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Improving the accessibility of touchscreen-based mobile devices: Integrating Android-based devices and Braille notetakers

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***Abstract* — The article presents the concept and pilot implementation of wireless (Blutetooth-based) integration of the Braille notetaker environment and the environment of touchscreen-based devices (such as smartphones) operating under the Android system. Advanced functions of Android-based devices are hardly accessible to the blind using a touchscreen; one aim of such integration is to enable accessing them with a notetaker. Another is to allow the blind who work with notetakers on a daily basis and use common touchscreen-based smartphones and tablets to write using the physical Braille keyboard of a notetaker as well as its editing functions; this would solve many problems encountered and prevent numerous errors made by the blind when using the virtual QWERTY keyboard of a touchscreen-based device. Pilot implementation of the concept included developing a communication protocol for a notetaker operated under Windows CE and an Android-based smartphone; services to be provided to notetakers by smartphones have been developed as well. The implemented services dealt with managing contacts and composing messages – operations that normally require considerable interaction with a QWERTY keyboard. Favourable results of initial research on pilot implementation conducted among the blind indicate a need for further development of this concept.**

I. Introduction

TOUCHSCREENS intended for the operation of graphical user interfaces are increasingly common in mobile devices and computers both used privately and made available to the public. Such solutions are hardly accessible to the blind: it is difficult for them to locate and select items visualised on the screen. Assistive technologies offered by mobile device manufacturers, such as Apple's VoiceOver used in iOS-based devices or Google's TalkBack and BrailleBack used in Android-based devices, do improve accessibility, but do not eliminate all the obstacles. One example of such barrier is the virtual QWERTY keyboard, where punctuation marks and other special characters are difficult to enter (it requires switching keyboard operation mode) and there is no point of reference like the bossed "J" key of a physical keyboard. Other examples include lack of haptic points on the screen (these would improve spatial orientation) and poor suitability of touchscreen gestures for the blind (they prefer gestures starting on the edge of the screen or in its close vicinity). The existing barriers create a need for research and new solutions that would improve the accessibility of touch interfaces. The concept of such solution presented in this article is based on two assumptions, tested positively for example in [3] and [4]:

- most of the tested blind smartphone users deem notetakers to be indispensable, especially for taking notes quickly;
- the use of a linear-sequential Braille interface by the blind, especially for entering text using a physical Braille keyboard, is much more efficient than the use of a virtual QWERTY or Braille keyboard.

Since, according to the research, smartphones and notetakers are indispensable in daily use for most of the blind, the main idea of the concept is to take advantage of the synergy obtained by functionally integrating devices of both types. This synergy results from combining their essential qualities: the efficient Braille interface of a notetaker and the advanced functions of smartphones and tablets. The use of a notetaker to improve touch interface accessibility gives more than just the possibility of using a physical Braille keyboard (which is accomplished by using BrailleBack app). Notetakers – computers operating under systems such as Windows CE – can provide programmable access to smartphone functions, which makes these functions available via the Braille interface. Besides, combined with a smartphone, a notetaker serves as a smart Braille keyboard with functions for efficient (quick, less error-burdened) text editing.

Advanced smartphone functions are made available through specific software that has been developed as part of concept implementation, operates under the Android system of a smartphone, and provides services for the notetaker. These services are called by specific software operated under system (Windows CE) of the notetaker and developed as part of the concept. The lowest level of integration includes communication software that runs on both devices and connects either the smartphone to the notetaker (for example for text editing) or the other way (in order to access the selected advanced smartphone function to use it as a remote service on the notetaker).

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The pilot implementation of the concept involved a Samsung Galaxy S III smartphone and a Polish notetaker Kajetek SD, see [9]; it included access to contact management and message composing services as well as editing text functions (remotely serving by the smartphone, realized by a blind user on the notetaker). Results of pilot implementation tests conducted on 7 blind users with different Braille and technical experience indicate a need for further development of the concept. The testers confirmed that the initiative was heading in the right direction: for solving touch interface accessibility problems encountered by the blind. The presented considerations and research results consist the area of dissertation work of the co-author, Daniel Kocieliński.

