Paper

PP_Clickwheel: Positional Prediction Khmer Text Input Interface with Clickwheel for Small Mobile Devices

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〈**Summary**〉 Mobile devices such as mobile phone, PDA, music player and game player are becoming to play an important role in today's communication, education and entertainment. Text typing with these small mobile devices is a challenging research topic for daily work such as emailing, word processing, browsing or searching information, note taking and adding a new contact address into a phone book and so on. In this paper, we propose a new text input interface for Khmer (language of Cambodia) for mobile devices using clickwheel like Apple iPod. We used our proposed Positional Prediction (PP) text input concept for predicting possible combinations of a consonant and vowels or a syllable, and named the new text input interface PP_Clickwheel (Positional Prediction with Clickwheel). We held user study for PP_Clickwheel with ten native participants in Phnom Penh city, Cambodia to judge its user-friendliness based on first-time users' typing speed. The results are acceptable and positive for the current version of PP_Clickwheel prototype.

Keywords: Positional Prediction, advanced smart terminals, mobile devices, text input, Khmer, syllabic scripts, user interface

1. Introduction

Mobile devices such as mobile phone, PDA and music player are now popular in Southeast Asian developing countries such as Cambodia, Laos, Myanmar, Thailand and Bangladesh etc. However, there are many difficulties to operate with their mother languages because all menus are displayed in English or Chinese, which does not support efficient typing or tapping method for their native languages. We believe that mobile devices will become more popular and necessary for daily work in Southeast Asian developing countries in the future. It is clear that text typing on mobile devices such as sending email, writing notes, searching information and saving the music title etc. is becoming daily work in developed countries. And thus, many researcher of Human Computer Interaction or Human Computer Interface (HCI) area focus on text input interfaces on small mobile devices even for English. To the best of our knowledge, most mobile phone users from Southeast Asian developing countries rarely do SMS messaging with their native languages but use mobile phones only for speech communication. One of the main reasons is that text typing is not easy on their mobile phones. Users have to memorize the keypad mapping and need much practice to get accustomed to the text typing method. Another reason is that typing speed is slow with annoying process on a mobile phone keypad. In the days to come, mobile devices will become smaller and very important for communication. We should not neglect the investigation of efficient text input interfaces on small mobile devices for mother languages in Southeast Asian developing countries.

In this paper, we propose the new text input interface PP_Clickwheel (Positional Prediction with Clickwheel) for Khmer (language of Cambodia). Khmer is a syllabic language, and thus, we use Positional Prediction (PP) text input concept for predicting possible combinations of vowels with a consonant or a

syllable[1]. PP_Clickwheel text input interface will be useful for typing similar syllabic languages such as Lao, Myanmar (Burmese), Thai, Nepali, Hindi and Bengali etc. with small mobile devices.

2. Related Works

In this section, we present some text input methods with clickwheel on small mobile devices such as iPod[2].

2.1 Keypad on Clickwheel

This input method logically divides clickwheel into eight sections like a mobile phone keypad (see **Fig. 1**) and detect users' tapping[4),5)]. Keyboard mapping is the same as mobile phone keypad mapping, e.g. 2 for (a, b, c), 3 for (d, e, f), 4 for (g, h, i) and so on. This method uses eight sections of the clickwheel (tapping only and no clicking) for text typing.

2.2 Cursive

Cursive text input method is based on the imagination of writing letters onto the scrollwheel[4),6)]. For example, to write a lowercase letter "a", from the top right (between the menu and next buttons on 1 and 2G iPods, below the play/pause on 3Gs), start rotating your thumb leftwards around the scroll wheel one complete turn. Then, for the tail of "a", scroll right one 1/4 turn. Example codes used by the current Cursive text input method can be seen in **Table 1**.

Fig. 1 Keypad layout on an iPod clickwheel

Table 1 Example codes used by Cursive text input

Unshifted	Shifted	Sequence
a	A	llllr
b	B	lllro
c	C	lll
d	D	rrrr
e	E	olll

Here, "l" or "r" represents a quarter turn in each direction ("l" represents anti-clockwise, "r" represents clockwise and "o" represents the center button).

