FULLY ACCESSIBLE TOUCH SCREENS FOR THE BLIND AND VISUALLY IMPAIRED

Shaun K. Kane, Jeffrey P. Bigham and Jacob O. Wobbrock
University of Washington

ABSTRACT

Recent advances in touch screen technology have increased the usability of touch screens for sighted users and prompted a wave of new touch screen-based devices. However, touch screens are still largely inaccessible to blind people because they require the user to visually locate objects on the screen. To address this problem, we developed an application called Slide Rule that uses audio output and gesture input to enable blind people to interact with touch screens. In this paper, we describe the design and development of Slide Rule, and a user study in which 10 blind people compared Slide Rule to a button-based Pocket PC. Results show that Slide Rule was significantly faster than the Pocket PC, and was preferred by 7 of 10 participants. Slide Rule has the potential to significantly increase accessibility on a wide range of touch screen devices.

BACKGROUND

Although touch screens have existed for decades, new advances in touch screen interfaces, as seen in products such as Apple's iPhone[1] and Microsoft Surface[2], have renewed consumer interest in touch interfaces. In addition to these devices, touch screens are increasingly being incorporated into other devices, such as photocopiers and other office equipment, supermarket checkout kiosks, airport ticket kiosks, automatic teller machines, elevator controls, and voting machines. These touch screen interfaces offer several benefits to sighted users. One such advantage is the ability to present varied interactive content in a single space. For example, a touch screen device can display a large-size map or image, and pop up a keyboard only when needed, providing additional functionality in a smaller space. Another advantage of touch screens is discoverability. Rather than requiring users to remember control keys, touch screens allow users to see a list of options and tap the desired option.

However, touch screens can present significant accessibility barriers to blind users. Most touch screens provide no audio or tactile feedback, making it difficult or impossible to locate items on the screen. Because of this, blind users may need to be shown the locations of on-screen objects by a sighted person, may need to use an alternative accessible interface (if available), or may be completely unable to use some technology. As more devices become touch screen-enabled, these accessibility barriers may prevent blind and visually impaired people from using consumer devices or performing essential job functions.

Some blind community groups have noticed this problem and have reached out to technology developers. Recently, Stevie Wonder visited the Consumer Electronics Show to remind device manufacturers to consider blind people when developing new products (1). However, very few

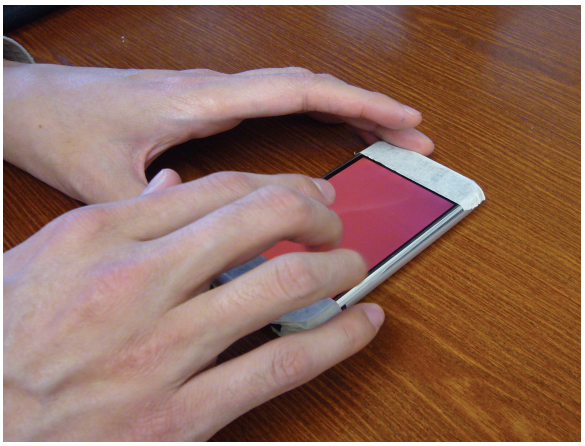

Figure 1. A blind person reads a list of email messages using Slide Rule on an Apple iPhone. Slide Rule uses audio output only and does not display information on the screen.

[1] http://www.apple.com/iphone/
[2] http://www.microsoft.com/surface/

touch screen-based devices currently provide any accessibility support for blind users. While some past research projects have attempted to increase the accessibility of touch screen-based systems (e.g. 2,3,4), these systems required both a touch screen and additional hardware, such as an external keypad or a tactile overlay. Since this hardware is not always available, these systems are not reliably accessible. Nokia is currently developing a touch screen with raised tactile buttons (5), but has not announced a release date for this product. The screen reader Mobile Speak[3] provides access to touch screen-based mobile phones, but provides relatively little access to the touch screen. Mobile Speak primarily provides access through the phone keypad, but allows users to tap the four corners of the touch screen as additional buttons. Thus, Mobile Speak is not usable on phones that do not have at least some physical keys.

