Evaluation of a Text Entry Method for Mobile Devices

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Abstract

While handheld devices such as cell phones and PDAs continue to proliferate, there is still debate over what methods are best for user interaction with these devices. Text entry, an important part of this interaction, becomes increasingly complex as devices shrink in size. This study tested a PDA text entry method that used a thumbwheel. The character set, which included letters, numbers, punctuation marks, and a space, was implemented as a continuous loop. Turning the wheel upwards or downwards displayed different characters on the screen, and clicking the wheel selected a character. A "snap-to-home" feature was also tested. Thumbwheel-based text entry methods are a viable alternative to keypad, stylus, and voice input on ultra-small mobile devices.

1 Introduction

This research looks at text entry on a personal digital assistant (PDA) using a thumbwheel. As the wheel is turned, different characters are displayed on the PDA's screen. When the thumbwheel is pressed, the character currently displayed is selected. Inspiration for this research came from devices such as the Dymo label maker, but the same principal has also been used on video games and other electronic devices for character entry using knobs or wheels. The movement of a thumbwheel can also be simulated using three keys – two for the clockwise and counterclockwise motions, and one for selection. Research such as MacKenzie (2002) has explored the performance of three key and similar key-based text entry methods. However, our research is unique because:

- the study used text entry that included numbers and punctuation in addition to alphabetic characters;
- the entry technique was evaluated using a realistic mobile device form factor (a PDA) rather than a simulated environment; and
- a thumbwheel was used for text input, rather than a set of keys of buttons.

2 Background

This section briefly discusses some of the performance testing that has been done with different text entry techniques on mobile devices. A comprehensive review of text entry methods for mobile computing can be found in MacKenzie and Soukoreff (2002). In addition, Tarasewich (2002) provides a discussion of interface design and usability issues for mobile devices.

To appear in Proceedings of HCI International 2003

Recent research has been addressing the usability concern of how well users can perform tasks using the assortment of keypads and keyboards found on many wireless devices. Looking at keypad text entry performance, Silfverberg, MacKenzie, and Korhonsen (2000) created models to predict the entry rates for multi-press, two-key, and linguistic-based keypad text entry methods. Using empirical data, they estimated that expert users could achieve rates of up to 27 words per minute (wpm) using thumb (one-handed) or index-finger (two-handed) input with the multi-press and two-key methods.

MacKenzie (2002) reported the results of an experiment that tested various three-key text entry methods. The keys were left and right arrow keys used to maneuver a cursor over a set of characters (the English alphabet) and a third key to select a highlighted character. One method tested kept the characters in alphabetical order during the selection process. The other method used "linguistic enhancement" to reorder the characters after each selection. This reordering, based on letter pairing probabilities in common English, was an attempt to minimize the cursor distance to the next chosen character. Both methods placed a space character first (before the characters), and "snapped" the cursor home to this position after each entry. Entry rates for each technique were about 9 wpm. Subjects performed slightly better using the enhanced technique than with the characters in a fixed order, but the difference was not statistically significant.

There have been many studies on soft keyboard performance. Those by Lewis, LaLomia, and Kennedy (1999) and MacKenzie and Zhang (1999) found that users could achieve speeds of up to 40 words per minute with a QWERTY layout on a soft keyboard, although speed varied with the devices used, the tasks performed, and the amount of practice. Alternate soft keyboard layouts can produce even higher text entry speeds than the QWERTY configuration, but usually after much experience with the alternate layout (e.g., MacKenzie & Zhang, 1999). A study by Zha and Sears (2001) showed that the size of a PDA soft keyboard did not affect data entry or error rates.

If a stylus is used to write input on the screen of a mobile device (using gesture or handwriting recognition), performance is generally much poorer compared to using any type of keyboard. Studies such as MacKenzie and Chang (1999) found that data entry rates of up to 18 wpm can be achieved using various gesture recognition systems. But these studies did not test performance using handheld devices. More recently, Sears and Arora (2001) compared Jot and Graffiti using Pocket PC and Palm devices, respectively. They used tasks that they felt were more realistic than previous studies, and kept track of data entry times and error rates. Novice data entry rates of 7.37 wpm were obtained for Jot and 4.95 wpm for Graffiti.

Voice recognition technology continues to improve, but there is still the question of how well it works for different applications and tasks. De Vet and Buil (1999) listed some general findings from user studies on the use of voice control compared to entering text data on limited-key devices. User operations that favor voice control included 1) direct addressing of content (e.g., calling out someone's name), 2) menu navigation and option selection, and 3) setting a range (e.g., the starting and stopping times on a VCR). The operation of scrolling through a long list favored the use of cursor keys rather than voice commands for people who were browsing.

3 Methodology

A Sony Clié PEG-S320, with a monochrome screen and the Palm operating system, was used for this study. The device measured 4.6" by 2.9" by 0.6". On the left-hand side of the PDA, near the top, was a thumbwheel (approximately 0.5" in diameter). The standard Palm memo pad application was used as the foundation for a thumbwheel-based text entry application. The memo application provided basic functionality, such as creating, saving, and deleting memos. The applications character set consisted of the space character, the letters A through Z, the numbers 0 through 9, and the punctuation marks { . , ? ' " ( ) ! }. Only upper case letters were implemented. The characters appeared on the PDA's screen. When the wheel was turned downwards, the character set was traversed left-to-right. Turning the wheel upwards traversed the sequence of characters in the opposite direction. Pressing the wheel wrote the selected character on the screen. Three functions, "Done", "Back," and "Enter," were traversed using the wheel as well. Scrolling past "!" got to "Done", and scrolling past "Enter" brought the cursor back to the space character. A "snap-to-home" feature was also implemented. With this feature enabled, the cursor "snapped" back to the "home" character (the space). Otherwise, the cursor remained at the last letter selected.