2.3 Thumbscript

Thumbscript text input method is based on a simple 9 pixel drawing tablet and drawing or tapping pictograph of English alphabets on it[7]. For example, drawing orders for "a", "b", "c", "u", "w" and "y" can be seen in **Fig. 2**. All letters are formed from top to bottom, but when "start" and "stop" are on the same row, the order is from left to right. Reverse drawing or tapping order will be used for punctuation, and symbols such as reverse drawing order of "c" will be typed "(" and reverse drawing order of "u" will be typed "\".

This method will work with fourth and fifth generation, second generation mini, photo, and color iPods. It uses eight sections of the clickwheel and the action button as a telephone keypad, and rewind and forward buttons to move the cursor[4].

2.4 Discussion on Current Clickwheel Text Input Methods

Here we will make a brief discussion on current clickweel text input methods.

"Keypad on Clickwheel" method is usable for alphabetic languages such as English, Spanish and French etc., but is not directly applicable to Khmer. This is because Khmer is a syllabic language, which has triple numbers of characters (i.e. 74 characters excluding subscript characters) of English. And thus, keyboard or keypad mapping on 9 buttons is a challenge and KSPC (Keystrokes per Character) will be higher[8].

Text input interface of "Cursive" and "Thumb-

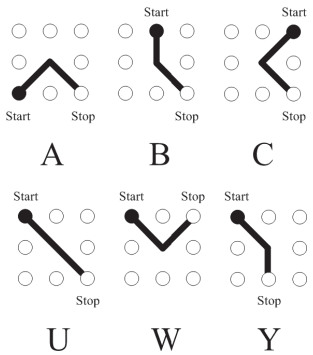

Fig. 2 Thumbscript text input method

script" methods are interesting but difficult even for English. First-time users have to memorize the coding for "a" to "z", and several practice times are required for getting used to it. Some coding and tapping pictographs do not look like actual glyph or shape of the English alphabets. "lll" is for "c" or "C", "llll" is for "o" or "O", and "ll" is for "l" or "L", which is easy to understand, however, "lllro" is for "b" or "B", "ror" is for "i" or "I", "lro" is for "k" or "K", "rrrro" is for "m" or "M", and "irrr" is for "n" or "N" etc., which is very difficult for first-time users in Cursive method [6]. Another example is pictographs of "U", "W" and "Y" (see Fig. 2). Although it is possible to create Cursive coding or Thumbscript tapping pictograph for syllabic scripts e.g. in Khmer language, we may need to design many codes or pictographs (e.g. 33 consonants, 24 dependent vowels, 12 independent vowels and some other directive signs etc.) And another important factor is that the shape or glyph of Khmer is difficult to create pictograph or shorthand writing (see an example of Khmer words in **Fig. 3**).

Other text input interfaces for mobile devices with clickwheel (e.g. iPod) have been proposed e.g. "On-Screen Keyboard", "Four-Button Telephone Keypad", "Unicode Hex Input", "Kana Palette", "Wheelboard and Multilingual Wheelboard" and "Morse Code" etc. [4]. Most of the input methods mentioned above are based on English alphabet, and not all interfaces take into consideration writing natures of syllabic languages. Among them, "On-Screen Keyboard" and "Wheelboard and Multilingual Wheelboard" input interfaces are applicable to Khmer language, but it may be difficult to distinguish Khmer characters due to their similarity in shape on a limited-sized screen (e.g. "ក" (ka), "គ" (ko), "ត" (ta) and "ភ" (pho) etc.)

