From Tapping to Touching: Making Touch Screens Accessible to Blind Users

Tiago Guerreiro, Paulo Lagoá, Hugo Nicolau, Daniel Gonçalves, and Joaquim A. Jorge
Technical University of Lisboa

The NavTouch navigational method enables blind users to input text in a touch-screen device by performing directional gestures to navigate a vowel-indexed alphabet.

Mobile phones play an important role in modern society. Their applications extend beyond basic communications, ranging from productivity to leisure. However, most tasks beyond making a call require significant visual skills. While screen-reading applications make text more accessible, most interaction, such as menu navigation and especially text entry, requires hand–eye coordination, making it difficult for blind users to interact with mobile devices and execute tasks. Although solutions exist for people with special needs, these are expensive and cumbersome, and software approaches require adaptations that remain ineffective, difficult to learn, and error prone.

Recently, touch-screen equipped mobile phones, such as the iPhone, have become popular. The ability to directly touch and manipulate data on the screen without using any intermediary devices has a strong appeal, but the possibilities for blind users are at best limited. In this article, we describe NavTouch, a new, gesture-based, text-entry method developed to aid vision-impaired users with mobile devices that have touch screens. User evaluations show it is both easy to learn and more effective than previous approaches.

NavTap and NavTouch

NavTap is a text-entry method that we developed to enable blind users to input text in a keypad-based mobile device.[1] It rearranges the alphabet (see Figure 1) so that users can tap four keys (2, 4, 6, and 8) on the keypad to navigate through the letters using vowels as anchors, therefore eliminating the need to remember which letters are associated with which key. Taking advantage of the raised marker on key 5, keys 4 and 6 enable users to navigate horizontally in the alphabet, while keys 2 and 8 allow them to jump between vowels. We can use the joysticks available on many devices to the same effect. Users select letters after a timeout or by pressing the 5 key. This navigation method requires no memorization beyond knowing the sequence of letters in the alphabet. Even users with mental-mapping problems can navigate at leisure until reaching the desired letter. Users with richer mental-mapping abilities can follow the shortest path to the desired letters (shown in green in Figure 1). Constant audio feedback reads each letter to users as they select it, drastically reducing the number of errors while increasing text-entry task success and user motivation to improve writing skills. Additionally, NavTap eliminates the cognitive load associated with memorizing key-to-letter relations present in mobile devices.

For touch screens, the same approach can be used. NavTouch is a similar approach we developed for use with touch screens. Using NavTouch, people navigate the alphabet (see Figure 1) by performing directional gestures on the screen. Again, all interaction uses simple navigation and constant audio feedback. To complement navigation, we placed special actions (such as OK, erase, and so on) on screen corners. When compared to NavTap, NavTouch shows improved performance. Users don't need to find the navigation (or 5) key—each gesture can be performed anywhere on screen—and they don't need to take their finger off the screen but can continue navigating by maintaining the pressure on the screen or sliding it in another direction.

1070-986X/08/$25.00 © 2008 IEEE Published by the IEEE Computer Society

User evaluation

To validate our approach, we performed tests using three groups of five blind users each. Eight were female and seven male, ranging from 36 to 65 years old, with different education levels (40 percent completed elementary school, 40 percent attended secondary/middle school, and only 20 percent attended high school). One of the users had a university degree but had no previous text-entry experience on mobile devices. We randomly assigned each group of users to a specific input method: traditional MultiTap, NavTap, and NavTouch (see Figure 2). All methods featured speech feedback. Each test took three sessions on three different days with a day in between each test day. In each session, users wrote specific sentences using each method (different phrases of similar complexity were used for each session).

The first session included a maximum training period of thirty minutes to learn the appropriate text-entry method. We observed that users were able to understand NavTap and NavTouch after a few minutes, while MultiTap was more difficult for them to learn. This was reflected in MultiTap trials as users experienced difficulties associating keys and letters, leading to much worse results than we expected. Indeed, the error rate when using MultiTap increased across sessions (47 percent, 60 percent, and 71 percent), while it decreased with NavTap (17 percent, 6 percent, and 4 percent), and NavTouch (27 percent, 17 percent, and 14 percent).

We measured the difference between the proposed and transcribed sentence using minimum string distance (MSD). For MultiTap, the average MSD error rate was 15.6 percent, much higher than for NavTap (10 percent) and NavTouch (4 percent). It's important to note that although users tend to erase more letters with NavTouch, the final result was better than with NavTap. On the other hand, the number of errors and the final result were always worse with MultiTap as users often felt confused and lost track of progress.

While MultiTap has a theoretical advantage regarding keystrokes (or gestures) per character, and although the results were as expected in the first session (MultiTap had 4.96 keystrokes per character, NavTap had 8.07, and NavTouch had 6.02), navigational approaches outperform MultiTap as users start to navigate using shorter

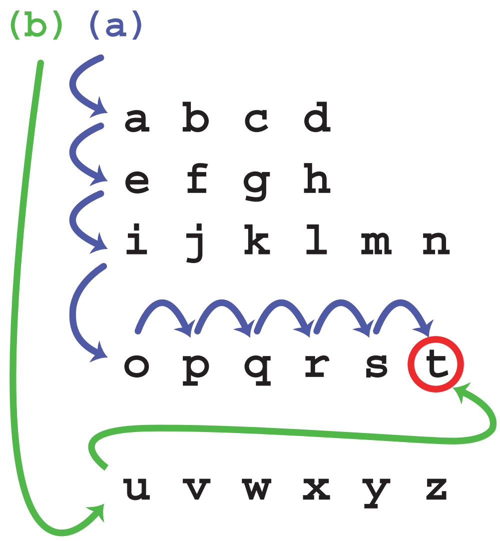


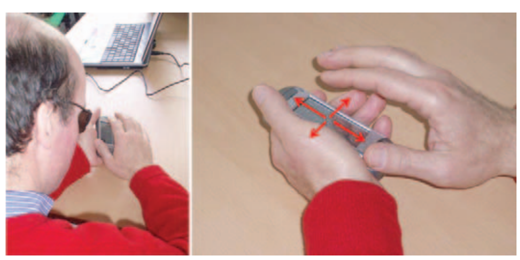
Figure 1. NavTap—two navigation alternatives to reach the character 't'.

