Developing an Accessible Interaction Model for Touch Screen Mobile Devices: Preliminary Results

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ABSTRACT
Mobile devices are becoming the mass IT platform of the future, reaching people that have never accessed the digital world. Aiming at digitally including visually impaired people also, it is necessary to address solutions that overcome natural barriers originating from the touch screen feature – a growing market trend. This concern has already triggered a number of researches and also some commercial solutions. However, a survey conducted to identify user requirements with blind and partially-sighted people evidenced that the few solutions available on market and the cutting-edge research are far from the reality for visually impaired people in a developing country scenario. To bridge this gap, this paper defines a set of guidelines that has been applied on the development of an accessible interaction model for mobile devices in the Brazilian context.

Keywords
Accessibility, Touch screen, Assistive technology, Visually impaired, Screen reader.

1. INTRODUCTION

Worldwide, mobile devices have been used to connect people from different ages and experiences to the digital world, becoming the mass IT platform of the future [5].

In Brazil, mobile phone penetration rate has reached an average of over 100% in 2010 – more than 120% in urban areas; and forecast to increase still more, while in the rural areas the rate is still around 60% due to the lack of coverage [9]. This technology advance has reached even less privileged people: around 78% of smartphone owners are from the lowers socioeconomic layers [11].

Applications development constraints are not associated with technical aspects of miniaturization anymore, but to human factors related to input and output, driving investments to create interaction models that fit human needs [5].

In line with the Natural User Interface trend [4], gesture inputs and touch screens are growing in the market, being considered an effective mode of input when compared to mere physical solutions such as keypads or joysticks, due to the flexible and rich interactions they provide [4][20].

But when we intend to provide universal access to technology, these trends naturally create barriers to visually impaired people due to requiring the user to locate symbols on the touch screen. These constraints have been driving a number of researches and some commercial solutions, but once in contact with the target-audience in our scenario, a huge gap between the state of the art and the reality of visually impaired people could be noticed.

Evidencing this disparity, this research focuses on identifying user needs aimed at developing an accessible solution for screen-readers on mobile phones, considering also technological trends such as touch screen and smartphones, but especially aimed at digitally including visually impaired people.

This paper presents preliminary results of this user-centered design development and is structured as follows: Section 2 presents the state of the art of accessible solutions in mobile devices and touch screens. In section 3, the research scenario is described, and some findings are presented according to an informative survey with visually impaired participants. Section 4 presents the design recommendations that are guiding development. And section 5 indicates future works and concludes the paper.

2. THE STATE OF THE ART

This session presents an analysis of related works that also consider accessibility on mobile phones, including an overview of guidelines, as well as a summary of solutions available on the market.

Accessibility in touch screen interfaces is not a recent concern. Researchers have been dealing with this issue in screen-based devices, such as touch screen kiosks [7] and touch tablets [8] for over two decades.

More recent researches have been exploring different approaches to improve accessibility for blind people in the mobile context. Some solutions rely on additional hardware to provide feedback and data input, while software solutions for touch screen usually employ gestures recognition associated with screen readers:

2.1 Hardware-based solutions

The Braille system both as input and as feedback is the basis of solutions such as [23], a mobile phone specially designed for visually impaired people with braille display;

10th Brazilian Symposyum on Human Factors in Computer Systems & 5th Latin American Conference on Human-Computer Interaction. IHC+CLIHC'2011 October 25-28, 2011, Porto de Galinhas, PE, Brazil.

in turn, both [12] and [3] developed an additional display to be connected to mobile devices via Bluetooth.

In [24], the tactile feedback is explored semantically by five vibration motors attached on the back of a mobile device, providing different vibration parameters such as frequency, rhythm, strength and texture. This approach increased user efficiency and performance on executing simple tasks, such as dialing through a virtual keyboard.

2.2 Software-based solutions for touch screens

Most of the solutions found in literature enable accessible interactions by accepting gestures as input and providing speech, audio and regular tactical feedback as output. When based on basic gestures, touch screens may offer a rich experience in terms of discoverability, allowing users to directly manipulate items on the screen instead of requiring them to memorize input commands [14]. According to Kane et al [15], interaction models based on gestures can be categorized in three groups:

- **Menu browsing:** users explore the screen through continuous touch gesture and perform an action to select an item, such as stroking the fingers or tapping to move the cursor [15]. It allows a flexible screen layout, which potentially encompasses a solution closer to the universal design approach, addressing both blind and partially-sighted users, as well as sighted ones. Menu browsing technique is part of solutions like the Slide Rule [14], a non-visual approach based on natural gestures; the NavTouch [13], an input text method for touch screen by performing directional gestures; and it is present also in commercial solutions such as the Mobile Accessibility [17] and the Voice Over [2].
- **Discrete gestures:** this approach associates specific actions with predefined gestures, such as the solution proposed by [16]. It is suitable for systems that count on a small set of possible symbolic gestures for text entry or commands, otherwise may lead to a heavy cognitive load to user to memorize all gestures.
- **Fixed regions:** specific regions of the screen, like corners, top and bottom are mapped to recognize predefined gestures, as well as physical buttons are applied for initiating typical tasks. This approach can be improved applying a physical overlay to bound regions. Mobile Speak [18] is an example of the fixed region solution.

