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ポジショナル・ジェスチャ：クメール語のための単純なジェスチャ文字入力

イェ チョウ トゥ、オッ パヴィー、浦野 義頼
早稲田大学大学院 国際情報通信研究科

クメール語の音節文字の多くは、子音、従属母音記号、付加記号、下付き子音などから形成されているため、文字入力は難しい課題である。本論文では、クメール語の筆記の特性に沿って、音節文字入力のための非常に単純なジェスチャ認識を提案する。ポジショナル・ジェスチャでは、クメール語の文字入力において、単純なジェスチャ・コマンド（原則として左、右、上、下、中）が使用される。我々の考案したポジショナル・ジェスチャモデルでは、5人のネイティブユーザの平均入力速度は、マウスを使用した場合17.68文字／分、トラックボールを使用した場合17.72文字／分となり、カンボジア国家ICT庁（NiDA）のソフトウェアキーボードを使用した場合（29.13文字／分）より遅い。しかしながら、ポジショナル・ジェスチャ文字入力手法は、初心者にも使いやすく、また、タブレットPC、携帯電話、PDA、ポータブルゲームプレイヤといった多くのモバイルコンピューティングデバイスにも適用可能である。さらに、この手法は、ミャンマー語、バングラ語、タイ語、ヒンディー語のような他の音節文字にも展開することができる。

Positional Gesture: Simple Gesture Text Input for Khmer

YE KYAW THU, OUK PHAVY and YOSHIYORI URANO
Graduate School of Global Information and Telecommunication Studies (GITS), Waseda University

Text input of Khmer language poses a challenge because many syllabic characters are formed by combinations of consonants, dependent vowel signs, diacritics and subscript consonants etc. In this paper, we propose very simple gesture recognitions for syllabic scripts text input based on their writing natures. Positional Gesture uses simple gestures commands (basically Left, Right, Up, Down and Center) for Khmer text input. With our Positional Gesture prototype, average typing speeds of 5 native users are 17.68 characters per minute by mouse and 17.72 characters per minute by trackball. Although this typing rate is slower than the one of NiDA (National Information Development Authority of Cambodia) software keyboard (which is 29.13 characters per minute), Positional Gesture text input method is accessible even for first time users and also applicable for many mobile computing devices such as tablet PCs, mobile phones, PDAs and portable game players etc. The concept of Positional Gesture can be extended to other syllabic scripts such as Myanmar, Bangla, Thai and Hindi etc. as well.

1. Introduction

In our previous works [8][9][10][11], we presented concept of Positional Mapping for mobile devices. We also proved that Positional Mapping can be applied to many syllabic languages such as Myanmar, and Bangla. In the current work, we combine Positional Mapping concept with gesture input called "Positional Gesture" (PG). We developed Positional Gesture prototype for Khmer language (official language of Cambodia) and conducted user experiments. The merits of Positional Gesture text input are simple, user-friendly, usable with various input devices, and applicable to other similar syllabic based languages.

2. Related Works

In this section we discuss some of the current handwritten or gesture based text input methods for touch screen interfaces.

Since traditional handwritten recognition had many limitations like slow typing speed, Goldberg and

Richardson introduced Unistroke alphabet in 1993 [1]. In Unistroke, each character is represented by a single stroke and can be used even by blind people. And thus, there is no segmentation problem in the recognition process. However, users have to spend some time for learning Unistroke characters, which is difficult to learn and recall [2]. If we apply this concept to syllabic scripts, it will become more complex and require more learning time of users.

GraffitiTM is another handwriting alphabet developed by Palm Computing for Palm Pilot PDA product series. It requires minimal time for learning Graffiti alphabet because they are very similar to normal English alphabets. For the recognition process, however, Graffiti strokes are more complex compared to Unistroke strokes.

EdgeWrite is also based on unistroke text entry idea for handheld devices like PDAs, and is designed for people with motor impairments [3]. Text can be entered by traversing the edges and diagonals of a square hole imposed over the usual text input area of PDA. In EdgeWrite, recognition algorithm is checking not only pattern recognition but also the sequence of corners that are hit. The authors of EdgeWrite mentioned that users can type 18% more accurate than Graffiti ($p<.05$), with no significant difference in speed.

