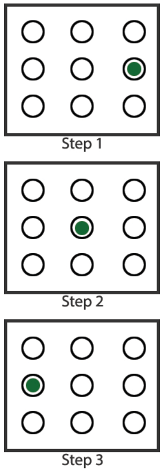

figure 3. A sequence of 3 stimuli made in steps to form a "turn left" sign. Each coloured mark represents a single stimulus.

- Function 2 – relies on symbolic messages that has to be taught to the user to enable the identification of commonalities criteria i.e. age, sex and occupation. An alphabetical character is chosen to represent each a separation commonality i.e. 'A' is for age; 'S' for sex; and 'O' for occupation. The mapping of messages into tactile "words" in this task is more complex than the processes required in function 1, due to the use of set of letters that involves ways of writing and reading that are different from one subject's to another's. Orientation of tactile "letters", start/stop points and angular of curves are examples that easily cause confusion to letter recognition. The pattern of the letter 'C' can be made by vibrating seven motors at the same time. However, the duration of vibration can become an issue; too long can cause two or more different vibrating points perceived as one whereas too short can be inadequate for the subject to feel and recognise the letter.

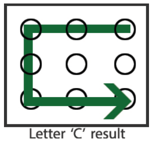

figure 4. A diagram of 3 by 3 grid motors with a vibration result of letter 'C' sign that is formed with a sequence of 7-step stimuli (shown in figure 5).

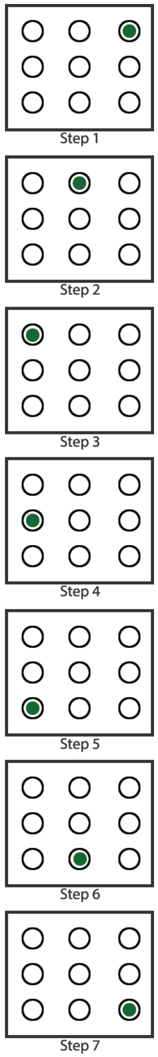

figure 5. A sequence of 7 stimuli made in steps to form letter 'C' symbol. Each coloured mark represents a single stimulus.

Pilot test

The goal for our experiment is to examine the suitability of the upper volar arm in recognizing dynamic *tactons*.

Test subjects

Four female and two male subjects aged between 22 and 45 years from Lean Mean Fighting Machine and Queen Mary University participated in the test. The subjects were asked to wear the armband on the right upper arm with an array of motors attached to the volar side of the arm and in the middle position between shoulder and elbow. The test per subject took about 25 minutes including times for defining *tactons* and giving feedback via an answer sheet.

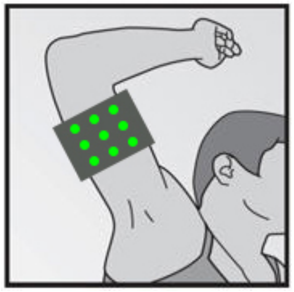

figure 6. A diagram shows armband position on upper arm with vibration motors attached to the volar side.

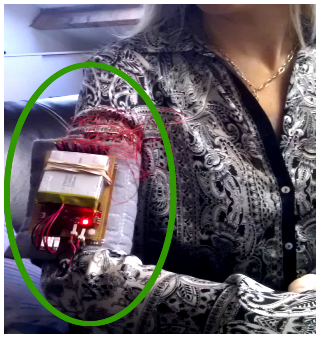

figure 7. A test subject wearing Vibrosign with a controller circuit, battery pack and motor circuit attached on the outer side of the armband.

Setup

Based on the functions set for Vibrosign the test is separated into three parts:

- Part 1 – find out the lowest intensity and shortest pulse duration at which the subject could feel the vibration. This part required only one motor. For the intensity test, three levels of intensity generated with three voltages: 1.7V, 2.5V and 3.3V were presented at a time. The subject reported after each level presented whether he/she could feel it or not. For the pulse duration test, 500 and 1000 milliseconds periods were displayed once at the previously defined lowest intensity. The lowest intensity and shortest pulse duration were recorded as default parameters for each subject in later parts.

- Part 2 – examine the subject's ability to distinguish left and right movement of *tactons*. Two directional signs were generated with the method described in the previous section: Method for messaging, Function 1. Like other unconventional communicative devices that require users some time to become familiar with their utilities, we started Part 2 with a short training phrase by presenting each *tacton* and asked whether the subject knew the correct answer. This was repeated three times or less if the subject recognized the meaning conveyed by each *tacton*, either left or right direction. The tester revealed the correct answers if the subject could not. In the assessment, four directions (two in each direction) were presented in a random order i.e. left-right-right-left or right-left-right-left. The subject was asked to draw the perceived direction on the answer sheet.

- Part 3 – examine the subject's ability to recognise symbolic messages represented with continuous *tactons*. Two symbols 'L' and 'R' were generated using the method described in the previous section: Method for messaging, Function 2. The training phrase, assessment and replies were made identical to those in the Part 2 test. Four messages (randomly picked from 'L' and 'R' symbols) were presented i.e. 'L'-'L'-'R'-'R' or 'L'-'R'-'R'-'L' in this part.

Note: *tactons* in all testing parts were controlled by a tester using an Android that is connected to the armband via Bluetooth communication.

Result and discussion

The results from Part 1 suggest 3.3V intensity and 500ms pulse duration as a combination of effective parameters for the use of single motors. For directional recognition, the result appeared according to our assumption; all subjects recognized both directions correctly in the initial training. The same result appeared in the assessment when directions were randomly displayed. For recognition of letters, the accuracy rate of letter 'L' 66.5% – four times higher than the letter 'R' (16.5%). However, all subjects could distinguish both letters in the assessment session when both letters were displayed in a random sequence – no misinterpretation of the letter 'R'. To this, we hypothesise that this high accuracy rate was a result of ability to distinguish the difference between both letters' parameter i.e. numbers of vibrating motors and starting/ending positions, rather than recognizing letters' symbol. Longer training sessions in future experiments may be needed for the subject to be familiarised with letters' orientation and the way each is formed. An adjustment of number of stimuli (e.g. extended to 4 by 4 to permit more freedom in generating complex letters) as well as additional parameters (i.e. inter-pulse duration) and refinements of their values will be useful in further studies.

Conclusion

We have suggested Vibrosign as a wearable technology for easing social networking. Yet, the design concept and wireless network are not fully implemented but the result from our preliminary test informs feasibilities of vibrotactile to transmit deictic and symbolic messages, and leads to a modification of prototype and setup in the further experiments. This addresses possibilities for complex messaging that will be useful for wireless communication in social events.

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