3. Khmer (Language of Cambodia)

Khmer — the language of one of Southeast Asia countries, Cambodia belongs to the Mon-Khmer family languages. Khmer alphabets closely resemble Thai and Lao alphabets, but Khmer is not a tonal language. Some vocabularies are borrowed from Sanskrit, Pali, French and Chinese in Khmer. Khmer uses a phonetic alphabet with 33 consonants (e.g. "ក", "ខ", "គ", "ឃ", "ង", "ច", "ឆ", "ជ", "ឈ" and "ញ" etc.), 24 dependent vowels (e.g. "ា", "ិ", "ី", "ុ", "ូ", "ួ", "ើ", "ឿ" and "ៀ" etc.), 12 independent vowels (e.g. "ឥ", "ឦ", "ឧ", "ឩ", "ឪ", "ឫ" and "ឬ" etc.) and some other diacritic signs (e.g. "ំ", "ះ", "ៈ", "៉", "៊" and "់" etc.) [9]. Most consonants have reduced or modified forms called subscripts (e.g. "្ក", "្ខ", "្គ", "្ឃ" and "្ង" etc.) when they occur as the second member of a consonant cluster. Vowels may follow or precede consonants, or go above or below, or combinations of before, after, above and below.

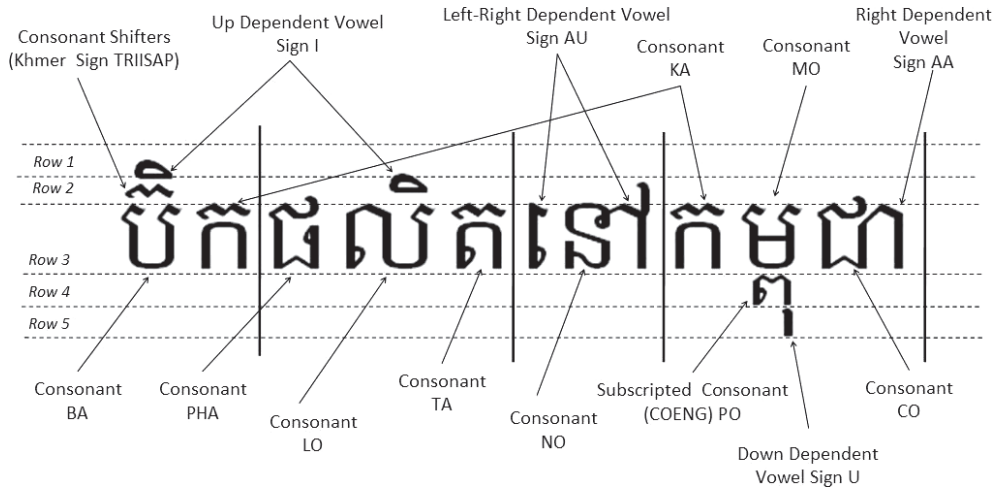

Fig. 3 Word formation in Khmer Language (Bic Phalit Nau Kampuchia, pen made in Cambodia). Vertical lines indicate pronunciation breaks of "Bic", "Phalit", "Nau" and "Kampuchia".

12 independent vowels can exist without a preceding consonant. Khmer writing begins on the top left of a page, and proceeds to the right. The word order follows SVO (subject + verb + object) pattern as in English. Khmer writing does not put a space after each word; instead, spaces are used to denote the end of phrases or sentences. An example of Khmer writing system is shown in Fig. 3.

4. Writing System of Khmer

When we make an analysis of Khmer sentences, it is basically considered that Khmer characters are written in three levels (upper, middle and lower) like in Myanmar (Burmese) and Bangla languages. However, five levels are sometimes required for subscript characters. And most characters have their defined positions (e.g. vowel signs "ᦵ", "ᦷ" should be written in the left side of consonants, vowel signs "ᦱ", "ᦸ" and "ᦹ" etc. should be written in the right side of consonants, vowel signs "ᦳ", "ᦴ", and "ᦶ" etc. should be written as lower characters and vowel signs "ᦻ", "ᦼ", "ᦽ" and "ᦾ" etc. should be written as upper characters). In Fig. 3, a Khmer sentence "Bic Phalit Nau Kampuchia" (a pen made in Cambodia) is formed by the combinations of left, right, upper and lower characters, which takes five rows. Here, four vertical lines indicate pronunciation breaks of "Bic", "Phalit", "Nau" and "Kampuchia". In the word "Kampuchia", "pu" (Po + U) is written as a subscript consonant. In Khmer language, some dependent vowel symbols are written in the place of two rows above or two rows lower than consonant. From our analysis, we have found that Khmer writing systems is based on adding of left, right, upper and lower characters to a consonant, basically. The logical combination structure found in Khmer writing system can be seen in **Fig. 4**.

