Stylus Based Text Input Using Expanding CIRRIN

Jared Cechanowicz, Steven Dawson, Matt Victor, Sriram Subramanian
Computer Science Department, University of Saskatchewan
Saskatoon, Saskatchewan, Canada, S7N 5A9
jec394@mail.usask.ca, srd179@mail.usask.ca, mjv917@mail.usask.ca, sriram@cs.usask.ca

ABSTRACT
CIRRIN [3] is a stylus based text input technique for mobile devices with a touch sensitive display. In this paper we explore the benefit of expanding the letters of CIRRIN to reduce the overall difficulty of selecting a letter. We adapted the existing CIRRIN to expand the characters as the stylus approached it to create a new text entry technique called expanding CIRRIN. In a small user study we compared the standard CIRRIN and expanding CIRRIN for different sentences. Our results indicate that expanding CIRRIN increases error rates and text input times. We observed that expanding the letters often made the stylus enter the CIRRIN ring adjacent to the intended letter, thereby increasing error rates. We discuss the implications of these results, and possible applications of expanding targets with other text input techniques such as the Metropolis [7] soft keyboard.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Graphical User Interfaces, Input Devices and Strategies.*

General Terms
Design, Human Factors.

Keywords
CIRRIN, Expanding Targets, text entry, touch sensitive display, stylus, Fitts' Law.

1. INTRODUCTION
With the increasing popularity of mobile devices with touch sensitive screens, it is becoming increasingly important to achieve a fast and reliable method for text input on such devices. The most common methods of text input continue to be software based QWERTY keyboards, hardware keyboard add-ons, and character recognition "graffiti"-like input methods. Generally these methods do not allow a user to string together multiple characters. None of these three methods mimic the movements of the more natural, word-level writing style we use when writing on paper

One viable option that allows for a more natural, flowing movement of the stylus is the CIRRIN device proposed by Mankoff and Abowd [3] This method involves a circular display of all of the letters of the English alphabet. The letters are ordered based on popular digrams and trigrams of the English language.

To enter text the user simply has to move their stylus over the letter while pressing down on the screen. The user drags their stylus on the screen while moving from letter to letter until they have completed the desired word. When the user needs to enter a space, they simply lift their stylus and begin entering the next word (see Figure 1).

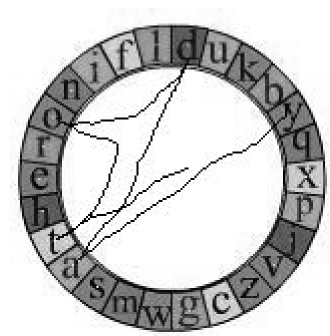

Figure 1. An example of the original CIRRIN showing a stylus path that would result in the word "today".

With CIRRIN the distance between letters is fixed. Because the most commonly used digrams are nearest to each other, distances traveled from letter to letter are usually shorter than those that must be traveled by the stylus when using a QWERTY based software keyboard. The circular based design means that when the user places their stylus in the center of the CIRRIN device, the distance to each letter is equal. This arrangement should facilitate faster target selection much like a pie menu [2].

McGuffin and Balakrishnan [1] describe how expanding targets can improve target acquisition times by expanding the size of a target as the pointing device approaches it. This allows users to select a larger target making the task easier to accomplish. This idea can be applied to CIRRIN so that the letters expand as the stylus approaches them. We hypothesize that combining expanding targets with the CIRRIN text input device will result in better performance than the original CIRRIN device.

We tested our hypothesis in a small user study comparing a standard CIRRIN implementation with an expanding targets CIRRIN implementation. The subjects were tested twice with three sentences on both implementations over a period of two weeks. Our results indicate that the user's performance with expanding CIRRIN is slower and more error prone than standard CIRRIN.

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These results were unexpected based on the findings of McGuffin and Balakrishnan, suggesting that target size is not the only factor involved in improving the speed and accuracy of stylus based text entry. We will discuss the implications of our findings in more depth later in this paper.

2. IMPLEMENTATION

We implemented two versions of CIRRIN for our study, one standard CIRRIN designed as described in the original work [3], and expanding CIRRIN built with expanding targets, based on the ideas presented by McGuffin and Balakrishnan [4]. Our implementation was done in Flash.

