The Benefits of Physical Edges in Gesture-Making: Empirical Support for an Edge-Based Unistroke Alphabet

Jacob O. Wobbrock
Human-Computer Interaction Institute
Carnegie Mellon University
jrock@cs.cmu.edu

The Problem: Handheld Text Entry is Difficult for People with Motor Impairments

As part of the Pebbles project, we have developed a handheld application called Remote Commander that allows people with motor impairments to control their PCs entirely from handheld devices. The conventional keyboard and mouse require gross motor control, which many motor-impaired users lack, whereas using a PDA largely requires fine motor control. However, text entry with "soft" keyboards is difficult because the keys are hard to hit and take up precious screen space. What's more, Graffiti is difficult due to tremor and rapid fatigue. What is needed is an easier, more stable means of text entry for those with motor impairments.

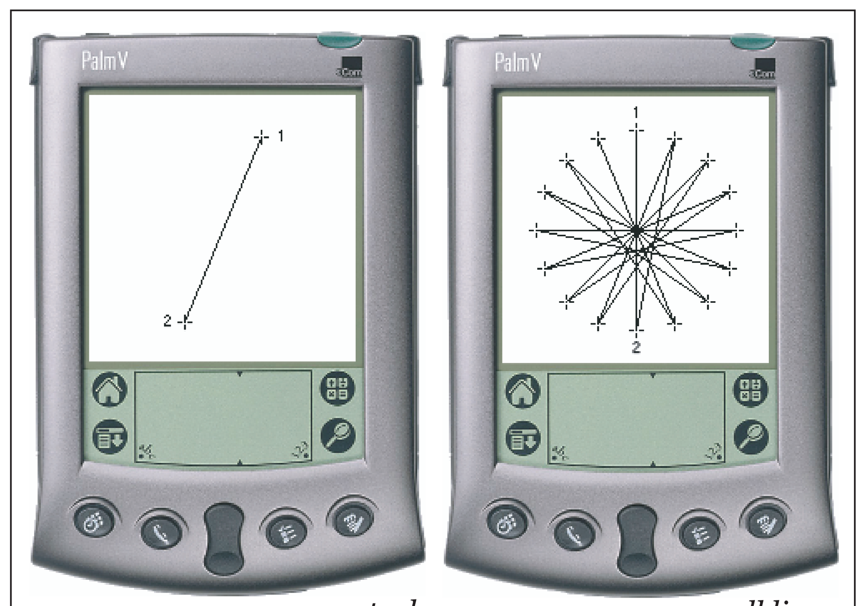
The Approach: Use Physical Edges to Provide Stability, Accuracy, and Speed

Our hypothesis was that physical edges, such as those that surround a handheld screen, or those imposed by a plastic attachment, can provide stability, accuracy, and speed during movement with a stylus. Perhaps physical edges could be used in interaction techniques to provide stability for those with motor impairments. Fitts' Law tells us that acquiring targets on edges is easier than acquiring targets "in the open." But what about movement along an edge? Would users with motor impairments be able to exert enough pressure against an edge while moving to gain any benefits? What exactly would those benefits be?

Study #1: Understanding Movement Along and Away From Edges

We conducted a small study with 3 users with motor impairments: 2 with Cerebral Palsy, 1 with Muscular Dystrophy. The study involved tracing lines of 5 different position types on the Palm PDA, shown below. The line position types varied according to presence or absence of an edge along the task-axis, and presence or absence of an edge behind the task-axis end-point. Subjects' movement data was logged on a laptop PC over a serial cable. It was analyzed according to the measures described in the side bar. The PDA screens below show multiple lines at once, but subjects only saw one line at a time.

For all path analysis measures below, smaller values are better. Means are reported along with standard deviations, in parentheses. Units are as follows: MT (seconds); TAC, MDC, ODC (no. per trial); ME, MO, MV, SE, EE (pixels). See the side bar for more details.