paths (MultiTap had 5.68 keystrokes per character, NavTap had 5.47, and NavTouch had 4.68). The decrease in MultiTap performance can be explained with the training session performed before the first session (users forgot key-to-letter associations in subsequent sessions), while NavTouch outperforms NavTap because of the additional effort in finding the appropriate directional key with NavTap.

Indeed, we found that users are able to quickly navigate in all four directions with NavTouch as gestures can start at almost any point on the screen with no extra associated load. Furthermore, users are able to write sentences more quickly with navigational approaches, improving their performance across sessions (see Figure 3). Overall, experimental results show that navigational approaches are far easier to learn and users are able to improve performance without further training. Moreover, NavTouch was more effective than NavTap because of the more fluid mapping of gestures to actions.

Future work

Future topics for research include assessing the feasibility of NavTouch for users with



(a) **(b)**

Figure 2. NavTouch: (a) user testing device and (b) close-up and directional options.

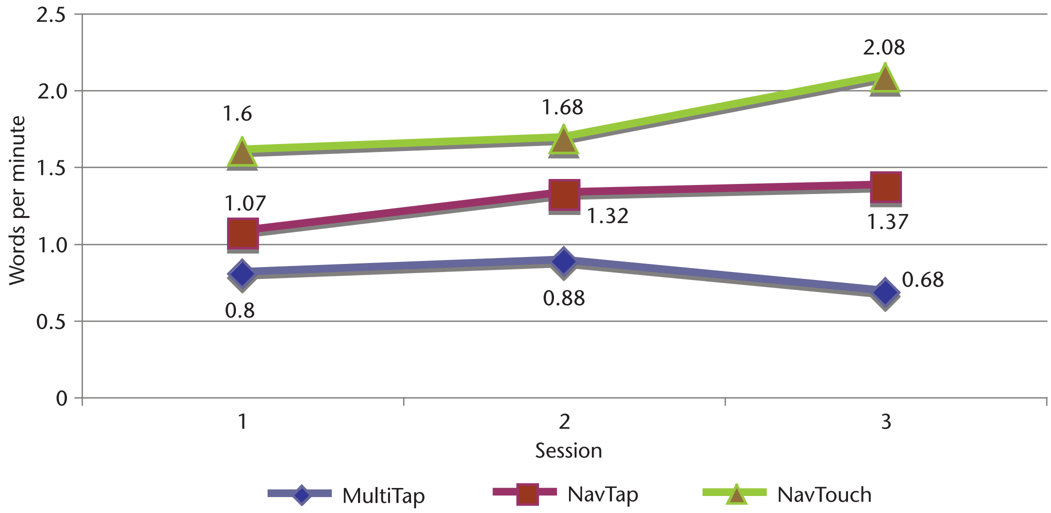


Figure 3. Evolution of word- per-minute figures across different sessions.

sensitivity problems, for example, for people who have lost their eyesight due to diabetes. We are currently conducting large-scale, long-term user tests to better assess our approach. One interesting challenge is comparing the performance of blind or low-vision people who've had previous experience with mobile phones, as opposed to first-time users. **MM**

Reference

1. T. Guerreiro et al., ''NavTap and BrailleTap: Non-Visual Texting Interfaces,'' *Proc. Rehabilitation Engineering and Assistive Technology Society of North America Conference* (Resna), 2008.

Tiago Guerreiro is a PhD candidate at Instituto Superior Técnico, Technical University of Lisboa. His research interests include mobile accessibility, assistive technologies, and human–computer interaction. Guerreiro has an MSc in information systems and computer engineering from Instituto Superior Técnico, Technical University of Lisboa. He is a member of the ACM and Eurographics. Contact him at tjvg@immi.inesc-id.pt.

Paulo Lagoá is an MSc student in mobile device interaction for blind users at Instituto Superior Técnico, Technical University of Lisboa. His research interests include human–computer interaction, accessibility, and mobile computing. Contact him at paulo.lagoa@tagus.ist.utl.pt.

Hugo Nicolau is an MSc student in orientation systems for blind people at Instituto Superior Técnico, Technical University of Lisboa. His research interests include human–computer interaction, accessibility, and mobile computing. Contact him at h.nicolau@gmail.com.

Daniel Gonçalves is a researcher at the Visualization and Multimodal Interfaces group of INESC-ID and an assistant professor at Instituto Superior Técnico, Technical University of Lisboa. His research interests include information visualization and human–computer interaction. Gonçalves has a PhD in personal information management from the Instituto Superior Técnico, Technical University of Lisboa. He is a member of the ACM and Eurographics. Contact him at daniel.goncalves@inesc-id.pt.

Joaquim A. Jorge is a professor at the Instituto Superior Técnico's Department of Computer Science and Engineering, Technical University of Lisboa. His research interests include accessible user interfaces, e-learning, and graphical modeling. Jorge has a PhD in computer science from Rensselaer Polytechnic Institute, New York. He is editor in chief of *Computers & Graphics Journal* (Elsevier) and a member of the IEEE, ACM, and Eurographics. Contact him at jorgej@ieee.org.