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Visualizing Results of Digital Ink Stroke Matching in Chinese Based on Multi-Perceived Hierarchy

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Abstract. Stroke matching is the mainstream method for evaluating the quality of Chinese characters. Visualization of matched strokes is necessary to evaluate the validity of the matching method and the prerequisite for manual correction. To reduce the cognitive burden, visualization based on multi-perceived hierarchy is proposed. According to the features of matched strokes and information contained, the approach proposes a multi-perceive hierarchy composed of colors, graphic symbols and number indexes. After experimental verification, the visualization is effective in operational complexity and efficiency.

1. Introduction

In the field of Chinese character intelligent research, many scholars have been exploring in recent years [1–3], and developed some can be applied to the actual teaching system of Chinese characters teaching [4–8], but whether from the implementation method or teaching performance, the effect is slightly less. In general, the computer system for the basic process of teaching Chinese characters for the user (especially studying Chinese as the second language) using handwriting input device to enter the Chinese characters into the computer system, the system firstly recognizes the handwriting character to the text character and then find the corresponding template character in the template library. After extracting and matching strokes of the writing and the template character, according to the matching results, writing errors are classified and recognized. Finally, writing feedback is given. In the process of intelligent processing of digital ink Chinese characters, the system needs to classify the writing errors according to the correct stroke matching results. In the case that there are many writing errors in the written Chinese characters of the foreign students, it is difficult to completely and correctly match all the strokes of all the Chinese character data. Therefore, a manual method is needed to correct the stroke matching result. Adopting human-computer interaction correction, visualization of the stroke matching results is needed. The accurate and intuitive visualization can improve the efficiency of human-computer interaction correction. Therefore, this paper presents a multi-perceived hierarchical approach to visualize the result of handwriting Chinese characters' stroke matching.

The research on visualization of matching stroke results is insufficient at present. According to different objects to utilized, there are three kinds of approaches to visualize. The first common way is the color approach [9]. However, when the number of strokes increasing, the color of strokes is repeatedly rendered that produces more cognitive burdens. In addition, only colors cannot fully express the information of extracted results, such as order information of strokes. The second kind is to visualize strokes by stroke indexes. Hu [3] uses template strokes index (a, b, c...) referring to sample strokes by index(1, 2, 3...) that is effective way to visualize matching result with few strokes. While number of strokes increases, it is also confusing. The last kind approach is proposed to visualize



extracted Chinese characters [10] which applies graphics like rectangles or convex hulls as bounding box. This approach can distinguish the boundary between two visualized objects; but it would cause interface misperception when rendering repeatedly.

In this paper, the approach of visualize the results of matched strokes is based on multi-perceived hierarchy to reduce the cognitive burden. The rest of this paper is organized as follows: Section 2 presents a multi-perceived hierarchy. Section 3 proposes the visualization approach. Sect. 4 describes the experimental results and analysis. Sect. 5 draws conclusion from the experiments.

2. Multi-perceived Hierarchy

Visualization of stroke matching results is the premise of human-computer interaction correction. An intuitive and accurate visualization can effectively reduce the cognitive burden of operators and improve the working efficiency of operations. According to the characteristics of the visualized object and the need of the correction operation, this paper presents a multi-perceived hierarchical approach to visually express the matching results of the digital ink Chinese strokes.

Rendering different strokes in Chinese characters in different colors is the most direct visualization, that is illustrated in the study of the cognitive performance of hue, brightness and saturation by Wu [11]. It is said that hue can affect cognitive speed and visual preference, but the impact is less than brightness and saturation. Therefore, according to the color psychology three attributes (hue, lightness, saturation) in the color perception distance proposed by Munsell, the proposed visualization in this paper presents different colors as the first perception level to render adjacent strokes.

Graphics are applied to visually represent pen direction information as the second perception level. The orientation of strokes, that is, the direction of Chinese strokes, has basic rules of writing. The error of orientation is one of the mistakes that students often encounter. After stroke matching process, the orientation information of each stroke needs to be visualized, so that the essential information of the stroke can be better understood when the human-computer interaction is corrected. The circle graphic is used to illustrate the orientation information of the stroke visually, wherein black indicates the start and white indicates the end.