II. Related work

The research is focused on overcoming the two greatest difficulties faced by the blind when using touchscreen-based mobile devices: enabling efficient navigation through graphical elements and their correct selection and developing a method for quick and correct text input. There are many different ways to interact with interfaces of touchscreen-based devices: a simple single tap, several simultaneous or successive taps, directional and scanning gestures as well as fixed and adaptive layouts of function fields comprising the screen.

However, software developers often neglect to adapt their methods to the needs of a blind user. Findings of Kane et al. presented in [1] point to differences in preferred gestures and ways of making them between sighted and blind users. Oliviera et al. demonstrated in [2] that the blind input text using different methods more or less efficiently depending on their personality traits and personal experience. D'Andrea found out that most of the tested blind students prefer using smartphones with Braille notetakers and value their Braille skills, especially for the possibility of taking notes, see [3]. Southern et al. in turn noticed lower erroneousness in case of entering text in Braille, using a physical or virtual keyboard, see [4] and [2]; according to [4], the use of a physical Braille keyboard is the most efficient method. Azenkot et al. confirmed these findings in [5] and [4], comparing the more efficient various Braille text input methods to entering text using a QWERTY keyboard and with the aid of Apple's VoiceOver. The virtual QWERTY keyboard has been enhanced e.g. by Findlater et al. in [6], applying extensions available through specific user gestures. In [7] Costagliola and Capua suggest implementing into the virtual keyboard an additional menu displayed upon making certain gestures around a given character. In [8] Ruamviboonsuk et al. suggest entering numbers sightlessly (to enable quicker dialling), using specific multi-touch combinations. Improvements suggested in [6], [7] and [8] have not been tested by the blind nor designed for this group of users.

In [4] the authors suggest a fixed virtual Braille keyboard that would have 6 keys: 3 on the left and 3 on the right side of the screen, near its edges. [5] in turn suggests a dynamic virtual Braille keyboard appearing where 3 fingers of one hand or 6 fingers of two hands are placed.

III. Integration concept

The main idea behind the presented research is to provide blind users with intuitive, friendly access to the advanced functions of touchscreen-based devices (such as smartphones). As a mean of improving accessibility of smartphone and tablet (hereafter referred to as smartphones) functions we propose using Braille notetakers, which are common among the blind, and Bluetooth communication mechanisms for exchanging data between touchscreen-based devices (such as smartphones) and notetakers. The adopted concept assumes that establishing a wireless connection between the notetaker and a specific smartphone will allow the user to access its advanced functionalities (given by services of Android OS and installed apps) using the physical keyboard of the notetaker and its well-known, convenient Braille interface.

As opposed to the case of graphical smartphone interfaces, where users interact with applications by making touch gestures on items displayed on the screen, operation of notetakers is based mainly on Braille keystrokes and sequential-hierarchical access to functions. Preferred interaction methods, which speed up and facilitate blind users' actions and are usually integrated in notetakers, include:

- function selection lists activated by pressing appropriate navigation keys,
- handy command menus available through hierarchical navigation or called using keystrokes,
- sets of Braille keystrokes that provide access to all the important notetaker functions at any time,
- editing functions that allow to enter text using six- and eight-dot Braille and navigation through the text quickly.

The aim of our research is to find ways of translating the graphical interface of touch-based devices (specially of smartphones) into a Braille interface that would include navigation and text input methods preferred by the blind. Our pilot work resulted in formulating basic assumptions concerning wireless operation of a smartphone with the Braille interface of a notetaker.

