ACCESSIBLE HANDHELD AND DESKTOP TEXT ENTRY FOR PEOPLE WITH MOTOR IMPAIRMENTS

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ABSTRACT

In recent years there has been much effort to make desktop computers more accessible to people with motor impairments. However, computing today increasingly takes place off the desktop on small handheld devices such as personal digital assistants (PDAs) and mobile phones. But little attention has been paid to making these devices accessible, particularly to those who have motor impairments such as tremor or spasm. To address this, we have developed a new text entry method for PDAs and mobile phones called *EdgeWrite*, which provides physical stability to people entering text on a Palm PDA. Our studies show that EdgeWrite is significantly more accurate than the built-in method Graffiti for people both with and without motor impairments. We have also adapted the EdgeWrite design to common input devices for desktop computer access, thus lowering the cost for adequate computer access in the workplace.

BACKGROUND

In 2002, we conducted field studies that found that while many people with muscular dystrophy (MD) or cerebral palsy (CP) could not comfortably use a conventional keyboard or mouse, they could effectively negotiate the small expanse of a PDA screen (1). Inspired by this, we created *Remote Commander* software for the Palm PDA that allowed the PDA to be used for computer access by connecting it directly to the desktop computer (Figure 1). A person could move a stylus or finger across the small expanse of the PDA screen and thereby move the mouse cursor across the large expanse of the computer screen. Similarly, by tapping anywhere on the PDA screen, a person could actuate a mouse-click on the computer screen. Remote Commander proved quite useful for some people with motor impairments, and was even featured in an issue of *Quest*, the magazine of the Muscular Dystrophy Association, for helping a girl who was home-schooled to complete her homework (2).

Figure 1. Kevin, a 12-year old boy with MD, is operating his desktop PC via a Palm PDA running our *Remote Commander* software.

However, although mousing was improved, text entry was still lacking. The two built-in text entry methods on Palm PDAs—Graffiti and virtual keyboards—are inadequate for people with tremor, low strength, or spasm. *Graffiti* is a script alphabet written with a stylus much like a person writes with a pen on paper. A difference, however, is that all Graffiti characters must be made with a single stroke (called “unistrokes”) and be the appropriate size and shape. Deviations outside the allowable range of size and shape result in mis-recognitions or non-recognitions. This happens frequently for people with poor control of their hands. *Virtual keyboards*, on the other hand, are miniaturized keyboards drawn on the PDA screen for use by tapping with a stylus. The problem with virtual keyboards is that their keys are only a few pixels tall and wide, making it hard for a person with motor impairments to tap on them accurately. Thus, a great deal of errors result.

STATEMENT OF THE PROBLEM

Our challenge was to develop a more accessible text entry method for handheld devices, and to make our software freely available via the Internet at www.edgewrite.com. We also envisioned adapting the handheld design to common desktop input devices, such as joysticks and touchpads. The goal in this latter case is to lower the cost of computer access by using common off-the-shelf input devices with a more effective means of text entry. We reasoned that if our design can provide physical stability and high accuracy on a Palm PDA, perhaps it also could be useful on the desktop.

RATIONALE

The "digital divide" will only increase as handheld devices become ubiquitous if people with motor impairments are unable to access them. More workplace activities will involve the use of handheld devices for tracking inventories, acquiring pricing information, making field investigations, and communicating among employees. Text entry will be fundamental to all of these activities. Furthermore, the challenge of desktop accessibility has not been fully solved, especially with respect to cost, complexity, and maintenance. Many of the same issues that plague handheld text entry for those with motor impairments also hinder desktop text entry, such as accuracy and the need for physical stability. Thus, we seek to address both domains with a single reusable design based on the use of physical edges.