To begin writing, the user presses the stylus down anywhere in the central white area of the CIRRIN wheel, and begins drawing over the letters they want to input. To enter a “Space”, they lift the stylus from the display. A “Backspace” button is provided just outside of the wheel. There is no “Caps Lock” or “Shift” to enter capital letters, and there is no way to enter characters other than the 26 letters shown on the wheel. The layout of the letters on the wheel is consistent with the original CIRRIN. The letter blocks have been colored only to aid with learning and recognition.

For expanding CIRRIN, each of the 26 letter buttons expand based on their distance from the coordinates of the stylus. Expansion is controlled by two variables of the program, the maximum expansion ratio, and the expansion activation distance which is measured in pixels. The maximum expansion ratio specifies the maximum expansion of a letter, while the expansion activation distance specifies the distance between the stylus and letter at which the expansion starts. No matter what expansion ratio and activation distance are chosen, all expansion is completed by the time the tip of the stylus is directly adjacent to a button.

We used the occlusion model for expanding targets rather than the sliding buttons model. This means that when the letter buttons expand, the smaller buttons will be partially concealed by nearby expanded buttons as shown in Figure 2. We decided to use the occlusion model, because with the sliding buttons model the buttons on the opposite side of the wheel would have to shrink in order to maintain the size of the wheel. Buttons to the left and right of the expanding buttons would slide along the wheel, changing their position on the wheel and reducing a user’s ability to use spatial memory with targeting.

2.1 Test Design

For our experiments we tested 4 subjects, all who have familiarity with using a stylus on Tablet PCs. The subjects were all right-handed males between 20 and 25 years of age. We presented each subject with 3 sentences on both standard CIRRIN and expanding CIRRIN. The sentences were the same for all subjects, and were presented in the same order every time. Half of the subjects started with the standard CIRRIN and then tried the expanding CIRRIN, while the others started with the expanding CIRRIN. The subjects were all tested twice, the second test taking place about two weeks later.

The expanding CIRRIN for the experiments used a 60% expansion ratio and a 50 pixel expansion activation distance. The standard CIRRIN used for the experiments was identical to the expanding CIRRIN design with a 0% expansion ratio.

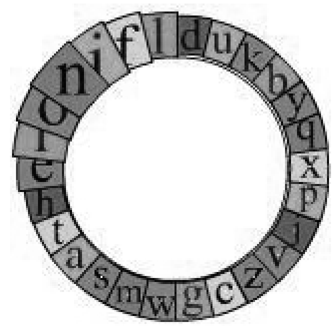

Figure 2. Expanding CIRRIN with 60% expanding targets. Notice that the largest button, and all partially expanded buttons overlap nearby smaller buttons, showing the occlusion model.

The sentences were shown to the subjects in advance of the test, and they were given as much time to practice as they wanted before the test started. When subjects were ready, they pressed a start button, starting the timer. The timer stopped when they finished the sentence correctly. Subjects could take as much time between sentences as they wished.

The test sentences were “go to the dishwasher and get me a shiny clean plate”, “i am finished with the remote control which i love”, and “underneath the dresser is a quiet weasel eating my sock”.

For our tests we recorded time, in milliseconds per sentence, and errors per sentence. Errors are determined by character comparisons at the character positions of the test sentence. So for the test sentence “go to the dishwasher and get me a shiny clean plate”, entering “gt to the” registers as one error, and “gto to the” registers as nine errors.

3. RESULTS

We analyzed the number of errors and text entry speed. Due to the limited number of subjects we did not do a significance test, however our data was rich enough to reveal interesting results about the two techniques.

Overall, we found that the users were faster with the standard CIRRIN than with expanding CIRRIN. Figure 3 shows the average characters per second for each technique. In the case of standard CIRRIN, subjects were dramatically faster (about 0.2 characters per second, a 35% improvement) in the second trial which was done about two weeks later. There is also an increase in speed of about 0.12 characters per second for expanding CIRRIN.

We found that on average, subjects made about 8 errors with standard CIRRIN and 20 errors with expanding CIRRIN. Figure 4 shows the number of errors per technique. The graph shows that subjects were consistently less error prone when using the standard CIRRIN over the expanding CIRRIN. Users committed less errors in the second set of trials with both expanding CIRRIN and standard CIRRIN. In the case of standard CIRRIN, 3 out of 4 subjects made no errors in the second set of trials conducted two weeks later.

