Research and Implementation of a Braille Input System: Postprint

Authors: Wang Xiangdong, Xie Shuhua, Zhang Boning, Wang Chao, Qian Yueliang, Lin Shouxun

Date: 2016-11-02T00:00:00+00:00

Abstract

Existing human-computer interaction methods are predominantly designed for sighted individuals, posing significant challenges for blind users in text input on computers. To address this issue, this paper proposes a braille dot input system entirely consistent with the daily writing habits of blind individuals, comprising two components: a braille dot input device and dot processing software. The system captures user-inputted braille dot information via circuit contacts and transmits it to the computer through a USB interface; the braille dot processing software on the computer processes this information and employs natural language processing techniques to automatically convert entire braille sentences into Chinese characters. Experimental results validate the effectiveness of the proposed braille-to-Chinese character conversion method.

Full Text

Preamble

Vol. 7 No. 3 Information Technology Letter Vol.7 No.3
Research and Implementation of a Braille Dot Input System
Wang Xiangdong, Xie Shuhua, Zhang Boning, Wang Chao, Qian Yueliang, Lin Shouxun

Abstract

Most existing human-computer interaction methods are designed for sighted individuals, making it extremely difficult for blind people to input text on computers. To address this issue, this paper proposes a Braille dot input system that fully conforms to the daily writing habits of blind users, comprising both a Braille dot input device and dot processing software. The system captures user-input dot information through circuit contacts and transmits it to the computer via a USB interface. The Braille dot processing software on the computer processes this information and employs natural language processing techniques to automatically convert entire Braille sentences into Chinese characters. Experimental results demonstrate the effectiveness of the proposed Braille-to-Chinese character conversion method.

Keywords: Braille; Braille dots; Chinese character input; Braille input; computer systems for the blind

1 Introduction

According to 2006 statistics from the China Disabled Persons' Federation, China has approximately 12.33 million blind individuals. In today' s information society, as China' s informatization level continues to improve, information technology has become widely applied in people's work, study, and daily lives. However, nearly all information products, particularly their human-computer interaction methods, are designed for sighted individuals without considering the needs of people with disabilities. This prevents blind individuals from enjoying the convenience brought by information technology like normal people, continuously widening the information gap between blind and sighted individuals, further restricting blind people' s ability to survive and develop in the information society, and making it difficult for them to integrate into mainstream society.

The human-computer interaction problem involves two aspects: input and output. The former refers to inputting text or commands into computers through devices such as keyboards and mice, while the latter involves outputting text or other information to users through visual and auditory means. As speech synthesis technology has matured, converting text to speech output has become a reality. Therefore, for blind users, text input difficulty is the key factor restricting their computer usage.

To solve the problem of text input for blind people on computers, researchers have conducted extensive studies and developed various systems. The main approaches fall into two categories: one utilizes standard computer keyboards and existing Chinese input methods, while the other employs keyboard configurations corresponding to Braille and associated input methods. Currently, most computer systems for the blind support standard keyboards and existing Chinese input methods [1,2], but this approach has two problems: First, standard keyboards have too many keys, making them unsuitable for quick tactile reading by visually impaired users; second, because blind individuals have weak concepts of character shapes and Braille uses phonetic spelling methods different from Chinese Pinyin, using existing Chinese input methods is very inconvenient. To address this, some computer systems for the blind use keyboard configurations corresponding to Braille and associated input methods [1-3]. The main idea is to define six keys on a standard keyboard or adopt a specialized six-key keyboard, making the six keys correspond to the six dots of Braille ( ). When one or several of these six keys are pressed simultaneously, they correspond to a

Braille character. This method corresponds to Braille symbols and is relatively more consistent with Braille input habits. However, because it requires pressing multiple keys simultaneously, which does not conform to normal typing habits, it often requires a period of training to use proficiently.

In the second approach mentioned above, users input Braille. When they need to communicate with sighted people, they must convert it to Chinese characters. Many domestic researchers have studied Braille-to-Chinese automatic conversion technology [2, 4-6]. Since Chinese Braille is essentially a phonetic writing system (for example, in current Braille, one Braille cell represents an initial or final, and their combination forms a syllable), existing Braille-to-Chinese conversion technologies mainly adopt methods similar to existing Pinyin input methods, using n-gram language models combined with appropriate rules to convert entire sentences of phoneme streams into Chinese character strings.

