Accessibility of Android-Based Mobile Devices: A Prototype to Investigate Interaction with Blind Users

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Abstract. The study presented in this paper is part of mobile accessibility research with particular reference to the interaction with touch-screen based smartphones. Its aim was to gather information, tips and indications on interaction with a touch-screen by blind users. To this end we designed and developed a prototype for an Android-based platform. Four blind users (two inexperienced and two with experience of smartphones) were involved from the early phase of prototype design. The involvement of inexperienced users played a key role in understanding expectations of smart phones especially concerning touch-screen interaction. Skilled users provided useful suggestions on crucial aspects such as gestures and button position. Although the prototype developed is limited to only a few features for the Android operating system, the results obtained from blind user interaction can be generalized and applied to any mobile device based on a touch-screen. Thus, the results of this work could be useful to developers of mobile operating systems and applications based on a touch-screen, in addition to those working on designing and developing assistive technologies.

Keywords: mobile accessibility, touch-screen, blind users.

1 Introduction

The use of mobile devices is rapidly increasing especially with smartphones, which can provide additional functionalities compared to traditional phones. Generally speaking, it is a challenge for the visually-impaired to use these mobile devices. The interaction modality which is increasingly used for these devices is mainly via a touch-screen display. The absence of hardware keys makes the interaction with smartphones more difficult and complex for those who are blind. Interaction modalities based on gestures and taps can be a practicable solution, provided they are well designed and simple to use. Apple has already put on the market devices accessible to users with disabilities, such as iPhone 3G, 4 and 4S (http://www.apple.com/accessibility/). At the same time there are also some active projects aimed at studying how to provide access to devices based on the Android (http://eyes-free.googlecode.com/svn/trunk/documentation/android_access/index.html). However, all these solutions and studies are still at the early stages. It is therefore important to understand the suitability

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of the new interaction modalities with touch-screen devices for people with vision impairment. Our aim is to evaluate if there are still aspects to be made more accessible and usable for user interaction. In [8] the authors observed some usability issues encountered by blind users while interacting with the tablet iPad, although the Voice-over support seems to be generally accessible. This implies that there are still mobile accessibility issues to be analysed and evaluated in order to enhance blind user interaction with a touch-screen.

Our objective is to understand how a blind person – especially a beginner user - can interact easily with a mobile device through a touch-screen. This was done by involving the end users in the collection of preliminary information and comments useful for designing the interface. The Android platform is the system developed by Google as its solution for the mobile world. Devices based on this platform are still not particularly accessible and usable by blind people. By selecting the Android platform, we wanted to contribute to research in connection with this widely-used device. Furthermore, this system is very suitable for development due to the fact that it is more open. However, the main features identified and proposed can be generalised apart from the mobile operating system.

This study is part of the European project "Smarcos" (`http://www.smarcos-project.eu/`) that includes among its goals the development of services which are specifically designed and accessible for blind users. In this paper we present the prototype application designed to make the main phone features available in a way which is accessible for a blind user – especially for an unskilled one. The prototype has been developed to firstly evaluate the interaction modalities based on gestures, audio and vibro-tactile feedback. A preliminary evaluation with blind people was conducted in order to involve end users at an early stage of the prototype development.

After a brief related work section, the prototype will be introduced by describing the main features and functionalities. In particular, the preliminary evaluation results obtained by observing and interviewing a group of blind users will be discussed.

2 Related Work

A multimodal approach can be a valuable way to support various interaction modes, such as speech, gesture and handwriting for input and spoken prompts. The tests described in [2] showed that user performance significantly improves when haptic stimuli are provided in order to alert users to unintentional operations (e.g. double clicks or slips during text insertion). However, the study mainly focuses on the advantages of exploiting the haptic channel as a complement to the visual one and is not concerned with solutions for blind users. By combining various interaction modalities, it is possible to obtain an interactive interface suitable for users with varying abilities. A well-designed multimodal application can be used by people with a wide variety of impairments. Multimodal approaches and gesture-based apps can certainly facilitate interaction for users with impairments; however, creating accessible touch screen interfaces for the blind user still remains a challenge [1], [4] and [5]. Several studies investigate on multimodal interaction for people with disabilities using mobile devices. In [3] the authors evaluated a combination of audio and vibro-tactile feedback on a museum guide, which had a positive response for the user with vision impairments. With regard to user interface (UI) design, the work presented in [10] suggests an important principle which should be considered when designing a product: developers should focus on ability rather than disability. This interesting concept has been considered in several pilot projects, including Slide Rule which aimed to study touch screen access for blind users. In particular, Slide Rule is a prototype utilizing accuracy-relaxed multi-touch gestures, "finger reading," and screen layout schemes to enable blind people to use unmodified touch screens [6]. The study [7] found out preliminary results concerning gestures preferred by blind persons. Evaluated gestures include screen corners, edges, and multi-touch (enabling quicker and easier identification). Also new gestures in well-known spatial layouts (such as a qwerty keyboard) have been considered in the study. In our work we would like to further investigate on this kind of interaction modality by using an Android touch-screen based device.