All of the input methods mentioned above are based on English alphabets, and it is difficult to create Graffiti like characters or Unistroke based characters for Khmer script. Because of that, most of the Khmer consonants (e.g. ក, គ, ឃ, ឈ, ញ, ឭ), subscripts (sub-consonants) (e.g. ្ង, ្ឈ, ្ឍ, ្ឫ) and independent vowels (e.g. ឥ, ឦ, ឱ, ឳ, ឫ, ឬ, ឭ) require more than one stroke.

Gesture Keyboard (GKB) for Devanagari (one of the Indic scripts) is based on handwritten gesture recognition technology, which was proposed by R. Balaji, V. Deepu, Sriganesh Madhvanath and Jayasree Prabhakaran [4]. GKB input method is very much appropriate with the nature of syllabic scripts writing system. In this input method, users do not need to write down Devanagari consonants and they are already shown on a tablet keyboard. Users can type a consonant by giving a special gesture command (i.e. strike through over a consonant). Other matras (i.e. vowel signs) can be typed by writing at a specific position relative to the glyph of the base consonant. This input method is smart and can be applied to other similar syllabic scripts. Recognition accuracy and typing speed can increase compared to normal handwritten techniques. However, users have to write down vowel signs or other combination symbols correctly, which may lead to reduce typing speed. And then, it is still necessary to create recognition engine for vowel signs or other characters.

Although QWERTY based soft keyboards or visual keyboards are one of the possible solutions for syllabic languages, typing syllabic languages with QWERTY based software keyboards are still difficult and not easy for novice users. And they are not suitable for small mobile devices, because it is difficult for Khmer characters to be distinguished from other similar characters in small soft keyboards.

Khmer software keyboard is developed by Tavultesoft based on the standard NiDA (National Information Technology Development Authority) keyboard layout [5]. It was created just after Khmer Unicode 4.0 was released. The Khmer Unicode keyboard layout differs from the one of old version which is not in Unicode in which the subscripts of the consonants are not spread on the keyboard anymore. Instead, a subscript sign (្) is used to indicate that the next consonant is subscript of the cluster, and that the typing order is not from left to right in the same order of hand writing, but in the order of word spelling.

3. Khmer Language

Khmer or Cambodian language is an official language of Cambodia. It is classified as a member of the Eastern branch of the Mon-Khmer language family. 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. It consists of 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. ឣ, ឤ, ឥ, ឦ, ឧ, ឩ, ឪ and ឫ etc.) and several diacritic symbols (e.g. ំ, ះ, ៉, ៊, ់ and ៌ etc.) [6]. All consonants have modified forms, called sub-consonants (e.g. ្ក, ្ខ, ្គ, ្ង, ្ច etc.), when they occur as the second member of a consonant cluster. Overall writing direction is from left to right. The word order follows SVO (Subject + Verb + Object) pattern as in English. In a Khmer text there are no spaces between words, and spaces indicate the end of a clause or sentence instead. An example of Khmer writing system can be seen in Fig.1

4. Khmer Language Writing System

When we make an analysis of Khmer sentences, we can basically consider that Khmer characters are written in three levels (upper, middle, lower) like in Myanmar and Bangla languages.