1 An n-gram is a commonly used language model in natural language processing and large-vocabulary continuous speech recognition, detailed below.

This paper proposes a Braille computer dot input system to address the problems existing in current text input methods for blind users. The system employs an input device fully consistent with Braille writing habits, combined with a Braille-to-Chinese conversion algorithm, enabling blind users to freely input Braille symbols and convert them to Chinese characters without any learning, achieving input speeds comparable to normal Braille writing speeds.

2.1 Introduction to Chinese Braille

China currently employs two main Braille schemes [7]. One is the "Current Braille" scheme promulgated by the former Ministry of Education in 1953 and implemented nationwide. This scheme has 21 initials, 34 finals, and includes tone symbols and punctuation marks. It uses Beijing pronunciation as the standard, Mandarin as the foundation, and words as units, adopting word segmentation and connection rules. The other Braille scheme is the Braille reform scheme approved for trial promotion by the State Language Commission in 1988, referred to as "Chinese Double-Pinyin Braille." This scheme can represent the three elements of Chinese sound, rhyme, and tone within two Braille cells. The entire system includes an alphabet, punctuation, homophone differentiation methods, abbreviation methods, silent character determination methods, etc., also adopting word segmentation and connection rules.

Since Double-Pinyin Braille appeared later and is more complex with more rules than Current Braille, Current Braille remains widely used in China today. Both in terms of published books and actual use in schools for the blind, Current Braille accounts for a large proportion. Therefore, the algorithm research in this paper mainly focuses on Current Braille, which is currently the mainstream application.

Both Braille schemes use the "Braille cell" as the basic structure, arranged according to encoding schemes, and perceived through touch (also called dot characters). A Braille cell consists of six dot positions ( ). One Braille cell is also referred to as one "square." By arranging combinations of raised dots on these six positions, corresponding text symbols can be expressed. Chinese Braille is actually a writing system that uses dot patterns to represent phonetic methods, essentially making it a phonetic writing system. Additionally, Braille has an important rule called word segmentation and connection, where words are the units in Braille, with empty squares between words. This rule largely eliminates ambiguity caused by pure Pinyin and greatly helps determine the meaning of Chinese characters from Braille dots.

Braille writing and reading are quite special. Braille writing is achieved by punching holes on special paper, generally using a Braille guide plate composed of several squares of Braille cells. Under the guidance of the plate, holes are punched from right to left according to the Braille encoding scheme. When reading, the paper with through-holes is turned over and read by touch from left to right, as shown in Figure 1 [Figure 1: see original paper].

Figure 1. Braille writing method: (a) Braille guide plate and stylus; (b) Placing the Braille guide plate on Braille paper; (c) Braille writing

2.2 Function and Module Division of the Braille Dot Input System

This paper proposes and implements a Braille computer dot input system based on the actual needs and daily writing habits of blind users. The system abandons keyboards that are inconvenient for blind users and adopts an input device fully consistent with Braille writing habits, combined with Braille dot processing software, enabling blind users to freely input Braille symbols and convert them to Chinese characters just like writing Braille, achieving normal writing speeds.

The Braille dot input system consists of two parts: hardware and software. The hardware part is the Braille dot input device, and the software part is the Braille dot processing software. The Braille dot input device mainly includes a dot board and a stylus, with its appearance shown in Figure 2 [Figure 2: see original paper]. The basic principle of the device is to install the Braille guide plate used daily by blind people on a sensing board and equip it with a dedicated stylus. When blind users input dots on the board, the sensing board can input the dot coordinates to the computer for processing by the system software. The sensing board and stylus in the device can adopt various methods such as pressure sensing, electromagnetic induction, and circuit switches. Due to its low cost, reliable performance, and simple implementation, the circuit switch method is used as the primary example for introducing the Braille dot input device below. The Braille dot input device connects to the computer via a USB interface and supports plug-and-play.

Figure 2. Appearance of the Braille dot input device

The main functions of the Braille dot processing software include: (1) acquiring dot information, which involves converting the dot coordinate information transmitted from the dot board into Braille cells and accumulating a string of Braille cells in memory; (2) Braille-to-Chinese conversion, which uses natural language processing techniques to automatically convert entire sentences or phrases of Braille cell strings into Chinese characters—this is the core function of the system; and (3) character-by-character proofreading based on speech synthesis. Generally, after whole-sentence Braille-to-Chinese conversion, the resulting Chinese characters can already meet the needs of daily text communication such as web browsing, chatting, and email writing. However, in situations requiring high accuracy, blind users need to proofread the resulting Chinese character string character by character. The main method involves the system reading candidate words one by one through word grouping and speech synthesis for user selection, with voice output such as "First, 'shāng' as in 'shāngdiàn' (store), second, 'shāng' as in 'shāngxīn' (sad), ⋯" Since the core technology of the software lies in Braille-to-Chinese conversion, the algorithm for this part is mainly introduced below.

