Chinese Pinyin Input Method in Smartphone Era: A Literature Review Study

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Abstract. This study conducted a literature review on the latest academic publications concerning smartphone-based Pinyin input method. The objective is to explore what academic endeavors have been made to address the key concerns of today's Pinyin input method. Results show that much work has been concentrated in advancing Pinyin-to-character conversion, by forging a more powerful algorithm more capable of tolerating, detecting and correcting error. Besides, a serial of interface layout optimization attempts have been tried. Based on the analysis of the review result, comments of the existing work and suggestions for future research direct are proposed.

Keywords: Pinyin input method · Usability · Interaction design · Layout · User behavior

1 Introduction

1.1 Background

If there is a behavior most Chinese today would do in their daily life, that would definitely be the use of smartphone. Indeed, according to Statista, in 2017 China has around 663.37 million smartphone users, a number greater than the whole population of USA and Brazil combined. The widespread application of smartphone has brought the whole Chinese nation into an unprecedented social media era when interpersonal communication has been dramatically facilitated regardless of space and time limits.

To support such frequent and effective communication, many smartphone-based social media tools are playing key roles. Take the most successful one: WeChat as an example, it is a mobile instant messaging (text and voice) communication service invented by Tencent (腾讯) in 2011. WeChat bridges the communication between millions of users by means of text messages (SMS), hold-to-talk voice messages, group chat, video conferencing, free voice call, location sharing, contact sharing and Moments (photo and video sharing). Among these communication methods, text message is undoubtedly the most widely and frequently used function. Consequently, the need for a convenient way to input Chinese text messages becomes increasingly important [1].

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1.2 Pinyin Input Method

To edit a piece of Chinese message on a smartphone, Chinese input methods are always needed. Basically they are categorized into two types, as seen in Table 1:

1. Pronunciation based input method; 2. Structure based input method.

Table 1. Examples of some famous Chinese input methods

Pronunciation based	Structure based
Pinyin 拼音	Wubizixing 五笔字型
Shuangpin 双拼	Wubihua 五笔划
Jianpin 简拼	Cangjie 仓颉
Bopomofo 注音	Sucheng 速成
	Sanjiao 三角
	Dayi 大易

Among various Chinese input methods, Pinyin input method is apparently the most popular means. In 2014, 76.7% of Chinese smartphone users choose Pinyin input method [2]. Pinyin (Pinyin Romanization (https://en.wikipedia.org/wiki/Romanization)) is a system that transcribes the pronunciation of Chinese characters into a string of Roman letters [3]. The mechanism of Pinyin input method is that by typing Pinyin, computer will automatically recognize and match all possible corresponding Chinese characters, phrases, and sentences for user. For example, one wants to input "兽医" (veterinary) on a smartphone. First, he needs to type the Pinyin of 兽医, which is "shouyi". Then smartphone will list a cluster of candidate Chinese characters and phrases that are pronounced as "shouyi", such as:

手艺 craftsmanship; 受益 benefit; 收益 earnings; 兽医 veterinary; 寿衣 shroud.

Finally, a user completes the texting by just tapping characters "兽医" (see Fig. 1).

Fig. 1. An example of how to input Chinese character with Pinyin input method (T9 Pinyin keyboard).

1.3 Research Question

Pinyin input method was born to confront with a sheer challenge: Modern Chinese has merely less than 500 pinyin syllables that disproportionately represent over 6,000 commonly-used Chinese characters, which leads to serious ambiguities for pinyin-to-character mapping [4]. Therefore, lasting efforts are still required both from academia and industry to continuously improve the efficiency of pinyin-to-character conversion.

The advent and widespread of touchscreen technology revolutionarily change human behavior of texting. While typing on a physical QWERTY keyboard is one thing, typing with a virtual keyboard on a smartphone touchscreen is another story. Instead of using all ten fingers, tapping on a soft keyboard only requires one or two thumbs. In this sense, people may optimistically believe that this radical change facilitates user's typing behavior since no touch typing would ever be needed. However, scientific study has found that the speed and accuracy of Pinyin typing would be significantly reduced when using a smartphone virtual keyboards due to the difficult nature of tapping small targets on virtual keys [5]. Hence, more rigorous research is needed to seek optimal layout design of a Pinyin input method interface.