PROBLEM STATEMENT

Most current non-tactile touch screens cannot be easily used by the blind and visually impaired. These users may encounter several problems when attempting to interact with a touch screen: 1) lack of accessible audio or tactile feedback when performing actions; 2) lack of ability to determine the current state of the touch screen device; and 3) difficulty in selecting the desired item on screen. Slide Rule addresses these concerns by allowing users to gesture on a touch screen without visual feedback. Furthermore, while touch screen accessibility can be improved through the addition of tactile overlays, physical buttons, or other hardware, users cannot rely on this additional hardware being available for every touch screen. Thus, Slide Rule provides full touch screen accessibility using the touch screen only, and does not require any hardware buttons. Finally, a truly accessible touch screen solution should provide blind touch screen users with all of the advantages that sighted users have when interacting with touch screens, such as allowing the users to interact with different application layouts on a single screen, and allowing users to easily discover the features of the touch screen software, rather than needing to memorize the locations of on screen objects. Slide Rule provides accessible methods for exploring and using a variety of touch screen applications.

RATIONALE

As touch screens become more common in computers, mobile phones, and other electronic devices, blind and visually impaired users risk being excluded from using these devices. This exclusion could cause new and severe accessibility barriers for blind users, and could impair their ability to perform tasks at work, access information in public spaces, and share devices with sighted friends and family. Our vision for Slide Rule is to fully leverage the abilities of blind users, allowing them to interact with touch screen-based devices as efficiently as a sighted person. Many blind people are used to reading Braille documents with their fingers, and with using a screen reader to access a computer. Therefore, a blind person should be able to interact with touch screens, provided that the touch screen provides voice feedback. In practice, however, existing solutions either require additional hardware, or provide extremely limited access to the touch screen. Rather than building new, specialized hardware, we developed new ways of using a touch screen that enable blind and visually impaired people to efficiently access existing touch screen devices.

DESIGN

We followed a user-centered design process in developing Slide Rule. At the beginning of the project, we visited several blind community organizations, including the local chapter of the National Federation of the Blind and the Seattle Lighthouse, to discuss our ideas for the project and gauge interest in our work. After receiving positive feedback from these organizations, we

[3] http://codefactory.es/en/products.asp?id=283

conducted a series of interviews with 8 blind[4] mobile device users. Our interviews focused on informants' current use of mobile devices, as well as their experiences with, and thoughts about, touch screen-based devices.

The results of these interviews are described in depth in a prior publication (6), and are summarized here. Overall, we found that many of our informants were excited by the idea of using an accessible touch screen, but had some concerns about them. Informants said that they rarely used touch screen devices, but occasionally needed to, such as when interacting with a microwave oven or a touch screen kiosk at work. However, these encounters with touch screens were often frustrating, and typically required the informant to ask for help from a sighted person to use the touch screen. Many informants said that they would like to use an accessible touch screen, but were concerned about being unable to find objects on the screen or accidentally performing some task, such a deleting a file.

Based on our interviews and early prototypes, we created a set of design principles for accessible touch screen systems, and used these principles to develop a prototype of Slide Rule. This prototype was tested iteratively by 3 blind and 2 sighted colleagues. Feedback from this early evaluation was used to refine the design of Slide Rule and improve overall usability.

Design of Slide Rule

We developed a prototype version of Slide Rule on a mobile touch screen phone (Figure 1). This prototype uses speech and audio for output and touch for input, but does not provide visual feedback or use any physical buttons. We chose these strict constraints for our initial prototype to ensure that Slide Rule was fully accessible with minimum hardware requirements, requiring only a touch screen and audio output to function. Extending Slide Rule with physical buttons, tactile feedback, and visual output are exciting opportunities for future research.

Slide Rule provides access to four applications: 1) a home screen for starting other applications and accessing the current time; 2) a contact list for searching and dialing contacts; 3) an e-mail client; and 4) a music player. We chose these applications because they are often used on a mobile phone. Slide Rule provides uses gestures to interact with these applications (Fig. 2).

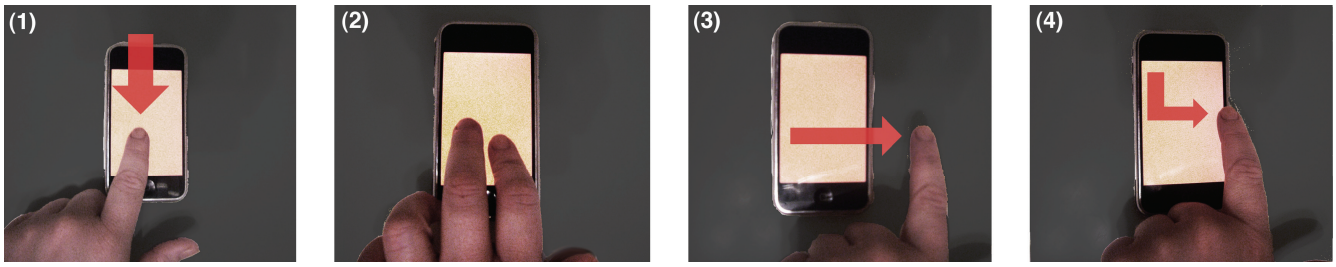

Figure 2. Slide Rule uses gestures to interact with applications. (1) Scanning with one finger is used to browse lists; (2) Tapping with a second finger selects items; (3) A *flick* gesture is used to flip between pages of items or a between songs; (4) Scanning with a finger in an *L*-shape is used to browse hierarchical information, such as musical artists and song names.

