Text Input to Handheld Devices for People with Physical Disabilities

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Abstract

There has been little study of how to adapt handheld devices for use by people with physical disabilities. We found that the tiny stylus keyboards on PalmOS devices work well for some people with Muscular Dystrophy, who tend to have good accuracy but little strength or range of motion. However, for people with other disabilities, such as Cerebral Palsy, Parkinson's Disease and other neuro-muscular disorders, accuracy is a problem. Text entry is also difficult on handhelds for able-bodied users some situations, such as when using small mobile devices while walking or riding. The EdgeWrite text entry technique is a new design which provides better stability of motion due to tracing along physical edges, ease of learning due to the similarity of its letters to Roman characters, and a simple implementation on a wide variety of input devices. Studies suggest that EdgeWrite works well when implemented for use with a stylus on a handheld device, a joystick on a power wheelchair or a videogame controller, and for a touchpad on a desktop computer. Future implementations will explore desktop text entry using a trackball and mobile phone text entry using tactile bumps.

1 Introduction

People with physical disorders, like the rest of the population, are increasingly using computers. However, motor impairments place significant physical demands on text entry methods. Tremor, spasm, poor coordination, low strength, and rapid fatigue make it difficult to enter text with a QWERTY keyboard or Personal Digital Assistant (PDA) stylus (Wobbrock, Myers, & Kembel, 2003). Tremor and fatigue make it difficult or impossible for some people to draw character forms recognizable by a text entry system like Graffiti, or to select characters on the tiny stylus keyboards of some devices. As small devices proliferate in an aging population, the number of users with motor impairments will only increase. But although work exists on accessible text entry for desktops, little work exists on accessible text entry for handhelds.

About 250,000 people in the United States have Muscular Dystrophy (MD), which is the name given to a group of noncontagious genetic disorders where the voluntary muscles that control movement progressively degenerate. One form, called Duchenne Muscular Dystrophy (DMD), affects about one in every 4,000 newborn boys. With Duchenne, boys start to be affected between the ages of 2 and 6, and all voluntary muscles are eventually affected (MDA, 2001). First affected are the muscles close to the trunk, and nearly all children with DMD lose the ability to walk between ages 7 and 12. In the teen years, activities involving the arms, legs or trunk require assistance. Becker Muscular Dystrophy is a much milder version, and the onset can be in late adulthood. A related disorder is Spinal Muscular Atrophy, which is an inherited neuromuscular disease that causes weakness in the body, arms, and legs. It affects both boys and girls starting at 6 months to 3 years, and progresses rapidly (MDA, 2001). We have found that handheld devices, such as Palm PDAs, can be useful for people with MD because such people often lack the strength to use conventional keyboards but retain the accuracy needed for stylus keyboards.

Even on desktops, there is still a need for accessible text entry. Many people who need adaptations for text entry do not use them because of cost, complexity, and maintenance (Fichten, Barile, Asuncion, & Fossey, 2000). If we had a text entry technique that could be used with standard input devices, cost could be lowered and the need for intervention reduced. In addition, motor-impaired users often need to switch among devices, distributing strain and fatigue over different muscles. Thus, if the same technique could be used on different devices, learning would be eased when transitioning from one device to the next.

People who use power wheelchairs often need assistance moving their hands to computer input devices. An integrated text entry and mouse control solution for desktop computers that works with the joystick or touchpad already being used to control the wheelchair would be desirable (Guerette & Sumi, 1994).

A related problem is that able-bodied users incur "situational impairments" (Sears, Lin, Jacko, & Xiao, 2003) when using small mobile devices. The spatial constraints of small devices necessitate the use of compact (if not cramped) input techniques demanding accurate movement and careful control. These demands are intensified while walking or riding, since "on the go" use can reduce visibility, divide attention, and impair physical stability. But unfortunately, most mobile text entry methods are not sufficiently tactile or physically stable to be accessible while in motion. The need for physical stability, tactility, accuracy and control felt by "on the go" text entry users is thus not unlike the need felt by motor-impaired text entry users. An accessible design for text entry that benefits one group may therefore benefit the other.

To address these issues, we have developed a new text entry technique called "EdgeWrite" that can be useful for people with a wide variety of physical or situational impairments.