As Nielsen and Norman [19] state, this variety of accessibility techniques and the lack of consistency among touch screen applications forces visually impaired users to learn a new interaction model every application they use. Gesture interfaces in general face a lack of guidelines beyond accessibility issues, and ignore previously established standards of interaction, leading to usability disaster [20].

Some initiatives were found regarding accessible touch screens guidelines. Based on participatory interviews, Kane et al [15] suggest to:

- avoid symbols used in printed writing such as letters, numbers, or punctuation;
- favor physical edges, corners, and other landmarks;
- reduce the demand for location accuracy by increasing targets size;
- limit time-based gesture processing to avoiding errors;
- reproduce traditional spatial layouts when possible, such as the QWERTY keyboard or telephone keypad.

And McGookin et al [16] state in their guidelines to:

- do not use short impact related gestures, e.g. tap, that can easily occur incidentally;
- avoid localized gestures;
- provide a discernable tactile "home";
- use different button shapes to quickly, and easily, identify location and functionality;
- ensure that buttons are of adequate size and are sufficiently separated (ideally 1.5cm on each side and 0.5cm between them);
- provide feedback for all action.

2.3 Accessibility of commercial solutions

An European Commission initiative made available instructions and tools to provide mobile devices heuristic evaluation strongly focused on user needs [10]. This set of guidelines supplied us with a number of important requirements for mobile operation; even though it does not address touch screen neither smartphones features.

Manufactures are starting to improve the accessibility of touch screen devices. The Apple iPad® and iPhone® have been considered good examples of accessible devices by some blind people [1], especially because they are originally provided with accessibility tools (screen reader and adaptive gesture interface) for blind or partially sighted, fostering user's autonomy once they do not need a first additional installation. Although, their autonomy may be restrict at the computer side for synchronization.

There are also solutions available for download and installation for the Android operating system (even though not standardized) such as the Mobile Accessibility [17], and the Talk Back [22], a screen reader in English for native applications.

Although many solutions were found in the state of the art, a formative interview with a group of visually impaired people in a developing scenario made clear that these solutions are not easily reached by them, whether due to the software or device costs (specially smartphones), unavailability in Brazilian market such as the [12], or lack of the Portuguese language speech support.

3. THE RESEARCH SCENARIO DESCRIPTION

As stated by [21], a sighted designer cannot easily understand how blind people mentally represent their environment or a task execution. Elements of meaning, such as socialization or independency (or autonomy), efficiency, flexibility and control strongly influence the use of digital and non-digital artifacts.

Aimed at understanding the target-audience's relationship with technology, their real needs and expectations, we conducted a focus group session with visually impaired people (both blind and partially sighted) as part of a meeting at the Blindness Prevention Center in Americana, São Paulo state, Brazil.

Our study included 12 participants, seven females and five males, aged from 16 to 65 years old. Six were blind and six partially sighted, and at various educational levels – four of them concluded elementary school, five were high-school graduate, two undergraduate, and one graduate. Most of them were low-digital-literacy skilled, although with some familiarity with screen-readers on PC since they had just started computing classes. 10 out of 12 participants owned a mobile phone, but none featured a touch screen.

The activity had two different moments: in the first part, participants were separated into four groups of three people each for an informative interview (Figure 1); then, they were invited to freely explore smartphones featuring a screen reader.

Figure 1 - Focus group session with blind and partially sighted people

Examples of questions applied during the interview:

- How do you like your current mobile phone? What would you want to be different?
- Why did you choose this specific mobile phone?
- How was the experience of buying and using it for the first time?
- Would you like to have another one? Why?
- Do you need someone's assistance to (make calls/ receive SMS/ send SMS)?

In the second part, participants freely explored the Apple iPhone with Voice Over© [2] and the Nokia N95© featured with a screen reader (Figure 2a and 2b). The researchers did not intend to evaluate or compare solutions, but to observe participant's impressions, difficulties and interests.

3.1 Main findings

Although all participants demonstrated a strong interest in using screen readers on mobile, especially the touch screen featured one, none of the participants knew about the possibility for using a touch screen device.

Figure 2a and 2b - Free exploration of mobile phones with screen readers

Only one owned a mobile phone featured with a screen reader, while others did not know about this technology availability for mobile devices until then. The second part of the meeting was for most of them the first ever contact with these technologies.

One participant said that her mobile phone should have a screen reader, but she could not reach the configuration set because it is not accessible, and people who she trusts do not know how to configure it. This fact evidences the importance of a post-purchase experience, unaddressed by most mobile-phone sellers or manufacturers. Assistive technology, when available, is usually disabled by default. All our participants needed help from someone else to set up the mobile for them.

When asked about the criteria to buy a new mobile phone, all of them agreed that the tactile experience of finding number keys is the main reason. The mobile phone features do not matter, since they use only strictly basic functions as related subsequently.

Describing how they make use the mobile phone, it was evidenced that participants have a limited ability to place calls due to the inaccessibility of the contacts list, so they have to rely on someone else to read them the number or they have to memorize it themselves.