The fact that smartphone-based Pinyin input method use is so widespread in today's China and no systematic work has been done to review related academic research makes the present research extremely important and motivated. By reviewing the latest academic works, the present study tries to explore what academic efforts have been spent:

1. To improve the functionality and usability of Pinyin input method?
2. To better understand user behaviors during the interaction with Pinyin input method interface?

As a result, a summary in forms of tables will be proposed as a guideline for future Pinyin input method development.

2 Methodology

2.1 Literature Criteria

Academic studies that discussed smartphone-based Chinese Pinyin input method (The input of Pinyin is achieved by finger-tapping on virtual keyboard based on touchscreen). Candidate publications are set to be from 2005, in forms of either peer review journal articles, conference proceedings, reports or books. They can be both written in Chinese and English.

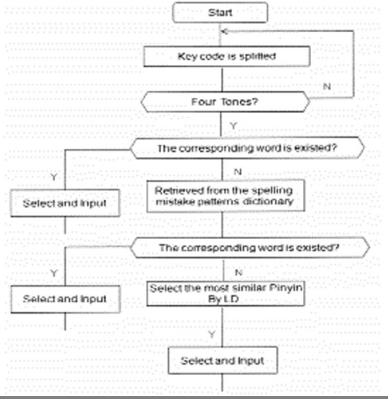
2.2 Keywords

Pinyin input method, smartphone, touchscreen, interaction design, layout, usability.

3 Results

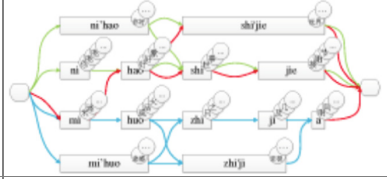
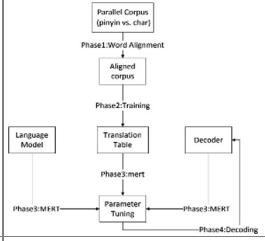
Initially, thirty publications in both English and Chinese have been found from the following online database: Google Scholar, Springer, ELSEVIER, IEEE Xplore Digital Library and Research Gate. After carefully sieving, 13 articles have been eventually selected and a summary covering their basic information such as author, year, problem, solution, result has been established in the form of Table 2, as shown below.

Table 2. Summary of literature review

<table>
<tr><th>Authors</th><th>Functions</th><th>Problems/Defects</th><th>Solutions</th><th>Results</th></tr>
<tr><td>Zheng, Li, and Sun [6]</td><td>Mistyping detection and correction</td><td>Current IME is inefficient to recognize and correct typos</td><td>A novel error-tolerant IME “CHIME”, (CHinese Input Method with Errors)
Mechanism: Finding Similar Pinyins ->
Ranking Similar Pinyins - >
| Pinyin-to-Chinese Conversion with Typos</td><td><table><tr><th>Metric</th><th>CHIME</th><th>Sougou</th></tr><tr><td>DectER</td><td>37.40%</td><td>70.62%</td></tr><tr><td>CorrER</td><td>52.43%</td><td>91.19%</td></tr><tr><td>ConvER</td><td>53.56%</td><td>91.75%</td></tr></table></td></tr>
<tr><td>Wu, Kato, and Yang [7]</td><td>Frequent typos advice function</td><td>Indication function needed to avoid frequent spelling error</td><td>Advice prompt on frequent spelling error
 
</td><td>Prompt advice on patterns of frequent spelling errors</td></tr>
</table>

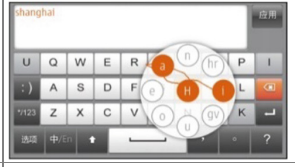
(*continued*)

Table 2. (*continued*)