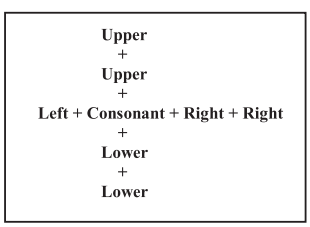

Fig. 4 Combination structure of Khmer consonant with vowels

5. Concept of Positional Prediction

In making an analysis of Khmer word formation, we have found that writing system largely depends on adding of left, right, upper and lower characters to a consonant (i.e. consonant clusters). Here, left, right, upper and lower characters mean Khmer dependent vowels, directives and subscript consonants that are always written with a consonant. They have to be written always with consonants (i.e. dependent), and their positions are defined when they are combined with consonants. Taking this into consideration, we propose a new consonant cluster prediction method based on given positional information of dependent characters. For example, [Ka + Left] for "ᦅᦵᦀ", "ᦅᦷᦀ", "ᦅᦲᦀ" and "ᦅᦻᦀ", [Ka + Right] for "ᦀᦱ", "ᦀᦸ", "ᦅᦹ", "ᦅᦱᦂ", "ᦅᦱᦃ", "ᦅᦷᦆ", "ᦅᦲᦆ" and "ᦀᦺ", [Ka + Up] for "ᦀᦻ", "ᦀᦼ", "ᦀᦽ", "ᦀᦾ", "ᦀᦶ", "ᦀᦴ", "ᦀᦳ", "ᦀᦵ", "ᦀᦷ" and "ᦀᦻ", [Ka + Down] for "ᦀᦳ", "ᦀᦴ", "ᦀᦶ", "ᦀᦶᦸ" and "ᦀᦶᦹ", [Ka + Down + Up] for "ᦀᦶᦻ", "ᦀᦶᦽ" etc. Our assumption for "Left", "Right", "Up" and "Down" characters is as follows:

- **Left:** "ᦅᦵ", "ᦅᦷ", "ᦅᦲ" and "ᦅᦻ"
- **Right:** "ᦱ", "ᦸ", "ᦹ", "ᦅᦹ", "ᦅᦱ", "ᦅᦱᦂ", "ᦅᦱᦃ", "ᦅᦷᦆ" and "ᦀᦺ"
- **Up:** "ᦻ", "ᦼ", "ᦽ", "ᦾ", "ᦶ", "ᦴ", "ᦳ", "ᦵ", "ᦷ", "ᦲ", "ᦀᦵ", "ᦀᦷ" and "ᦀᦶ"
- **Down:** "ᦅᦳ", "ᦅᦴ", "ᦅᦶ", "ᦅᦶᦸ", "ᦅᦶᦹ"and "ᦅᦶ"

Here "ᦅᦶ" is for subscript characters such as "ᦎᦶ", "ᦓᦶ", "ᦑᦶ", "ᦗᦶ" and "ᦘᦶ" etc.

The vowel positional information adding order follows Khmer Unicode input order. Logically, it can also support handwriting orders (e.g. Consonant + Up + Down or Consonant + Down + Up). Users only need to mention positional vowel information once even for the words that need to be combined with more than one positional vowel. Based on the given positional vowel information, the system calculates all possible consonant cluster combinations, then, removes impossible vowel combinations for a given consonant (i.e. unpronounceable or no meaningful combinations), and after that, sorts possible consonant clusters with average usage frequency. Here, note that there is no proper or standard usage frequency table for Khmer characters and words yet, and thus, we use our own usage frequency table. Fi-

nally, the system sorts the consonant cluster according to users' typing history. The example process of positional prediction for "A + Up + Down" is shown in **Fig. 5**.

