# Towards Designing User Interfaces on Mobile Touch-screen Devices for People with Visual Impairment

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**ABSTRACT**
Although touch screens have great input flexibility, they are largely inaccessible to people with visual impairment. One of the issues with touch screens is the lack of clear tactile feedback, which is critical for visually-impaired people. We developed SemFeel, a tactile feedback technology that can express some semantic information by using multiple vibration motors in concert. We believe that the rich tactile feedback offered by SemFeel enables people with visual impairment to better use mobile touch-screen devices. In this paper, we report our findings from semi-structured interviews with three participants who have visual impairment about their experience of mobile devices. We then discuss a gesture-based user interface with tactile feedback for people with visual impairment.

**ACM Classification:** H5.2 [Information interfaces and presentation]: User Interfaces. – Haptic I/O.

K.4.2.[Computers and society]: Social issues – assistive technologies for persons with disabilities.

**General terms:** Human Factors

**Keywords:** Tactile feedback, touch screen, visually-impaired people, mobile device, multiple vibration motors.

## INTRODUCTION

Many recent mobile devices integrate touch screens. Touch screens support flexible input by allowing the user to interact with the device with hand gestures, such as tapping, swiping, and pinching. However, user interfaces on touch screens significantly rely on visual feedback, which is inaccessible to people with visual impairment. Instead, auditory and tactile feedback technologies can be used to enable such users to interact with mobile devices. One of the most common technologies used to generate tactile feedback is a vibration motor. However, the ability for tactile feedback with a single vibration source to convey semantic information is significantly limited compared to auditory feedback. Therefore, tactile feedback has not been widely applied in mobile interaction yet.

To increase the expressiveness of tactile feedback, we developed a tactile feedback technology for a mobile touch-screen device called SemFeel [9]. SemFeel embeds multiple vibration motors in a mobile device and can express some semantic information by using the multiple vibration motors in concert. Although initially SemFeel was designed to overcome the lack of tactile feedback on a mobile touch-screen device, we believe that the rich tactile feedback that SemFeel offers can also be useful for people with visual impairment.

In this paper, we propose a tactile user interface to support gesture-based interactions on mobile touch-screen devices for people with visual impairment. Because hand gestures do not require the user to target any particular control to execute the command, they could be a more appropriate form of user interfaces for people with visual impairment than a button-based interface. However, the awareness of gestures is only provided visually and users with visual impairment have difficulty knowing whether their gesture is being recognized correctly. In our system, different vibration patterns enabled by the SemFeel technology are used to provide the awareness of a hand gesture that a user is performing to support accurate interactions with gesture-based user interfaces on mobile touch-screen devices.

We first discuss the relevant research on tactile feedback technologies for people with visual impairment. Next, we present our prototype SemFeel system. We then describe the semi-structured interviews we conducted with three

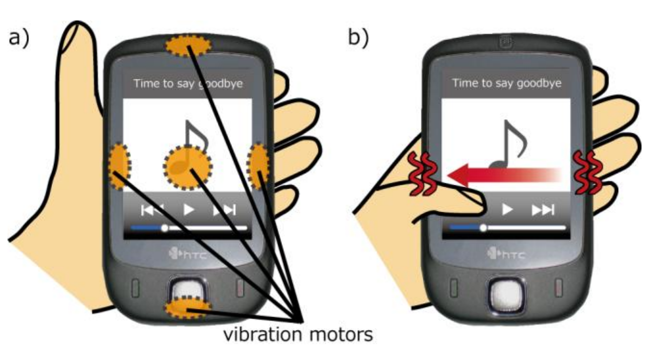


Figure 1. The SemFeel system concept: a) Multiple vibration motors are embedded in the back side of a mobile touch-screen device. b) The system generates a vibration from right to left as feedback in response to when the user touches the "previous track" button.


*UIST'09*, October 4–7, 2009, Victoria, BC, Canada.

visually-impaired people. Finally, we propose a tactile user interface to support hand gestures for people with visual impairment.

## RELATED WORK

User interfaces with tactile feedback have been built to support the interactions of visually-impaired users with computers. Wall and Brewster illustrated that graph information can be conveyed through a mouse with tactile pin arrays [7]. Their system offers tactile feedback to inform users when they are touching bars in the graph, as well as how high each bar is by vertically moving the pin. Ghiani *et al*. developed a guide system for people with visual impairment that uses two strips with vibration motors worn on the index finger and thumb of the hand holding the device [2]. They used vibration motors to present the direction to turn (*e.g.*, right vibration means "turn right"). Recently, Rantala *et al.* developed a method for presenting Braille characters on a mobile touch-screen device [4]. Their system used different peaks of the pulses to generate raised and lowered dots. Their experiment with three different presentation methods of Braille tactile feedback revealed that experienced Braille users could recognize letters at 91 – 97 % accuracy.

