Dynamic Candidate Keypad for Stroke-based Chinese Input Method on Touchscreen Devices

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Abstract - **With the popularity of touchscreen devices, physical button-based keyboards are being replaced by finger-operated virtual keyboards. Entering text on these touchscreen devices is no longer limited by finger tapping activities on the keys. Text input can be performed by finger sliding over the virtual keyboard, which is well realized by the Swype technology on a typical QWERTY keyboard. Such shorthand gesturing for text input, however, may be inefficient when directly applied to Chinese input, especially in Chinese stroke-based input method. In this paper, a novel dynamic candidate keypad with use of unidirectional finger gesture on the stroke key for character selection is proposed for enhancing stroke-based Chinese input method. The new design can enhance frequently used Chinese characters searching and input using stroke-based input. The new method is implemented on the Android 2.2 platform for performance evaluation using Traditional Chinese characters set. Experimental results show that the proposed method enables users to input popular Chinese characters easier than conventional stroke-based input methods.**

Keywords: virtual keyboard, touchscreen, dynamic keypad, Chinese input method, stroke-based, gesture, handheld devices.

I. Introduction

One trend in smartphone is to replace physical keyboard with touchscreen finger-operated virtual keyboard [1-6], which is controlled by finger's gestures or tapping instead of key pressing. Recently, touchscreen-based smartphone users are rapidly increasing and on-screen virtual keyboard can also be found in tablet PCs, game consoles, kiosks, television, and remote controls. The revolutionary touchscreen device available in early 2010 is the Apple iPad with a 9.7-inch display. Companies such as Samsung, Dell, Motorola and HTC have also released various kinds of touchscreen devices, e.g. Samsung Galaxy Tab with 7-inch touchscreen; Dell Streak with 5-inch screen; Motorola and HTC continue to manufacture smartphones or tablet devices with screen sizes varied from 3.7 to 7 inches. Most of these companies see the finger-operated virtual keyboard as future text input interface for mobile devices.

Fig. 1 and 2 show typical touchscreen virtual QWERTY and Cangjie (倉頡) keyboards of smartphone, respectively. Due to the limited screen size of smartphones, however, key sizes of these virtual keyboards are relatively small as compared with our fingertips especially for the portrait (vertical) display mode. Users find it difficult to tap the correct key due to these small keys are placed very close together. This drawback significantly reduces the accuracy of the text input and results in many typos as well as requiring undo or corrective activities.

Fig. 1. A virtual QWERTY keyboard of an Android Smartphone.

Fig. 2. A virtual Cangjie (倉頡) keyboard for Traditional Chinese character input.

Fig. 3. An example of entering "chinese" by Swype.

Solutions that try to improve the input accuracy do exist. Localized zooming is an alterative method to tackle this problem, in which the keyboard's software increases the size of keys near the pointer to give a better visibility [7]. Shift technique [8] has also been proposed for selecting small targets with a finger. Another way to address the problem of key's size is to reduce the number of keys that are displayed [9, 10]. This leads to a multiple-page keyboard or to ambiguity due to more than one character assigned to each key. In short, these methods have not yet provided a complete solution.

Recently, Swype technology [11] was employed in some smartphones to improve the typing speed and accuracy of virtual keyboards. Besides tapping on an individual key, Swype allows users to input a word by sliding a finger from alphabet to alphabet and lifting only between words. There is a visual blue trail that marks the finger movement. Fig. 3 shows how the word "chinese' is entered by using Swype. It uses error correction algorithms and a language model to predict the possible word intended to be input by the users. Thus, it does not matter if other keys are touched when sliding the inputting word, as the Swype dictionary will recognize the intended word. If more than one words are estimated, a popup box containing some suggested words will appear. The estimated maximum speed for entering English characters using Swype is up to 55 words per minute.