6. Positional Prediction Text Input Interface with PP_Clickwheel

Clickwheel provides only 7 operations or commands, which are left click, right click, up click, down click, center click, clockwise scrolling and anti-clockwise scrolling as shown in **Fig. 6**. Therefore, we designed text input method or text input interface for Khmer (i.e. consonants, independent vowels, dependent vowels, punctuations and numbers) with the 7 commands.

We assigned the 7 commands for Khmer text typing with clickwheel as follows:

Clockwise and Anti-clockwise Scrolling: Highlighting a group of characters in the main menu or a character in a candidate list

Left, Right, Up and Down Click: Giving parameter for vowel combinations (e.g. "ក" (ka) + Right for "កា")

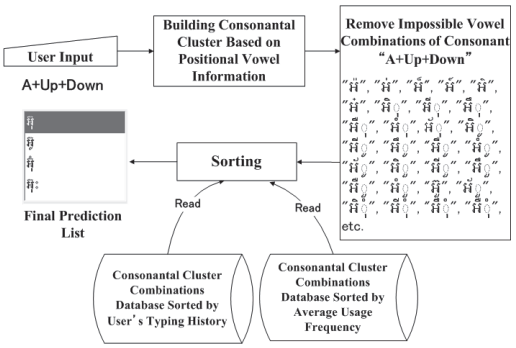

Fig. 5 Process flow of Positional Prediction for Khmer consonant "A" with vowel information (Up + Down)

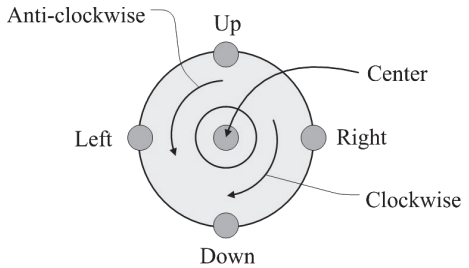

Fig. 6 Operations provided by clickwheel

Center Click: Selecting a character group or typing a character

The main menu or characters groups are 1) កខគ (consonants), 2) ឲឥឦ (independent vowels), 3) ១២៣ (numbers), 4) ។។ះ (punctuations, ligatures and symbols), 5) Freq (frequently used Khmer words such as "ខ្ញុំ" (I, me, my), "វា" (he, she, they, it), "គាត់" (he, him, his, she, her), "អញ្ជ" (I, me, my), "នាង" (Miss, young lady, girl, you) etc.) and 6) Mode (for other languages or text editing process) (see **Fig. 7**). The typing steps for Khmer syllable are 1) select a group, 2) select a consonant, 3) give parameters for vowel combinations and 4) select a syllable from a suggested candidate list.

7. PP_Clickwheel Prototype Implementation

Here, we present Positional Prediction text entry prototype with clickwheel (PP_Clickwheel) for Khmer language, which was developed with Microsoft Visual Basic. For the implementation, Visual Basic programming language was chosen, which is simple coding and suitable for rapid development. The prototype can be seen in Fig. 7.

7.1 PP_Clickwheel interface

Our PP_Clickwheel text input interface for Khmer syllables, words and conjunct consonants is based on the following 4 simple steps:

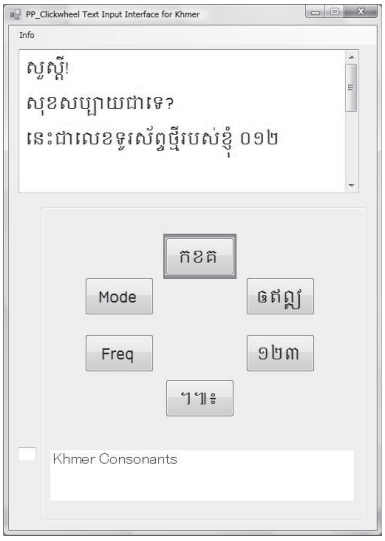

Fig. 7 Main menu of PP_Clickwheel prototype

1) Choose "កខគ" (Consonant) menu from the main menu
2) Choose a consonant that you want to type from a candidate consonant list
3) Give parameter or vowel combination structure. (e.g. [Ka + Left] for "ក", "ក", "ក" and "ក", [Ka + Right] for "កា", "កាំ", "កះ", "កោ", "កៅ", "កឿ" and "កៀ", and [Ka + Down + Up] for "កុំ", "កូ" etc.) This concept is based on Positional Prediction (PP)[1].
4) Select a syllable or a word from a candidate list of suggested possible vowel combinations with the consonant that you have chosen.

Typing steps of "តា" ("Taa", grandfather) with PP_Clickwheel can be seen in **Fig. 8**.

7.2 Keystrokes Per Character (KSPC)

Keystrokes Per Character (KSPC) is the number of keystrokes or stylus strokes required, on average, to generate each character of text using a given interaction technique in a given language[8),10),11)]. It is difficult to calculate exact KSPC value for PP_Clickwheel because our prototype uses clickwheel for selecting menu, character, syllable and word. Time required to press a key is different from the one to scroll a clickwheel. And thus, we evaluated the typing speed with Characters Per Minute (CPM); how many characters are typed in a minute, for PP_Clickwheel prototype[8)].

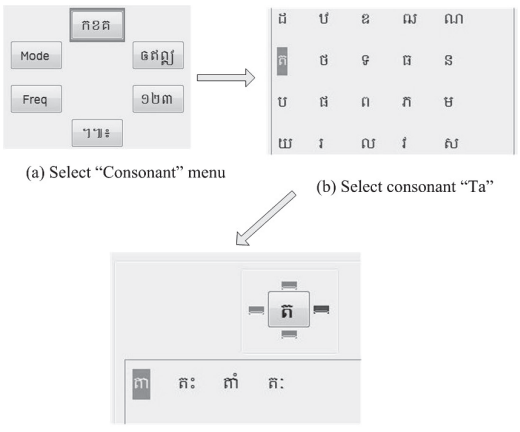

Fig. 8 Typing steps for "តា" ("Taa", grandfather) with PP_Clickwheel

8. Method

8.1 Participants

Ten volunteer participants (6 males and 4 females) were recruited in the Phnom Penh city, Cambodia. Participants ranged from 22 to 35 years ($mean = 26.4$, $sd = 3.6$). All of them were familiar with PC but had no prior experience of Khmer text typing with Positional Prediction text input method, and it was the first time for them to use clickwheel.

8.2 Apparatus

The experiment was conducted with native users in Phnom Penh. We used a notebook computer equipped with optical clickwheel mouse (BOMU-RHW01/SWH, Buffalo Inc.) for simulation of using mobile device with clickwheel[12)] (see **Fig. 9**). A Khmer text used for user study is as follows:

សួស្តី!
(Hello!)
សុខសប្បាយជាទេ?
(How are you?)
នេះជាលេខទូរស័ព្ទថ្មីរបស់ខ្ញុំ ០១២ ៧១៧៣១៨។
(This is my new telephone number 012717318.)
ពេលណាទំនេរទូរស័ព្ទមកខ្ញុំផងណា។
(Call me when you are free.)
ជួបគ្នាថ្ងៃក្រោយ។
(See you next time.)

The text consists of 109 characters including 44 consonants, 26 vowels, 10 subscript consonants, 3 diacritic signs, 9 numbers and 5 symbols.