3 Braille Dot Input Device

As described above, the main function of the Braille dot input device is to obtain dot coordinate information and input it to the computer through a USB interface. The device acquires user input and transmits it to the computer through a microcontroller unit (MCU). Since the device only needs to determine whether a dot position has been clicked by the user and does not need to obtain precise coordinates or click force information, directly adopting a circuit contact method is the most straightforward approach. The main principle is to set a contact point for each dot position of each Braille cell and connect the stylus to the system circuit through a wire. When the stylus contacts a dot position' s contact point, the circuit is closed, and the device can obtain this information and transmit it to the computer.

The specific implementation of the above method is shown in Figure 3 [Figure 3: see original paper]. For each dot position of a Braille cell, a dot-shaped pad is designed according to the dot size standard. This pad is connected to ground through a high resistance and then to a port of the microcontroller. If the stylus (connected to Vcc) contacts the pad, the pad connected to the microcontroller port will be set to a high level, and the microcontroller can collect this information.

Figure 3. Schematic diagram of circuit-based dot device implementation

3.1 Circuit Design of the Braille Board

According to national Braille standards, a Braille guide plate generally contains 5 rows with 28 squares per row. Implementing a dot board according to this specification would require 6×28×5=840 ports if each contact point at every dot position were connected to an MCU port. Obviously, for such a huge number, it is unrealistic to connect each port to the MCU and scan them in real time. To address this problem, we adopt a port multiplexing method based on Braille writing patterns.

According to Braille writing conventions, dot input proceeds continuously from right to left, and generally, it is not allowed to return and modify previously input Braille cells when inputting a cell. Therefore, ports can be multiplexed by connecting some distant ports to each other. In the dot input system we developed, considering cost and usability factors, we decided to multiplex every 4 squares. This results in using 24 ports total. As shown in Figure 4 [Figure 4: see original paper], every 6 dots form one square, and the arrangement order of squares is the same as the national standard order, which provides convenience for subsequent software design.

Figure 4. Port multiplexing method for the Braille board

In terms of specific design, we adopted a separation mechanism between the dot board and the logic circuit board. This approach has the following advantages: (1) The separated design is more convenient for circuit wiring; (2) It reduces the overall area and saves costs; (3) It facilitates future upgrades of the logic circuit part without repeated redesign.

3.2 Circuit Design of the Braille Stylus

Figure 5 [Figure 5: see original paper] shows the design circuit of the stylus. The tip of the stylus is a metal probe, the same as the tip of a regular stylus. Connected to the metal probe is a conductive transmission rod, which is connected to a microswitch via a wire. The microswitch is then connected back to the circuit board via a connecting wire. There are two reasons for using a microswitch in the design: First, after using a microswitch, when users click on a dot position, there is obvious tactile feedback, consistent with Braille writing habits and facilitating user confirmation (the paper used by blind people in daily writing is relatively thick, so dot writing has tactile feedback); second, using a microswitch can reduce jitter during circuit connection. If only a regular conductor is used for connection, irregular burrs will be generated when the tip contacts, potentially bringing many unwanted signals.

Figure 5. Schematic diagram of stylus circuit design

4 Braille-to-Chinese Character Conversion System

Through the Braille dot input device, user input can be interpreted as Braille cells and transmitted to the computer. However, ordinary computers still cannot recognize and process Braille information. If blind people want to use the Internet or communicate with sighted people, they need to further convert the input Braille into Chinese characters. The Braille-to-Chinese conversion system can achieve conversion from Braille input from the dot board to Chinese characters, solving the difficulties blind people face when using computers.