DESIGN AND DEVELOPMENT

Our first design for more accessible text entry attempted to improve virtual stylus keyboards by placing the keys around the perimeter of the PDA screen (Figure 2). We reasoned that the elevated physical edge surrounding the PDA screen would provide a "backboard" against which the stylus could hit, making the virtual keys easier to acquire with the stylus by tapping or "swooping." Such a win is predicted by Fitts' law and is thus theoretically grounded; however, we did not generate such a win in our formal evaluations because any improvements in target acquisition time were dwarfed by increases in visual search time and distance of movement. It simply took subjects too long to find the keys and to move their stylus to them.

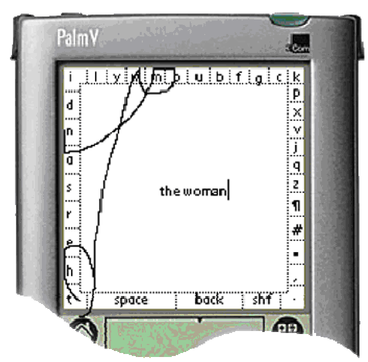

Figure 2. Our initial design for a more accurate text entry method for PDAs placed the keys along the elevated physical edges of the PDA screen.

We then reasoned that to improve speed, the physical edges used to provide stability must be brought closer together. Thus, rather than rely on the edges surrounding the PDA screen, we decided to impose our *own* physical edges. We created a plastic template with a square hole measuring 1.3×1.3 cm (Figure 3). Such a hole is too small to contain key regions for a virtual keyboard; instead, we invented a new alphabet based closely on the Roman alphabet for high learnability (Figure 4). We called this new alphabet *EdgeWrite*, because all letters are made by stroking along the edges and into the corners of the physical square hole (3). This provides stability.

Because we were designing for people with motor impairments, we needed our character recognizer to be tolerant to wiggle. As mentioned previously, wiggle often causes the built-in recognizers of Graffiti to recognize incorrectly. To accomplish this, we chose to recognize EdgeWrite letters solely by the order in which the corners of the input square are hit. All EdgeWrite letters have a different shape, and thus accrue a different sequence of corners as they are written. This means that wiggle and tremor do not deter high recognition rates even though they may alter the shape of the letters. This simple method of recognition and the presence of physical edges and corners to stabilize the stylus resulted in a highly accurate text entry method.

The EdgeWrite design and approach to recognition is computationally and physically simple enough to be applied to other devices besides handhelds. Currently, many computer access devices are prohibitively expensive, overly complex, or require ongoing maintenance. For example, abandonment rates are high among users of voice recognition systems due to these issues (4). We thus adapted EdgeWrite to some common input devices, such as joysticks and touchpads, in hopes of providing integrated mousing and text entry on inexpensive off-the-shelf devices.

Since commercial technology already exists to control a computer mouse with a power wheelchair joystick (e.g. see www.switchit-inc.com), we felt that providing a joystick text entry method to accompany mouse control would create a single integrated computer access solution. The result was EdgeWrite for power wheelchair joysticks (Figure 5), which uses the same alphabet and the same recognition principle (i.e. corner-hit sequences) as the PDA stylus version. Although it would be very difficult for users to "write" English or Graffiti letters with a joystick, it is easy to write EdgeWrite letters because of the stability provided by the edges and corners of the plastic square.

Finally, we also applied our design to commercial stand-alone touchpads. Like joysticks, touchpads can already be used to control power wheelchairs, but there are no integrated text entry methods for them. The touchpad version (Figure 6) works much the same way as the version for PDAs does, except that a person can use his finger instead of a stylus.

Figure 3. Our EdgeWrite template across the customary text input area on a Palm PDA. The stylus makes EdgeWrite letters by moving along the edges and into the corners of the square hole.

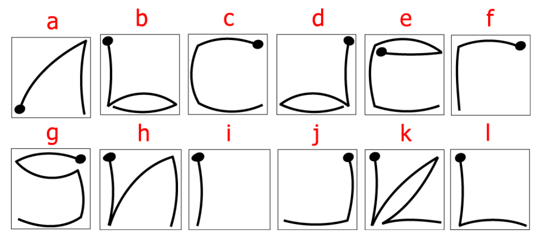

Figure 4. Some example EdgeWrite letters. Note that the bowing of segments within the letters is for illustrative purposes only; all strokes are made in straight lines between corners of the square. There are, in fact, multiple forms of most letters, increasing learnability and guessability.