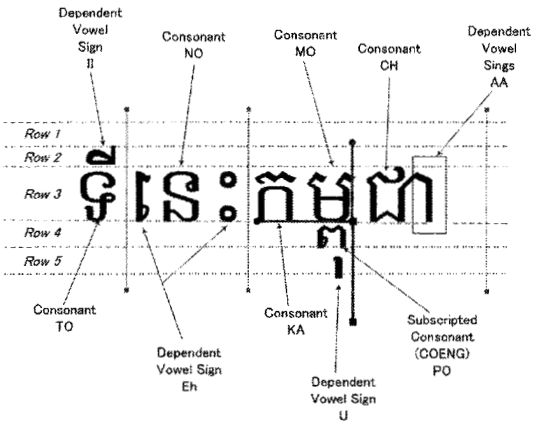

Fig.1 Characters combinations in Khmer language

And most characters have their defined positions (e.g. vowel signs "ᩉ", "ᩤ" have to be written in the left side of the consonants, vowel signs "ᩣ", "ᩢ" and "ᩦ" etc. should be written in the right side of the consonants, vowel signs "ᩩ", "ᩪ", and "ᩫ" etc. should be written as a lower characters and vowel signs "ᩰ", "ᩱ", "ᩲ" and "ᩳ" etc. should be written as a upper characters). In Fig.1, a Khmer sentence "Ti Nih Kampuchia" (This is Cambodia) is formed by the combinations of left, right, upper and lower characters and it takes four rows. Here, three vertical lines indicate the pronunciation breaks of "Ti", "Nih" and "Kampuchia". In the word "Kampuchia", "pu" (Po + U) is written as 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 written systems is based on adding of left, right, upper and lower characters to consonant, basically. The logical combination structure found for Khmer writing systems can be seen in Fig.2.

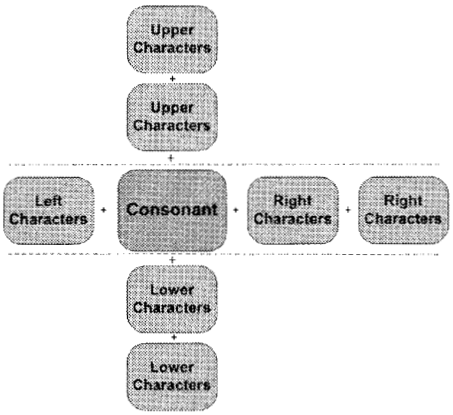

Fig.2 Logical structure of word formation in Khmer

5. Concept of Positional Gesture

"Positional Gesture" is a simple gesture text input method for computing devices based on common characteristics of syllabic scripts writing system. The concept is totally based on four simple gesture commands, which are "Left", "Right", "Up" and "Down". "Left gesture command" is for left characters or symbols, "Right gesture command" is for right characters or symbols, "Up gesture command" is for upper characters or symbols and "Down gesture command" is for lower characters or symbols. Here, as a concept "Left gesture command" can be "dragging mouse pointer to left" or "moving data glove to left" or "pressing left arrow key" or "moving eye ball to left" or anything. For the consonant characters, we can use additional gesture like "drawing dot" or "writing circle" or anything. In our prototype, we use "Double Click" for Khmer language to make it simple. Positional Gesture text input concept can be seen in Fig.3.

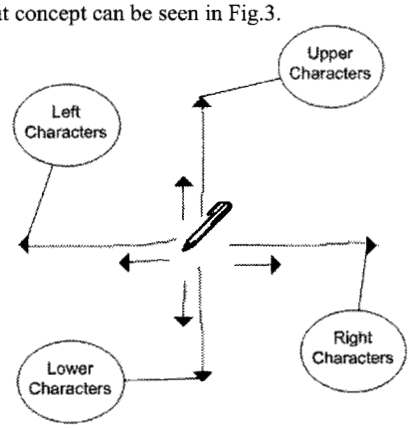

Fig.3 Positional gesture text input concept

6. Prototype Implementation

Here, we present Khmer Language Positional Gesture text input interface prototype (see Fig.4), which was developed with Microsoft Visual Studio .Net 2003. This prototype can be used with pen stylus, trackball, TrackPoint or mouse.

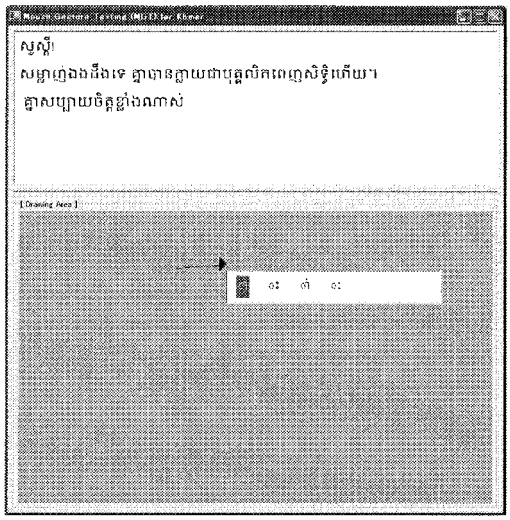

Fig.4 Positional Gesture prototype for Khmer

For the basic text editing, we use "mouse dragging to the left direction by pressing right click button" for "Back Space" function and "mouse dragging to the down direction by right click button" for "Enter" function. Recognition algorithm for our prototype is very simple because it is only necessary to check drawing direction, left click or right click and length of the path. And there is no need to be straight line, and we allow drawing within angle of 60 degree range for each direction (i.e. Left, Right, Up and Down). In our prototype, all of the gesture lines will be shown with four directions of arrow heads. And the color of the gesture lines will change from blue to red for text editing commands. One limitation of current prototype is that pen stylus should provide left and right click feature.