More precisely, in our work we intend to investigate if gestures and voice and vibro-tactile feedback can be useful for the blind to confirm an action on an Android-based smartphone. The Android platform includes a built in text-to-speech engine and a screen reader to enable phone manufacturers to deliver accessible smartphones. Android phones can also be highly customized by downloading third-party accessibility applications that make nearly every function possible without sight, including making phone calls, text messaging, emailing and web browsing (`http://www.google.com/accessibility/products/`). [9] describes an example application developed for the blind using an Android-platform device. However, the proposed work on accessibility support is still in progress and input/output modalities need to be investigated in order to identify the most appropriate modalities to interact with a touch-screen.

3 Methodology

As mentioned, this research is aimed at investigating the accessibility and usability of interaction with a touch-screen-based smartphone for blind users. For this purpose, we developed a prototype application which makes some essential smartphone features available and accessible. An Android platform was used for this. The functionalities we included in our prototype were chosen according to the interaction modalities to be investigated. This application was used as a starting tool to gather evidence and evaluate user interaction involving a group of blind people. In this way, we applied a user-centred design approach to our study. The methodology used can be summarised as follows:

- Analysis of the interaction between blind users and a smartphone touch-screen. In order to identify users' requirements, a small group of four totally blind people was involved in the design-development cycle;
- Development of a prototype for the Android system able to give access to the functionalities chosen during the analysis. The prototype works on the basis of the main interaction gestures to be investigated;

- Collection of preliminary data and first impressions of the prototype by the end users. To this aim, the group was closely observed and interviewed for their feedback;
- Evaluation of the feedback collected during the interviews, which could be useful to improve user interface design.

4 User Requirements and Main Interaction Features

To gather information useful to identify the main features to be included as well as the main interaction aspects to be evaluated; four totally blind users were involved in our study. All four had knowledge of using ITC technologies and smartphones with screen readers. However, only two had experience of devices with a touch screen. The two less experienced users were included in the group in order to record their expectations of interacting with a touch-screen smartphone. The two more skilled members of the group were involved in order to gather suggestions and comments for more usable and appropriate interaction modalities.

All the users showed interest in a smartphone based on the Android platform for a number of reasons. One important aspect is the wide range of smartphone models available on the market with a variety of prices and features. Furthermore the users agreed on the basic functionalities necessary on a smartphone: first of all the phone functionalities such as calls, contacts and short messages should be accessible and easy to use. If these functionalities are provided, then the users would consider evaluating more complex features.

On the basis of feedback from users, it was clear that some aspects of interacting with a touchscreen needed to be considered when designing the prototype. Therefore we took into account (1) how the commands should be organised and sequenced, and (2) how the interactive elements should be designed and developed. The main issues and aspects observed by the user can be summarised as:

- **Keys and touchable elements as reference points:** 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. he 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 touchscreen 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.

- **Organisation of commands and functionalities**: The two less experienced participants said that the commands and actions on the Nokia phones are organised in a way which makes it simple for a blind user who is familiar with menus and submenus. This means that they gave a positive evaluation of the opportunity to use a hierarchical menu for commands and actions.
- **Simplicity and usability of common functions**: The most widely used functions and commands need to be carried out as easily and naturally as possible. Some examples locating the main buttons quickly, exploring the objects following a logical pattern, and learning to use the smartphone for the first time with little effort. The more experienced users suggested placing some specific command buttons in a fixed position to make it easier to detect them. Furthermore they also proposed the idea of exploiting multimodal interaction in order to provide alternative and complementary forms of interaction with the smartphone. Particular attention should be paid to two particular aspects. First the way the UI elements are explored. Secondly the method used to select and confirm an action in order to avoid activating an undesired command involuntarily.

5 The Application Prototype

This prototype is an application for the Android system on mobile devices. It was tested on Samsung Galaxy S, Samsung Nexus S and Huawei IDEOS. The application is not in any way intended to replace screen reading software. Instead it implements the set of features and functionalities used to observe and assess how the users interact with the touch-screen. Thus, when designing the Android application we considered the following aspects with reference to user requirements:

1. Organization and arrangement of the UI items and the instructions to use the phone. The following points were analysed:

   - The structure and the logical order employed to organize the information (e.g. flat or nested in macro topics);
   - The division of the UI so that it contains all the elements needed to exploit the application. Two aspects were important in choosing the position and size of the elements on the screen (I) making identification of elements simple and (II) making use of previous knowledge of the usual positions for elements (e.g. exit/back button element on the top left which is similar to the typical ESC key position on a computer). In order to facilitate some main actions, four buttons were placed at the four corners of the screen. For most cases, these buttons are used to: (I) identify the current position (II) repeat the last action performed (III) confirm the last action performed (IV) close the current task.