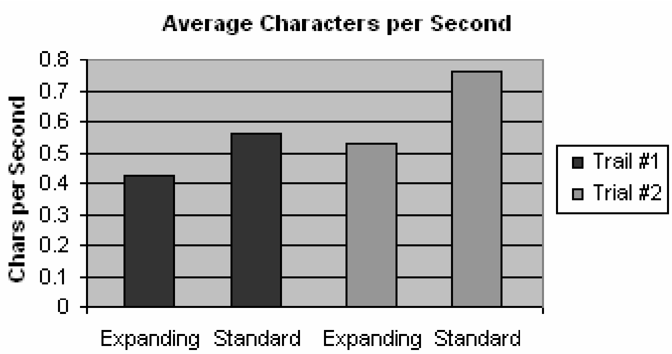

Figure 3. Bar graph showing average characters per second with expanding CIRRIN and standard CIRRIN across two trials.

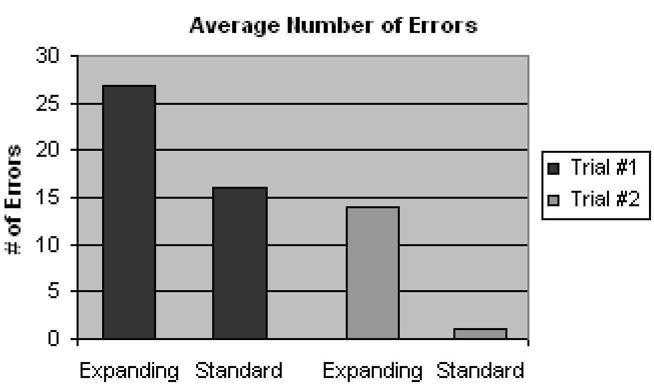

Figure 4. Bar graph showing the average number of errors with expanding CIRRIN and standard CIRRIN across two trials.

4. DISCUSSION

The results from this study, and especially the results from the second set of trials, show that CIRRIN with expanding targets is slower and prone to more errors than standard CIRRIN. The hypothesis that expanding targets would increase a user's text entry speed seems intuitive based on the results from the study done by McGuffin and Balakrishnan on Expanding Targets [4]. However, there is strong evidence to suggest that our hypothesis is flawed, even though we did not do a significance test on our data. Why this difference?

Our observation revealed that most errors with expanding CIRRIN occur when a user is moving towards one of the letter buttons they intend to target, but their stylus comes closer to one of the nearby buttons as they are making their final movement (see Figure 5-Left). At this moment, the new closest letter button becomes the largest target as shown in Figure 5-Right and an error occurs as the user selects the wrong button. The errors that occur with expanding CIRRIN are caused almost exclusively by this phenomenon, and as such, are largely unintended. This unintended error phenomenon has several explanations.

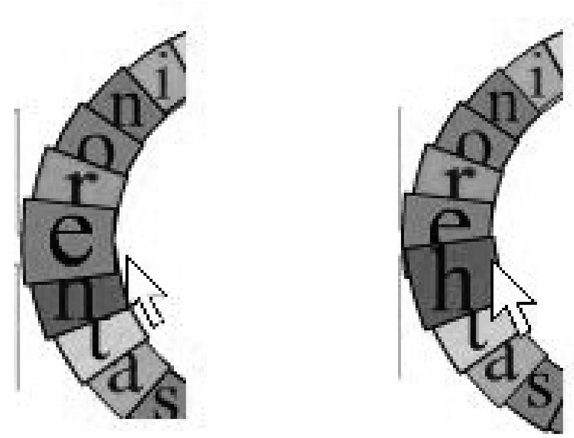

Figure 5. In the image on the left, the user is intending to target the "e" letter button, but their approach is going to take them physically closer to the "h" than the "e". Notice that in the image on the right that the "h" letter button becomes largest at the last moment, and an unintended error occurs.

One possible explanation is that expanding targets are more effective when arranged on a vertical or horizontal bar, as tested in the original work. With expanding CIRRIN, the targets are arranged in a wheel, and are always approached from the concave side (see Figure 5). In this arrangement, the distance from the "e" letter button to a nearby stylus coordinate inside the wheel will be nearly the same as the distance from the "h" letter button to the same stylus coordinate. Because of this, it is much easier for the user to commit an error than if the buttons were arranged on a bar, as in the original expanding targets paper.

Another possible explanation is that these types of errors occur all of the time with expanding targets, as they were not considered or recorded in the original work. Their tests required that users click the mouse button to indicate target selection and the end of the trial. It is very likely that subjects accidentally highlight other buttons first on their way to their intended target. This fact does not matter much when a click is required before target selection, but for expanding CIRRIN it can be disastrous. Every time the user accidentally moves over an unintended target an error occurs.

