Keyboards Redux:
Fast Mobile Text Entry

Thad Starner

Text entry research is in vogue again, and inventors are flocking to conferences and meetings worldwide to show their methods. What's causing this resurgence of interest in a topic that's been dormant for so long?

WIRELESS MESSAGING

In 2003, wireless messaging accounted for US$16 billion in revenue for mobile phone service providers. Some forecasters predict that between 1 and 2 trillion messages will be sent this year, and analysts say that mobile email will be the next big market for the European industry. Other markets, such as mobile gaming and location-based services, will also use text entry. However, two barriers exist for these markets: appropriate displays and text-entry speed.

Mobile device displays have improved steadily. Several recent PDAs, such as the Sharp Zaurus 6000, feature color 640 × 480 displays that are crisp and readable in daylight. Mobile phone displays are also improving, driven by the integration of cameras and PDA-like functions. Additionally, mobile head-up display manufacturers such as MicroOptical, Microvision, and Interactive Imaging are selling the most useable and affordable displays to date. Although still too expensive for consumers, these head-up units are drawing interest from mobile phone manufacturers.

However, mobile text entry remains a difficult problem for handset manufacturers. In certain circumstances, terse messages can be appropriate. For exam-ple, when messages were sent across continents by telegram, senders would use abbreviations to keep the message cost low, and the recipient could still understand the message. Similarly, abbreviations are common in today's short message service messaging. For example, "CUL8R" means "see you later" in common parlance. These abbreviations, some of which can be quite complex and cryptic, have probably evolved both because of the slow typing speed the telephone keypad allows and because of the messaging culture itself. However, if mobile phone service providers want to enable mobile email, faster typing methods must be devised.

The typing rates of today's text-entry methods using the mobile phone's number pad are two to five times slower than that expected with a desktop keyboard. For example, in 2003 the world's fastest mobile "texter" typed 29 words per

Figure 1. A typical mobile phone number pad design.

minute,[1] more than six times slower than the Guinness record of 192 wpm for the desktop qwerty keyboard.[2]

MULTITAP

The most common style of text entry using a mobile phone's number pad is multitap, where multiple letters are mapped to the same key (see Figure 1). Holding the keypad toward you, you can enter text with one or two hands using one or two fingers or thumbs. You press the key to cycle through the letters until the desired one appears onscreen. You can then proceed to the next letter if it's on a different key. If the desired letter is on the same key, you must wait a short time for the phone to accept the letter. Alternatively, many phones use the "#" button to force the phone to the next letter. For example, you could type the word "deaf" entering "3#332333." Usability studies have found average rates of 8 to 20 wpm[3–5] for this method's experienced users. (The rates vary owing to incentives given during testing, training time, the phrase sets used, and a particular device's haptics, including key size, key spacing, and key resistance.)

T9

Another common typing method on mobile phones is T9, which uses a dictionary to disambiguate the user's input. Just like multitap, multiple letters correspond to the same key. However, you press keys with the corresponding letters only once. As you enter the word, the
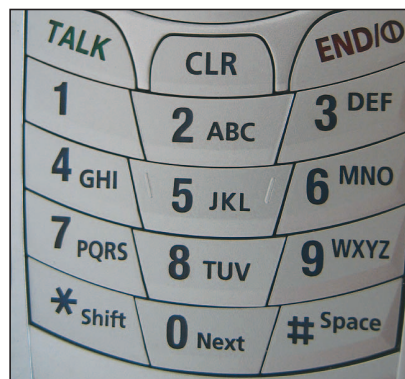
WEARABLE COMPUTING