A study was performed to test the thumbwheel interface design and the methodology described below. Subjects were student volunteers from an information science class. Participants were told they could hold the PDA and use the thumbwheel in any manner they wished. If an error was made, subjects were told to ignore it and continue with the next character (i.e., not to use the back function). Subjects were told to use the "enter" function when they completed each sentence.

Testing consisted of a training session and two task sessions. In the training session, subjects entered a single sentence (see Figure 1 for sentences used in the study). During the training session, subjects saw a tabular representation of the characters on the lower part of the screen. This was done in an attempt to help subjects learn the character order faster. The tabular representation was not visible during any of the subsequent sessions. In each task session, the subjects entered three sentences. The first session consisted of either sentence set one or set two (randomly chosen), and the second session used the other set. The sentences were primarily taken from a set used by MacKenzie (2002), although punctuation and numbers were added for this study. In one of the two sessions (randomly chosen), the snap-to-home feature was enabled; in the other session, it was not. Data was collected on task completion time and error rates for each sentence. After the sessions, subjects were asked for their opinions on the text entry method.

Set	**Sentence**	**Text of sentence**
	Training	we are having spaghetti.
1	1A	my watch fell in the water!
	1B	prevailing wind from the east.
	1C	the address is 195 main street.
2	2A	I can see the rings on saturn.
	2B	physics and chemistry are hard?
	2C	he can be reached at extension 482.

Figure 1: Sentences Used in Experiment

4 Results

Three female and seven male subjects (average age = 22 years) were tested. To see if the snap-to-home feature made any difference in entry times or error rates, a Mann-Whitney nonparametric test was performed for each of the sentences (Table 1). For three of the six sentences (1A, 2A, 2B), the entry rate was significantly lower (at the .05 level) with the snap-to-home feature enabled. The entry rate for sentence 2C was also much lower for snap-to-home, but not at the .05

significance level. The error rate was not significantly different with the snap-to-home feature enabled or disabled for any of the sentences.

Table 1: Entry Times and Error Rates With and Without Snap-to-Home Feature						
Sentence	Snap-to-Home Enabled		Snap-to-Home Disabled		Significance	
	Entry Time (seconds)	Errors	Entry Time (seconds)	Errors	Entry Time	Errors
1A	126	0.5	164	0.75	.029	.686
1B	153	2.25	148	1.75	.486	.686
1C	148	2	143	0.5	.914	.114
2A	128	1	172	0.4	.016	.286
2B	141	3	186	2.4	.036	.571
2C	141	0.75	169	1.2	.063	.413

A record was kept on how each subject held the PDA and used the thumbwheel. Given the position of the thumbwheel on the PDA, it was expected that most subjects would hold the PDA in the left hand and use the left thumb to operate the wheel. However, only five (out of ten) people used the device this way. Of these five people, two steadied the device with their right hand during text entry. Of the remaining five subjects, one held the device in their right hand, and used the left thumb. Two subjects held the device in their right hand and used their left index finger. Two subjects held the PDA in their right hands, and used their right index finger. One of these people also used their left hand to steady the device. Some of the subjects switched hands part way through the experiment.

Many subjects commented that a larger thumbwheel, or one that had a smoother motion or smaller turning radius, might have worked better. Many subjects had problems "clicking" the wheel to enter a character; sometimes the wheel would "slip," causing an error. For example, a person would dial to "g" and click the wheel, but the wheel would turn a bit more in the process and actually print "h" on the screen. It may be that this slippage is the cause of many of the errors recorded during the sessions.

Most participants had mixed feelings about the snap-to-home feature. It was viewed positively for two reasons. First, it encouraged downward use of the thumbwheel, which was seen as much easier and more comfortable. Scrolling downwards meant the letters were in alphabetical order and the numbers were in numerical order. One subject commented on passing desired letters when scrolling upwards because they were not used to going backwards through the alphabet. Second, having the cursor return to the space, which was used fairly often in each sentence, was seen as saving time and effort. However, the snap-to-home feature was also viewed negatively because it made it more difficult to type in two letters that were the same or close to each other in the alphabet (e.g., "st").

5 Discussion

At approximately three words per minute, the average entry speeds observed in this study are lower than the speeds found by MacKenzie (2002). But this study is unique in several ways that may explain the increased entry times, including a larger character set and the use of a PDA rather than a simulated environment. With additional training and continued use, entry speeds may significantly increase. The snap-to-home feature seemed to improve text entry speeds, although this may be related to the makeup of the sentences (e.g., number of spaces and repeated characters). Testing with a greater number and variety of sentences is needed. Text entry speeds and error rates could also be affected by the way people held the PDA, something that also needs to be more carefully controlled in future studies. It may be possible to develop more efficient methods for thumbwheel text entry by reducing the total number of keystrokes required. This might be done through "hierarchical" methods. For example, an upper menu may consist simply of the three choices "A", "M", and "0." Clicking on "0" would then present the numeric choices of "0" through "9". An additional click would select one of these lower level choices.

While thumbwheel entry methods may not prove suitable for large amounts of text, they should work well for short notes and messages. Wristwatch-size PDAs are now available (e.g., the onHand PC), and such devices may one day be used for wireless messaging. Their small screen sizes, however, are not conducive to virtual keyboards or to gesture recognition. Voice input is one alternative for these devices, but voice recognition technology is sometimes inappropriate to use due to environmental conditions (e.g., in noisy factories). Thumbwheels may provide one of the few feasible ways of entering text on very small devices in a wide variety of settings.

6 Acknowledgements

The author would like to thank Myra Dideles for programming the PDA used in this study, and for her input into the tasks and methodologies used.

7 References

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