one task *all lines*

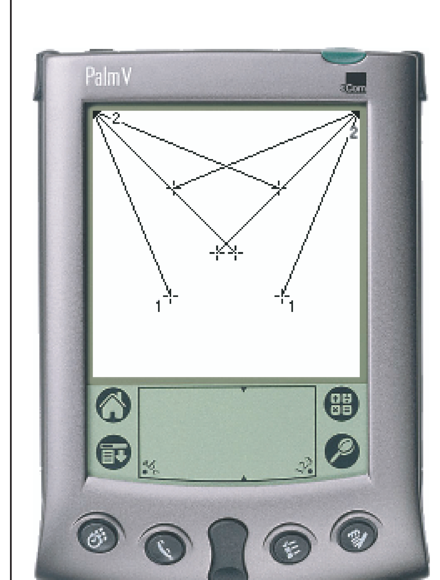
No Edge, No Corner

MT:	2.7 (1.4)
TAC:	3.1 (4.4)
MDC:	40.1 (23.0)
ODC:	5.1 (5.5)
ME:	3.9 (2.1)
MO:	3.1 (2.8)
MV:	2.2 (1.5)
SE:	6.5 (3.9)
EE:	9.0 (14.8)

Adapted to PDA from ISO 9241-9 task for measuring desktop pointing devices.

No Edge, Corner

MT:	2.1 (1.0)
TAC:	3.2 (3.3)
MDC:	29.6 (17.3)
ODC:	3.1 (3.4)
ME:	4.5 (4.0)
MO:	2.4 (5.4)
MV:	3.3 (2.8)
SE:	8.3 (7.6)
EE:	4.6 (8.5)



Edge, Corner

MT:	1.5 (0.9)
TAC:	0.0 (0.0)
MDC:	0.8 (1.7)
ODC:	1.2 (1.3)
ME:	0.4 (0.9)
MO:	0.4 (0.9)
MV:	0.6 (0.7)
SE:	8.9 (6.3)
EE:	1.9 (2.9)

Edge, No Corner

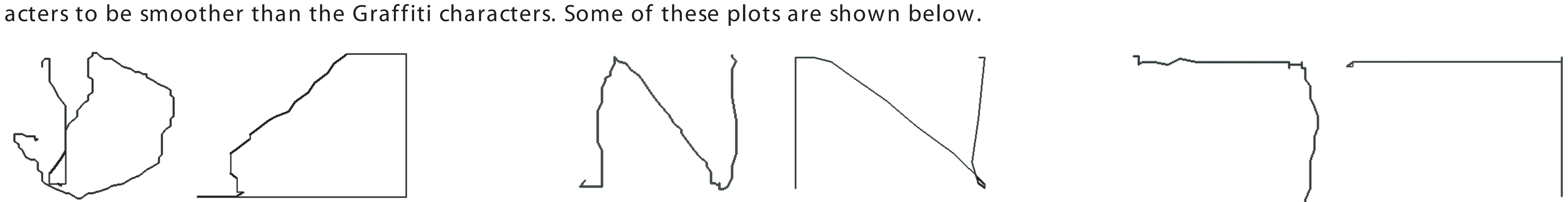
MT:	2.0 (0.9)
TAC:	0.0 (0.0)
MDC:	3.6 (5.5)
ODC:	2.8 (2.7)
ME:	1.6 (5.7)
MO:	0.4 (5.9)
MV:	1.0 (2.3)
SE:	9.6 (13.7)
EE:	11.0 (19.8)

Edge Behind Target

MT:	2.4 (1.4)
TAC:	1.3 (1.3)
MDC:	10.3 (6.6)
ODC:	1.6 (2.8)
ME:	3.3 (3.3)
MO:	2.6 (3.6)
MV:	2.4 (2.9)
SE:	6.6 (3.8)
EE:	5.2 (9.0)

Study #2: Analyzing Unistroke Characters by the Motor-Impaired: Graffiti and EdgeWrite

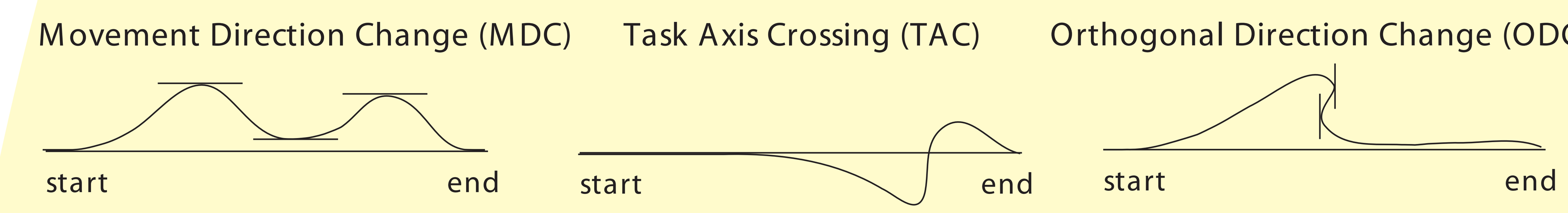
The same 3 motor-impaired subjects that participated in Study 1 made 11 letters 3 times each in both Graffiti and EdgeWrite (side bar). The letters were K, T, X, U, G, N, V, J, E, D, and Y. Graffiti letters took an average of 2.47 seconds from pen-down to pen-up. EdgeWrite letters took an average of 2.82 seconds, a non-significant difference. Graffiti recognition was a mere 64.6%. Subjects were shown a 3x5 card with the intended letter on it, so this recognition rate is not confounded with users' misconceptions about what letters to make, or how to make them. At the time of this study the EdgeWrite recognition engine was still under development. Movement plots show the EdgeWrite characters to be smoother than the Graffiti characters. Some of these plots are shown below.