2 First Investigations

In a preliminary case study of four people with MD (Myers et al., 2002), we found that our Pebbles applications (http://www.pebbles.cs.cmu.edu/) successfully allowed the use of the PC for extended periods of time for people who found it difficult or impossible to use a conventional keyboard and mouse. In particular, we adapted the Pebbles Remote Commander program, which allows the Palm to be used as if it was the PC's keyboard and mouse. In general, the Pebbles project is studying many ways that handheld computers can interoperate with PCs, with each other, and with smart appliances (Myers, 2001). These applications are aimed at business meetings, offices, classrooms, military command posts, and homes. The Pebbles software is available for downloading from: http://www.pebbles.hcii.cmu.edu/. Pebbles stands for **P**DAs for the **E**ntry of **B**oth **B**ytes and **L**ocations from **E**xternal **S**ources. See Figure 1 for an example of a test user.

Figure 1: 12-year old Kevin has Duchenne Muscular Dystrophy.
He is operating his PC by using two hands to
control the stylus on a Palm running the
Pebbles Remote Commander program.

The observations we made about the use of these applications for people with Muscular Dystrophy include:

- A conventional keyboard and mouse is usually faster than our software on a Palm for people who can still use those devices. However, using our software as an alternative input method is still valuable because they can switch to using the Palm when their hands become tired using conventional input devices.
- The physical buttons on the Palm device (and on commercial touch pads) require too much force for our subjects to push. Providing on-screen buttons that could be lightly tapped with a stylus was more successful. Since the Palm power button was too difficult to press, we added an option in software to prevent the Palm from turning itself off.
- It is useful to have a complete small keyboard on a single screen since the users have difficulty moving. The ability to adapt the keyboard to individual requirements is also desirable.
- The provided stylus for the Palm is too short and heavy. An inexpensive long plastic stylus works better.
- Seeing the Palm screen is an issue. Unlit Palm screens, such as on the old Palm V or current Palm Zire 21 model, often require additional lighting at the computer. The lit color screens are better, but still may be difficult to read. A long power-providing cord from the PC to the Palm is also necessary.
- Using a Palm with replaceable batteries, such as the Palm III is not workable, because the batteries only last about 3 days. Rechargeable models need a way to connect to the power and the Hotsync cable to the PC while they are sitting flat on the table (as shown in Figure 1). Models such as the Palm Tungsten E, which come with a backlit color screen, and separate Hotsync and power cables that are plugged into the device, are ideal.
- We needed to change the Remote Commander software to allow the key-repeat to be turned off, to provide easier ways to pop up the on-screen keyboard, to make it easier to tap to generate left mouse click events, and to add word completion. The current version of the software incorporates all of these improvements.

3 EdgeWrite

Although using Remote Commander was somewhat successful for people with Muscular Dystrophy, it was completely unsuitable for people with other disabilities. Tremors, for example, made the use of the stylus keyboards on the PDA impossible. Stylus keyboards also require the user to fix his or her attention on the keyboard rather than on the output (MacKenzie & Soukoreff, 2002). Furthermore, gestural text entry techniques, such as Graffiti, do not solve the problem of text input for people with motor impairments, because tremor and fatigue dramatically impact a user's ability to make smooth, accurate, and controlled movements (Keates, Hwang, Langdon, Clarkson, & Robinson, 2002). Tremor makes it difficult or impossible for some subjects to make character forms recognizable by a text entry system like Graffiti (see Figure 2).

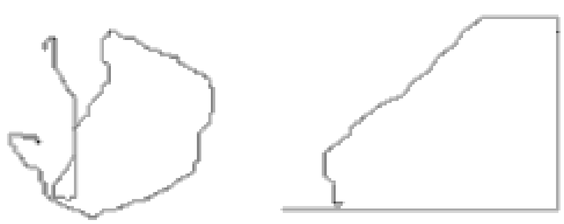

Figure 2: A subject with Cerebral Palsy attempting to make a "d" in Graffiti (left) and EdgeWrite (right). The Graffiti "d" was misrecognized as an "h", whereas the EdgeWrite "d" was recognized correctly. The jagged diagonal does not deter recognition in EdgeWrite because only the order in which the corners are hit matters. Note the straight lines where the subject moved along the edges of the plastic template.

Another result of tremor is that many users "bounce" the stylus on the screen, triggering unwanted modes and unwanted characters. In fact, this problem renders Graffiti entirely unusable for some people with impairments such as Parkinson's. A more stable means of text entry is necessary for users of handheld devices who have motor impairments.

