Mobile Phone Keypad Design for Fast Chinese Text Entry by Phonetic Spelling

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1. MOTIVATION

The growth of Short-Messages-Service (SMS) on mobile phones has been phenomenal in the last decade. The monthly volume has increased from 4 billion in year 2000 to 24 billion in 2002 through GSM (Global System for Mobile communication) networks [1]. Due to the size limitation, text entry on a mobile phone has created interesting problems and become an active research area in Human Computer Interaction. Many text entry techniques and different interface designs have been developed to make text entry on mobile phones more efficient. However, the problem becomes much more difficult with Chinese text entry due to the large phonetic alphabet and homophonic Chinese characters. Still, there is a huge body of Chinese mobile phone users; the number has reached 320 million in 2004 [2]. Therefore, the Chinese text entry process represents a challenging and rewarding research problem.

2. BACKGROUND

How to Input Chinese Text

Chinese is an ideographic language, and its minimal unit is a character, which can sometimes correspond to more than one pronunciation and more than one meaning. Due to the enormous character set, Chinese characters cannot be mapped to a keyboard for input into a computer system or an electronic device. Thus an intermediate step is necessary for Chinese text entry. The prevailing solution on a full-size keyboard to enter a Chinese character, such as the one shown in Figure 1, is to use phonetic spelling as an intermediate step.

Figure 1. Chinese character for "fly" -- pronounced "fai"

There are two commonly used Chinese phonetic spelling systems, Pin-yin and Zhu-yin. The Pin-yin system uses the English alphabet and is widely used in China, while the Zhu-yin system has a separate alphabet and is used more in Taiwan and areas still using traditional Chinese. For this project, we focus on the Zhu-Yin phonetic spelling system, which has 37 letters, as shown in figure 2.

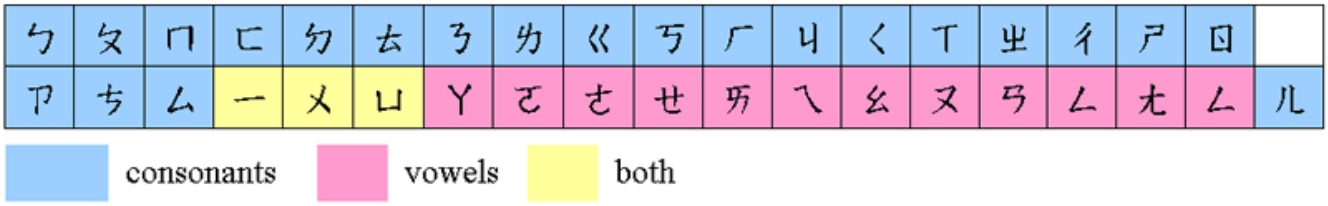

Figure 2. Zhu-yin Alphabet

Here is an example of how to enter a Chinese character with the Zhu-yin letters:

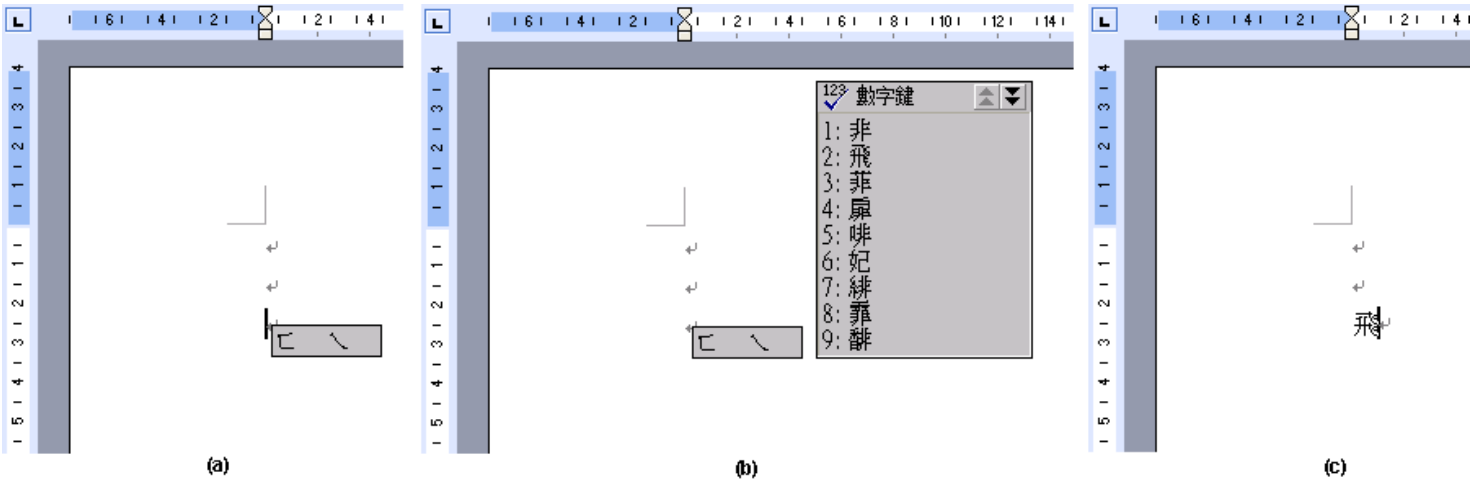

Figure 3. Steps for entering the Chinese character "fly": (a) Enter Zhu-yin letters "f" and "ai" to obtain Zhu-yin sequence "fai" (b) Select the character (No. 2) from the list of characters pronouced "fai" (c) The desired character is entered.

Focus on the Zhu-Yin Phonetic Spelling System

We focus on the Zhu-yin phonetic spelling system over Pin-yin for the following reasons:

- Pin-yin shares the English alphabet, so designing solely for Chinese text entry using Pin-yin is impractical. Zhu-yin has its own alphabet.
- Current commercial systems using Zhu-yin all use an alphabetical order of some sort, but there is no standard Zhu-yin keyboard layout for a mobile phone. Thus, introducing a new layout is feasible.
- Zhu-yin has a larger alphabet than English, and thus creating a layout offers a more interesting research challenge.

3. PROBLEM

As in English, Chinese text entry on a mobile phone is more complicated than on a computer since the number of letters greatly exceeds the number of keys. With more than one letter per key, a sequence of key presses can be ambiguous. Chinese text entry on mobile phones thus requires an additional step of selecting the intended Zhu-yin sequence from a list of Zhu-yin sequences before selecting the intended character from the list of homophonic characters.

Figure 4. Keypad layout by Sony Ericsson

For example, to enter the character into a mobile phone with the keypad shown in Figure 4, the user needs to press 1 and then 8, which leads to 12 valid Zhu-yin sequences, as illustrated in Figure 5. The desired sequence is the 11th in the list of 12 Zhu-yin sequences, so the user has to go through three sub-lists to select it.

Previous work [3] found that the time taken for a user to react and choose from a list of multiple items was the primary bottleneck in Chinese text entry.

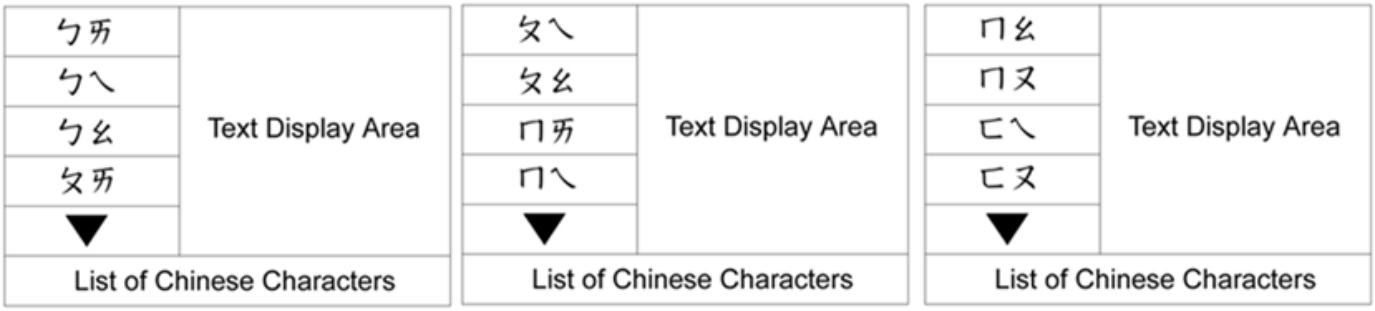

Figure 5. Screens displayed after the user presses 1, 8. Pressing the down arrow in screen 1 leads to screen 2, and pressing the down arrow in screen 2 leads to screen 3.