In a follow-up study on the original expanding targets, Zhai et al [6] investigated the number of errors users made when using expanding targets. The results of their study showed that consistently expanding targets with higher index-of-difficulties can actually increase error rates. These results seem to be consistent with our own, and could explain the error rates we recorded.

However, the results of their study showed improved speed despite increased errors, while our results show that expanding CIRRIN is slower than standard CIRRIN. It is likely that this decrease in speed between expanding and standard CIRRIN is due to error recovery. Error recovery is slow due to the "Backspace" button being outside the CIRRIN wheel. Better locations for the "Backspace" button need to be explored for faster error recovery.

It is also worth mentioning that there are practical problems inherent with an expanding CIRRIN design. For expanding targets arranged in a ring, Pythagorean Theorem is required to compute accurate distance measures, meaning that many square root operations are required every time you move your stylus.

CIRRIN would be most useful for PDAs, and Tablet PCs, which may not be able to meet the processing requirements of expanding CIRRIN without significant "lag". Even after adding a heuristic to avoid unnecessary computations, we found that as many as 6 square roots per mouse move were required with an expansion activation distance of 50 pixels, which is not practical for smaller devices at this time.

5. CONCLUSIONS AND FUTURE WORK

In this paper we investigated the effectiveness of target expansion in CIRRIN. Even though expanding targets have been shown to be effective in desktop pointing conditions, our results suggest that adapting them to stylus based text entry might result in reduced performance.

In the future we plan further testing of expanding CIRRIN with different expansion ratios. For example, by comparing the results of 0%, 10%, 20%, 30%, 40%, and 50% expansion ratios, one should be able to observe the correlation between the occlusion of the letter buttons and the number of errors caused by the unintended error phenomenon described earlier, and illustrated in figure 5.

Another future research direction is to explore the effectiveness of expanding targets on other stylus based text entry techniques. The Metropolis keyboard [7] combined with expanding targets may provide interesting insights. This text entry technique is similar to a traditional soft keyboard, but with an optimized layout. Because the stylus is lifted off the screen while typing, hover detection would be essential to track the location of the stylus point and expand the letters of the keyboard accordingly. Unlike CIRRIN, a tap with the stylus is required to select a target, and because of this it seems likely that a Metropolis keyboard with expanding targets would cause fewer errors than the expanding CIRRIN design we tested. But just like expanding CIRRIN there will be a threshold issue when the stylus is directly between two adjacent targets. During the final tapping motion of the stylus it is possible that an unintended adjacent target could become the closest target, causing it to expand into the foreground. It would be interesting to compare the characters per second and error rates of Metropolis with expanding Metropolis, as well as expanding Metropolis with expanding CIRRIN.

We are particularly interested in exploring the benefits of desktop pointing techniques in stylus based applications.

6. REFERENCES

[1] P. M. Fitts, The information capacity of the human motor system in controlling the amplitude of movement. *Journal of Experimental Psychology*, 47., pages 381-391, 1954.

[2] D. Hopkins. The Design and Implementation of Pie Menus. *Dr. Dobb's Journal*, December 1991.

[3] J. Mankoff, and G. D. Abowd. CIRRIN: A word-level unistroke keyboard for pen input. *Proceedings of the 11th Annual ACM Symposium on User Interface Software and Technology.*, pages 213-214, November, 1998.

[4] M. McGuffin, and R. Balakrishnan. Acquisition of Expanding Targets. *Proceedings of the SIGCHI conference on Human factors in computing systems*., pages 57-64, April 2002.

[5] R. W. Soukoreff, and I. S. MacKenzie. Theoretical upper and lower bounds on typing speed using a stylus and soft keyboard. *Behaviour & Information Technology, 14,* pages 370-379, 1995.

[6] S. Zhai, S. Conversy, M. Beaudouin-Lafon, Y. Guiard. Human On-line Response to Target Expansion. *Proceedings of the CHI Conference on Human Factors in Computing Systems*. pages 177-184, April 2003.

[7] S. Zhai, M. Hunter, B. A. Smith. The Metropolis Keyboard – An Exploration of Quantitative Design Techniques for Virtual Keyboard Design. *Proceedings of the 13th annual ACM symposium on User interface software and technology.* pages 119-128, November 2000.