Similar to Swype, shorthand gesturing technique [12] can be applied to Chinese input methods such as Pinyin (拼音), Zhuyin (注音), Cangjie (倉頡), Wubi (五筆), and Stroke-based method (筆劃) [15]. The improvement, however, to the above conventional Chinese input methods may not be as effective as English input, particularly in stroke-based method. It is because the stroke-based Chinese input method has only five keys such that the virtual key size can be much larger than the alphabet keys of QWERTY keyboard. In addition, the character collision rate of stroke-based method is very high and it always needs to use the candidate window to select the intended character.

In this paper, a new dynamic candidate keypad (DCK) with the use of unidirectional finger gesture on the stroke key for character selection is proposed for enhancing stroke-based Chinese input method. The most likely Chinese characters are dynamically updated on every input of stroke key and eight unidirectional finger gestures are designed to directly select the intended character on the stroke key. The proposed method is implemented and evaluated on a HTC Desire smartphone running Android version 2.2.

This paper is organized as below. Section II gives a brief review of conventional Chinese input methods for touchscreen devices and particularly more details on stroke-based method. The proposed DCK for stroke-based Chinese input method is described in section III and performance evaluation of the proposed method is given in section IV. Finally, a conclusion is drawn in section V.

II. Touchscreen Chinese Input Methods

Chinese input on touchscreen devices is usually realized by handwriting recognition or virtual keyboard for Pinyin, Cangjie and stroke-based method. In handwriting recognition, the Chinese character is drawn on the touchscreen and the software tries to recognize the pattern and come up with a candidate list for selection. The input speed is slow as users are required to draw the Chinese characters stroke-by-stroke and some of the characters are very complex with many strokes. Pinyin is the pronunciation of a Chinese character in the form of Roman characters such that it can be implemented by virtual QWERTY keyboard on touchscreen devices as shown in Fig. 1. Cangjie is a radical-based input method while it also uses the Roman letter keys to map the pre-defined Chinese character's radicals and strokes. The virtual Cangjie keyboard is shown in Fig. 2 and it can achieve very high input speed for well-trained users using physical keyboard. However, the typing speed and accuracy of Pinyin and Cangjie are significantly reduced when using virtual keyboards on small touchscreen devices. This is because tapping small targets on these virtual keys is a difficult task.

Fig. 4. A virtual keypad for stroke-based Chinese input method.

On the other hand, stroke-based Chinese input method [15], that uses only 5 basic strokes to code Chinese characters, is very popular on mobile phones. It is because the stroke-based method conforms to the conventional writing practice (from top to bottom, and from left to right) providing easy and intuitive Chinese input. Those who know how to write Chinese should understand the 5 basic types of strokes and their writing order. Moreover, stroke-based input method also meets the stroke order specification that standardized and established by China's State Language Commission. The five basic stroke types are:

(1) Horizontal strokes [橫]: 一
(2) Vertical strokes [豎] : 丨
(3) Left-falling strokes [撇]: 丿
(4) Right-falling strokes or Dot strokes [點, 捺]: 丶
(5) Turning strokes [折]: フ

Users simply type in the basic strokes of a character according to the writing order. For example, the strokes for typing the Chinese characters of "不" and "的" are as follows:

不 : 一 丿 丨 丶
的 : 丿 丨 フ 一 一 丿 フ 丶

A typical stroke-based Chinese input virtual keypad for touchscreen based mobile phones is shown in Fig. 4. Because of 5 strokes only, the virtual keypad can allow much larger keys than the alphabet-symbol keys in QWERTY keyboard. Thus, stroke-based Chinese input method can achieve relatively higher key tapping accuracy. Moreover, an important feature of stroke-based method implementation is the fast built-in intelligence. For each stroke input, the software will update the candidate window with the most likely Chinese characters for selection. In Fig. 4, for example, only the first two strokes of "一丿" are tapped, the most likely characters like "不,在,有,大,而,成,面,感,原,研" are listed for selection in the candidate window. These are frequently used Chinese characters and they can be predicted based on the first two strokes. By using a linguistic database, the software can ensure the most likely characters are always presented first (in leftmost position). Thus, the user can instantly select the desired character with a few strokes input for most frequently used characters. In this paper, a new stroke-based keypad with most likely characters dynamically updated around the stroke keys is proposed to further improve the searching and input speed of the most frequently used Chinese characters. Moreover, the character selection is replaced by unidirectional finger gesture on the stroke keys instead of tapping on the character.