Despite its non-visual interface, Slide Rule lays out objects on the screen spatially using linear lists (see Fig. 3). A user browses through lists of items by sliding their finger vertically across the touch screen. Touching the screen with a single finger will not perform any action, so users are safe to

[4] In this research, we defined blind users as desktop screen reader users.

touch and explore the screen. Items on the screen are read as the user touches them. Slide Rule reads the first letter of each item, and then the full name of the item, allowing the user to quickly scan through a list. When the user wishes to select an item, she keeps her finger on the screen and touches anywhere on the screen with a second finger. This removes the need to tap accurately on the screen. These gestures are used throughout Slide Rule for browsing and selecting items.

The user can also search hierarchical data using an L-shaped gesture. For example, in the music player, scanning one's finger down the left side of the screen lists available artists. Once the user has found the artist she is searching for, she can scan her finger to the right to search through songs by that artist (Figure 3). The user can also flick the screen to perform certain actions, including switching between songs (left, right), reading the current application and system status (down), or returning to the home screen (up). Finally, the user can physically rotate the device sideways to open an on-screen touch keyboard, although we did not evaluate this feature in our initial study.

DEVELOPMENT

Our prototype of Slide Rule is an Objective-C program running on an Apple iPhone or iPod Touch. This is a commercially available device that retails for approximately $200. No additional hardware is needed to run Slide Rule. Speech is generated in real time on the iPhone, but can also be pre-generated on a PC for better voice quality. Because the design of Slide Rule requires reformatting mobile device applications, we developed custom applications rather than using the device's native programs. For evaluation purposes, Slide Rule applications use pre-generated content (e.g. contact names and e-mail messages), but a future version will connect to actual phone data. The Slide Rule application is not yet publicly released, but we intend to publish it on the iPhone App Store. This will allow a user to purchase an iPhone or iPod at a store, bring it home, install Slide Rule over the Internet, and begin using it immediately.

EVALUATION

Our criteria for evaluating Slide Rule were its ability to improve accessibility, its performance, and user satisfaction. To evaluate these criteria, we conducted a usability and performance evaluation in which 10 blind people performed tasks using both Slide Rule and a comparison device. Because the iPhone is completely inaccessible without Slide Rule, we could not use it for this comparison. Instead, our comparison device was a Pocket PC using the Mobile Speak screen reader. The Pocket PC provided both a touch screen and a 4-way directional keypad, while Slide Rule used the touch screen only. Participants performed 3 tasks: dialing a specified contact, reading an email message from another specified contact, and playing a specified song. Participants performed five trials of each task on each device. Tasks and devices were randomly ordered. Overall, participants performed tasks faster with Slide Rule than with the Pocket PC. However, participants sometimes accidentally selected an item on the touch screen with Slide Rule, while they made no such selection errors with the Pocket PC. Fortunately, these accidentally selected items generally did not have negative effects for the user, and did not significantly

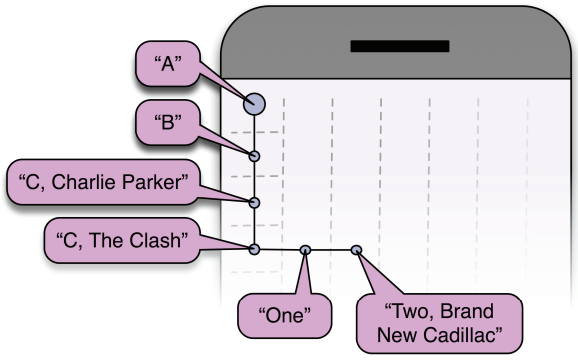

Figure 3. User performs an L-gesture by scanning their finger down a list of artists, then across a list of songs. Slide Rule says the first letter of each item to enable quick scanning.

reduce task speed. These errors can be addressed in future prototypes by requiring confirmation for potentially harmful actions, such as deleting a file.

We also asked participants to compare Slide Rule and the Pocket PC based on a number of factors. Although participants found the Pocket PC to be more familiar and somewhat easier to use, 7 out of 10 participants preferred Slide Rule overall. This result suggests that, despite participants' familiarity with more traditional devices such as the Pocket PC, and despite the challenges of learning a new user interface, participants recognized the potential for Slide Rule to improve access to touch screens. One participant stated, "I've never seen a touch screen that accessible before, and that was pretty cool." For more information on our study results, please refer to prior work (6).