Braille is essentially a phonetic writing system. Whether it is the current Braille where most characters are not tone-marked, or the Chinese Double-Pinyin Braille where every character is tone-marked, the phenomena of multiple pronunciations for one Chinese character, multiple characters for one pronunciation, and ambiguity in natural language more or less cause difficulties in Braille-to-Chinese conversion, resulting in conversion errors or ambiguities. Therefore, during the conversion process, it is necessary to utilize various knowledge, rules, statistical information, and natural language processing techniques to improve conversion accuracy as much as possible. At the same time, to make full use of context information, whole-sentence or whole-paragraph conversion is generally adopted. In the Braille-to-Chinese conversion system implemented in this paper, considering user input characteristics and the need for context awareness, we decided to adopt a sentence-by-sentence or phrase-by-phrase conversion method. That is, whenever a comma or period is encountered (Braille also has corresponding punctuation marks), the system automatically converts the current sentence. At the same time, to avoid overly long sentences, when users input a relatively complete phrase that has not yet formed a sentence, forced conversion can also be requested.

Since Braille-to-Pinyin conversion has relatively few ambiguities, and Pinyin-to-Chinese conversion is similar to operations in Pinyin input methods, some current Braille-to-Chinese conversion systems adopt the technical solution of first converting Braille to Pinyin strings using Braille rules, and then converting Pinyin strings to Chinese character strings using Pinyin input method techniques. However, in fact, errors may occur when converting Braille to Pinyin, thereby affecting the accuracy of Braille-to-Chinese conversion. Therefore, this paper adopts a one-step Braille-to-Chinese conversion method, which no longer converts Braille to Pinyin during conversion but directly achieves Braille-to-Chinese decoding under the guidance of Braille rules (a dictionary mapping Braille cell strings to Chinese word strings) and Chinese language models. This approach both improves time efficiency by reducing steps and enhances conversion accuracy by fully utilizing Braille information. In the conversion process from Braille word strings to Chinese word strings, a pre-trained statistical model is used for decoding to obtain the Chinese character string with the maximum probability. Unlike current research that almost exclusively uses n-gram models, this paper experiments with two statistical models widely used in natural language processing: the n-gram model and the perceptron model, and attempts to fuse the results of the two models to obtain better results.

4.1 Braille-to-Chinese Conversion Algorithm Based on n-gram Model

The n-gram model is currently the most popular statistical language model, widely used in Pinyin input methods, speech recognition, and other technologies. Assuming a sentence S is composed of a word sequence $W_1, W_2, ..., W_n$, the probability of this sentence occurring is:

$$P(S) = P(W_1)P(W_2|W_1)...P(W_n|W_1...W_{n-1})$$

where $P(W_1)$ represents the probability of the first word W_1 occurring, $P(W_2|W_1)$ is the probability of the second word W_2 occurring given the first word W_1, and so on. It is not difficult to see that the probability of each word depends on all preceding words.

However, this method has fatal flaws: computationally, the parameter space is too large to be feasible, and data sparsity is also severe. To solve this problem, we assume that natural language conforms to a Markov process, that is, the probability of a word occurring depends only on the preceding $n-1$ words and is independent of any other words. Under this assumption, the probability of sentence S occurring is expressed as:

$$P(S) = \prod_{i=1}^{n} P(W_i|W_{i-n+1}...W_{i-1})$$

The model for calculating sentence probability based on this assumption is called the n-gram model. In practice, the most commonly used are the bigram model ($n = 2$) and the trigram model ($n = 3$).

Before performing Braille-to-Chinese conversion, it is necessary to train with a large amount of Chinese corpus. Through training, parameters are estimated and a language model is established. The most commonly used simple and effective method in the training process is maximum likelihood estimation, that is:

$$P(W_i|W_{i-n+1}...W_{i-1}) = \frac{C(W_{i-n+1}...W_i)}{C(W_{i-n+1}...W_{i-1})}$$

where $C(\cdot)$ represents the number of times a word sequence appears in the training corpus. After training, a statistical information database is obtained, consisting of data such as the occurrence probability statistics of all words and adjacent word co-occurrence probabilities in the corpus. With this training-formed statistical information database, during the Braille-to-Chinese conversion process, when encountering Braille that corresponds to multiple Chinese character (word) candidates, the data in this statistical information database can be used to sequentially calculate the occurrence probability of each candidate character (word), and finally select the most likely candidate character (word) as the conversion result based on this criterion. It is not difficult to see that this method has a data sparsity problem, that is, word sequence combinations that do not appear in the corpus will have a probability of 0, resulting in the probability of the entire sentence being 0 and causing decoding failure.