Authors	Functions	Problems/Defects	Solutions	Results
Jia and Zhao [4]	(1) Pinyin-to-character conversion (2) Typo correction	Inefficient to correct a typo and generate the expected sentence, which often requires extra user's corrective effort and thereby leads to a poor user experience.	Jointed graphic model (Markov Hidden Model and K-shortest paths) 	The new model outperformed both academic systems and existing commercial IME in reducing conversion error
Yang, Zhao, Wang, and Lu [8]	Pinyin-to-character conversion	Serious ambiguity of Pinyin-to-character corresponding	A monotone phrasal SMT based approach 	The new Machine Translation (SMT) approach outperformed in whole sentence accuracy and time cost Model \ Dataset: 10K / 100K / 1M ME: 0.075 / 0.169 / 0.302 SMT: 0.402 / 0.429 / 0.454
Chen, Zhao, and Wang [9]	Predictive performance	Neural network language models (NNLMs) fails to support real-time human machine interaction due to its heavy computational cost nature	Recalculating the probabilities of n-grams in the BNLMs with NNLMs: (1) A BNLM and a NNLM are respectively trained on the same corpus. (2) Extract all the n-gram from the BNLM and calculate the probability of them with the NNLM (3) Rewrite the BNLM with the probability computed by NNLM 4) Re-normalize the probabilities of BNLM	New method effectively improved the predictive performance of pinyin IME in terms of hit rate of the first candidate sentence (HRF) with no extra time cost **Test / Models / HRF / HRF10 / CA** 10K / Baseline / 74.72 / 89.92 / 96.80 10K / Our model / 75.71 / 90.14 / 96.80 400K / Baseline / 67.02 / 86.08 / 95.46 400K / Our model / 67.68 / 86.45 / 95.59
Yang, Zhao, Wang, and Lu [8]	Pinyin spelling checking	Ineffective Pinyin-to-Hanzi (character) translation and recommendation function which leads to a wrong decoding of a Pinyin	A hybrid model (mini-path + LM) incorporating Minimized-Path Segmentation and Statistical Criteria	F-score (F = 2RP/(R + P)), a common measure of spelling checking system's performance) achieved a 12% improvement over the baseline, it also performed much better in Precision and Recall

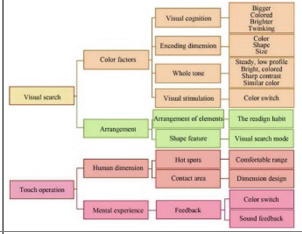
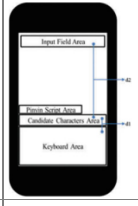
(*continued*)

Table 2. (*continued*)

Authors	Functions	Problems/Defects	Solutions	Results
Zhang [10]	Pinyin-to-character conversion	Big space for conversion efficiency to be improved.	(1) New approach based on large scale hybrid language model and word lattice decoding algorithm (2) Integrating dynamic information such as recent context, recent user profile, automatic prediction algorithm and machine learning technology	Accuracy of conversion significantly improved *First character accuracy*: *New model* 92.1%; *MS Pinyin* 87.6% *First page accuracy*: *New model* 96.2%; *MS Pinyin* 94.9%
Suzuki and Gao [11]	Online spelling correction	Existing input methods fail to identify and correct minor typos to the desired target Chinese characters	(1) Substring-based spelling correction using a log-linear model (2) A unified model enabling character conversion with spelling correction (Noisy channel model)	The proposed method outperforms all these baselines to reduce the CorrER to 7.12: A 35% reduction VS no correction baseline, A 20% reduction VS Zheng's design A 10% reduction VS noisy channel baseline
Authors	Interface designs	Problems/Defects	Solutions	Results
Liu, Chen, Wang, Zhang and Li [12]	Soft keyboard	Optimal layout for soft keyboard designed for Pinyin input has not been explored.	A pie-menu augmented soft keyboard 	(1) Slower text entry rate (2) Slightly fewer errors (3) Users better remember the layout of pie menu
Liu, Ding, and Liu [13]	Virtual keyboard	To test the usability of new Pinyin virtual keyboard VKB	VKB: a consonant keyboard with a vowel keyboard to complete a pinyin 	(1) Lower error rate (2) Significantly slower text entry rate (3) Significantly fewer the keystrokes per character (KSPC)

(*continued*)

Table 2. (*continued*)