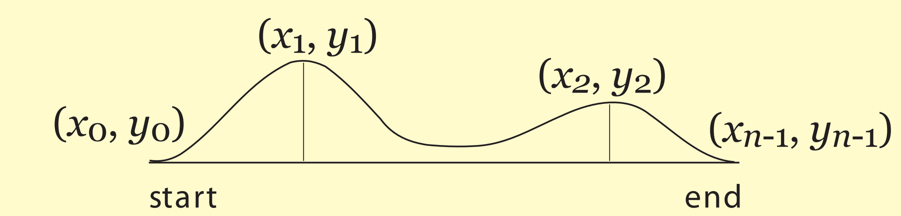
Graffiti D   EdgeWrite D   Graffiti N   EdgeWrite N   Graffiti T   EdgeWrite T

Analyzing Pointer Device Movement

From MacKenzie et al. "Accuracy Measures for Evaluating Computer Pointing Devices." Proc. CHI 2001 (Seattle). ACM Press, pp. 9-16.



The formulas listed below use this path description and assume $y_{start} = y_{end} = 0$.



$$\text{Movement Variability (MV)} = \sqrt{\frac{\sum (y_i - \bar{y})^2}{n-1}}$$

$$\text{Movement Error (ME)} = \frac{\sum |y_i|}{n}$$

$$\text{Movement Offset (MO)} = \bar{y}$$

Measures added for handheld analysis:

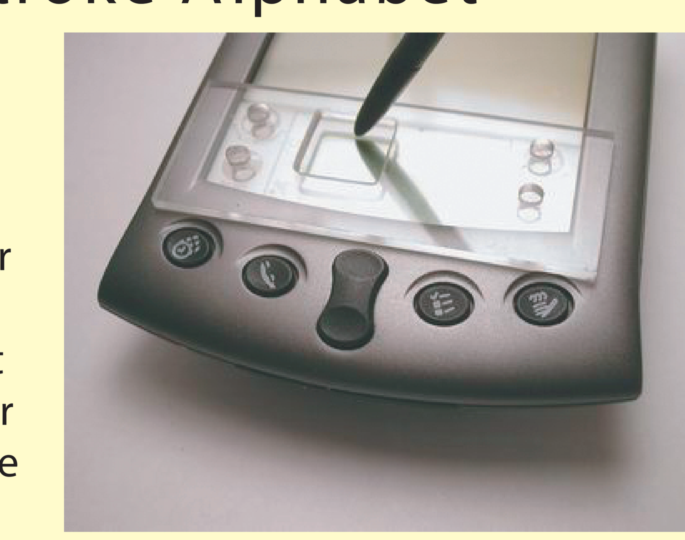
$$\text{Start Error (SE)} = \sqrt{(y_0 - y_{start})^2 + (x_0 - x_{start})^2}$$