Therefore, we have been investigating multiple approaches to providing stability through the use of physical edges. Edges offer many desirable properties. Applying pressure against an edge while moving a stylus provides:

- *Greater Stability*: Decreased movement variability and movement offset.
- *Greater Speed*: Ability to move quickly yet remain on the target line.
- *Higher Accuracy*: Targets along an edge or in a corner are easier to acquire.
- *Tangible Feedback*: No longer is visual feedback the only means of self-correction during movement, as tactile feedback is available.
- *Fitts' Law Benefit*: Edges allow for "target overshoot," where acquiring targets on edges is easier than acquiring targets "in the open" (MacKenzie, 1992).

We call our new input technique "EdgeWrite" because one writes along the edges of a square. Figure 3 shows an example implementation using the Palm PDA with a plastic template over the input area.

Figure 3: A Palm PDA with an EdgeWrite template over the text input area. A user makes all letters, numbers, and punctuation inside the square hole by moving the stylus along the edges and across the diagonals of the square. Small holes in the template provide access to the four soft buttons on the Palm.

3.1 Overview of EdgeWrite

EdgeWrite is a unistroke input technique similar to PalmOS Graffiti. Unlike Graffiti, however, EdgeWrite relies on physical edges and corners to provide stability during motion. A user moves his or her stylus, finger, or joystick along the physical edges and into the corners of a square bounding the input area (Figure 3). Recognition does not depend on the whole path of motion, but on the order corners are hit. This means that moderate wiggle and tremor do not deter good recognition. It also means that to add a custom gesture, a user needs only to perform it once, indicating the desired order of corner-hits.

A key design goal for EdgeWrite was to make the characters easy to learn. All of the character strokes are designed to look and feel similar to the way that characters are hand-printed. Figure 4 shows the current chart for the alphanumeric characters in EdgeWrite. There are also EdgeWrite forms for all punctuation and other characters. EdgeWrite does not require separate areas or modes to distinguish letters and numbers as in Graffiti. Note that multiple distinct forms exist for most characters. This is to increase learnability and guessability. The character forms are a product of a formal guessability study in which we asked 20 subjects to invent their own alphabets with no prior knowledge of any existing design (Wobbrock, Aung, Rothrock, & Myers, 2005). We then tested the resulting alphabet with other users. After showing them only one form for each letter, many subjects discovered and used several of the alternate character forms. Overall, these studies showed that EdgeWrite can be learned in about 15 minutes, comparable to the time needed to learn Graffiti.

