Investigating the Use of Vibro-tactile Feedback for Mobile Interaction by Blind Users: the Numeric KeyPad Case

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Abstract

For visually-impaired people interacting with touch-screens can be very complex because of the lack of hardware keys or tactile references. We investigate how a multimodal approach can overcome this issue. We propose a prototype which exploits haptic feedback as a support for detecting the numpad and special buttons.

Author Keywords

Mobile accessibility, touch-screen interaction, haptic interaction, blind users.

ACM Classification Keywords

H.5.2 [Information Interfaces and Presentation]: User Interfaces – Input devices and strategies, Voice I/O, Haptic I/O. K.4.2. [Computers and society]: Social issues – assistive technologies for persons with disabilities.

General Terms

Design, Experimentation, Human Factors.

Introduction

Nowadays mobile devices are increasingly used for a variety of purposes. The interaction modality is mainly via a touch-screen display. The absence of hardware keys and any tactile reference makes the interaction with smartphones more difficult and complex for those who are blind. Apple has already put on the market devices using VoiceOver software, such as the iPhone, iPod and iPad, in order to give blind users access to their applications(http://www.apple.com/accessibility/). At the same time there are also some active projects aimed at providing access to devices using the Android system (http://eyesfree.googlecode.com/svn/trunk/documentation/android_access/index.html). In both cases audio support is mainly used as feedback. Vibro-tactile response has been recently introduced into the Android accessibility support system for a small number of activities.

In [5] the authors observed some usability issues encountered by blind users while interacting with the VoiceOver-based devices. In general interaction seems to be relatively accessible via gestures. However, to increase accessibility for these users, certain factors could be considered when designing the interface (UI). We investigate the use of its structure (e.g., menus, buttons, etc.) as well as multimodal feedback.

Moreover, in [2] the authors discuss suggestions for developers concerning touch-screen usage by blind users. These suggestions were based on the biggest issues expressed during the study (1) the lack of keys and touchable elements as reference points - i.e. tactile controls which are easy to feel, learn and remember – (2) the organization of commands and functionalities (menus), and (3) the simplicity and usability of common functions (i.e. making a call).

In our study we focused on how to organize functions and buttons, and how to give multimodal feedback by combining vocal messages with vibro-tactile feedback. In this work we present a prototype application primarily designed to investigate the interaction modalities based on gestures, audio and vibro-tactile feedback. In particular we focused on the usability of a numeric keypad.

The Problem

A very critical aspect for blind people is related to editing when using a touch-based screen. This is especially due to the lack of hardware keys. Buttons, keys and other control items on a touch-screen cannot be felt in the same way as a physical interface, thus detecting a key in a simple and reliable way is rendered problematic. This is especially the case in potentially difficult situations (e.g. a noisy environment). The study reported in [4] describes some issues and difficulties experienced by blind people when interacting with a touch-screen device. The participants who had not previously experienced touch screens felt that they did not provide enough feedback for purposes of interaction. Participants were aware of tactile overlays and tactile adhesive bumps, which could be used to structurally map the layout of objects on the interface. In addition, participants suggested that when in a noisy environment, shorter salient speech cues would be presented, or potentially through the presentation of other forms of feedback to reduce the speech burden (e.g. tactile and non-speech audio cues).

In the study [2], the users pointed out that the hardware keys as well as all the elements clearly felt by a finger (e.g. buttons, edges, points, etc.) play a crucial role for a blind person. The main problems encountered by the users are related to the absence of hardware keys on the smooth screen of a smartphone. In particular the less experienced users were apprehensive about their ability to find their way around the screen as well as the different options. Using the numpad is one of the most worrying issues for the users. In particular, editing a phone number is considered to be the first functionality that should be not only accessible but especially usable. Furthermore, although a screen reader is generally available to announce the number touched, the users said that they usually rely on the "marked" five (5) key to find their way around the numpad when editing a number. As a result they requested this important feature on the touch-screen as well as. They also stated that because the hardware keys are clearly perceivable and the "five" key can help in moving around the numpad, a blind user can edit a number even in situations when there is a lot of noise, and a screen reading voice would not be heard very well. A similar option should also be available on a touch-screen device. In addition, the more experienced users suggested placing some specific command buttons in a fixed position to make it easier to detect them.

Several approaches and methodologies have been proposed to investigate possible simpler editing modalities. The study in [6] describes a method that includes just four gestures to navigate the alphabet and very few buttons to confirm or delete characters. In [1] the authors proposed a virtual keyboard based on nine multi-functional buttons were arranged into pie-menus. Through such solutions some issues in well detecting the buttons have been still observed. The proposed approaches rely on just audio feedback and do not consider vibro-tactile as potential feedback. This means that the user might encounter several difficulties in editing a number or sentence when they are in a noise or uncomfortable environment. Our approach is aimed at investigating how the key detection could be improved through vibro-tactile feedback.

