Comparative Study of Stroke Correspondence Search Algorithms for Online Handwriting Recognition

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1. Introduction

Various stroke correspondence algorithms are proposed with application to stroke order free handwriting recognition. A comparative study for clarifying the relative superiority of algorithms are desired. As a first stage of the study, two algorithms —cube search method (CS) [1] and a method based on stable marriage (SM) [2][3]—are experimentally compared, mainly in regard of recognition accuracy.

2. Algorithms studied

〈2.1〉 Basic principle

We define the input character as a stroke sequence,

$$A = A_1 A_2 \cdots A_k \cdots A_N, \quad (1)$$

where the kth stroke A_k is the time sequence representation of local feature (for example, moving direction and coordinate of pen point.).

Similarly, we define the reference pattern as,

$$B = B_1 B_2 \cdots B_l \cdots B_N, \quad (2)$$

We use $\delta(k,l)=D(A_k, B_l)$, which is called stroke distance and is calculated by utilizing dynamic programming (DP) matching, to express the dissimilarity measure between stroke A_k and B_l. The distance between characters A and B is the summation of $\delta(k,l(k))$, where $l(k)$ is a unique on to-mapping(correspondence) from A_k to $B_{l(k)}$.

The problem is how to get the optimal correspondence $l(k)$. In this paper, we compare two algorithms described below.

〈2.2〉 Cube search (CS) [1]

In this algorithm, the distance between characters A and B is the minimum value of the summation of $\delta(k,l)$ and it is formulated as,

$$D(A,B) = \min_{\{l(k)\}} \left[\sum_{k=1}^{N} \delta(k, l(k)) \right] \quad (3)$$

An N-dimensional cube graph is used to impose uniqueness on the mapping $l(k)$. An efficient DP algorithm searches for the best path on the cube graph.

〈2.3〉 Stable marriage (SM) [2]

Respecting everyone's preferences, SM algorithm is to find the most stable one-to-one matching between two groups (for example, input strokes and reference strokes) with equal number. As for the stroke correspondence problem, a more natural way to express the preferences is to have each stroke list in the order of value of $\delta(k,l)$. Clearly, these preferences often conflict. The sense of the stable matching is to remove unstable couples one at a time, until some stroke finds a spouse stroke which can match the stroke stably [3].

3. Experiment and discussion

As the test patterns, a total of 18041 stroke order free Kyouiku kanji (882 classes) handwritten characters, with no stroke connection, was used. Table 1 shows the experimental results including recognition rates, recognition times, and correspondence search times. Fig. 1 shows the examples of misrecognition.

It may be said that the high accuracy of CS comes from the fact that it is based on the well defined objective function (3), and the global optimum solution is achieved by DP.

4. Conclusion

We discussed two kinds of one-to-one stroke correspondence search algorithms of CS and SM, and compared their features by experiments. As for the recognition accuracy, relative superiority of CS is established.

References

[1] H. Sakoe, J. Shin, "A Stroke Order Search Algorithm for Online Character Recognition," Research Reports on Information Science and Electrical Engineering of Kyushu University, Vol.2, No.1, pp.99-104, 1997.

[2] T. Yokota et al., "An On-line Cuneiform Modeled Handwritten Japanese Character Recognition Method Free from Both the Number and Order of Character Strokes," IPSJ Journal, Vol.44, No.3, pp.980-990, 2003.

[3] R. Sedgewick, "Algorithms," Addison-Wesley, second edition, pp.499-504, 1988.

Table 1 Experimental results

algorithm	CS	SM
Recog. rate(%)	99.10	97.58
Recog. time/per character(*s*)	0.41	0.31
Search time/per character(*ms*)	102.4	2.2

夫→五 草→革 称→株 利→判

(a)

賃→資 児→見 営→覚 働→勧

(b)

Fig. 1 Misrecognition examples. (a) and (b) show the samples which were recognized correctly with CS but misrecognized with SM and vice versa, respectively.