8.3 Procedures

The experiments procedures are

Fig. 9 User study with PP_Clickwheel prototype

1) explaining the concept of Positional Prediction text entry
2) making demonstration of text input with PP_Clickwheel text input prototype
3) allowing 5 to 10 minutes practice time to each user to learn text input with our prototype
4) recording the users' typing speeds of short Khmer message (5 sentences) for 10 times (including error correction time)
5) discussing with the users and getting their responses

9. Results and Discussion

We evaluated typing speed with *Characters per Minute (CPM)* instead of *Word per Minute (WPM)*[8]. This is because there is no standard definition for a word in Khmer like in English (i.e. common definition of a word = 5 characters, including spaces) (Yamada, 1980)[8]. Thus, the formula for computing CPM is as follows:

$$CPM = \frac{|T| - 1}{S} \times 60$$

Here, T is the typed transcribed string entered by a user, and $|T|$ is the length of this string. T may contain Khmer characters, numbers, punctuation, spaces etc. but not backspaces. S is seconds measured from the entry of the first character to the last.

9.1 Characters Per Minute (CPM)

The user study results show that the average typing speed of first-time users with PP_Clickwheel prototype to finish five Khmer sentences by clickwheel mouse is 18.9 CPM. With the current PP_Clickwheel prototype, the fastest typing speed is 28.9 CPM and the slowest typing speed is 8.2 CPM. **Fig. 10** shows CPM comparison for ten native users for ten trial times to finish five Khmer sentences.

9.2 Participants Questionnaire

Questionnaires were conducted to the users immediately after the typing experiments. We set four Likert scales questions (1 to 5) to rate the user-friendliness of PP_Clickwheel text input method. These four scales are (1) Difficult-Easy (2) Painful-Enjoyable (3) Slow-Fast and (4) Dislike-Like. **Table 2** shows the average or arithmetic mean results of Likert scale questions. From the results, we can generally say that all of the users preferred text entering with PP_Clickwheel.

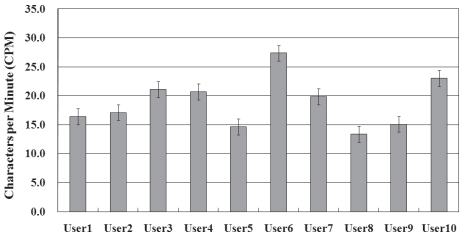

Fig. 10 Characters per Minute of 10 users with PP_Clickwheel

Table 2 Ten users' evaluation for PP_Clickwheel prototype

User	Evaluation with Likert Scales (1 to 5)			
	Difficult-Easy	Painful-Enjoyable	Slow-Fast	Dislike-Like
1	4	4	4	5
2	4	5	4	4
3	3	2	4	3
4	5	5	5	5
5	3	4	4	4
6	4	5	5	5
7	4	4	4	5
8	3	4	3	4
9	4	5	4	5
10	4	4	5	4
Mean	3.8	4.2	4.2	4.4
Note: Likert Scales (1-5): 1 = worst, 3 = neutral and 5 = best				

9.3 Discussion

There is no predictive text entry method for Khmer language yet. Although PP_Clickwheel is a new predictive text input interface, even first-time users can understand and type with appropriate typing speed. However, we have noticed that users sometimes face difficulties in dividing one consonant syllable from a word. This is because there are various syllable structures such as a consonant, a consonant with a vowel and a consonant with some vowels etc., and some vowels have a combined structure. As far as we know, there are around 45 syllable structures in total. The followings are 10 Khmer words formed by various syllables:

1. [C+C]: អ + រ = អរ (happy)
2. [C+DV]: ទ + ៅ = ទៅ (go)
3. [C+DV+C]: យ + ា + យ = យាយ (grandmother)
4. [C+DV+C+DV]: ស + េ + រ + ី = សេរី (free)
5. [C+DV+C+DV+C]: ច + ុ + ណ + េ + ញ = ចំណេញ (profit)
6. [C+DV+C+C]: ស + ា + គ + រ = សាគរ (sea)
7. [IDV+C]: ឯ + ង = ឯង (you)
8. [IDV+C+DV]: ឯ + ណ + ា = ឯណា (where)

9. [IDV+C+DV+C]: ឪ + ព + ុ + ក = ឪពុក (father)
10. [C+CS+C]: ប + ◌ឿ + ង = ប៉ង (wish)

Here, C = consonant, IDV = independent vowel, DV = dependent vowel and CS = consonant shifter.

