On-line Recognition of Hand-written Characters by General Contour Vector Sequence Method

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1. Introduction:

Many methods of character recognition are dependent on font or type of character, which may be insufficient to the practical applications in this country. When we read characters, we will pay attention to the curvature of strokes rather than to the direction of them. The method in this paper is to transform the shape of the stroke to a graph of the direction of the tangent to the stroke and to compare the graph with the help of philosophy of dynamic programming. This method would be applicable to almost every type of characters, and attained fairly good recognition score. This paper describes the principles of the shape analysis of strokes by this method, the analysis of positional relations between strokes and the recognition procedures.

2. Abstruction of characteristics in hand-written characters:

It is most difficult to select the characteristic parameters when there is a lot of dispersion in one pattern like hand-written characters. A character has two components; the shape of the strokes and the geometrical relationship between the strokes. In this paper, the shape of the stroke is represented by the vector sequence of the tangent to the stroke; and the geometrical relationship is defined as the direction between the center of each successive stroke.

When we analyze the shape, we must absorb the individual differences. There are two types of individual differences; (1) partial difference of strokes, such as starting or ending clicks and corners. To recognize these different shapes as the same pattern in a character, each stroke should be identified globally neglecting partial differences. However, there are some cases that need partial differentiation; for example, 「し」 and 「レ」, which would be distinguished by the existence of the corner. (2) Sometimes patterns which are composed of different strokes are interpreted as the same character. One possible way to solve this problem, is to increase the items of the pattern dictionary paying the cost of the time to search the dictionary. We have

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introduced the similarity of strokes and compared the shapes of characters as the combination of the strokes.

3. Shape analysis of a stroke:

This chapter describes the General Contour Vector Sequence (GCVS) method which can analyze the shape of strokes both globally and partially. The GCVS can also reserve the original information for the partial identification.

3.1 Contour Vector:

When we observe strokes, we pay attention to the change of the direction rather than to the direction itself. So, first the input x-y coordinate sequences are transformed to the direction sequences of the contour vectors. And the vector is encoded one of twenty-four possible directions as shown in figure 1. The range of value of the vector direction is $[-\infty,+\infty]$ to include the information of rotational angle.

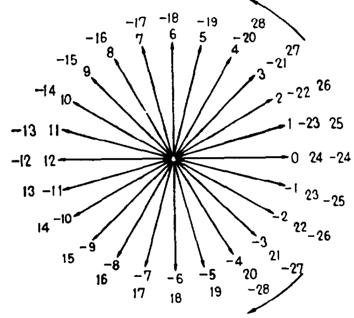


Fig. 1 Code for stroke direction

3.2 Selection of the vector sequence:

The sequence of the coded vectors is called General Contour Vector Sequence(GCVS) and defined using the following rules: (1) The initial value of the direction of the contour vector is determined in the range between -11 and 12. (2) Other values of the direction are determined so as to minimize the difference of the two successive contour vectors.

The GCVS reserves the original information about the shape of the stroke precisely; such as the corner, the direction of rotation, the degree of rotation, the length and the curvature.

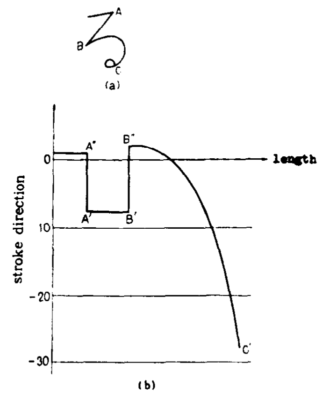


Fig. 2 An example of GCVS curve

3.3 Encoding of GCVS:

The length of GCVS curves differ from curve to curve. It is rather convenient to normalize length for the purpose of shape comparison or recognition. Experimentally, more than one characteristic point does not appear within the vicinity of the ten percent length of the strokes. So, eleven points are sampled at nearly equal spacing from GCVS. If the GCVS curve has an extreme value in any section, the nearest sampled point is replaced by this extreme value.

3.4 Distance of two GCVS:

The distance of two GCVS's could be defined as:

$$\int |G_1(x)-G_2(x)|\,dx \qquad (1) \qquad\qquad \min_v \int |G_1(t)-G_2(v(t))|\,dt \qquad (2)$$

where G_1, G_2 are two GCVS's and v is increasing function in t. Strokes usually have some fluctuation both in the direction and in the length. But if this fluctuation is always permitted, different patterns are sometimes recognized as the same. The expression (1) show a big error when the position of the discontinuous points in two GCVS curves do not come close. While the expression (2) also has two defects: a) computing time is big. b) Sometimes G_1 is only partially matched with G_2. So it is reasonable that the expression (2) should be used to match the discontinuous points of GCVS curves. This means that v(t) in expression (2) is selected so that the corners match each other and the error function become minimized. The detailed algorithm is shown in figure 3. We call this algorithm the GCVS method. Figure 4 shows examples of how the GCVS method works.