7. User Experiment with Prototype

We conducted two user experiments with our developed prototype in order to know the users' typing speed for Positional Gesture text input. The first user study was conducted with PC mouse and trackball for five Cambodian native participants who are between 24 and 26 years old.

The second user study included an additional participant of 24 years old, in order to prove that our Positional Gesture prototype can be used with various input devices. With this user, we recorded Khmer text typing speeds of Positional Gesture prototype with mouse (IBM Mouse, Model Number: MO32BO), trackball (Kensington Expert Mouse, Model Number: K64325), touchpad (IBM ThinkPlus USB travel keyboard, Model Number: SK-8845L), TrackPoint (IBM ThinkPlus USB travel keyboard, Model Number: SK-8845L) and tablet PC (IBM Lenovo X61 Tablet PC running Windows Vista Ultimate OS Version 6.0).

All of the six participants in total are familiar with PC and touch typists in English (with QWERTY keyboard) but not in Khmer language. Three of them are familiar with notebook PC built in touchpad. But none of them has an experience of using stylus pen, trackball, TrackPoint or tablet PC.

We used our Positional Gesture prototype and Khmer language Tavultesoft Keyman Desktop Professional 7.0 (it is used NiDA keyboard layout) for user study. NiDA (National Information Development Authority of Cambodia) Unicode keyboard layout is standard and widely used in Cambodia. This software keyboard has "Unshifted Mode" (Fig.6), "Shift Mode" (Fig.7), "Right Alter Mode" (Fig.8) and "Shift Right Alter Mode".

The experiments procedures are as follows:

1) Explaining the concept of Positional Gesture text input
2) Making demonstration of text input with Positional Gesture prototype and NiDA software keyboard
3) Allowing 10 minutes practice time for each user to learn text input with Positional Gesture prototype and software keyboard
4) Recording users' typing speeds of short Khmer message for 5 trial times (including error correction time)
5) Getting users' feedback for our Positional Gesture prototype and NiDA software keyboard with small questionnaires

Khmer short message (5 sentences which contain 135 characters including spaces) used for user study can be seen in Fig.5.

Table 1: Gesture commands for Khmer

Gesture Commands	Character Assignments
Left (long)	Left characters ('ឿ', 'ឿ', 'ោ' etc.)
Right (long)	Numbers ('១', '៦', '៣', '៤' etc.)
Up (long)	Symbols ('។ ', ',', '?', '!', '#' etc.)
Down (long)	Independent vowels, Symbols and frequently used characters ('ឆ', 'ឣ', 'ៗលៗ', '៖' etc.)
Left (short)	Left characters ('ើ', 'ែ', 'ៃ', 'ីៃ')
Right (short)	Right characters ('ា', 'ះ', 'ាំ', 'ុះ')
Up (short)	Upper characters ('ិ', 'ឹ', 'ឺ', 'ិ' etc.)
Down (short)	Lower characters ('ុ', 'ូ', 'ួ' etc.)
Double Click	Consonant characters ('ក', 'ខ', 'គ', 'ឃ', 'ង' etc.)

សួស្តី!

(Hi!)

សម្លាញ់ឯងដឹងទេ គ្នាបានក្លាយជាបុគ្គលិកពេញសិទ្ធិហើយ។

(You know ,friend, I am now accepted to be a contract employee.)

គ្នាសប្បាយចិត្តខ្លាំងណាស់។

(I'm extremely happy.)

ថ្ងៃទី២០ ខែនេះគ្នានឹងបានចូលធ្វើការហើយ។

(I will start my work on 20 of August.)