Research also has been conducted to convey semantic information over the tactile feedback channel by using different vibration parameters such as frequency, rhythm, strength, and textures. For example, Brewster and Brown showed that their Tactons system could use different rhythms and frequencies to provide users with richer information than a simple vibration [1]. Hoggan *et al*. demonstrated that the texture of physical buttons could be mapped into parameters that are later used to produce tactile feedback for buttons on touch-screen devices [3]. Their study showed that different actuators and rhythms can be used to emulate different textures of physical buttons.

## SEMFEEL INTERFACE

SemFeel is a tactile user interface designed for mobile touch-screen devices [9]. SemFeel embeds five vibration motors in different locations of the back side of the device (*i.e.*, the top, bottom, right, left, and center of the device). This hardware configuration allows SemFeel to produce a single-point vibration in specific locations, as well as a "flow" of the vibration (*e.g.*, a vibration moving from the left of the device to the right as Figure 1a shows).

We built the SemFeel hardware as shown in Figure 2. This hardware has five vibration motors on the top, bottom, right, left and center of the back side of a mobile touch-screen device. We also manufactured a special sleeve (shown in Figure 2) that goes under a touch-screen device and curves to fit the shape of the user's hand when holding the device. This sleeve allows us to embed the vibration motors on the back side of the device while placing the motors as close to the palm and fingers as possible.

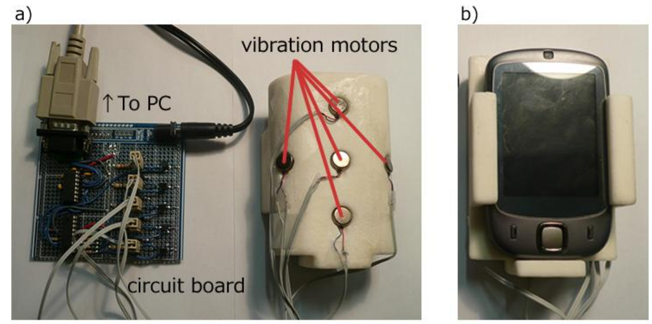


Figure 2. The SemFeel prototype: a) the circuit board and mobile device with five vibration motors on the back side; b) the front side of the mobile device.

Our current SemFeel prototype can produce five single-point vibration patterns (top, bottom, right, left, and center), four linear vibration patterns (from top to bottom, bottom to top, right to left, and left to right), and two circular vibration patterns (clockwise and counter-clockwise). These patterns are intended to be easy for the user to perceive and to associate with a specific meaning based on the context of the current application. Figure 1b presents an example use of SemFeel in a music player application. When the user touches the "previous track" button, she feels a vibration flowing from the right of the device to the left in the palm and fingers of her hand.

We conducted two user studies with sighted users to understand the efficacy of SemFeel. We found that the participants can distinguish all the vibration patterns except the counter-clockwise pattern at approximately 90% accuracy, and that SemFeel supports more accurate eyes-free interactions in a number entering task than a user interface without any tactile feedback or with tactile feedback using a single vibration source.

## INTERVIEWS WITH VISUALLY-IMPAIRED PEOPLE

Although we initially designed SemFeel for a mobile touch-screen device for sighted users, we believe that the SemFeel technology can address mobile interaction problems experienced by visually-impaired people. To understand how to integrate the SemFeel technology in mobile interaction support for visually-impaired people, we conducted semi-structured interviews with three mobile phone users who have visual impairment.

### Procedure

The interview consisted of three parts. We first asked participants about the general usage of their mobile devices and problems they encounter when using their mobile devices. We then explained our SemFeel prototype and demonstrated the eleven vibration patterns that SemFeel can produce. After the demonstration, we asked several open-ended questions about how they envisioned SemFeel could be used in their lives. The interview lasted approximately 45 minutes long. We compensated each participant with

$20 CAD. All the conversations during the interviews were audio-taped. Despite the small number of participants involved in this study, we uncovered several interesting findings about how the SemFeel technology could facilitate mobile interactions for people with visual impairment.

### Limitation of Auditory Feedback

Our interviews revealed that audio is the most common feedback provided by the participants' mobile phones, with the exception of the simple vibration when the phone is in silent mode. Auditory feedback presents information such as the key pressed by the user or a brief description about items being selected. But, auditory feedback often does not work for the reason expressed by one of the participants.

> *[The] software [on my mobile phone leads to] a little bit of a hearing problem… Let's say I'm in traffic and it's really noisy, where I couldn't access to some information by touch… I try to listen to the voice [feedback from the mobile phone, but] it's almost impossible.*

Another problem with the auditory feedback is that it does not provide the full application context. Another participant shared with us his story about text messaging on his mobile phone.

> *The only problem that I have is like staying within 160 characters. [The mobile phone] doesn't say when you are finishing 160 characters.*

When the mobile phone is locked, auditory feedback is disabled. The mobile phone that one of our participants uses has a training mode. In this mode, the phone conveys which key on the phone he presses, including the key to unlock the phone, and thus he can learn the location of each key. However, this mode is designed specifically to help the user learn the key positions and the key press is not linked to an interaction in any application. The participant had difficulty unlocking the phone because he was not familiar with the mapping between the keys and their functions.