Tactile feedback (e.g. vibrations) can provide one solution to reducing the burden on the visual channel. [7] proposes perceivable tactile icons (tactons) to aid in non-visual interactions with mobile applications: i.e. pairs of tactons to convey two-state signals (e.g. on/off). Similarly we intend to investigate how the vibration can improve key perception.

The Prototype

The proposed prototype is an application for Android-based smartphones. The application was specially designed to give blind users access to a set of useful services. Four blind people (two inexperienced and two with experience of smartphones) were involved from the early phase of prototype design in order to discuss potential multimodal aspects. During brainstorming activities, they suggested some potential solutions based on their experience and expectations. In particular, we discussed and analyzed multimodal interaction applied to the following aspects: (1) appropriate method to dial a phone number via a software numpad; (2) reference points to help users to explore better; and (3) the organization and structure of the user interface (e.g. menus and buttons).

Gestures

The application is based on gestures over the screen. To be able to compare with the state-of-the-art touch-enabled screen reader for the mobile, we implemented a screen-reader interface replicating the main gestures available in VoiceOver. In particular, the gestures considered are: (1) Slow swiping of the finger on the screen, to know the elements on current screen; (2) Flicks from left to right and from right to left, to navigate items and lists of elements (i.e. the voices of a menu); (3) Single-tap and double-tap, to select an element.

Multimodal Feedback
Both audio and vibro-tactile feedback was used to provide UI information. In relation to the audio feedback, we considered:

Vocal messages. All the spoken messages are created by a voice synthesizer available on the device.

Short sounds**.** A very short beep was used to notify the beginning and end of an item list. While navigating a list of elements using left or right flick , when the focus is over the first or last item a short sound announces the end of the list.

Vibro-tactile feedback. We exploited the vibration functionality available on the phone for:

Action confirmation. A very short vibro-tactile response was provided when selecting a UI element (e.g. menu item or button). This feedback is in addition to a spoken message with a different speech rate.

Button and key detection. To allow the user to quickly detect a button or a key, a short vibro-tactile response can be perceived when touching the item. This solution is in particular applied to the keys of the numpad.

Our Proposal

Special Commands and Common Buttons
We analyzed aspects relating to the organization of the UI such as the best structure and the most appropriate position of the items. In particular, we were interested in defining some reference corner points always present on the screen, which would allow the user to obtain some basic information at any time. To this end, four buttons were placed at the four display corners:

- (1 - top left) 'exit/back' to go to the previous step,
- (2 - top right) 'Position' to know the current position status,
- (3 - bottom left) 'Repeat' to read the edited phone number in order to check if there is any error,
- (4 - bottom right) 'Done' to be used as an 'OK' button to confirm the current action.

Keys (2) and (3) are particularly useful to obtain the current status at any time thus avoiding the need to explore the whole screen. In this way, gestures are used to navigate between the items (e.g. menus and submenus, table cells, etc.). whereas the special four commands are always visible and can always be used to request information (keys (2) and (3)) or to 'go back' (key (1)) or to confirm the current task (key (4)).

The study [3] suggests that blind subjects prefer gestures that use screen corners, edges, and multi-touch (enabling quicker and easier identification) and identifies new gestures in well-known spatial layouts (such as a qwerty keyboard). With regard to the four buttons placed at the corners, our study confirmed that blind users appreciate these UI elements which are easy to locate or the fact that they are perceivable (e.g. vibro-tactile feedback).

Numpad Detection
The virtual numpad usually is made accessible via TTS-voice by reading each digit when it is tapped. If the users cannot hear the voice synthesizer because they are in a noisy environment, editing a phone number could become a difficult and frustrating task. This may not happen with a traditional phone thanks to the usage of the marked key '5' as reference touchable point to orientate on the numpad. Our idea is to use the vibration mechanism to make the virtual keys perceivable even by touch. In the prototype the numpad keys were identified using (1) number

vocalization and (2) key vibration. In a first prototype version, the vibration was used to mark only the number '5' as it is commonly used in the hardware numpad. Based on the preliminary comments received from the end users during the prototype development, the solution implemented in the current version provides different vibro-tactile feedback:

Figure 1. Numeric keypad

- Single vibration for even numbers (2, 4, 6, 8, 0);
- Double vibration for the odd numbers except for '5' (1, 3, 7 and 9);
- Triple vibration for the number '5'.

Conclusions

Touch-screen interaction continues to present accessibility and especially usability issues for blind users. Virtual numeric keypad interaction is usually supported only via voice feedback, i.e. each key or button is announced when tapped. In this work we proposed a possible solution which uses vibro-tactile feedback to improve key detection when touching the numbers and buttons. The use of a variety of vibrations has been evaluated in order to provide a possible mechanism to easily identify numbers by touch. This could be useful in proposing an approach which can be used to implement a virtual keypad that can also offer extra support in potentially difficult situations and for discretion purpose [7] as well. Furthermore, in order to improve user interaction when performing certain commands, specific vibro-tactile buttons could be placed in fixed positions. Given the encouraging feedback from our preliminary study group, which seems to testify the effectiveness and usefulness of this proposed solution, we plan to carry out more detailed user testing.

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