Figure 2. (a) The Twiddler one-handed chording keyboard; (b) chording the letter "k." with the Twiddler.
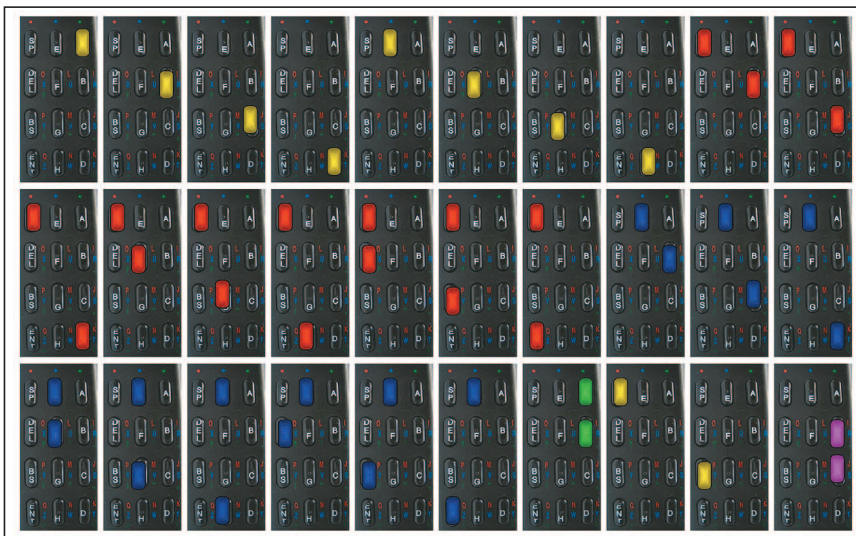

Figure 3. You can produce letters, symbols, numbers, or words on the Twiddler by pressing one or more buttons. The alphabet is sequential and simple to learn. Starting from the top left and going to the bottom right, the letters resulting from the chords above are the 26 letters of the alphabet, period, space, backspace, and "the."

phone continually guesses what word you're typing. You can cycle through potential words by pressing the "#" key. For example, you'd type "3323" for the "deaf" example mentioned earlier. However, the first word T9 would guess is "dead." You'd press the "#" key until the phone displayed the proper word.

Researchers have observed average text entry rates of 20 wpm when all words entered are in the phone's dictionary.[4] However, T9 can be frustrating and slow if you're entering words the phone doesn't recognize. Interestingly, the world texting rate record was set using multi-tap, and the record's holder dismisses T9

as inefficient for text entry (see www.jamestrusler.com).

LETTERWISE

In contrast to the dictionary-based disambiguation T9 uses, Letterwise uses just the preceding letters to disambiguate the letter you're typing. For example, if you type "th" and press "3," Letterwise fills in an "e" as the next letter. If this interpretation is wrong, you can cycle through that number's other possible letters—in this case "d" and "f,"—using a "next" key (such as "#"). Researchers have reported rates of 21 wpm with Letterwise.[3] This method has the advantage of letting you type any letter combination because it doesn't rely on a dictionary.

TWIDDLER CHORDING

Handykey's Twiddler keyboard uses the same three column by four row button design that a mobile phone's number pad does. You operate each row of keys with one of your four fingers (see Figures 2 and 3). You press multiple keys simultaneously to enter letters, numbers, and symbols—a process called chording. You can type any letter on the Twiddler by pressing one or two keys concurrently.[5] The Twiddler also allows multi-character chords (MCCs), where you type frequent words and letter sets such as "and," "the," and "ing" using a single chord.

When I lecture on wearable computing, I'm always asked how fast I can type on the Twiddler and how long it takes to learn chording. Two students, Kent Lyons and Daniel Plaisted, took an interest in these questions, and we designed experiments to determine the answer using methods similar to those Scott MacKenzie reported at the User Interface Software and Technology Conference (UIST) and the Conference on Human Factors in Computing Systems (CHI) in recent years.[3] Surprisingly, we found that the learning rate was quite fast. In less than seven hours, our 10 subjects reached an average rate of 26 wpm using the Twiddler. In par-

allel, we had the same subjects type with multitap on the Twiddler keyboard using the same procedure, and they reached an average of 20 wpm. We might explain this high rate by the Twiddler's better spacing and button resistance versus other 3 × 4 button keypads. Another contributing factor might be that we paid the subjects on the basis of their speed and accuracy. However, the multitap rates stopped improving significantly, while the Twiddler chording rates continued to improve dramatically.[5]

To better predict what an expert Twiddler user might achieve, we offered our subjects the opportunity to continue the study; five of the 10 subjects accepted. Fortunately, the average typing rate of those five was similar to that of the entire group. After 25 hours, the typing rates stopped increasing dramatically, and the average rate was 47 wpm. Interestingly, this amount of practice is significantly less than the 60 hours done in a semester-long typing class, where the goal is 40 wpm. Another surprise is that the top Twiddler typist actually exceeded my letter-by-letter (no MCCs) typing speed at 67 wpm (I've been typing on the Twiddler for over 10 years).[6] Although directly contrasting learning curves between studies is unwise, these resultant averages compare favorably to even desktop speeds (Table 1 provides a survey of typing rates). This result suggests that, with sufficient motivation, Twiddler novices might reach adequate desktop-level typing speeds relatively quickly.