Stroke order is the order in which Chinese strokes are handwritten, and there are also basic rules. Due to the large difference between the handwriting characters of the non-Chinese character culture circle, the stroke order error is also a common writing mistake for the foreign students at the primary level. In this paper, the serial index is used to represent the stroke order information of Chinese characters as the third perception level. According to the writing rules of Chinese characters, “from left to right, from top to bottom”, the stroke order number is placed in the upper left corner of the starting point of the stroke to avoid overlapping with the others. Rendering color is the same with the stroke of which it represents, to reduce the cognitive burden caused by adjacent strokes.

3. Visualization of Stroke Matching Results

3.1. Colours

In order to visualize adjacent strokes more intuitively, the color perception level is proposed. The color perception level is the difference between the significant differences of colors in the psychological perception, forming different perceptual depths. HSB (hue, saturation, brightness) coding is adopted to describe the color perception distance of different strokes. By increasing the color perception distance between adjacent strokes, it delivers different color perception levels, thereby reducing the cognitive burden between adjacent strokes and improving cognitive efficiency.

The specific steps are that: First, according to the number of template strokes Num, the weight W in the HSB encoding is determined, which is $180/\text{Num}$; then, the stroke sequence ($i = 0, 1, 2 \dots \text{Num}-1$) is traversed; when i is even, the stroke color is the average distribution of the hue in HSB circle; When i is odd, the stroke color is rendered in the threshold hue value, and both the brightness and saturation are half values. The specific process is shown in Fig. 1.

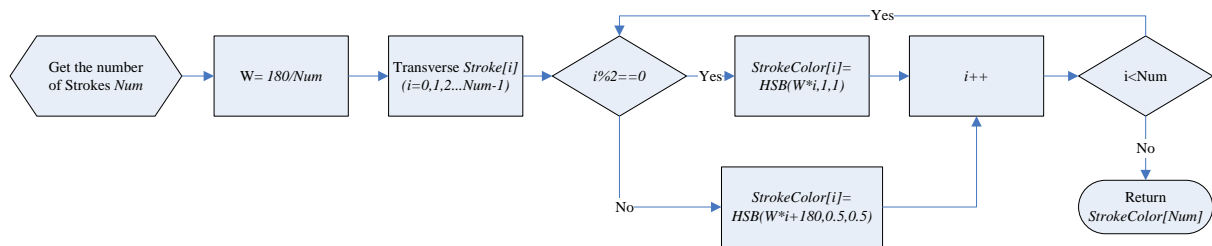


Figure 1. Visualization of the color perception level.

The illustration is shown in Fig. 2, where (a)(b) is the average of hue for each stroke, (c)(d) is the inverted value of hue between adjacent strokes, and (e)(f) is the proposed approach. Fig. 2 is a step-by-step demonstration of the generation process of the color perception level. In Figure (a)(b), the value of hue is divided by the number of strokes, rendering each stroke. So that each stroke is distinguished by different color; but the colors of adjacent strokes are also adjacent in the chromatogram, which makes not much difference between adjacent strokes. In order to solve this problem, in (c)(d), the values of hue between adjacent strokes are inversed in the chromatogram. Furthermore, to improve the cognitive efficiency, in (e)(f), the adjacent strokes of the method not only invert the hue value, but also change the brightness and saturation, so that different color perception levels are generated, thereby further reducing the cognitive burden.

