A stroke corresponding scheme for learner's performance evaluation in Chinese character writing

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Abstract: In recent years, learning Chinese has become popular in the world. Chinese characters are an important foundation in the process of learning Chinese. The interactive design of a Chinese character writing system provides the necessary assistance for learners of Chinese who are learning without a qualified instructor. The interactive quality of a Chinese character writing system will depend on the system's ability to evaluate characters of learners' handwriting and give appropriate feedback. The evaluation has three phases: 1) stroke corresponding phase, 2) score calculating phase, and 3) feedback providing phase. This paper focuses on the stroke corresponding phase. This study proposed a grid comparison method to deal with the stroke corresponding problem. We invited 20 subjects to input Chinese characters using a tablet and collected 593 online handwritten Chinese character samples. These sample characters would include some production errors and the stroke sequences might be different from the model stroke sequence. According to the results of this study, the method is still inadequate due to writing production errors and writing position offsets by learners. In future works, our research will be based on the grid comparison method to enhance the stroke corresponding accuracy for the interactive design of a Chinese character writing system.

Key words: Grid comparison method, Stroke corresponding, Chinese character writing evaluation

1. Introduction

In recent years, learning Chinese has become popular in the world. More and More foreign learners have started to learn Chinese. Chinese characters are an important foundation in the process of learning Chinese, which are logographs composed of strokes in a particular sequence. Foreign learners are not familiar with the rules of writing Chinese characters, so each Chinese character is like a picture for them, but they are difficult to remember. For foreign learners to more easily remember how to write Chinese characters, they must understand the pronunciation, meaning, components, and stroke order of these Chinese characters. The interactive design of a Chinese character writing system provides the necessary assistance for learners of Chinese who are learning without a qualified instructor.

We investigated 24 Chinese character learning websites [10], and these helped us to understand the problems associated with these Chinese character learning systems. One usability testing format for Chinese character writing systems is used by the Ministry of Education's E-innovation School and E-bag Experimental Teaching Program in Taiwan [9]. When technology is used to assist learning Chinese character writing, the interactive quality of a Chinese character writing system will depend on the system's ability to evaluate characters of learners' handwriting and give appropriate feedback. Currently Chinese character learning systems are weak in writing practice, and in fact, most do not provide this function. Some providers have failed to provide a good interactive mode, that is, a mode that after writing practice can evaluate handwriting. With such a mode learners can know the results, including scores, mistakes of writing, and how to improve [10].

Handwriting education applications are different from handwriting recognition. One reason is that the system knows the Chinese characters from writing practice in hand-writing education applications, but the system must to guess the written Chinese character in the handwriting recognition, because it is an unknown state. In handwriting education applications research, it contains a learning writing mode [3], a teaching system [6], the error detection of writing results [4], and the score of writing results [2, 8].

In the research of [4], attributed relational graph (ARG) matching is applied to locate the stroke production errors and stroke sequence error. Then post processing is used to find out the spatial relationship errors between strokes. Although they proved the error rate of the proposed method is lower than others, it still does not point out clearly under what circumstances problems will arise, or the proportion of correct and error types of verification data.

During the writing process, users may produce stroke sequence errors and/or stroke production errors [5]. We can classify the mistake types that learners commonly make, but it is difficult to predict what will actually happen. The biggest challenge for Chinese character writing systems is how to make stroke corresponding between handwriting and model Chinese characters, and be able to point out the learners' mistakes. The evaluation has three phases: 1) stroke corresponding phase, 2) score calculating phase, and 3) feedback providing phase. This paper focuses on the stroke corresponding phase.

The remainder of the paper is organized as follows: In Section II, our proposed method is described. Then, the experiments and results are discussed in Section III. Finally, Section IV is devoted to the conclusion and future work.

2. The Proposed Method

The writing modes of currently used Chinese character learning systems can be divided into two categories: with tracing and without tracing. Furthermore, those with tracing can be subdivided into tracing with whole characters and tracing stroke by stroke. Tracing provides writing guidelines for learners, so in this case, the most common mistakes are stroke sequence errors. When learners write Chinese characters without tracing, stroke sequence errors, stroke production errors, and stroke relationship errors are more likely to occur. As mentioned above, the evaluation of Chinese character writing systems has three phases: 1) stroke corresponding phase, 2) score calculating phase, and 3) feedback providing phase. This paper focuses on the stroke corresponding phase.