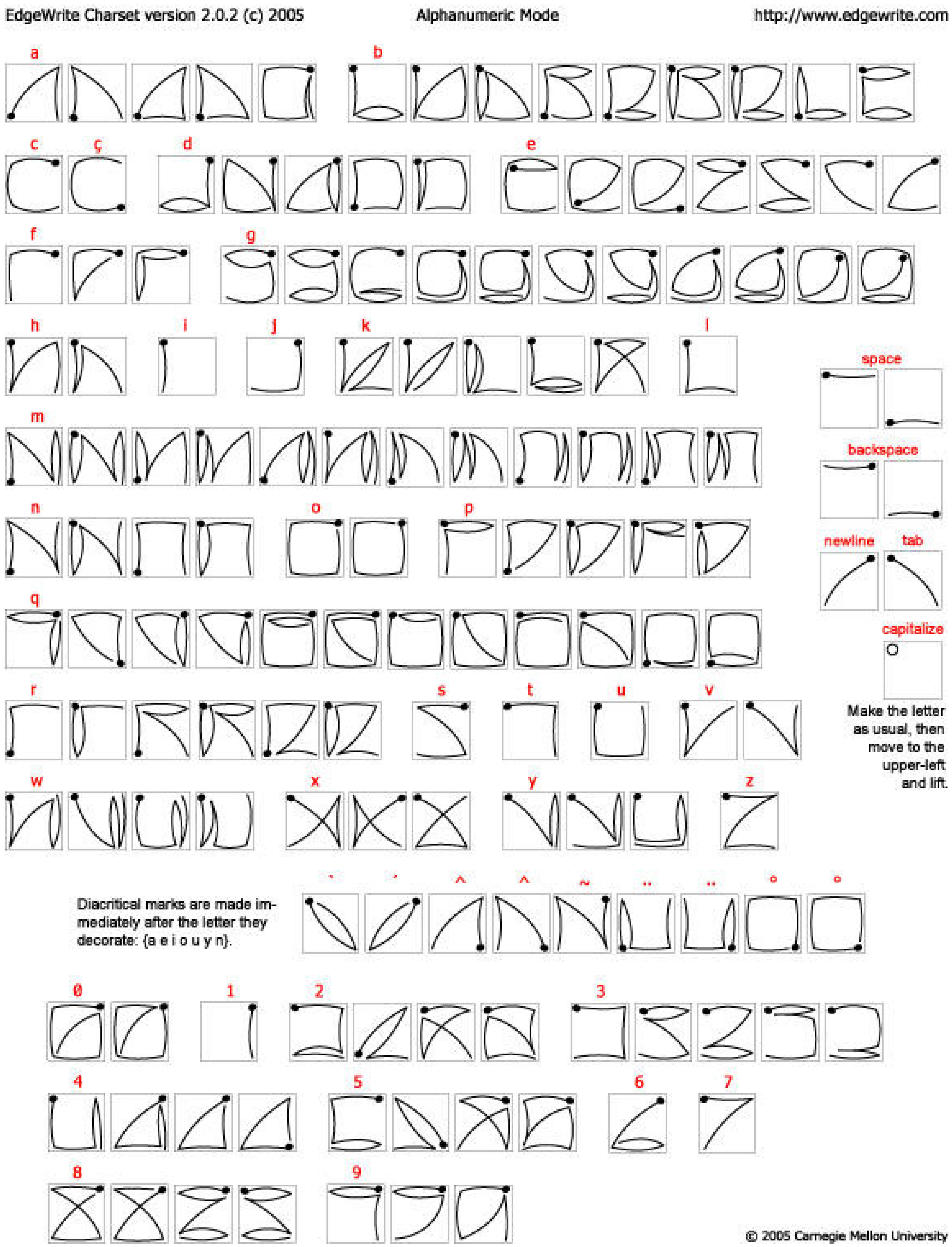

Figure 4: The alphanumeric characters in EdgeWrite. Unlike as in Graffiti, letters and numbers in EdgeWrite do not require distinct entry areas or modes. The alphanumeric mode is the default entry mode in EdgeWrite. Two other modes also exist for punctuation and extended characters.

3.2 EdgeWrite on Palm

Our first study with EdgeWrite (Wobbrock et al., 2003) used the stylus version on a Palm device (Figure 3). First, we had 10 able-bodied users either try Graffiti or EdgeWrite to help assess its speed and accuracy and to validate its design. There was no statistically significant difference in speed of entry ($F_{1,152}$=.02, n.s.), but EdgeWrite was over 18% more accurate than Graffiti ($F_{1,56}$=9.32, $p<.02$). Encouraged by these results, we then tested four subjects with motor impairments. With so few subjects, we could not achieve statistical significance, but the results were quite dramatic nonetheless. Subject 1 was a middle-aged woman with Parkinson's Disease and severe tremor. Out of 72 letters attempted with Graffiti, only 22 were correctly recognized (31%). However, with EdgeWrite, 68 of 72 were correct (94%). Two other subjects had Cerebral Palsy. One entered a target sentence without errors in EdgeWrite, but had 8 errors with Graffiti. The other left 2 errors with Graffiti but none with EdgeWrite. When switching to EdgeWrite from Graffiti, she exclaimed, "This is a lot easier than before. Much easier, my goodness." Finally, another user had Muscular Dystrophy with a small baseline tremor. Using Graffiti, he was unable to make *b*, *d*, and *f* after multiple tries and gave up on them. Using EdgeWrite, there were no letters that he could not make. In entering a sentence, he left 3 errors with Graffiti but none with EdgeWrite.

3.3 EdgeWrite on Game Controllers

We also tested EdgeWrite as a text entry method for able-bodied users on game controllers (Wobbrock, Myers, & Aung, 2004). Today's computer game industry would benefit from better text entry for game consoles, which often have only game controllers as input devices. If they have keyboards at all, they are sold separately at extra cost. Many game consoles are now networked, and require extensive text entry during configuration before they allow game play. For example, registration for the Xbox Live! service requires entering personal and billing information and can take more than 30 minutes using a joystick and an on-screen selection keyboard. Furthermore, many networked games allow for communication among players using short bursts of instant messenger-style text. With only selection-based text entry methods for game controllers, this can be awkward or infeasible. We adapted the EdgeWrite alphabet for use with the joysticks that are built into today's game console controllers (see Figure 5).