Therefore, it is also necessary to smooth the maximum likelihood estimation results so that the probabilities of all word sequence combinations are non-zero. The specific smoothing method used needs to be selected based on the amount of corpus, which will not be elaborated here.

As mentioned above, a word list mapping Braille words to Chinese characters is needed for Braille-to-Chinese conversion, which can be obtained from Braille rules and a Pinyin-Chinese character (word) list.

Assuming a Braille sentence $Y_1Y_2...Y_m$, where Braille word Y_i corresponds to Chinese candidate words $C_{i1}, C_{i2}, ..., C_{ik}$. During conversion, it is first necessary to construct a conversion multi-partite graph: create a node for each Chinese character (word) candidate corresponding to Y_i, and connect all nodes corresponding to adjacent Braille words Y_i and Y_{i+1} pairwise, setting the weight of the formed edges to the conditional probability of the Chinese character (word) corresponding to Y_{i+1} appearing after the Chinese character (word) corresponding to Y_i. For example, the weighted multi-partite graph formed by "Beijing welcomes you" is shown in Figure 6 [Figure 6: see original paper], where each edge is weighted.

After completely constructing the conversion multi-partite graph for a Braille sentence, the one or N Chinese character strings with the maximum probability can be searched on this graph. The most commonly used algorithm in this search is the Viterbi algorithm, which is a method based on dynamic programming. Since this paper adopts a trigram model, directly using the Viterbi algorithm for decoding results in a large decoding space and requires significant time overhead. To reduce the search space and improve decoding efficiency, this paper adopts beam search for decoding, which performs pruning on the search space. The specific approach is to retain only the N best results in each decoding state column as historical information for the next column. Due to pruning, the search process may not obtain the optimal solution, but it is generally believed that the performance loss caused by pruning is small while decoding speed can be greatly improved, making it worthwhile to adopt.

Figure 6. Weighted multi-partite graph formed by converting the Braille sentence "Beijing welcomes you"

4.2 Braille-to-Chinese Conversion Algorithm Based on Perceptron

The perceptron algorithm was introduced into the field of natural language processing in 2002. It is a simple and effective supervised training method. Compared with the n-gram model-based algorithm, the main difference lies in the training process.

The core of the perceptron-based training algorithm is the selection of feature templates. Table 1 shows all feature templates used in this method during the Braille-to-Chinese conversion process in this paper, where C represents a Chinese character (word) in a sentence, the subscript of C represents the position of C relative to the current Chinese character (word) in the sentence (0 represents the current position), and M represents a Braille character (word). As can be seen from the table, each feature vector includes the Chinese character (word) at the current position C_0, which not only considers the context of the sentence but also includes the current Chinese character (word), making the feature scores generated by training dependent on the current Chinese character (word) and thus more reasonable.

Table 1. All feature templates used in the perceptron model during Braille-to-Chinese conversion

C_0
$C_{-1}C_0$
C_0C_1
$C_{-1}C_0C_1$
$C_{-2}C_{-1}C_0$
$C_{-1}C_0C_1C_2$
M_0C_0
$M_{-1}M_0C_{-1}C_0$
$M_0M_1C_0C_1$

After feature templates are selected, training can be conducted sentence by sentence using training samples. The training samples are Braille corpus X and corresponding Chinese corpus Y. Since Braille is a word-segmented text (words are separated by an empty character), both Chinese corpus Y and Braille corpus X have been segmented according to Braille word segmentation principles. During training, one sample is input each time, i.e., a sentence pair (x, y). Let $GEN(x)$ represent the set of all candidate Chinese sentences generated by converting Braille sentence x, and let Φ represent the mapping of each training sample $(x, y) \in X \times Y$ to a feature vector $\Phi(x, y)$. Let $\alpha \in \mathbb{R}^d$ be the parameter vector corresponding to this feature vector, initialized to 0, where d represents the dimension of the vector space, i.e., the number of features per sample. Among all candidate Chinese sentences for a certain x, find $z \in GEN(x)$ such that:

$$z = \arg \max_{y \in GEN(x)} \alpha \cdot \Phi(x, y)$$

where $\alpha \cdot \Phi(x, y)$ represents the inner product of the feature vector $\Phi(x, y)$ and the parameter vector α. If z is not the same as the given y in the sample, the parameter vector needs to be adjusted:

$$\alpha = \alpha + \Phi(x, y) - \Phi(x, z)$$

This formula indicates that the parameter values corresponding to features present in sentence y but not in sentence z are increased, while the parameter values corresponding to features present in sentence z but not in sentence y are decreased. Training each sample sequentially in this manner is called one round of training. For a sample set (corpus), several rounds of training are usually required. The specific number of training rounds needs to be determined based on various factors such as the size of the sample set. After training according to the above principles, all features will have their respective scores, which are stored for use in the decoding process.