After the system records the writing process of the character, the handwriting path will correspond with a model character. This study proposed a grid comparison method to deal with the stroke corresponding problem. The grid pattern underlies the writing field for references in locating the beginning phase, the movement phase, and the ending phase of a stroke and its relationship with other strokes and character components, such as quadruple cross grid, diagonal grid and cross grid. The process of stroke corresponding can be divided into three steps: 1) smoothing; 2) analysis of the turning point; and 3) handwriting strokes corresponding with model strokes. These processes are described below.

2.1 Smoothing

Data for handwriting Chinese characters has coordinates at intervals of 10 ms, and they will as a stroke from the starting point, the movement, and the end point. These intervals enable the reproduction of the writing process (the movement of the pen point) of the character. Due to learner's writing speed differences, one stroke has its own coordinate nodes with different quantities. After the system records learner's handwriting, the pre-process of smoothing can remove excess nodes, reducing the complexity degree of the corresponding process.

Fig. 1(a) shows a stroke that has been constituted by several coordinates of nodes. The system accesses the coordinate positions of the P1 and P2 nodes, and calculates the length of P1 to P2, and if the length is less than the threshold, then removes the P2 node, and checks the length of the P1 to P3 nodes whether less than the threshold or not. If the result is false, the P3 node serves as a new start point and the length of the P3 to P4 nodes are checked. Fig. 1(b) shows the strokes after smoothing, and we can find the nodes that too close so that they have been removed. Fig. 2 shows the smoothing process of an actual Chinese character. In the figure, the left nodes still faithfully respond to the Chinese character stroke characteristics.

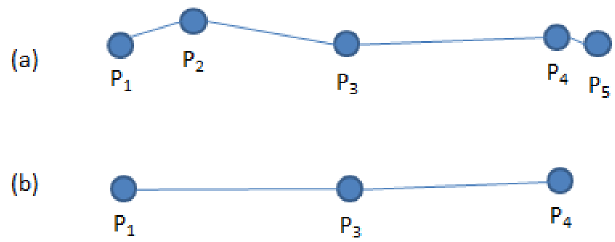


Fig. 1 (a) A stroke that is constituted by several coordinates of nodes. (b) The stroke after smoothing.

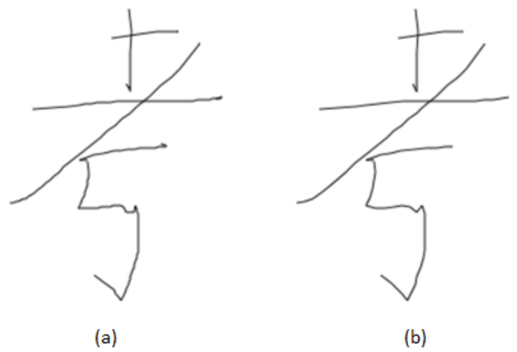


Fig.2 (a) The original Chinese character "考". (b) The result after smoothing process.

2.2 Analysis of the turning point

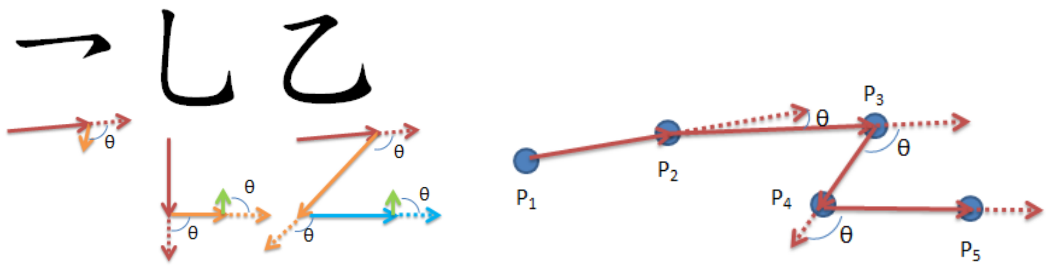
Chinese characters are composed of many basic strokes (Fig. 3(a)), and the strokes are rendered by horizontal stroke, vertical stroke, left oblique stroke and right oblique stroke. Several basic strokes can be combined into a compound stroke, and the contact of two strokes is the turning point (Fig. 3(b)).

A compound stroke has three features: direction, angle and proportion. It means the writing direction of a compound stroke must change, and the angle is greater than the threshold. Moreover, the writing stroke's length after changing direction is greater than the threshold. If it does not satisfy these conditions, the compound stroke is not established. When the direction of the stroke changes, then its angle is less than the threshold and there may be some unintentional jittering. When the proportion of the basic stroke length, before and after turning point, is less than the threshold, there may be some unintentional moving. This situation is particularly likely to occur at the start and end of a stroke.