III. Dynamic Keypad for Stroke-based Chinese Character Input Method

National Language Committee of China for Chinese character frequency research indicates that the top 1000 Chinese characters can cover about 92% cases [12]. The top 600 Chinese characters are normally sufficient for written communication. Recent results on mobile short message context indicate that top 600 can cover about 93% [13] of all the used Chinese characters. That means if we can improve the stroke-based Chinese input method for searching and entering these Top 600 characters will significantly enhance the efficiency of stroke-based input method even for inexperience users.

3.1 Dynamic Stroke Keys with Candidate Characters

As mentioned in section II, the keys of the stroke-based Chinese input method can be quite large even on a 3-inch touchscreen. It is, therefore, possible to display the most likely characters in the padding space of the stroke keys, surrounding the stroke symbol as shown in Fig. 5. These eight candidate characters are the most likely characters based on the usage frequency and these characters start with the stroke of that key.

In order to make the candidate's priority listing to be consistent and understandable, the candidate characters are displayed from left-to-right and top-to-bottom manner, as shown in Fig. 6. The most likely character is displayed at upper-left corner of the key as indicated in position (1), and then second most likely character is displayed in position (2), etc. With this dynamic candidate stroke keys design, 40 frequently used characters can be displayed on the keypad without any code input. In Traditional Chinese character set, these 40 characters are all within the top 600 and top 1000 frequently used characters as shown in Table 1. That means these 40 characters are possible to input with one single touch of the virtual keypad.

If the users cannot find their intended character on the initial dynamic keypad, they can input the first stroke of the intended character. Then the dynamic keypad will be updated with new candidate characters on each stroke key as shown in Fig. 7, in which candidate characters of each stroke key are updated after entering the first stroke of "一". Theoretically, it can display another 200 frequently used characters on this dynamic keypad after one stroke input as there are five types of stroke and each stroke with 40 candidates (5x40=200). Due to some of the characters being repeated in the first 40 characters in the initial keypad, the total number of distinct characters can be displayed, is a little bit lower than 200. Based on the Traditional Chinese character set, 193 distinct characters including the first 40 characters can be displayed on the dynamic keypad with one or no stroke key input as shown in Table 1. Within these 193 characters, there are 171 and 181 characters belonging to top 600 and top 1000 frequently used Chinese characters, respectively. They also represent 28.5% and 18.1% of top 600, and top 1000 characters, respectively. Users can continue to enter strokes for

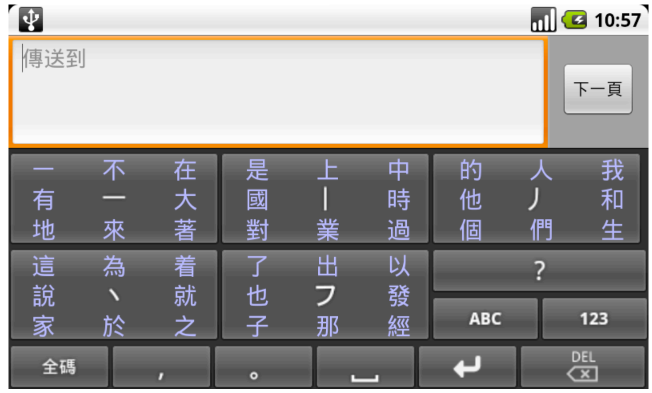

Fig. 5: The proposed dynamic keypad with eight most likely characters displaying around the stroke keys.

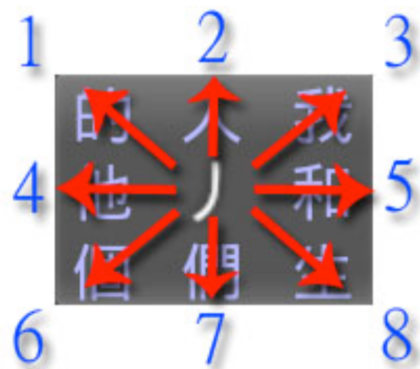

Fig. 6: The candidate characters displaying positions and the eight unidirectional gestures for the "丿" stroke key.