DISCUSSION AND CONCLUSIONS

In this paper, we presented Slide Rule, a system that uses audio output and gesture input to provide full access to touch screens for blind and visually impaired users. Slide Rule is a software program that can be used on an existing touch screen device without any additional hardware buttons or accessibility modifications. Slide Rule's design is based on interviews with blind computer users and on user-centered design with blind people. Our user study shows that blind users are able to complete tasks more quickly with Slide Rule than with a button-based Pocket PC, and that they prefer Slide Rule to the more familiar Pocket PC.

These promising results demonstrate that Slide Rule can significantly improve the accessibility of touch screens for blind people, using everyday devices and without additional hardware. We are currently extending Slide Rule to include additional capabilities, including tactile feedback, hardware-based buttons, and visual output. We also intend to copy Slide Rule's gesture input to other devices, including large-sized touch screens. We hope that Slide Rule can serve as a model for accessible interaction across a variety of touch screen devices, and help ensure that blind users are not cut off from this important and widespread technology.

ACKNOWLEDGEMENTS

We thank Sunny Consolvo, Intel Research, and the Washington Research Foundation for equipment used in the study, and Hesham Kamel for his feedback on early prototypes.

REFERENCES

1. Carew, S. (2009). Touch-screen gadgets alienate blind. *Reuters.* http://www.reuters.com/article/newsOne/idUSTRE5080T320090109
2. Vanderheiden, G.C. (1996). Use of audio-haptic interface techniques to allow nonvisual access to touchscreen appliances. *Human Factors and Ergonomics Society Annual Meeting Proceedings*, *40*, 1266.
3. Landau, S. and Wells, L. (2003). Merging tactile sensory input and audio data by means of the Talking Tactile Tablet. In *Proceedings of EuroHaptics '03*. New York: IEEE Computer Society, 414-418.
4. Hill, D.R. and Grieb, C. (1988). Substitution for a restricted visual channel in multimodal computer-human dialogue. *IEEE Transactions on Systems, Man and Cybernetics, 18(2)*, 285-304.
5. Melanson, D. (2007). Nokia shows off Haptikos tactile touch screen technology. *Engadget.* http://engadget.com/2007/11/06/nokia-shows-off-haptikos-tactile-touch-screen-technology/
6. Kane, S.K., Bigham, J.P. and Wobbrock, J.O. (2008). Slide Rule: Making mobile touch screens accessible to blind people using multi-touch interaction techniques. In *Proceedings of ASSETS '08*. New York: ACM Press, 73-80.

CONTACT INFORMATION FOR FIRST AUTHOR

Shaun Kane
The Information School
Box 352840
University of Washington
Seattle, WA 98195 USA

ALTERNATIVE TEXT DESCRIPTION FOR FIGURES

Figure 1. A blind person is holding a touch screen-based mobile device (Apple iPhone), and moving his finger across the screen. Slide Rule, our research prototype, reads a list of email messages as the user moves his finger Slide Rule uses audio output only, and no image is displayed on the screen.

Figure 2. Four images of an Apple iPhone, numbered (1) through (4). Each image shows a hand performing gestures on a touch screen to interact with Slide Rule. (1)The user moves her finger across the screen to browse a list of items; (2) The user taps with a second finger on the screen, while holding the first finger still, to select an item on screen; (3) The user interacts with Slide Rule by flicking her finger over the screen and to the right; (4) The user moves her finger down the left edge of the screen, then to the right, making an L-shape.

Figure 3. A diagram shows the spatial layout of items on Slide Rule's screen. A line illustrates the path taken by the user's finger as she selects a song using Slide Rule's music player. The diagram shows what will be spoken as the user touches the screen, in sequence. First, the user scans her hand along the left edge of the screen. Slide Rule reads the following musical artists: "A", "B", "C, Charlie Parker", and then "C, The Clash". The user chooses The Clash, and begins to move her finger to the right. Slide Rule then reads the names of songs, in order: "One", "Two, Brand New Cadillac". The user selects the song *Brand New Cadillac* by The Clash.

VIDEO DEMONSTRATION

A video demonstration of Slide Rule is included with this submission. The Slide Rule demonstration video is also available on the web at http://vimeo.com/1928792

The video demonstration is presented both with and without audio descriptions. We chose to submit a version without descriptions so that the viewer can better hear the audio prompts from Slide Rule.