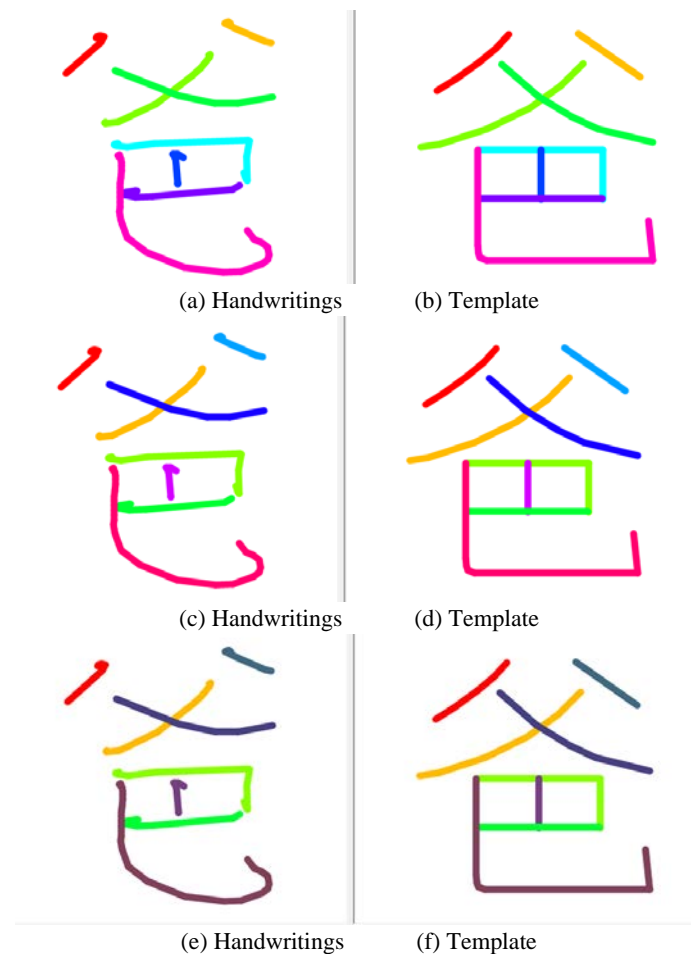


Figure 2. Demonstration of visualization of the color perception level.

3.2. Graphics

The orientation information of strokes is visually represented, which makes operators better understand the original handwriting information of strokes in the Chinese character during the human-computer interaction correction, and facilitate the accurate correction operation. Since a stroke can be seen as a feature of a continuous line segment, the visualization of its orientation information could adopt a way of distinguishing the start and end points. In this paper, the circle in the stroke width is used to render the start and end points of the stroke, the coordinate position of which is visualized to indicate its orientation information. The black circle indicates the starting point of the stroke, and the white indicates the end. The choice of black and white is to avoid duplication with the drawing color of the stroke itself, resulting in cognitive misunderstanding. The specific demonstration is shown in Fig. 3.

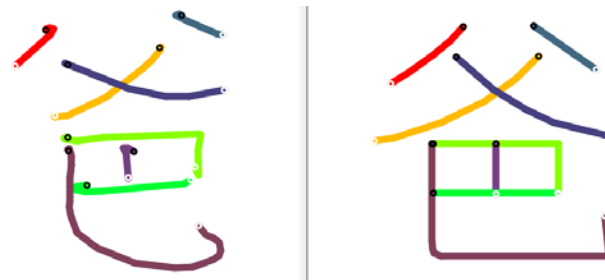


Figure 3. Demonstration of visualization of the graphics perception level.

3.3. Index

The visual representation of the order information helps to accurately recognize the handwriting stroke information when the human-computer interaction correction is performed, which is beneficial to alleviating the cognitive burden of the correction operation. In this paper, according to the writing rules of Chinese characters, “from left to right, from top to bottom”, the digit order index is adopted to indicate the stroke order information of the Chinese character based on the following rules:

- Position: The stroke order index is rendered at the upper left corner of the bounding box of the starting point of the stroke to avoid overlapping with the stroke. At the same time, a horizontal displacement of the stroke width is spaced between adjacent digits to avoid overlapping, as shown in Fig. 4.



Figure 4. Demonstration of displacement.