Traditional Chinese Character Set			
Number of Stroke keys input	Distinct Characters	Characters in Top 600 (covered %)	Characters in Top 1000 (covered %)
Initial keypad	40	40 (6.7%)	40 (4%)
After 1 key Input	193	171 (28.5%)	181 (18.1%)
After 2 keys Input	740	372 (62%)	474 (47.4%)
After 3 keys Input	2593	547 (91.2%)	832 (83.2%)

Table 1: The number of distinct Chinese characters can be displayed on the dynamic candidate keypad against number of keys input.

searching the intended character. Fig. 8 shows the dynamic keypad after entering two strokes of "一丿". Table 1 also shows the number of distinct characters that can be displayed after inputting 2 and 3 strokes. From these results, we can find that 2,593 distinct characters will be displayed using this dynamic keypad design with input no more than 3 keys. Moreover, 547 and 832 frequently used characters of top 600 and top 1000 are covered. That represents 91.2% and 83.2% of the top 600 and top 1000 characters can be searched with no more than 3 keys input using the proposed dynamic stroke keys design. This feature can significantly enhance the efficiency of stroke-based input method, especially for inexperience users.

3.2 Character Selection by Unidirectional Finger Gesture

To improve the input speed of these frequently used characters on the new dynamic candidate keypad and make use of the touchscreen feature, unidirectional finger gesture is proposed to directly select the intended character on the stroke key. That means the candidate characters can be directly entered from one of the eight unidirectional gestures on the stroke key as shown in Fig. 6. For example, to enter the most popular Chinese character "的", we can just slide toward the upper-left corner of the "丿" stroke key. This unidirectional finger gesture on the relatively large stroke keys is indeed much faster than tapping on the intended character from the candidates listed. In addition, these sliding gestures on the stroke keys are especially handy for entering text with thumb fingers. It is because people are most likely to use the thumbs to input Chinese characters due to their way on holding the smartphones.

As shown in Fig. 5, for example, sliding our finger vertically upward on the "一" key can directly enter the "不" character. For entering the "雲" character, we just need one tap on the "一" key and then a horizontal right gesture on the "丶" key as shown in Fig. 7. With experience, the user does not have to look at the dynamic keys, because the candidates are presented in a consistent location of the stroke keys and the selection of choice depends on direction only. An experienced user can soon get used to the candidate's direction as a part of the shorthand for that character. In addition, this design does not affect the normal stroke-based input style. User can still use the conventional stroke-based input method for entering some of non-frequently used characters.

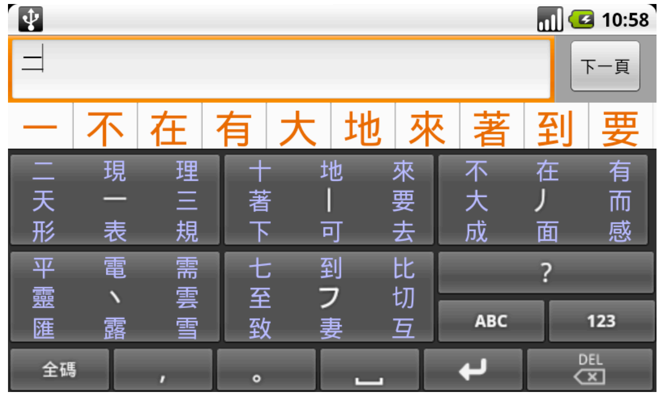

Fig. 7: The character candidates list of each stroke key is updated after tapping one stroke of "一".