$$\text{End Error (EE)} = \sqrt{(y_{n-1} - y_{end})^2 + (x_{n-1} - x_{end})^2}$$

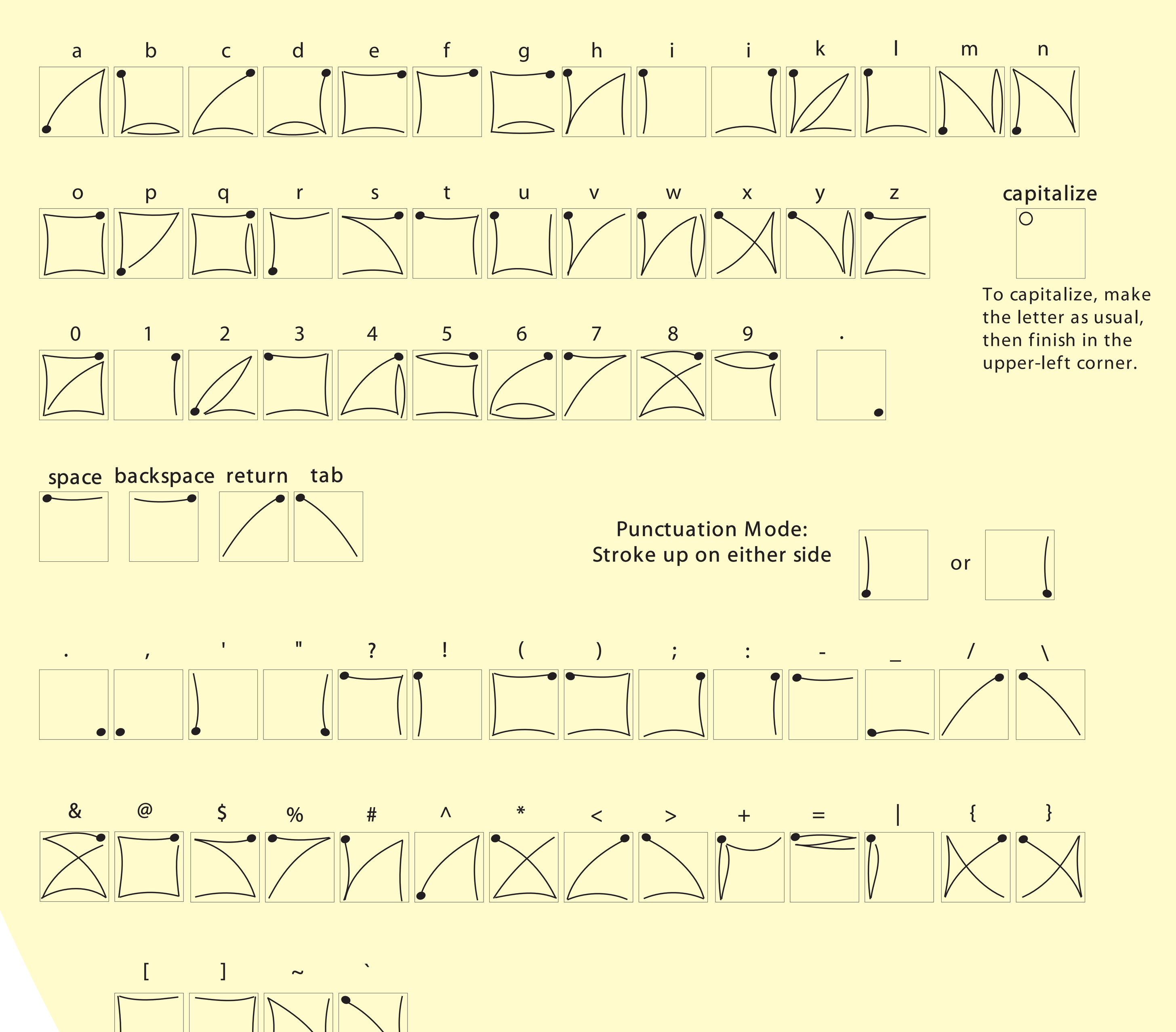
Movement Time (MT) = (Pen-up Time) - (Pen-down Time)

EdgeWrite: The Edge-Based Unistroke Alphabet

The "Edge, Corner" condition proved more stable (TAC, MDC, ODC, MV), more accurate (ME, MO, EE), and faster (MT) than the other line-placement conditions. Based on this, we designed an edge-based unistroke alphabet called EdgeWrite. EdgeWrite is similar to other unistroke text entry methods, but the recognition does not depend on the path of the stroke, but on the order in which the corners are hit. All character forms are made within a small (1.3 cm x 1.3 cm) square hole placed over the text entry area of the Palm PDA.



Our recent work shows that EdgeWrite is 18% more accurate than Graffiti for able-bodied users who have no prior experience with either technique. In our recent study, this came with a non-significant difference in speed: 7.2 wpm (Graffiti) to 6.6 wpm (EdgeWrite). Our future work will continue to improve this input technique.



CHI 2003, Ft. Lauderdale, FL, April 5-10, 2003