The process of converting Braille to Chinese characters using the perceptron-based algorithm is very similar to that using the n-gram model-based algorithm. Both first construct a conversion multi-partite graph based on the Braille sentence to be converted, and then use a decoding algorithm on this graph to find the optimal path. The Chinese sentences formed by the Chinese characters represented by the nodes on these paths are the Chinese sentences converted from the Braille sentence. In this process, the only difference between the two algorithms is the weight of each edge in the conversion multi-partite graph. As mentioned earlier, when performing Braille-to-Chinese conversion using the n-gram model-based algorithm, the weight of each edge in the constructed conversion multi-partite graph is the conditional probability of the adjacent two nodes obtained during training. In contrast, when using the perceptron-based algorithm, the weight of an edge in the conversion multi-partite graph is the sum of the scores of all features constituted by the current node reached by this edge. These feature scores can be obtained from the feature scores obtained during training. Apart from this, the conversion processes of the two algorithms are basically the same.

Compared with the n-gram model-based algorithm, the biggest advantage of the perceptron-based algorithm is that the training process is very flexible. Different feature templates can be formulated based on the sample set to extract features most conducive to conversion, thereby improving accuracy as much as possible.

4.3 Voting Method Combining n-gram Model and Perceptron Algorithms

We trained both algorithms on 28,000 news sentences and tested them on 1,000 news sentences. The experimental results showed that the accuracy rates of the two algorithms were very close, at 97.23% and 97.25% respectively. However, further research found that among the incorrectly converted Chinese characters (words) by both algorithms, about 30% were incorrectly converted by one algorithm but correctly converted by the other. This indicates that these Chinese characters (words) could potentially produce correct results through some method. This method is a voting system that can fuse the results produced by the two algorithms, recalculate scores, and improve conversion accuracy.

We borrowed the idea from the ROVER (Recognizer Output Voting Error Reduction) system developed by the National Institute of Standards and Technology (NIST) for automatic speech recognition [8]: when a Braille sentence is input, voting is performed on the N-Best results (i.e., the top N Chinese character strings with the highest scores) produced by each of the two algorithms, and the one with the highest voting score is selected as the converted Chinese sentence.

Following the method in [8], the occurrence frequency and confidence of Chinese characters (words) are used as the basis for voting. The occurrence frequency $N(w)$ of a Chinese character (word) w refers to the number of times a certain Chinese character (word) w appears in the N-best candidates converted by the n-gram model-based algorithm and the perceptron-based algorithm for a certain Braille character (word) in a Braille sentence, where $0 \leq N(w) \leq 2N$. When calculating the voting score, $N(w)$ represents the normalized occurrence frequency. The confidence of a Chinese character (word) w refers to the score obtained by the current Chinese character (word) during Braille-to-Chinese conversion. However, the two algorithms have different scoring principles and large score ranges. Therefore, before voting, the confidence of each Chinese character (word) in the voting candidates needs to be normalized first, with the normalized confidence represented by $C(w)$.

Then, the score of Chinese character (word) w is calculated using the formula:

$$Score(w) = \lambda_1 N(w) + \lambda_2 C(w)$$

where the weights λ_1 and λ_2 ($0 \leq \lambda_1, \lambda_2 \leq 1$) can be obtained empirically or trained on a development set. During voting, all Chinese characters (words) in the N-best candidates obtained by the two algorithms are scored again according to formula (5). The Chinese character (word) with the highest score is selected as the voting result for this Braille character (word). By sequentially calculating and selecting the Chinese characters (words) converted from all Braille characters (words) in the input sentence, the final output Chinese sentence can be formed.

4.4 Experiments and Results Analysis

To verify the effectiveness of the Braille-to-Chinese conversion algorithm, we conducted a series of experiments. The experiments used People' s Daily corpus, totaling 30,000 sentences. Among them, 28,000 sentences were randomly selected as the training set. Of the remaining 2,000 sentences, 1,000 were used as the development set and 1,000 as the test set. Since Braille corpus is difficult to obtain, the test corpus was automatically segmented and converted to Braille from Chinese sentences. To ensure the authenticity of the corpus, the obtained Braille sentences were appropriately manually corrected according to Braille rules.