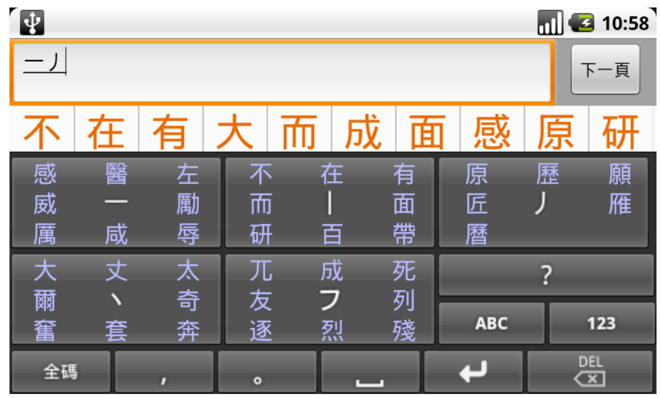

Fig. 8: The character candidates list of each stroke key is updated after tapping two strokes of "一丿".

IV. Performance Evaluation

To measure the impact of Dynamic Candidate Keypad (DCK) on improving stroke-based Chinese input method, user performance data with and without DCK was collected using G6 stroke-based Chinese input method [11]. The details of the evaluation are described in the following subsections.

4.1. Participants

Ten participants of ages from 22 to 30 were recruited. Nine are male and one is female. All participants were native speakers of Chinese (Cantonese). Nine are right-handed and one is left-handed. All participants were experienced users of touchscreen smartphones. Four participants, called Group1, are inexperienced users of conventional stroke-based Chinese input methods. Four participants, called Group2, were experienced users of T9, which are the stroke-based Chinese input method widely implemented in 12-key mobile phones in Hong Kong. In order to measure the trends in performance, two participants, called Group3, were experienced users of T9 and were given the proposed DCK before the experiment, which allows them to have a couple hours of experience on it.

4.2. Apparatus

As mentioned before, the proposed DCK was evaluated using G6 stroke-based Chinese input method [11]. G6 encodes a Chinese character with at most six strokes using the conventional 5 basic stroke types of horizontal (一), vertical (丨), left-falling (丿), right-falling or dot (丶) and turning (フ). The G6 coding rule is very simple that it is based on the (3+3) rule by using the first 3 strokes and the last 3 strokes. Two G6 stroke-based Chinese input methods using conventional keypad depicted in Fig. 4 and DCK depicted in Fig. 5 were implemented on HTC Desire smartphone with 3.7-inch touchscreen and running Android 2.2 OS for user testing. These two input methods were developed with Eclipse IDE for Java EE (JEE) Developers, Java SDK 6 and Android SDK 2.2 on Windows XP.

4.3. Procedures

The participants were given instructions for entering two paragraphs of text, which were randomly selected in the newspaper. One of the paragraphs contains 41 Chinese characters and the other one contains 45 Chinese characters. Half of the participants use G6 with and without DCK to enter first paragraph, respectively, and then enter the second paragraph using G6 with and without DCK, respectively. Another half of the participants would be on the contrary order.

Participants were instructed to input the text, excluding punctuations, as quickly and accurately as possible. Correction was allowed only using the backspace, no other navigation on the typed text was allowed. Associated character function was not allowed to be used during the test. The participants can hold the mobile phone and input texts with their own comfortable positions. During experiment, participants were seated in a quiet room to minimize distractions. Three kinds of the data would be analyzed. They are Key Strokes Per Character (KSPC) [16], including delete key and extra strokes due to errors, Error Rate, including wrong stroke identification, wrong character selection and other errors, and the Character Per Minute (CPM). These parameters are computed as follows:

$$KSPC = \frac{C+IC+F}{N} \quad (1)$$

$$Error\ Rate = \frac{E}{N} \quad (2)$$

$$CPM = \frac{N}{T} \quad (3)$$

where ***C*** is the correct keystrokes, ***IC*** represents the incorrect keystrokes, ***F*** is the keystrokes to fix errors, ***N*** is the total number of characters, ***E*** is the total number of errors and ***T*** is the total time.