Fig. 4(b) shows a compound stroke as defined in Table 1, where, $\overrightarrow{P1P2}$ will be the basis of judgment, the stroke vector code value would get one point, and then P2 node serves as the origin, and then we calculate the $\overrightarrow{P2P3}$ stroke vector code and compare it with the highest value of the stroke vector code. If the stroke vector code is the same, it means the same direction of $\overrightarrow{P1P2}$ and $\overrightarrow{P2P3}$, then the P2 node will not be the turning point, so it follows to compare with $\overrightarrow{P3P4}$.

If the stroke vector code is different (such as $\overrightarrow{P2P3}$ and $\overrightarrow{P3P4}$), then we compare the change in the angle value of the two segments to see whether it is greater than the threshold or not. If the result is true, we continue comparing the proportions of the two segments to see whether they are greater than the threshold or not. If the result is true, then P3 serves as a turning point, and the system restarts the match. Based on the judgments made about the turning points, the system can determine the handwritten Chinese character. It is based on how many turnings there are for each stroke, and a stroke with more than one turning point will be defined as a compound stroke, while the others are basic strokes.

Fig. 3 (a) Basic stroke. (b) Compound stroke.



(a) (b)

Fig. 4 (a) Characteristics of compound strokes. (b) Description of judgment process for compound strokes.

Table 1. Strokes vector defined.

Code	Stroke direction	Angle
1	→	10°< θ <-10°
2	↗	10°< θ <80°
3	↑	80°< θ <100°
4	↖	100°< θ <170°
5	←	170°< θ <190°
6	↙	190°< θ <260°
7	↓	260°< θ <280°
8	↘	280°< θ <350°

2.3 Strokes corresponding

The stroke direction as shown in Table 1 is rendered by horizontal stroke, vertical stroke, left oblique stroke and right oblique stroke. Unless a learner's handwriting produces the correct stroke sequence, and there are no production errors, such missing, extra, concatenated or broken strokes (Fig. 5), the system cannot use the stroke sequence mapping method. Fig. 6 shows the stroke sequence of handwriting that is different from a model Chinese character.

Then based on the grid pattern that assists learners to write, such as when making a quadruple cross grid, diagonal grid and cross grid, the grid is divided into different size areas (Fig. 7(a)). The system will extract the positional features based on the three points of each stroke from the model Chinese character and the handwritten Chinese character: the beginning point, the middle point and the end point (Fig. 7(b)). Then we use the concept of hierarchical processing, and follow the sequences to extract the horizontal, vertical, left oblique, right oblique, and compound strokes of the model Chinese character and the handwritten Chinese character to do stroke corresponding. Fig. 8 shows all horizontal strokes of the model Chinese character and the handwritten Chinese character, and there are a total of 16 correspondence relationships. We checked the three points of each stroke pair ($Model_i$, $User_j$), and a stroke pair ($Model_i$, $User_j$) would get one point if the point was the same as on the grid. This process is repeated to compare these 16 correspondence relationships for each grid, and finally the highest point of the stroke pair ($Model_i$, $User_j$) will be select the corresponding stroke.