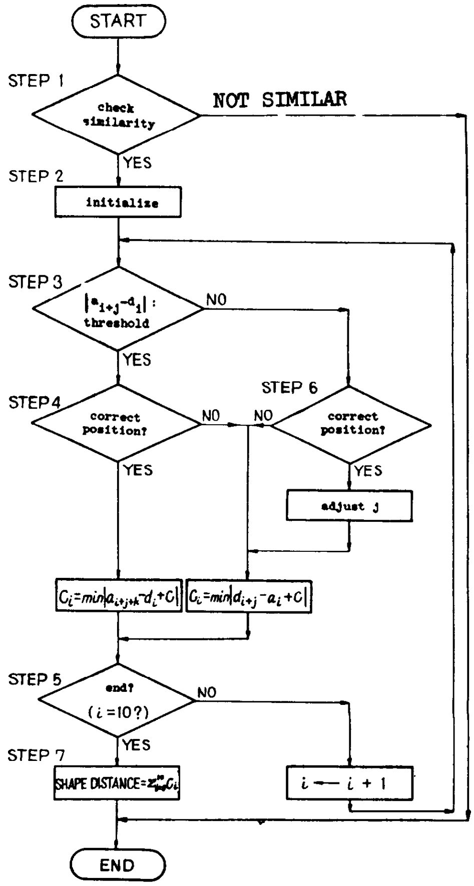
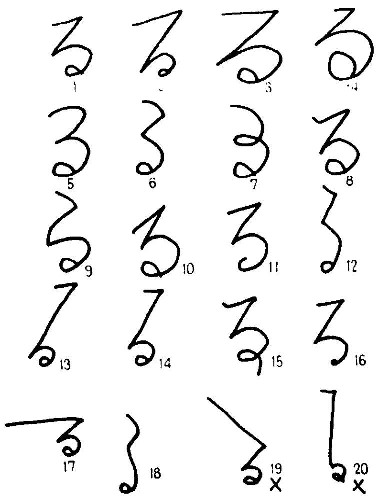


Fig. 3 Calculation of stroke distance



The reference pattern is 1. The pattern 19, 20 are rejected because of the big deviation in the shape.

Fig. 4 Examples of patterns which are taken as the same stroke

3.5 Complexity of a stroke:

Much computing time is needed to compare the input pattern with all items in the dictionary by the GCVS method. To reduce the number of comparisons, we employed the idea of the complexity of strokes as the quantity of total rotation of the stroke:

$$\text{COMPLEXITY (A)} = \sum_{i=0}^{9} |a_{i+1}-a_i| \qquad (3)$$

3.6 Similarity of shape:

Strokes which GCVS method regards as different patterns are sometimes included in the same character, such as 「L」and「⊥」in the first stroke of 「4」 and 「4」respectively. To resolve this problem, the similarity of shape is defined to each stroke in the dictionary as the coordinate of a point in x-y plane.

This coding is done in the heuristic manner so that the points which represent the similar strokes come close. The similarity is defined as the distance between two points.

4. Analysis of positional relation:

In some cases, parameters obtained from the positional relation of two succeeding strokes are useful especially for characters such as Chinese characters which are composed of many strokes each of which is a rather simple shape. The positional relation of two strokes is defined by the direction of the vector composed of the middle points of each stroke. The positional relation is not unique : (a) If the distance of two middle points is small or when two strokes cross each other, much error arises in the direction of the vector. (b) Positional relation depends on the writing order of the strokes. We have prepared as many dictionary entries as the different order of writing.

5. Other characteristic parameters:

GCVS method thinks little of local shape, such as a corner, and can not distinguish many similar shapes which are necessary to recognize characters.

a) the existence of a corner, b) the difference of the length, c) others.

6. Method of recognition:

We employed two types of dictionaries; that is the shape dictionary which is used to decide the shape of one stroke, and the character dictionaries which are composed of shapes of strokes, their positional relations and weight. The character dictionaries are used for deciding characters which are separately prepared for each number of strokes in a character. The recognition procedure is as follows:

(1) On-line hand-written character input: The x-y coordinate on the writing surface where the stylus pen is sensed every 220 micro seconds. Spatial filtering and smoothing is performed against these points.

(2) Primary selection by the positional relation and the number of strokes: The dictionary is selected by the number of strokes, and the characters which match in the positional relation are selected.

(3) Shape decision and secondary selection by shape: It is not necessary that all strokes be analyzed. Only those strokes which are dominant are analyzed by GCVS method to distinguish the characters selected in the primary selection. The character that matches in the shape analysis is selected.

(4) Distinction of the characters that have the same shape and the same positional relations: Characters such as「カ」—「刀」,「土」—「エ」need further distinction step using

auxiliary characteristic parameters described in chapter 5.

7. Experimental result:

Table 1 summarizes the results of the experiments by the GCVS method for characters of one, two, three and twelve strokes. Each character is written by seven persons.

8. Conclusion:

The GCVS methos can handle many types of characters in one way. The restricted dynamic programming method is valid to recognize the shape of strokes, neglecting the individual differences which come from the hand-written process. The similarity defined as the x-y coordinate of a point works well to reduce the size of the dictionaries. The positional relations which have been paid little attention to so far play a big role as the number of strokes increase. We are continuing this research for the characters whose number of strokes is other than 1, 2, 3 and 12. The method presented in this report could be used in many applications.

The ill-recognized characters are written in a shape which even a man can not read correctly if he reads it separately. To improve the recognition score, it will be necessary to incorporate context method. However, we separated this problem and did not use the context.

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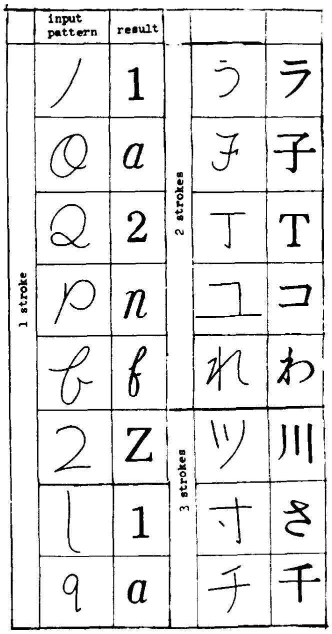
number of strokes	number of characters	recognition score	recognition time
1	61	97 %	300 msec
2	83	98 %	450 msec
3	60	99 %	600 msec
12	171	99.5 %	1000 msec

(a) Recognition score



(b) Examples of ill-recognized characters

Fig. 5 Result of recognition

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