> *In the training mode, it [provides auditory feedback]. Only it will give the pressed key, right? But that's different from [when the phone is] locked… If you put [the phone] in that mode (training mode), it doesn't do normal functions. It will only say different keys or function names or commas.*

### Summary

Although SemFeel can convey semantic information about what the user is interacting with, the feedback SemFeel provides is still limited compared to auditory feedback with the synthesized voice. However, auditory feedback does not always offer the complete awareness about the consequences caused by the user's interaction, just as one of our participants mentioned with the text messaging example. Therefore, using auditory and tactile feedback in harmony is the key to a successful interface design for people with visual impairment. Specifically, we envision that the SemFeel technology could be used to provide awareness about the recognition of hand gestures to the user with visual impairment. In the next section, we discuss a tactile feedback system to offer the awareness of hand gestures.

## TACTILE FEEDBACK FOR HAND GESTURES

Hand gestures do not require the user to target any particular control to execute the command. In this sense, a gesture-based user interface could be more appropriate for people with visual impairment. Kane *et al*. studied a gesture-based interface on a mobile touch-screen device for people with visual impairment, called Slide Rule [5]. Their study showed that Slide Rule was significantly faster than a button-based user interface. However, their study also revealed that their participants had more errors with Slide Rule than a button-based interface.

We believe that the higher error rate with Slide Rule in Kane *et al*.'s study was caused by lack of the awareness about how the gestures were being recognized. In Slide Rule, the user does not gain any clear feedback until she commits the gesture (*i.e.*, after she releases the finger contacting the screen). Therefore, the user cannot know if she is performing her intended gesture correctly.

### System

Figure 3 illustrates an example use of the system to provide awareness of the current gesture on the screen. In this example, the user can control the navigation by making gestures like swiping from left to right on the screen (Figure 3 b)). When the system recognizes the user's gesture, it provides tactile feedback corresponding to the gesture. The vibration flowing from left to right is given in this case (Figure 3c). This allows the user to learn whether she is performing her intended gesture correctly. Auditory feedback can keep providing content information, so the gesture that the user is performing does not disturb the read-out function. After the user releases her finger, the system executes the command associated with the gesture (Figure 3d).

### Design Issues

In addition to providing the awareness about the recognition of gestures, there are several issues that need to be addressed for gesture-based user interfaces on mobile touch-screen devices for people with visual impairment. McGookin *et al*. articulated five design guidelines [6]: Avoid quick or short gestures; avoid location-specific or object-specific gestures; provide a "home" button; use different button shapes; and provide feedback for all actions. However, we found a couple of aspects of gesture-based interactions that were not considered in McGookin *et al*.'s guidelines.

Tactile feedback in response to hand gestures may conflict with other tactile feedback designs. There needs to be distinctive tactile feedback patterns so the user can know whether the tactile feedback is responding to a gesture or offering the presence of a click-able object, such as a button or a hyperlink. We will investigate how we can solve such conflicts by iterating the user interface design with visually-impaired people.


Figure 3. Use of peripheral tactile feedback for hand gestures on the screen: a) A web browser application; b) The user performs a swipe gesture from left to right on the screen; c) The system provides tactile feedback corresponding to the gesture that the user is performing (in this case, a vibration pattern from left to right). This allows the user to know whether she is performing her intended gesture correctly; d) After the user releases her finger, the system executes the command associated with the gesture (in this case, moving to the next page).

Another design issue that we believe needs to be solved is the development of a meaningful mapping of hand gestures on mobile touch-screen devices for people with visual impairment. For example, a pinching gesture is commonly associated with the command of scaling up or down a visual object (*e.g.*, a map). However, such consequences are meaningless for people with visual impairment. Rather, the consequence of a pinching gesture could be a semantic zooming in which the system could provide auditory feedback with more detailed information of the pre-selected object or the object on which the user has made the gesture.

The use of bezels (screen edges) is another design point that we believe should be considered. Similar to EdgeWrite [8], one approach is to simplify hand gestures along the bezels. Users with visual impairment might use the bezel as an aid for positioning their finger with the touch screen. In this case, the system should simply ignore the contact along the bezel and start to recognize the user's gesture when the contact is far enough from the bezel. We will examine how the use of the bezel could help people with visual impairment use gesture-based user interfaces on mobile touch-screen devices by iterating user studies.

## CONCLUSIONS AND FUTURE WORK

In this paper, we reported on our semi-structured interviews with three visually-impaired participants and proposed a tactile user interface design to support gesture-based interactions on mobile touch-screen devices. This research is still in the early stages. We will continue this work to address the design issues discussed in this paper. We also plan to implement the system and evaluate it with visually-impaired people.

## ACKNOWLEDGMENTS

We thank Khai N. Truong and Alyssa Rosenzweig for giving their comments on this project and this paper. We thank all the participants for their time and effort.

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