Authors	Interface designs	Problems/Defects	Solutions	Results
Wu and Xi [14]	Interface layout	Seek optimal layout design user visual search behavior		General rules regarding three factors: dimension design, color features and arrangement of elements have been established for future HCI development.
Zhou, Rau and Salvendy 2014 [3]	Interface layout design	(1) The distance between candidate characters area and the keyboards area (d1) is too short (2) The distance between candidate characters area the input field area (d2) is too long	(1) Recommend 7 in. and 9.7 in. display size (2) Enlarge the Pinyin script area to be sufficiently big 	(1) Participant successfully completed more tasks on 9.7 in. display size than on 3.5 in (2) Participants perceived the 9.7 in. display size much more user-friendly than the 3.5 in
Bi, Smith, and Zhai [15]	Visual keyboard layout	Optimal keyboard layout design for Pinyin input is needed	K-Chinese r m l p w e d j x v f n a i h s k g o u z c t y b q	(1) Reduces the average movement distance from QWERTY's 3.85 keys to K5's 1.5 keys (2) Significantly reduced completion time and Fitt's time (3) Improves the input speed by 24% over QWERTY

4 Discussion

For convenience, two tables have been developed to separately discuss the literature review result Table 3 in two aspects: functional characteristics and design characteristics.

Table 3. Discussion regarding functions

	Functions
Comments	Pinyin-to-character conversion has drawn extensive attention from academia and substantial work has been done to enhance its efficiency by: Enhancing typos detection and correction ability Advancing error-tolerant in-built model Much more theoretical and practical endeavors are needed to further improve the existing Pinyin IME's prediction function, which matches the conclusion from the iiMedia Research Report that prediction is among the top usability concerns from Pinyin IME user's perspective [16]
Suggestions	The prediction function needs to evolve to be more intelligent. Thereby recommendations of developing following abilities are given: Predict characters from complete Pinyin acronyms: For example, by typing 'bjsdgjjc' instead of its full Pinyin 'bei jing shou du guo ji ji chang', Pinyin IME will be able to match the correct characters "北京首都国际机场" (Beijing Capital International Airport). This ability facilitates Pinyin typing of long proper noun (e.g. place name, people name and terminology) and common Chinese phrase Further, predict characters from incomplete Pinyin acronyms: For example, after typing 'gysqs', short for 'gong yu shan qi shi', corresponding "工欲善其事" (To Do A Good Job), Pinyin IME will automatically predict the rest part of this idiom "必先利其器" (One has to first sharpen his tool) without manual typing of its corresponding Pinyin. This function would greatly save user' effort in typing multi-phrase Chinese idiom and poetry Intelligent prediction of future characters based on conversation context: For example, given the first part of sentence "我还会做" (I can also cook), Pinyin IME could envision that the rest of the characters should relate to some kind of food, in this sense, when 'cf' is further typed, only character candidates meaning food will be listed, such as "炒饭" (full Pinyin as chao fan) Actually, the idea of context-based character prediction is the most innovative idea proposed by the present study. It is a fresh and inspiring example of machine learning application on human texting behavior. This ability enables Pinyin IME to understand human's language, thus being able to predict what human want to say next, and finally assist human by providing more precise range of candidate characters In addition, corpus needs to be further enriched by: Responsively adopting newly-born phrases such as popular Chinese Internet slang Memorizing characters based on recently-typed Pinyin

4.1 User Behavior

Analyzing user behavior provides novel perspective and is thus helpful in improving user experience and performance of Pinyin input method [17]. The result in this study reveals that users desire a Pinyin input method that could, to maximum extent, lesson human's physical (typing, visual searching) and mental (recognizing) loads and if better, could further understand the meaning and the logic of human language and thus be able to intelligently assist human in texting (Table 4).

Table 4. Discussion regarding interface design

	Interface design
Comments	Previous research primarily focuses on layout optimization of virtual keyboard by means of either rearranging keyboard elements or designing innovative new keyboard with irregular shape
Suggestions	More interface-related issues are pending to be explored such as: further simplifying layout, size-adjustable keyboard, color effect on user visual perception and other novel typing methods such as gesture typing and eye typing

5 Conclusion

The present study conducted a literature review regarding smartphone-based Pinyin input method. While thirty publications have been found, thirteen of them was eventually selected and summarized. As a result, it is found that much efforts have been implemented to enhance Pinyin-to-character conversion by integrating more powerful algorithm addressing issues over error detection and correction. For design issue, lots of work has been done to optimize visual keyboard layout to improve typing speed and accuracy. In the last, suggestions for future work such as strengthening prediction function, introducing size-adjustable keyboard and innovative typing methods have been proposed.

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