The question remains, however, whether mobile phone users will invest the time to learn chording. My group is currently investigating ways to encourage and increase learning speed using a typing tutor similar to that used for desktop keyboards. You can find the current version of "Twidor," the Twiddler tutor, at www.cc.gatech.edu/ccg/projects/twidor.

My students are also investigating how to improve the Twiddler's "walk-up" usability so that novices can quickly feel comfortable with the device. However, service providers could also offer incentives to increase their clients' typing speed. For example, they might design a mobile phone that worked in both multitap and chording modes. Users would receive a $50 rebate whenever they exceeded 30 wpm while typing a wireless message, thus encouraging chording. Presumably, with faster typing skills, users would send more wireless messages. Additionally, they might be more easily coaxed into advanced services, such as mobile email or wireless gaming.

CHORDTAP

Daniel Wigdor and Ravin Balakrishnan presented an intriguing compromise between walk-up usability and faster text entry through chording at the CHI 2004.[7] Their method, ChordTap, uses the current multitap layout plus three chording keys to disambiguate each letter. To type the word "deaf" as before, you'd press the number 3 plus the first chording key to indicate the first letter in the "def" triplet that appears on the 3 key. You'd then type "e" with the number 3 plus the second chording key, "a" with the number 2 and the first chording key, and "f" with the number 3 and the third chording key. Although ChordTap probably wouldn't be as fast as the Twiddler for an expert "chordist," the mapping is immediately accessible to a current multitap user.

In their CHI paper, Wigdor and Balakrishnan showed that ChordTap and multitap's initial rates were equivalent, presumably giving users an immediate sense of reward. With practice, ChordTap rates became significantly higher than multitap rates, reaching 16 wpm after 2.5 hours of testing. Meanwhile, multitap users averaged between 11 and 12 wpm by the study's end. Although the current data doesn't allow much extrapolation over 20 wpm, the ChordTap method suggests an interesting way to transition current mobile phone users into a chording framework.

TABLE 1
Noteworthy text entry speeds.

Words per minute	Method
192	Fastest qwerty speed[2]
120	Twiddler burst speed (author)
70–90	Highly skilled secretary
67	Fastest Twiddler user average (25 hours)[*6]
50	Highest US government pay grade for typists
47	Twiddler average (25 hours)[6]
40	Goal of semester typing class (60 hours)
35	Fastest Morse code keyer[1]
30	Average desktop rate (including hunt-and-peck typists)
29	Fastest mobile phone "texter" (multitap)[1]
26	Twiddler average (7 hours)
21	Letterwise average (10 hours)
20	Multitap on Twiddler (7 hours)[6]
20	T9 "expert" average[4]
16	ChordTap average (2.5 hours)[7]
16	Multitap average (10 hours)[3]
11	Multitap average (2.5 hours)[7]
8	Multitap "expert" average[4]
<10	Multitap/T9/Letterwise/ChordTap novice

*Times in parentheses indicate the subjects' amount of training.

WEARABLE COMPUTING

next issue

What security and privacy attacks can we expect now that mobile phones have become the world's dominant computer platform?

MINI QWERTY KEYBOARDS

Some phones and PDAs are now integrating miniature qwerty keyboards as part of their design. The difficulty with these keyboards, of course, is their buttons' size and spacing. Most people can use only two thumbs while typing. This

method is similar to "hunt-and-peck" typing on desktop keyboards, which averages around 23 wpm.[8] However, although I don't know of formal longitudinal studies on mini qwerty keyboards, a model William Soukoreff presents predicts a peak expert typing rate of 61 wpm.[9] What rate an average expert could attain with practice is still an open question.

BLIND TYPING

One attribute text entry researchers are investigating is "blind" typing, where users receive little or no visual feedback as they type. Such touch typing enables text entry in more varied situations, such as teenagers sending mobile phone messages while avoiding detection in class. Multitap, Twiddler chording, and ChordTap allow such blind entry. Owing to their dependence on context, T9 and Letterwise don't allow touch typing for most users. Mini qwerty keyboards should theoretically allow blind typing; however, anecdotal reports suggest that the user makes enough errors to require visual feedback for corrections. Interestingly, in our experiments with the Twiddler, blind typing had virtually no effect on either typing speed or error rates.