Figure 5: A game joystick showing the two thumbsticks which can be used to enter EdgeWrite. Each thumbstick is set within a square area.

There are two methods primarily in use today for text entry for game machines: date-stamp and selection keyboard. The *date stamp* method is familiar to people who have entered their initials on the high-score screen of an arcade game. This method gets its name from a post office stamp that has rotating dials for each character. While there are many variations on this method, ours uses the sequence [*space*][*a..z*][*0..9*](repeat). Moving the joystick down cycles the current character forward through the sequence (*a*→*z*). Moving the joystick up cycles the current character backward through the sequence (*z*→*a*). Moving the joystick right commits the current character and initializes a new stamp with "*a*." Moving the joystick left deletes the most recently committed character.

The other method is *selection keyboard*. The selection keyboard method uses an on-screen keyboard over which a user moves a selection halo up, down, left, or right. When the user presses a joystick button, the currently-highlighted key is "pressed." When a key is pressed, the halo remains where it is and does not jump to a home position. The halo can wrap around the keyboard horizontally or vertically, staying in the same row or column. Key-repeat behavior, identical in timing to the date stamp method, governs rapid movement of the halo. We based the layout we tested on selection keyboards from the Xbox *Live!* registration sequence and two popular Xbox games: *Halo* and *Brute Force*.

In our study, with untrained able-bodied users, text entry speeds were fastest using EdgeWrite at 6.40 words per minute (WPM), then selection keyboard (6.17 WPM) and slowest was date stamp (4.43 WPM). A main effects test for WPM was significant ($F_{2,466}$=217.20, p<.01). On a questionnaire, subjects preferred EdgeWrite to the other methods. They felt it was easier, more enjoyable, and faster. To see how practiced users fare with EdgeWrite, we tested 3 more subjects, one of whom was an author on this paper. These subjects had prior experience with stylus EdgeWrite and practiced with the joystick text entry methods for 30+ minutes, targeting difficult letters and entering many phrases in each method. The performance of these 3 practiced users with date stamp and selection keyboard was near to that of the subjects in the main study. But with EdgeWrite, the speed approached 13 WPM, showing that more significant performance gains are possible with practice for EdgeWrite but less so for selection-based methods.

3.4 EdgeWrite on Wheelchair Joystick

In another study (Wobbrock, Myers, Aung, & LoPresti, 2004), we implemented a version of EdgeWrite in C++ for the Everest & Jennings 1706-5020 power wheelchair joystick, which was removed from its chair (Figure 6), and in C# for a Synaptics touchpad (Figure 7). We compared EdgeWrite on each of these two devices, which are already available for controlling power wheelchairs, to the on-screen WiViK keyboard. We improved and tested the three techniques that we evaluated with the help of 7 power wheelchair users, six with Cerebral Palsy and one with Multiple Sclerosis. All but one of them used a conventional QWERTY keyboard for text input, but all of them said that they could only do so for less than one hour before becoming fatigued. For speed, touchpad EdgeWrite was fastest on average at 1.00 words per minute (WPM). Joystick WiViK was second at 0.84 WPM. Joystick EdgeWrite was third at 0.77 WPM. The questionnaire results showed that, of the 3 methods, participants felt touchpad EdgeWrite was easiest to use, easiest to learn, fastest, most accurate, most enjoyable, most comfortable, and most liked overall. Participants rated joystick WiViK second in all of these categories, and joystick EdgeWrite third (Wobbrock, Myers, Aung et al., 2004).

Figure 6: The Everest & Jennings 1706-5020 power wheelchair joystick we modified for EdgeWrite text entry. Note the plastic template around the stick, which provides a square boundary.

Figure 7: The Synaptics touchpad we used with a plastic template to create a square area for EdgeWrite text entry.

4 Future Work and Conclusions

Although EdgeWrite has already has been shown to be effective for some people with motor disabilities, we have much work we still want to do. Plans include a version for desktop text entry using a trackball, a design for fluidly accessing word completions while making strokes, further studies to characterize the skills of people for which EdgeWrite is effective, and designs and studies of EdgeWrite as a technique for text entry on mobile phones for able-bodied people while walking. In the meantime, the stylus version for Palm PDAs can be downloaded from our web site at http://www.edgewrite.com.

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