ជួបគ្នាថ្ងៃក្រោយ

(See you next time)

Fig.5 Khmer text for user study

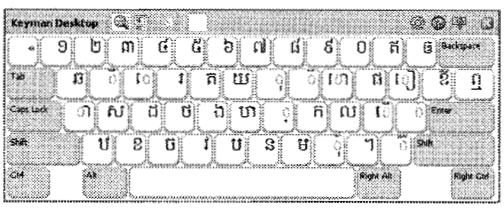

Fig.6 NiDA Software Keyboard Layout
(Unshifted Mode)

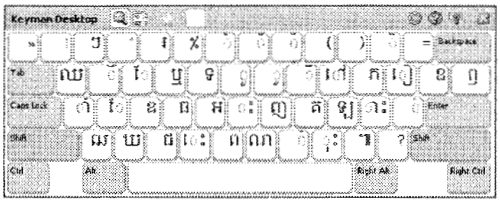

Fig.7 NiDA Software Keyboard Layout
(Shift Mode)

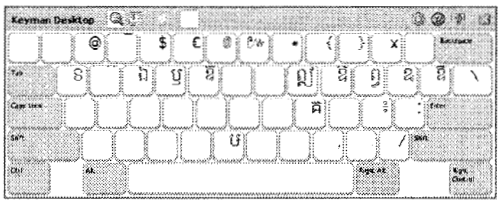

Fig.8 NiDA Software Keyboard Layout
(Right Alt Mode)

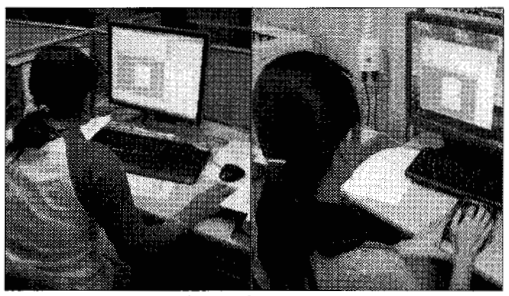

Fig.9 Photos from user study
(Left) Positional Gesture prototype with mouse
(Right) Positional Gesture prototype with trackball

Fig.10 Photos from user study
(Left) NiDA software keyboard with mouse
(Right) Positional Gesture prototype with tablet PC

8. Evaluations

We recorded the users' actual typing speed and calculated CPM (Characters per Minute) for evaluation process of our Positional Gesture prototype. We also conducted small questionnaires to

them in ordered to know their feedback for Positional Gesture text input.

Evaluations by Users' Typing Speed

Average typing speed of Positional Gesture text input to finish five Khmer sentences (see Fig.5) is 7 minutes 38 seconds by mouse (see Fig.11) and 7 minutes 37 seconds by trackball (see Fig.12). In general, all of the users' typing speed increases during five trial experiments (Fig.15). With NiDA software keyboard, average typing speed of 5 users is 4 min 38 sec (see Fig.13). We found that Positional Gesture text input method for Khmer language is 64% slower (for both trackball and mouse) than "NiDA Software Keyboard" (see Fig.14 and Fig.16).

Evaluations by Characters per Minute (CPM)

Although Word per Minute (WPM) is the most widely used measure of the text entry performance, we evaluate our Positional Gesture text input with Character per Minute (CPM). It is because we cannot find common definition of "word" in Khmer language. Importantly, the WPM/CPM measure does not consider the number of keystrokes or gestures made during entry, but only the length of the resulting transcribed string and how long it takes to produce it [7]. Based on the user study results, average CPM for Positional Gesture prototype and NiDA software keyboard are as follows:

Positional Gesture with mouse: 17.68 CPM
Positional Gesture with trackball: 17.72 CPM
NiDA Software Keyboard: 29.13 CPM

Evaluations by Users' Likert Scale Questions

The questionnaires were conducted immediately after typing experiments. We set four Likert Scales (1-5) on which to rate the Positional Gesture text input with 2 different input devices (trackball and mouse) and NiDA software keyboard with mouse. Mean and standard deviation of five users for Likert scale questions can be seen in Table 2. Labels for scale endpoints are in the most left columns and higher values are better.