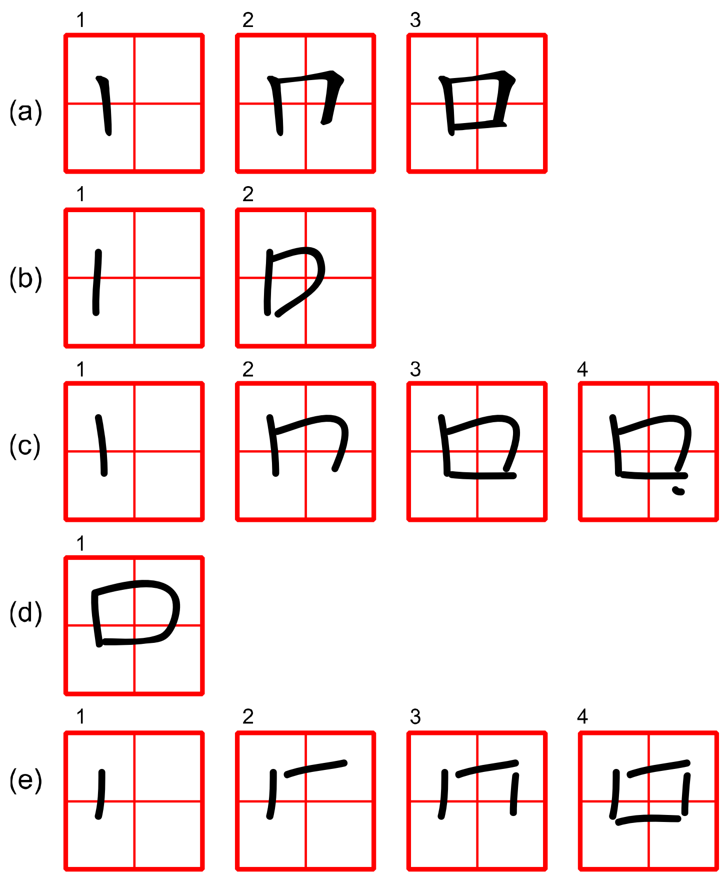


Fig. 5 (a) The standard stroke sequence of a model Chinese character "口". (b) The third stroke was missed. (c)The Fourth stroke was extra stroke. (d) All strokes were concatenated to one stroke. (e) The second stroke was broken to two strokes.

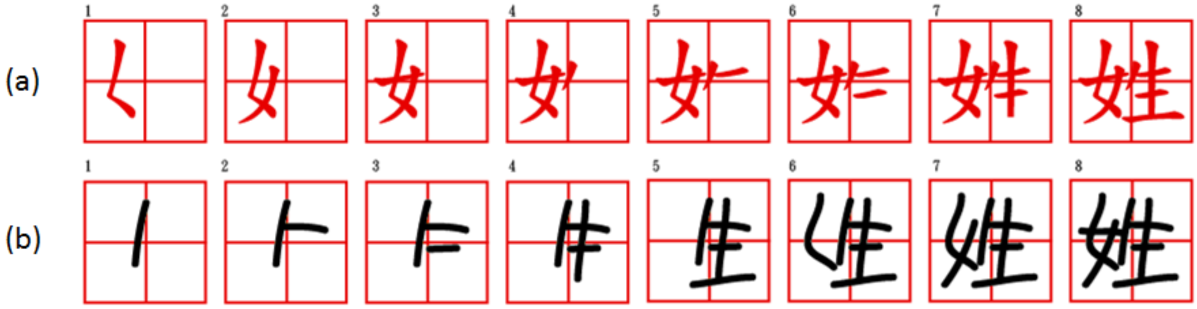
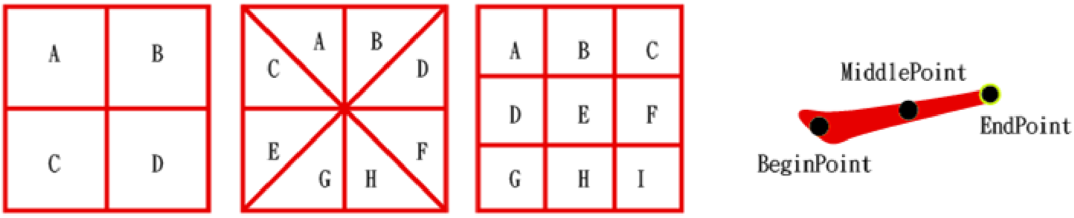
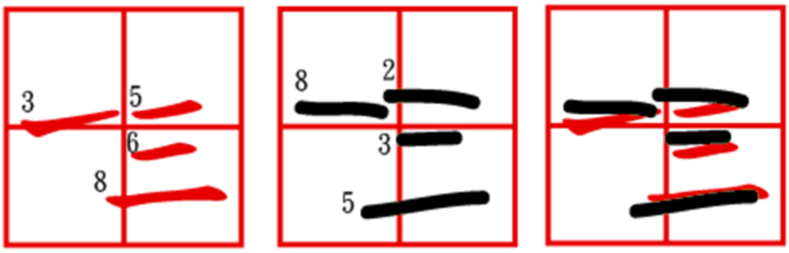


Fig. 6 (a) The standard stroke sequence of a model Chinese character “姓”. (b) The handwritten stroke sequence.



(a) (b)

Fig. 7 (a) From left to right, a quadruple cross, diagonal and cross grid illustrated. (b) The three points of comparison for a stroke.



(a) (b) (c)

Fig. 8 (a) The horizontal strokes of a model Chinese character “姓”. (b) The horizontal strokes of a handwritten Chinese character “姓”. (c) The horizontal strokes overlapping the model and handwritten Chinese character.