– The way to define interaction modalities, i.e. (I) the accepted gestures for the screen (e.g., scrolling, flicking, tapping, double tapping) in order to navigate and access information and (II) the resulting feedback (e.g., vibration, vocal messages). Working together with the users, we identified the appropriate gestures to adopt. We associated a category of actions to each gesture. For instance, a left or right flick for scrolling through elements such as SMSs or contacts, or tables. Another example is the double tap to select a command or confirm critical actions, such as sending or deleting an SMS. As regards the feedback, we tried to do the following (I) associate voice messages only to crucial stages in order to avoid confusing the user with too much feedback (II) formulate short but clear phrases to describe the actions taken by the user (III) use similar phrases for similar activities. Both expert and non-expert users requested the option to decide how much vocal feedback is provided. In fact, in the early stages of learning, it is useful to have voice assistance, but with practice the voice can become irritating and unnecessary.

2. Implementation of the basic functionalities (contacts, call, read/write an SMS and read information in table format).Particular attention was paid to virtual keyboards as regards: (I) the layout of keyboard keys on the screen (II) the selection mode of a key. In order to satisfy the request by users for easy identification of the number 5 our proposal was to place this virtual number at the point where you first tap the screen. On the basis of this first tap the user can move around to locate the position of the other numbers. However, this solution does not exploit the prior knowledge of users who can find the position of a key by remembering its location on the screen. As a result we decided to use a keypad with numbers in fixed positions on the screen. Even though using a standard layout could have been more user friendly, we decided to maximize the size of the numeric keys in order to exploit the full screen. This solution was immediately found to be effective and fast to use. Regarding the voice feedback, this required more detailed analysis. While scrolling, the user received very quick vocal feedback when moving from one number to another. Therefore we decided to introduce a silent gap between the keys in order to have an interval between the vocalization of two adjacent numbers. The result was a significant decrease in errors when selecting a number. During the analysis and implementation of software keyboards, interesting results were obtained from the choice of selecting keys. Users were offered two options for selecting the desired key once it was located. These were (I) double tapping on the screen, or (II) only lifting the finger. Experienced users immediately chose the second solution. Although they could use both methods without difficulty, the finger lifting gesture proved to be more rapid and led to a smaller number of errors. The novice users initially preferred the double touch option, but after testing it for a short time, they switched preference. For this and other reasons, we decided that the two modes of selection were to co-exist in the application. Regarding key selection, we again addressed the number 5 question. To this end, we associated a vibro-tactile feedback

when touching the number 5 on the screen. The users were very positive about this additional feature. For this reason, we are currently researching the idea of associating different vibration patterns to the different keys.

3. Implementation of more complex features in order to evaluate advanced functionalities and opportunities for users with vision impairments. Although this study is mainly devoted to the analysis of user-touchscreen interaction we wanted to analyze how the potentialities provided by a smartphone can be exploited by blind users. In this context, providing a QR code reader that vocalizes the result seemed to be a good starting point. This QR reader could be used to identify household objects known to the user or to label the aisles and shelves of a supermarket. Experienced users were very interested in this as a further opportunity to increase their autonomy and independence.

During this study we tried to exploit the user settings in order to allow the user to choose how to provide and receive information using the phone.

This prototype relies on the (`https://market.android.com/details?id=com.svox.langpack.installer&hl=it`) text-to-speech engine in order to generate the audio feedback, i.e. all the audio messages are created on the spot using a voice synthesizer.

6 Conclusions

This study investigated the interaction between blind users and touch screen mobile devices. To this end, we chose Android-powered devices and we developed a prototype application to implement some targeted functionalities. Involving four totally blind users who interacted with the application, we analysed and evaluated different gestures and feedback. Although the study is based on the Android system, the interaction mode is independent of the operating system and platforms. This means that many of the results discussed can be taken into consideration both by people who develop systems for mobile devices, and those who produce assistive applications.

In the future we plan to develop an advanced version of the prototype using the suggestions from the users as well as our own observations. In addition, the study highlighted the need for a thorough analysis of the following topics: (I) Editing text using the QWERTY keyboard and (II) More extensive use of vibration as feedback. With regard to the first point, the main difficulties were the limited size and proximity of the keys. In addition it would be worth studying an efficient way to correct errors made when writing. For the second aspect, a wider use of vibration could be useful to better distinguish between UI elements.

Following this additional research, we will carry out a more structured user test based on specific tasks in order to collect further data.

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