The awareness of battery level is a big issue, since the low-battery warning sounds when the battery is almost over, and it is the only clue participants have about their battery status.

Regarding privacy concerns, they demonstrated a strong desire to send and receive SMSs autonomously, without asking anyone else to read or eventually delete it for them.

Some features were presented and ranked by them according to relevance. Other features were spontaneously suggested, as presented in Table 1.

Table 1 - Ranked features

Relevance	Asked features	Features suggested
1	Battery Level (considered a mandatory need)	Time & Date
2	Make Calls	Camera
3	Contacts List	Music & Radio

4	Receive SMS	Mobile Settings
5	Send SMS	Alarm
6	Appointments	
7	Email & News	

A way to check the current time was the most popular suggested feature, followed by an accessible camera so they could take pictures of their relatives to show to other people. Older participants also asked for radio while the younger participants asked for an MP3 facility and sharing content via Bluetooth.

One of the participants, who was blind through diabetes (which also affected his tactile sensitivity) found that making calls is impossible without assistance. An audio feedback in all operations, however, would make this action accessible.

The data collected during this activity evidenced how the reality differs from the state-of-the-art, especially in a developing country scenario. Most of participants did not know about smartphones features and when they had contact with it for the first time, most of them immediately mentioned the cost barrier: *"I can´t afford it"*. It is interesting to note that all participants are computing students at the Blindness Prevention Center, so they do give value to Information and Communication Technologies in general.

Aiming at bridging this gap, this paper defines a set of guidelines that has been applied on the development of an accessible interaction model for mobile devices in Brazilian context, featuring a Brazilian Portuguese screen reader and also intended to be executed in middle price mobile phones, i.e. cheaper than smartphones.

4. RECOMMENDATIONS FOR DESIGN

Aggregating guidelines from literature and our research scenario user's needs, a set of recommendations was defined to guide the design of a framework based on screen reader and touch screen solution:

- Provide autonomy: autonomy is an important concept that leads to well-being, especially when we are dealing with people that frequently need help from others to execute simple tasks. The technology must allow autonomous behavior to promote connectivity and relatedness.
- Prioritize the access to tasks earmarked as the most important ones by the target-audience: although mobile phones usually offer a large number of features, mostly people are interested in the most basic ones, such as calling, sending text messages and managing contacts. It is also interesting to give the user the option to configure pages and menus to facilitate the access of their most commonly used features.
- Consider physical access to main features**:** some tasks demand rapid action by the user such as muting the phone or eventual screen reader initialization. Such tasks should have a physical shortcut (button) to perform such tasks.
- Economy in the use of gestures: the possibility of using touch screen resources and gestures to interact evoked a sense of "being part of a new technology" by the visually impaired participants. For this reason, it was considered important to explore gestures like strength of an interaction model, bearing in mind that gestures should not be overused, nor be too complex given that this special perception differs between the sighted and the visual impaired [15].
- Make one-hand interaction possible: usually blind people carry a walking stick or some other object to assist their mobility. For this reason, it is crucial that they can use the mobile phone for basic tasks such as answering a call using one-hand.
- Tactile and audio feedback: a customizable combination of different vibrations and sounds should be applied for feedback of operations such as plugging-in the phone, low-battery warning etc., as well as for actions execution such as selecting a menu item or delivering a message.
- Real-word metaphors: gestures and sounds configuration must be related to everyday tasks, e.g. representing the action of turning a page with a sound and gesture equivalent to performing the task in a book. Once gestures are still not standardized, other device conventions must also be considered.
- Provide tactile exploration: visually impaired people use touch to explore and recognize objects, including the mobile phone. Actions associated with buttons must be made available only when relevant, avoiding an action executed by mistake. Similarly, screen rotation must be carefully used, keeping the reference of content on the screen with physical cues built-in to the device.
- Privacy concerns: it is important to execute personal data reading (e.g. received text message) only when required by the user, and to consider that a blind person may not be constantly aware of the presence of someone else in the environment.

The technical solution under development intends to replace the operation system interface to make recommendations feasible in an operational way. Most commonly used physical buttons will be considered for creating shortcuts.

5. ADDRESSING FUTURE WORKS

According to Norman [20], gestural systems are *"indeed one of the important future paths for a more holistic, human interaction of people with technology"*. The activity with blind and partially sighted people evidenced their interest in being part of this technological trend. Norman goes beyond stating that gestures-based interfaces will "*enhance our control, our feeling of control and empowerment, our convenience, and even our delight*", a feeling compatible with the feedback we had when presenting accessible touch screen devices for people from our research scenario. Although gesture-based interfaces still need standardization, it is possible to consider some convention of basic gestures in a simple solution.

This project proposal is to develop an accessible software solution in all aspects, considering the ease of use for first-time users aiming at digitally include them, and also the cost of the solution. Screen reader, touch screen and speech recognition are planned to be combined to bridge the gap of affordable solutions in the market.

This paper presented the preliminary results of this project, which are guiding a software framework development. Future work encompasses more user-centered activities, including different groups of visually impaired, first to define requirements more precisely and then to constantly validate the solution proposals.

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