Such integration of the two environments – dedicated software of the notetaker and Android OS of the smartphone – allows a blind user to easily use such advanced functions of smartphones as speech recognition, cloud data (e.g. contacts) management, file sharing (e.g. Dropbox), web-based search engines, instant messaging, phonecalls or GSM and GPS navigation. Our concept makes it possible to use all the functions of a smartphone, as remote services, via a notetaker and eliminates the need for development aimed at implementing smartphone functions into notetakers. This way the blind would be able to use, conveniently, common touchscreen-based devices.

IV. Methodology

A. Implementation technology and test equipment

In order to test the concept we have developed pilot software consisting of two interacting modules: one running on an Android-based smartphone and one on a Kajetek SD

notetaker operated under Windows CE 5. Both modules support wireless Bluetooth connectivity and allow:

1) operating the smartphone with the physical keyboard of the Kajetek notetaker and
2) direct access to the advanced functions (as dedicated services) of the Android-based device.

The Android software has been implemented in Java, using Android API level 17, and tested on a Samsung Galaxy S III smartphone. During tests (navigation the contact list and input new contacts by virtual QWERTY keyboard) feedback was realised using text-to-speech, with the TalkBack screen reader.

The notetaker software is a C++ library that extends Kajetek application with support for a protocol used to communicate with the Android module. The communication protocol for the research has been developed as a sequence of XML query-response messages; the Bluetooth protocol serves as the transport layer.

B. Scope

During the research the basic concept assumptions have been tested by managing contacts using the remote interface between smartphone and notetaker. The pilot software allows the user to operate the smartphone's contact services using braille interface of Kajetek. In this way he or she can quickly navigate through contact items using notetaker keystrokes. The following contact management services have been implemented, as the remote interface, for the Kajetek notetaker:

- browsing contact lists (using specific Braille keystrokes),
- reviewing details of selected contacts,
- adding new contacts (using the editing functions integrated in Kajetek software),
- deleting contacts.

To find an appropriate input method that provides fast text entry we also measured performance of different input methods. We considered three ways of composing messages to selected recipients: using a virtual QWERTY keyboard, a virtual Braille keyboard, and the editing functions of the notetaker. Practical tests of text input speed have been conducted on a virtual QWERTY keyboard and on the physical keyboard of the Kajetek notetaker.

So, the test scenario included:

- navigating the contact list using the manufacturer's contact management app and TalkBack screen reader,
- navigating the contact list remotely, using the Kajetek Braille interface and appropriate services on the smartphone,
- adding new contacts using the manufacturer's contact management app and a virtual QWERTY keyboard,
- adding new contacts using Kajetek with its editing functions and the remote notetaker operation services on the smartphone.

C. Pilot test group

The tests have been conducted on a group of 7 users with different experience in the use of smartphones. Three of users are experienced in the use of smartphones: from a few weeks to a couple months; where one of the testers is an experienced iPhone and VoiceOver user. Next 3 of the users were able to use smartfone after training part of the tests. Seventh person said that touchscreen is too big challenge and gave up in tests on a virtual QWERTY keyboard of smartphone.

All testers know Braille well and are experienced in the practical use of Braille notetakers (5 of them are using Braille notetakers in daily work).

V. RESULTS

The results of tests proved that:

- item selection (tested on a list with 100 items) by interface of Braille notetaker is 2-3 times quicker than the item selection by the standard app of Android system (approximately from 4 to 10 seconds when using notetaker, and from 11 to 28 seconds when using standard app);
- the use of the editing functions of a Braille notetaker is much more efficient than using a virtual QWERTY keyboard (the text input speed for the slowest and the fastest tester reached, respectively, from 11 to 38 characters per minute – CPM when using a QWERTY keyboard, and from 87 to 173 CPM when using a notetaker).