4.4. Results

The KSPC, Error Rate and CPM for analyzing the impact of the proposed DCK are shown in Fig. 9, Fig. 10 and Fig. 11, respectively. These results indicated that Group3, the experienced DCK users, had improvement on all of the tests, which are 14.7% on KSPC, 61.3% on Error Rate and 19.3% on CPM. DCK method also reduced the 15% of Error rate for the Group1, which are the inexperienced users of stroke-based Chinese input methods. However, the experienced T9 users cannot be benefited with the DCK method, because they have already been used to the traditional stroke-based Chinese input methods and the custom cannot be changed at once.

4.5. Future Work

The above experimental result is encouraging. The DCK approach will be implemented to other developing input methods and which will be tested by more participants in order to reveal the full benefit of adopting proposed DCK.

V. Conclusion

A novel dynamic candidate keypad (DCK) with use of unidirectional finger gesture on the stroke key for character selection is proposed for enhancing stroke-based Chinese input method. The proposed DCK can display 547 frequently used Chinese characters of top 600 characters with no more than 3 keys tapped. This feature can significantly enhance the efficiency of stroke-based input method, especially for inexperience users. User performance data also shows that experienced DCK users can achieve 14.7% on KSPC, 61.3% on Error Rate and 19.3% on CPM. The new input methods can be applied across a variety of devices such as phones, tablets, game consoles, kiosks, televisions, virtual screens and more.

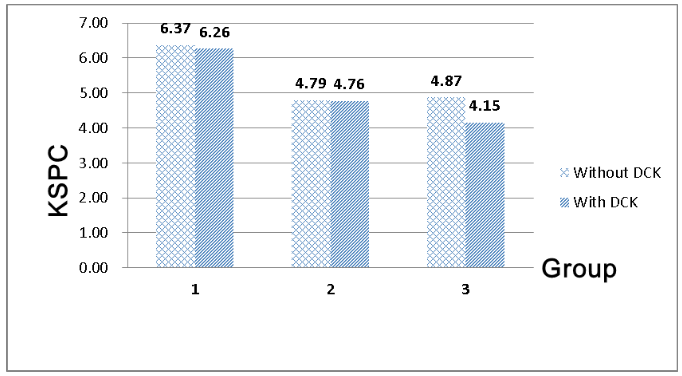

Fig. 9: KSPC of the 3 groups.

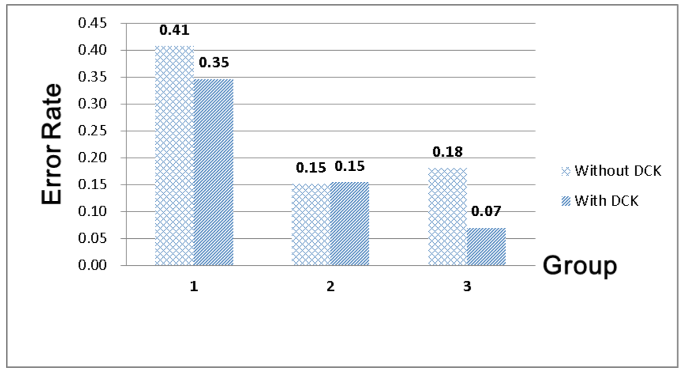

Fig. 10: Error Rate of the 3 groups.

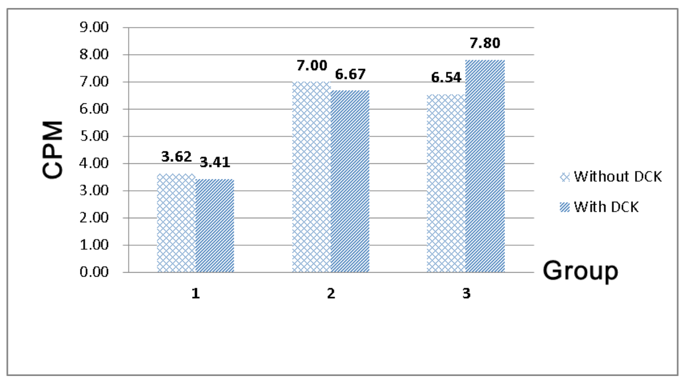

Fig. 11: CPM of the 3 groups.

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