From the questionnaire results with five participants, we have noticed that most users preferred Khmer text entering with mouse than trackball. One of the reasons might be that they used trackball for the first time in the experiments. The interesting point is that although Likert scales for trackball responded by the five users are lower than those of mouse (see Table 2), the average typing speed is nearly the same (i.e. 7min 38sec for mouse and 7min 37sec for trackball) (see Fig.14).

We also recorded Likert scale evaluations after the Positional Gesture text input experiment (i.e. second experiment) with various input devices. Likert scale responses for Positional Gesture with trackball, mouse, touchpad, TrackPoint and tablet PC can be seen in Table 3. From this Likert scale results, we found that Positional Gesture text input method is very much suitable with touch screen interface. The participant felt easiest and enjoyable typing with Tablet PC. Overall evaluation on Positional Gesture text input method by participants in both experiments is a satisfactory one (see Table 2 and Table 3).

Table 2: Mean (Standard Deviation) responses by five Khmer users for 5-point Likert scale questions

Likert Scales (range 1-5)	PG with Trackball	PG with Mouse	Software Keyboard with Mouse
Difficult-Easy	2 (1.22)	3.2 (0.84)	4.2 (1.30)
Painful-Enjoyable	2.6 (1.14)	3.6 (0.89)	3.8 (1.10)
Slow-Fast	2 (0.71)	3.4 (1.14)	3.8 (1.10)
Dislike-Like	2.8 (1.79)	4 (0.71)	4 (1.22)

Table 3: Mean responses by a Khmer users for 5-point Likert scale questions on Positional Gesture prototype with various input devices

Likert Scales (range 1-5)	Trackball	Mouse	Touchpad	TrackPoint	Tablet PC
Difficult-Easy	4	5	5	4	5
Painful-Enjoyable	3	4	4	4	5
Slow-Fast	3	4	4	3	4
Dislike-Like	3	4	4	4	4

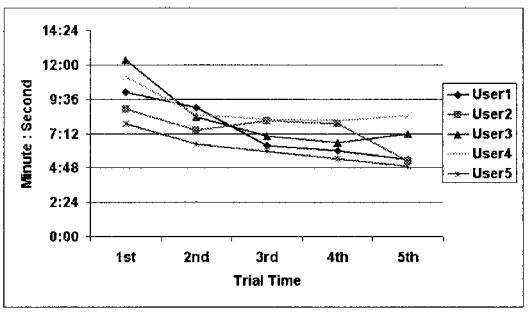

Fig.11 Typing speed of five Cambodian users by mouse

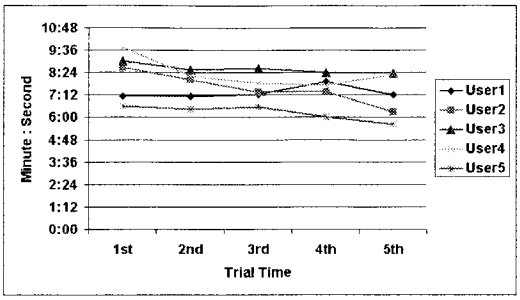

Fig.12 typing speed of five Cambodian users by trackball

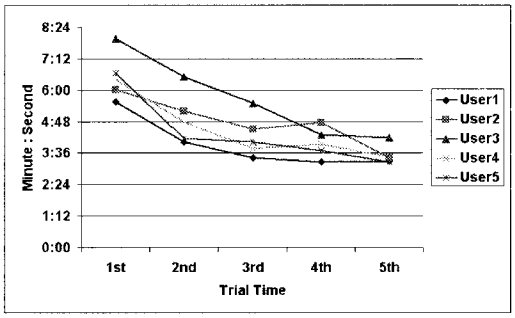

Fig.13 Typing speed of five Cambodian users by "NiDA Software Keyboard"

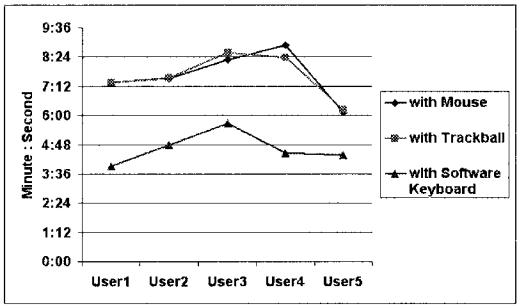

Fig.14 Typing speed comparison of five Cambodian users for mouse, trackball and software keyboard