The experiments compared the results of the n-gram model-based algorithm (NGRAM), the perceptron-based algorithm (PERC), and the voting method fusing these two algorithms (ROVER). By comparing the Chinese results converted from the 1,000-sentence test set with the standard Chinese documents, the conversion accuracy rate (the ratio of correctly converted characters to total characters) was obtained, as shown in Table 2 .

Table 2. Braille-to-Chinese conversion experimental results
Conversion Accuracy Rate
NGRAM: 97.23%
PERC: 97.25%
ROVER: 97.67%

The experimental results show that using only the n-gram model-based algorithm and using only the perceptron-based algorithm achieve basically the same conversion accuracy, while using the fusion voting method of the two algorithms improves the conversion accuracy to some extent, with the conversion error rate relatively reduced by 16.1%.

5 Summary and Outlook

This paper proposes a Braille dot input system and introduces the design and implementation of its hardware and software components. The system implements a Braille dot input device fully consistent with the daily writing habits of blind users. The device captures user-input dot information through circuit contacts and transmits it to the computer via a USB interface. The Braille dot processing software on the computer processes the dot information and automatically converts it to Chinese characters. Considering the characteristics of Braille, this paper adopts a one-step Braille-to-Chinese conversion algorithm without Pinyin conversion and uses relevant methods from natural language processing and speech recognition for Braille-to-Chinese conversion to obtain more accurate results. Experimental results demonstrate the effectiveness of the proposed method.

In future research, we will further conduct studies targeting the characteristics of Braille, such as appropriately adding commonly used Braille words to the dictionary to train the language model and using a certain amount of Braille corpus when training the language model. At the same time, as an input device, we will further enhance its personalization and usability by adding memory functions, association functions, and voice prompt functions, enabling blind users to input text information more conveniently and quickly.

References:

[1] China Braille Publishing House and Sunshine Software. http://www.gdmx.org.cn/Article/ShowArticle.asp?A
[2] Zhuang Li, Bao Ta, Zhu Xiaoyan. Speech and natural language processing technologies in computer software systems for the blind. Journal of Chinese Information Processing, 2004, 18(4): 72-78
[3] Song Wenlan, Zhu Shuangliu. Development and research of Chinese Braille

computer software. Microcomputer Applications, 2002, 18(5): 15-17
[4] Jiang MH, Zhu XY, Georges G, et al. Braille to print translations for Chinese. Information and Software Technology, 2002, 44: 91-100
[5] Jiang Minghu, Zhu Xiaoyan, Xia Ying, Tan Gang, Bao Ta. Research on Braille translation based on multiple knowledge sources. Journal of Tsinghua University (Science and Technology), 2000, 40(9): 69-73
[6] Bao Ta, Zhu Xiaoyan. Research and implementation of a Braille-to-Chinese conversion system. Computer Engineering, 2004, 20: 45-100
[7] National Standard of the People' s Republic of China. Chinese Braille. GB/T 15720-1995
[8] Fiscus, J.G. A Post-Processing System to Yield Reduced Word Error Rates: Recogniser Output Voting Error Reduction (ROVER). Proc. IEEE ASRU Workshop, pp. 347-352, Santa Barbara

Author Biographies:

Wang Xiangdong: Ph.D., Assistant Researcher, Pervasive Computing Center, Institute of Computing Technology, Chinese Academy of Sciences
Xie Shuhua: Graduate Student, Pervasive Computing Center, Institute of Computing Technology, Chinese Academy of Sciences
Zhang Boning: Graduate Student, Pervasive Computing Center, Institute of Computing Technology, Chinese Academy of Sciences
Wang Chao: Graduate Student, Pervasive Computing Center, Institute of Computing Technology, Chinese Academy of Sciences
Qian Yueliang: Senior Research Professor, Director of Pervasive Computing Center, Institute of Computing Technology, Chinese Academy of Sciences
Lin Shouxun: Ph.D., Researcher, Pervasive Computing Center, Institute of Computing Technology, Chinese Academy of Sciences

Note: Figure translations are in progress. See original paper for figures.

Source: ChinaXiv —Machine translation. Verify with original.