Feedback from the test group confirms that the existing accessibility mechanisms of the Android system (such as TalkBack and BrailleBack), especially the ones related to navigation based on the available gestures (e.g. implemented through TalkBack) and text input using a virtual QWERTY keyboard, are subject to significant limitations. The tests have proven that managing contacts with the interface of the Kajetek notetaker and its physical Braille keyboard is more efficient than doing so using the standard smartphone application for managing contacts combined with the TalkBack screen reader, gestures and the virtual QWERTY keyboard. Selecting desired contacts from the list using Kajetek is more efficient primarily because of lesser erroneousness of browsing actions; operating a touch interface requires greater manual precision. One of the testers suggested extending the list item selection functionality of Kajetek e.g. with a quick search function looking for the first few entered letters of a contact.

The received feedback also confirms that the existing smartphone accessibility mechanisms related to text input are insufficient. Message composing tests indicated a significant advantage of the physical Braille keyboard of a notetaker over a virtual QWERTY keyboard.

VI. CONCLUSIONS

The results of preliminary research on pilot implementation into the Android system, concerning functions like managing contacts and composing messages to selected recipients, confirm that the adopted concept of using interaction mechanisms for touchscreen-based devices and Braille notetakers is a promising direction for further research and give grounds for continuing works. Practical tests of pilot application have shown that the use of a notetaker to operate the interface of a smartphone is not only

a solution that improves a blind user's work efficiency and convenience. The tests proved that quick navigation and editing functions of a Braille notetaker can be great solution for the blind users for example with a dysfunction of touch of sense. The research suggests new ways of solving the essential problem, which is the inaccessibility of new, advanced technologies to the blind. The main cause of this problem is that hardware manufacturers and software developers usually marginalise this group of users by providing (mostly behindhand) only accessibility tools (such as screen readers) that rather adapt methods of operating graphical touch interfaces than provide other, suitable ones. The proposed solution for improving the accessibility of touch interfaces is quite unusual compared to those currently provided in smartphones: it is based on using a Braille interface, smart notetaker mechanisms and a dedicated communication protocol for convenient operation of advanced mobile device functions and services. Results confirm that the our concept is a promising direction for further research and development towards a complete and efficient working environment of touch devices for the blind users.

REFERENCES

[1] Kane, S.K., Wobbrock, J.O., Ladner, R.E. Usable gestures for blind people: Understanding preference and performance. Proc. CHI'11, ACM (2011), 413-422

[2] Oliveira, J., Guerreiro, T., Nicolau, H., Jorge, J., Gonçalves, D. Blind people and mobile touch-based text-entry: acknowledging the need for different flavors. Proc. ASSETS '11, ACM (2011), 179-186

[3] d'Andrea, F.M. Preferences and Practices Among Students Who Read Braille and Use Assistive Technology. Journal of Visual Impairment & Blindness, Volume 106, Year 2012, October-November 2012, 585-596

[4] Southern, C., Clawson, J., Frey, B., Abowd, G.D., Romero, M. An Evaluation of BrailleTouch: Mobile Touchscreen Text Entry for the Visually Impaired. Proc. MobileHCI'12, ACM (2012), 317-326

[5] Azenkot, S., Wobbrock, J.O., Prasain, S., Ladner, R.E. Input finger detection for nonvisual touch screen text entry in Perkinput. Proc. Graphics Interface, Canadian Information Processing Society (2012), 121-129

[6] Findlater, L., Lee, B.Q., Wobbrock, J.O. Beyond QWERTY: Augmenting Touch-Screen Keyboards with Multi-Touch Gestures for Non-Alphanumeric Input. Proc. CHI'21, ACM (2012), 2679-2682

[7] Costagliola, G., Fuccella, V., Di Capua, M. Text Entry with KeyScretch. Proc. IUI , ACM (2011), 277-286

[8] Ruamviboonsuk, V., Azenkot, S., Ladner, R.E. Tapulator: A Non-Visual Calculator using Natural Prefix-Free Codes. Proc. ASSETS'12, ACM (2012), 221-222

[9] Information about Kajetek SD on the manufacturer's website: http://www.ece.com.pl/index.php?option=com_virtuemart& page=shop.browse&category_id=5&Itemid=2