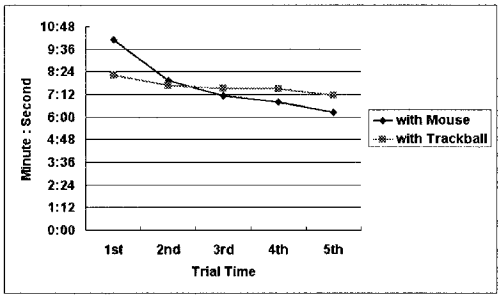

Fig.15 Typing speed improvements of 5 Cambodian users for positional gesture with mouse and trackball

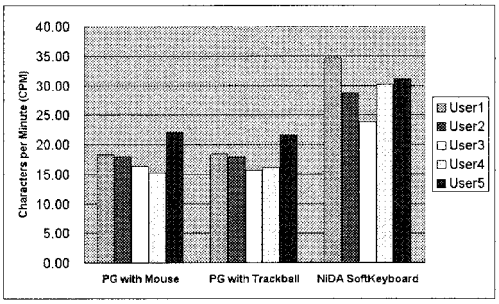

Fig.16 Average CPM comparison for PG with mouse, PG with trackball and NiDA software keyboard

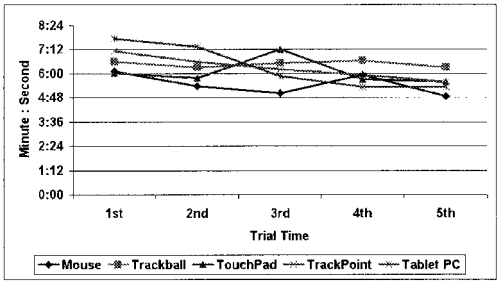

Fig.17 Typing speed differences of a user with different input devices

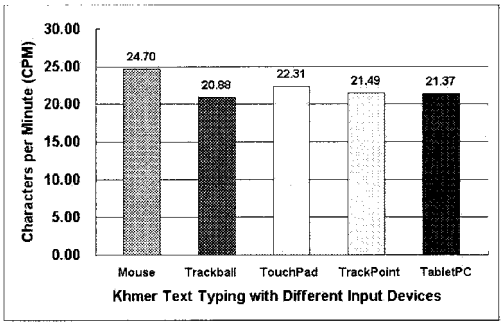

Fig.18 Average CPM of the same user with different input devices (Mouse, Trackball, TouchPad, TrackPoint and TabletPC)

9. Discussion

It is desirable to compare user study results of our prototype with handwritten; however, there is no handwritten text input system for Khmer language yet. And thus, we used "NiDA Software Keyboard" for evaluation process. From the user study, average CPM for Khmer Positional Gesture prototype is 17.72 with trackball and 17.68 with mouse (see Fig.16). The average CPM of the same user for Positional Gesture prototype with different input devices is not very different (standard deviation value = 1.51) (see Fig.18). When we compare the typing speed of

Positional Gesture with that of software keyboard, the former is 64% slower. The reason is that we use very few gesture commands in our prototypes for easier typing but software keyboards use generally one to one key mapping. The typing speed or CPM can slightly increase or decrease according to what type of input device is used (see Fig.17 and Fig.18). It also depends on how characters are mapped (i.e. characters grouping and sorting order). From the mean and standard deviation values of Likert Scale questions (see Table 2 and Table 3) and the user study results (see Fig.14 to Fig.16), we can prove that Positional Gesture is one of the possible Khmer text input interfaces for small mobile devices.

10. Conclusion and Future Work

In this paper, we have proposed Positional Gesture text input method for Khmer language. The proposed gesture idea is a very simple, user-friendly and possible Khmer text input method on computing devices. Moreover, the concept is applicable to many pointing devices or input devices such as mouse, TouchPad, TrackPoint, trackball, pen with tablet, touch screen and data glove etc. Positional Gesture with touch screen interface can be the best user interface. These findings were supported by two user experiments with six native participants.

We have conducted Positional Gesture text input experiments only with Khmer language so far. As a next step, we plan to extend it to Myanmar, Bangla, Thai and Hindi, and make an analysis on typing error rate as well.

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