Figure 5. EdgeWrite for power wheelchair joysticks allows a power wheelchair user to enter text on their desktop computer. Note the plastic template applied to the Everest & Jennings joystick provides a square input area in which EdgeWrite letters can be made.

EVALUATION

We have done numerous laboratory studies to assess and improve the efficacy of EdgeWrite in its various forms. A study (3) of the stylus version for Palm PDAs, for example, found EdgeWrite to be over 18% more accurate than Graffiti for able-bodied users ($p<.05$) with no significant difference in speed (both were about 7 WPM after 15 minutes of practice). We found even more dramatic results with motor-impaired users, who, on the whole, were 2-4 *times* more accurate with EdgeWrite than Graffiti. For example, one user with Parkinson's achieved only 22 of 72 correctly recognized characters in Graffiti (31%), but 68 of 72 in EdgeWrite (94%). This was because although she had a great deal of tremor, the plastic template stabilized the tip of her stylus as she made her strokes. Other motor impaired subjects that we tested were also much more accurate with EdgeWrite than Graffiti, and none were worse.

The joystick and touchpad versions of EdgeWrite have also been evaluated. Seven users with CP showed Touchpad EdgeWrite to be faster, more accurate, and more subjectively satisfying than the popular WiViK on-screen keyboard controlled by a joystick. Joystick EdgeWrite was only slightly slower than the WiViK keyboard. In all cases, EdgeWrite was surprisingly easy to learn, taking an average 15-30 minutes until subjects no longer had to look at a character chart.

Figure 6. EdgeWrite on a stand-alone Synaptics touchpad. The finger moves along edges and into corners of the square hole in the plastic template.

DISCUSSION AND CONCLUSIONS

The concept of using physical edges to provide stability during text entry has yielded a design which our studies have shown to be more accurate and satisfying for both able-bodied users and motor-impaired users than previous methods. We are encouraged by this because we believe that the coming ubiquity of handheld devices may bring a potential disadvantage to people with motor impairments if accessibility is not achieved. Our EdgeWrite design has some key properties that we believe can help achieve this accessibility: it is physically stable, highly accurate, spatially compact, computationally simple and fast, and capable of being implemented on a variety of devices and with varying degrees of hardware sophistication. We are currently pursuing a 4-button keypad version and a version for trackballs. EdgeWrite has already been used by others on the faces of wrist watches and in special education classes at a local school. With further development, it can be refined for widespread adoption among motor-impaired handheld and desktop users.

ACKNOWLEDGEMENTS

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Alternative Text

Figure 1:

Figure 1 shows Kevin, a 12-year old boy with MD, operating his desktop PC via a Palm PDA running our software.

Figure 2:

Figure 2 shows our initial design for a more accurate text entry method for PDAs that placed the keys along the elevated physical edges of the PDA screen.

Figure 3:

Figure 3 shows our EdgeWrite template across the customary text input area on a Palm PDA. The stylus makes EdgeWrite letters by moving along the edges and into the corners of the square hole.

Figure 4:

Figure 4 shows some example EdgeWrite letters, which have segments in them that are bowed. The bowing of segments within the letters is for illustrative purposes only; all strokes are made in straight lines between corners of the square. There are, in fact, multiple forms of most letters, increasing learnability and guessability

Figure 5:

Figure 5 shows an Everest & Jennings power wheelchair joystick with an EdgeWrite template on it, which allows a power wheelchair user to enter text on her desktop computer.

Figure 6:

Figure 6 shows EdgeWrite on a stand-alone Synaptics touchpad. A finger moves along edges and into corners of the square hole in the plastic template.