We found that most of the Khmer syllables contained (DV), and thus, positional prediction text input method is suitable. Based on the PP text input concept, users have to type consonants (C) and independent vowels (IDV) one by one. But possible vowel combinations with a consonant (C+DV) are predictable with left, right, up and down clicks. And thus, users have to divide syllables formed by one consonant from a word. For example, users have to divide (C+DV), (C+DV) and C from [C+DV+C+DV+C] syllable. We have to explain this grouping concept for first-time users but native users can understand within one or two practice times.

Although we can say that the PP text input concept is applicable to Khmer, it is difficult to define "left vowel", "right vowel", "up vowel" and "down vowel" clearly. This is because native people deem some of the vowel combinations as a vowel or a character such as "◌ា" (au), "◌ោ" (oo), "◌ើ" (oe), "◌ៀ" (ya) and "◌ែ" (ie). These vowels are known as "two-part dependent vowel signs" in the Khmer Unicode table. These two-part dependent vowel signs have glyph pieces which stand on both sides of the consonant[3]. In our PP_Clickwheel prototype, users can type these vowels with [Left + Right] or [Right] parameter.

10. Conclusion

This research is in progress, and we have introduced PP_Clickwheel text input interface in this paper. From the user study, we can prove that PP_Clickwheel is a possible text input interface for Khmer language, and Positional Prediction text input method is applicable for clickwheel mobile devices. We have received positive feedbacks from the native users such as "This is more user-friendly than software keyboard", "There is no need to memorize the keyboard mapping" and "If I get used to this clickwheel mouse, the speed will be faster" etc. We will make further refinements on the current prototype and follow-up analysis. We also plan to extend PP_Clickwheel prototype for other similar syllabic languages such as Myanmar, Nepali and Thai in the near future.

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References

1) Ye Kyaw Thu and Y. Urano: "Positional Prediction: Consonant Cluster Prediction Text Entry Method for Burmese (Myanmar Language)", Extended Abstracts of the 26th ACM Conference on Human Factors in Computing Systems (CHI 2008), Florence, Italy, pp.3783–3788 (2008).
2) iPod. http://en.wikipedia.org/wiki/IPod
3) Unicode Chart of Khmer. http://www.unicode.org/charts/PDF/U1780.pdf (Accessed date: 1 January 2009).
4) Text Input Methods for iPod. http://www.ipodlinux.org/wiki/Text_Input_Methods (Accessed date: 5 January 2009).
5) Keypad Text Input Method. http://www.ipodlinux.org/wiki/Keypad (Accessed date: 5 January 2009).
6) Cursive Text Input Method. http://www.ipodlinux.org/wiki/Cursive (Accessed date: 5 January 2009).
7) Thumbscript Text Input Method. http://www.thumbscript.com/
8) I.S. MacKenzie, and K. Tanaka-Ishii: Text Entry Systems (Mobility, Accessibility, Universality), Morgan Kaufmann Press (2007).
9) F.E. Huffman: Cambodian System of Writing and beginning reader with Drills and Glossary, Yale University Press (1970).
10) I.S. MacKenzie: "KSPC (keystrokes per character) as a characteristic of text entry techniques", Proc. of the Fourth International Symposium on Human Computer Interaction with Mobile Devices, Heidelberg, Springer Verlag, pp.195–210 (2002).
11) I.S. MacKenzie, J. Chen, and A. Oniszczak: "Unipad: Single-stroke text entry with language-based acceleration", Proc of the Fourth Nordic Conference on Human-Computer Interaction — NordiCHI 2006, pp.78–85. New York, ACM (2006).
12) Buffalo Optical Clickwheel Mouse. http://buffalo.jp/products/catalog/item/b/bomu-rhw01_s/ (Access date: 2 January 2009).

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