MOBILE KEYBOARDS' FUTURE MARKET

I've only covered a few methods of text entry on mobile devices, mostly focusing on the number pad. Other methods include virtual keyboards commonly included on PDAs, projected keyboards such as Canesta's design, and gesture recognition. Some pundits believe that speech recognition will prevail on mobile platforms. However, I believe a large market will always

exist for keyboards. Speech interfaces are interruptive in many social situations, such as when taking private notes during a meeting. Additionally, many people object to microphone use in everyday interactions for privacy reasons. Even when allowed, transcripts of conversations are often incomplete, misleading, and difficult to search. Finally, speech interfaces will always suffer from error and ambiguity. Meanwhile, mobile keyboards, especially one-handed ones, let you enter terse, private, and meaningful notes quietly and with little error while you're in public.

Already, mobile keyboard use is surging in highly populated areas such as Japan. According to *Newsweek*, more email is sent via mobile phones than home PCs in Japan.[10] One reason given is that a Japanese family can't afford the space to dedicate a room to computer use. This restriction limits the number of households with a PC. In contrast, you can use a mobile phone virtually anywhere. Another reason for mobile phone email use in Japan is privacy. Teenagers don't want their parents monitoring their conversations, and mobile texting provides a convenient mechanism for private communication.

For these reasons and others, I believe the demand for mobile keyboards will grow substantially. As computers spread throughout the third world in the guise of mobile phones, the demand for more rapid means of text entry for email and instant messaging will drive innovation. The first mobile phone service provider to enable fast text entry for large communities will reap big rewards. Novel keyboard design might also provide product "lock-in" or supplemental licensing revenue. Imagine the profits if every computer sold had to pay a licensing fee for its qwerty keyboard.

For inventors who think they have the solution to mobile input, I suggest reading recent papers by MacKenzie and his colleagues on text-entry evaluation methods.[3,8,9] Or download the Twidor tutor, develop rapid-text-entry skills, and challenge me to a race at the gadget show during the next International Symposium on Wearable Computers in Washington DC! P

REFERENCES

1. C. Folkard, ed., *Guinness World Records*, Bantam Dell, 2003.

2. M. Young, ed., *Guinness World Records*, Bantam Dell, 1998.

3. I. MacKenzie et al., "LetterWise: Prefix-Based Disambiguation for Mobile Text Input," *Proc. 14th Ann. ACM Symp. User Interface Software and Technology*, ACM Press, 2001, pp. 111–120; http://doi.acm.org/10.1145/502348.502365.

4. C.L. James and K.M. Reischel, "Text Input for Mobile Devices: Comparing Model Prediction to Actual Performance," *Proc. Conf. Human Factors in Computing Systems* (SIGCHI 01), ACM Press, 2001, pp. 365–371.

5. K. Lyons et al., "Twiddler Typing: One-Handed Chording Text Entry for Mobile Phones," *Proc. Conf. Human Factors in Computing Systems* (SIGCHI 01), ACM Press, 2004, pp. 671–678.

6. K. Lyons, D. Plaisted, and T. Starner, "Expert Chording Text Entry on the Twiddler One-Handed Keyboard," to be published in *Proc. IEEE Int'l Symp. Wearable Computing* (ISWC 04), IEEE CS Press, 2004.

7. D. Wigdor and R. Balakrishnan, "A Comparison of Consecutive and Concurrent Input Text Entry Techniques for Mobile Phones," *Proc. Conf. Human Factors in Computing Systems* (SIGCHI 01), ACM Press, 2004, pp. 81–89.

8. E. Matias, I. MacKenzie, and W. Buxton, "One-Handed Touch-Typing on a QWERTY Keyboard," *Human-Computer Interaction*, vol. 11, no. 1, 1996, pp. 1–27.

9. R. William Soukoreff, *Text Entry for Mobile Systems: Models, Measures, and Analyses for Text Entry Research*, masters thesis, York University, 2002.

10. K. Itoi, "Living the Wireless Lifestyle," *Newsweek Int'l*, Atlantic edition, 7 June 2004.