4. APPROACH AND RESULTS

The goal of this study is to speed up text entry by reducing Zhu-yin sequence disambiguation time. This is done in two steps:

1. Develop an evaluation metric to estimate the disambiguation time for a given keypad layout (based on a corpus of letter frequencies) [5].
2. Search for a keypad layout that minimizes this metric. Breaking away from alphabetical order offers potential to address the Zhu-yin sequence selection bottleneck.

Evaluation a Keypad Layout

We developed a "fitness function" to model the relative cost in time to select a target Zhu-yin sequence (assuming a reasonable, generic interface like the one in Figure 5). Each sequence selection scores 10 time units; each page selection scores 15 time units. For example, selecting with the keypad layout in Figure 4 scores 40 time units (30 for selecting down twice and 10 for selecting the target sequence).

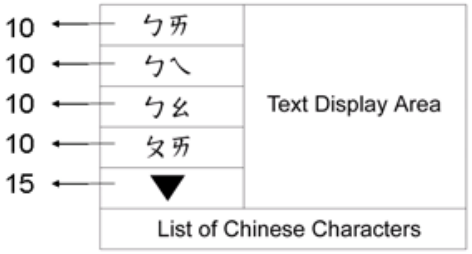

Figure 6. The fitness function - evaluation metric for modeling time for zhu-yin selection.

The set of valid Zhu-yin sequences is finite; therefore, we can compute the overall cost for a particular keypad layout by summing up individual cost weighed by sequence frequencies. The higher the overall cost, the worse the keypad layout.

Here are some results from evaluating four commercial keypad layouts:

Manufacturer	Keys Used	Score
Panasonic	11	2136900
Okwap	11	2266000

Motorola	9	2769955
Sony Ericsson	10	10158755

Generating a Good Keypad Layout

Commercial layouts all follow Zhu-yin alphabetical order in some way. These alphabetical orderings exacerbate the disambiguation problem by enforcing poor layout choices. Non-alphabetical ordering offers substantially better disambiguation. Furthermore, studies have shown that, even in terms of novice users' learning time, "alphabetically organized keyboards are slightly superior to a randomly organized one, but that this difference is too slight to be of any practical significance." [6]

What happens if we modify the layout in Figure 4, as shown in Figure 7? To enter character into a mobile phone with the keypad in Figure 7, the user presses 4 and 8, which leads to only 2 valid Zhu-yin sequences and reduces the cost.

Figure 7. A modification keypd layout in Figure 4.

Based on this idea, our goal is to generate an optimal keypad layout, trying to minimize the number of Zhu-yin sequences generated by each key press sequence. However, the space of options for 37 letters on 12 keys is 12 to the power of 37, so exhaustive search is not feasible. Therefore, we use a best-improvement search algorithm to find keypads whose scores are locally optimal, running many randomized trials to find high quality keypad layouts.

Results running the algorithm to generate keypads with a different number of keys are as follows:

Number of Keys	9	10	**11**	12
Score	1521460	1085885	**748870**	469320

The results are much better than the commercial layouts. To do a fair comparison, the layout that uses 11 keys scores 748,870, whereas the best commercial layout (Panasonic) which also uses 11 keys, scores 2,136,900.

Figure 8. The top scoring 11-key layout generated by the algorithm.

User Study

Based on the keypad layouts and user study recommendations from this study, Chan et al. [9] conducted a user study with subjects who are familiar with Zhu-yin but are novice Zhu-yin cell phone users indicate that subjects quickly become comfortable with non-alphabetic layouts but, at least initially, do not enjoy significant speedup in text entry. However, analysis of keypress timing indicates the potential for up to 20% speedup with careful layout, mostly by ensuring that the keys pressed for frequently used Zhu-yin sequences can indicate no other legal sequence. Future work should exploit these results to improve the algorithm's cost function and study the resulting new layouts.

5. CONTRIBUTIONS OF THIS STUDY

The contributions of this study include:

- Identified the disambiguation time during Zhu-yin sequence selection as the primary text entry bottleneck based on prior studies
- Designed a metric to model the text entry process to evaluate text entry costs for keypads
- Identified breaking alphabetical order as a possible solution to improve efficiency
- Developed a novel algorithm to generate good keypad layouts, using best improvement and random restart local search algorithms
- Produced a set of high quality layouts for Chinese mobile phone text entry

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