3. Experiment and Results

We invited 20 subjects to input Chinese characters with Lenovo X220t tablet PC. They were asked to write each character with tracing and non-tracing, the tracing is an outline of the character to be written and mapped on the grid in the writing field, and they could write each character more than one time. 11of the 20 subjects were foreigner learners of Chinese at the basic level. The remaining 9 participants were university students whose native language was Chinese. We collected online handwritten data by two groups, but this paper discusses the accuracy of stroke corresponding with grid comparison method rather than the group difference in handwriting. During the time that the subjects were writing the Chinese characters with the tablet PC, the moving speed and position of the writing was recorded. Afterwards, the system could reproduce the writing process.

The sample Chinese characters were randomly selected from a set of 593 Chinese [1]. The number of strokes of these test characters varies from 3 (very simple characters) to 23 (quite complicated characters), and covers a variety of features of Chinese character structure. Before subjects started the experiment, we did not any Chinese character writing demonstration. The subjects needed to complete the writing of the Chinese characters based on their own intuition. Thus, the collection sample data contains a wide variety of production errors, such missing, extra, concatenated or broken strokes, as well as stroke sequence errors. These errors have not removed from the collection sample data set. We collected a total of 593 online handwritten Chinese character samples as our data set, and there were a total of 5065 strokes. We have manually inspected each handwritten sample. Then, we categorized the error type and correct stroke sequence for each Chinese character sample. This was done to obtain the correct writing information of online handwritten Chinese characters. Then we applied the grid comparison method to identify the stroke pairs, and compared the results with the correct writing information. This was done to evaluate the accuracy of our proposed method.

Table 2 shows the experimental sample data and the corresponding accuracy of different number of Chinese character stroke. The analysis results show that when a Chinese character has more strokes, it means there is more complexity. In these cases, the probability for errors increases. In the experimental sample data set, the two types of most frequently made errors are the following: stroke sequence errors and concatenated stroke errors. Each handwritten sample may have a variety of errors. Table 3 shows the accuracy of different groups, include tracing and non-tracing, correct stroke sequence and stroke sequence error, concatenated stroke error and no concatenated stroke error, and no any production errors. We can find the accuracy with tracing is higher than without tracing, and the accuracy of no stroke sequence errors is higher than with stroke sequence errors, and the accuracy of no concatenated stroke errors is higher than with concatenated stroke errors. In other words, any production error will reduce the accuracy.

Table 2 The experimental sample data and the accuracy for different numbers of strokes.

Stroke number	Sample of Chinese character	Total sample Chinese character	Chinese character of corresponding correct	Corresponding accuracy
3	土巳己已	75	69	92.0%
4	午天牛王	72	69	95.8%
5	右	18	18	100.0%
6	好米考	62	51	82.3%
7	困	23	19	82.6%
8	姓法非	78	44	56.4%
9	飛	15	10	66.7%
10	哥病茶送	92	63	68.5%
11	做產	57	33	57.9%
12	單	26	14	53.9%
14	需	13	8	61.5%
16	嘴錢	31	4	12.9%
18	舊	16	6	37.5%
23	變	15	2	13.3%
Total		593	410	69.1%

Table 3 Accuracy of different groups.

Group	Total sample Chinese character	Chinese character of corresponding correct	Corresponding accuracy
Non-tracing	396	237	59.9%
tracing	197	173	87.8%
Stroke sequence error	235	118	50.2%
Correct stroke sequence	358	292	81.6%
concatenated stroke error	81	23	28.4%
No concatenated stroke error	512	387	75.6%
Completely correct	350	290	82.9%

Some failed cases have been investigated. These cases are due to the writing position deviating from the expected intermediate position, which leads to corresponding errors. The reason is that the grid comparison method assumes that the subject will write to follow the displayed position of the model Chinese character. However, when we use the grid to correspond the process, it is absolute position compare, so if the subjects were not writing to follow the position of the display of the model Chinese character, it is highly probable that there will be corresponding stroke errors.

4. Conclusion and Future Works

In this paper, we proposed a stroke corresponding scheme to evaluate learners' Chinese character writing performance. It looked at the writers' strokes, individually, in various ways as follows: from horizontal, vertical, left oblique, right oblique, and compound strokes. The above was done to determine the stroke pairing relationship of the model strokes and handwriting. The method is the basis of the interactive design of the Chinese character writing system, and the system evaluates the writing results of learners and provides feedback, such the scores and error messages. The grid comparison method currently proposed still has problems with accuracy. One reason for this is that the writing production errors and the writing position cannot be coordinated well with by the system . In future work, we will base our research on the grid comparison method to consider more characteristics of Chinese characters, and to enhance the stroke corresponding accuracy to improve it for the interactive design of Chinese character writing system.

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