- Colors: It is the same as the color drawn by the corresponding strokes, which alleviates the cognitive burden caused by adjacent strokes. The specific effect is shown in Fig. 5.
- Font Size: 1.5 times of the width of the rendering stroke is adopted. It is neither too small that causes a cognitive burden, nor too big interacted with other strokes.

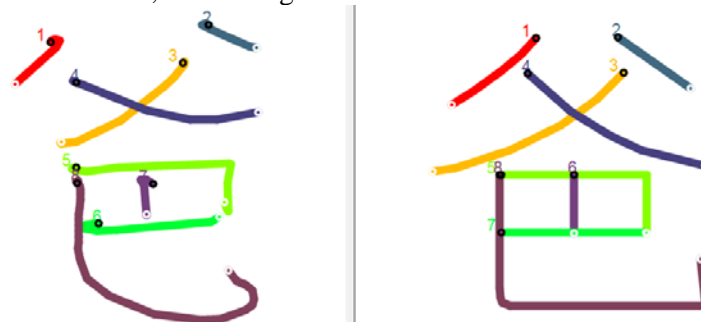


Figure 5. Demonstration of visualization of the index perception level.

4. Experimental Results

In this paper, about 1000 Chinese characters were extracted from more than 10,000 digital ink Chinese characters containing 515 Chinese character kinds. The program was tested on a PC with Inter Corei7 processor and 16G memory, and written by C#. In order to verify the effectiveness of the proposed approach, two quantitative experiments were designed.

Experiments on different types of stroke matching results, through a single hue SR, hue equalization AC (as shown in Fig. 2 (a) (b)), hue inverted RC (as shown in Fig. 2 (c) (d)) and the proposed approach VC (as shown in Fig. 2 (e)(f)) compared the accuracy [12] which is the ratio that all strokes in Chinese characters can be accurately distinguished (shown in Table 1) and the stroke cognitive time TC as shown in Table 2.

Table 1. Comparison of the Accuracy.

| Matching type | SC | AC | RC | VC |
|---------------|--------|--------|--------|--------|
| One to One | 100.0% | 100.0% | 100.0% | 100.0% |
| One to Multi | 77.78% | 88.89% | 100.0% | 100.0% |
| Multi to One | 71.43% | 92.86% | 100.0% | 100.0% |
| One to Null | 100.0% | 100.0% | 100.0% | 100.0% |
| Sub to Null | 72.00% | 92.86% | 100.0% | 100.0% |

Table 2. Comparison of cognitive time (seconds).

| Matching type | SC | AC | RC | VC |
|---------------|------|------|------|------|
| One to One | 0.86 | 0.71 | 0.71 | 0.71 |
| One to Multi | 0.89 | 0.78 | 0.78 | 0.78 |
| Multi to One | 0.86 | 0.79 | 0.79 | 0.79 |
| One to Null | 0.75 | 0.63 | 0.63 | 0.63 |
| Sub to Null | 0.89 | 0.79 | 0.79 | 0.79 |

It can be seen from the experimental results that the accuracy of the distinction between "one to one" and "one to null" are 100%, and the accuracy of other types of discrimination ranges from SC to VC. The proposed approach is up to 100%. From the cognitive time point of view, from SC to AC, and then to RC, the time of the approach in this paper is gradually reduced, and the "one to null" has the least time.

After the analysis of the experimental results, the "one to one" type has a fair distinction because of its writing quality and coordination to the template. "one to null" type is often beyond the mean value of the extra stroke due to the particularity of itself, that is easier to recognize and the cognitive time is shorter. From the comparison of cognitive time, of all four kinds of different visualizations, the proposed approach is the most ideal for multi-perceived hierarchy.

5. Conclusion

In this paper, a visualization approach for stroke matching results is proposed. Through the use of color perception level, graphic symbols and digital serial index composed as multi-perceived hierarchy, the cognitive burden of operators during correction is effectively reduced while accurately expressing the stroke matching result, stroke order and orientation relationship. The accuracy and efficiency of different visualization methods are compared by grouping experiments of different types stroke matching results. The experimental results show that the proposed method is the most effective.

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