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A Stroke Extraction Method for Handwritten Letter Recognition and its Application

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Abstract:Discussed is stroke identification technique for automatic recognition of kanji characters without using the order of drawing strokes of a character.
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1.Introduction

Handwritten letters are difficult to automatically recognize because of individual habits in drawing letters. The authors are developing an automatic recognition technique, using PC networking and automatic experiencing.[1] A stroke is an element of a letter drawn by one movement of pen without raising the pen during drawing that particular stroke. In the case of Japanese "kanji" characters, some tens of strokes of different kind exist. Some recognition techniques use the real time information about writing a letter in which not only the shapes of strokes but also the order of drawing them can be known automatically. Here in this paper, only the information about the shape of a letter is used as is the case in which recognition is made after finishing writing the whole document. This idea is useful in identifying characters in a scene depicted as a mixing of characters and figures.[2,3] In the present method, extracting connected lines which finally constitute a letter is the operation to do first. Then each of those connected lines is examined if it is considered to be a stroke. That is, in the case of a kanji character, more than two strokes are often drawn connected or crossed as a correct letter. So, they must be separated. And sometimes, strokes which must be drawn connected are separated due to a small error in hand motion. This is also taken into account in identifying a particular letter.

2.Brief Review of Letter Recognition Methods

Letter recognition has been discussed and developed by many researchers. Hence so many ideas exist, but they can be largely broken down into the following two ideas; i.e., the pattern matching method and the method based on feature extraction. Templet matching and chain code will be briefly reviewed as their typical instances.

2.1 Templet Matching

This is one of the old methods and a basic one undergoing many improvements. The idea is apparent. A templet of the letter to be identified must be ready to apply. The letter to be identified is superposed on a templet. If the matching is successful with respect to every pixel between the letter and templet, then the letter inputted is judged to be the letter of the templet. Templet matching is advantageous in the sense that processing templets and adding available templets newly are easy. In the case of handwritten letters, habit of writing differs from writer to writer and so the shapes are not identical at all. Hence the shape of the templet applied can not absorb such a variety of difference in shape. To get over this difficulty, a templet must be prepared to apply to each of the habit. Thus this method is not appropriate for recognizing handwritten letters.

2.2 Chain Code

This idea, first, needs the preprocessing of thinning the lines constituting a letter. The chain code method translates 2-dimensional features of a letter into a single dimensional features. This isusually an advantage. But if a part of a handwritten letter is depicted in two parts, then a different state transition diagram is required. From this point of view, it is a disadvantage of the chain code method.

3. Strokes Constituting a Letter

Stroke extraction technique in the present methodology will be discussed. A stroke is a trace of drawing by a single motion of writing. The single line (sometimes folded at some points and sectionally linear) constituting a stroke and it is considered to

be a connected combination of short straight line elements (imaginarily) existing along the contour of a stroke. That is, usually a straight line of a handwritten letter is not exactly straight. So, a straight line is considered to be a combination of short straight lines of a length determined depending on the thickness of lines drawn, which are lying in the same direction within a prescribed tolerance. Each of those short lines on the contour will be called a line element. And it is vectorized.

3.1 Extraction of Line Segments

Boundary tracing of the contour of a letter is made in order to extract line elements and hence a straight line segment which is a line enclosed by line elements. The length of a line element depends on the thickness of original lines drawn, as is mentioned above. As shown in Figs.1a and 1b, tracing the contour of a stroke(s) is made in the basis of direction vector. Depending on the thickness of strokes drawn, a portion of the contour line is regarded as a vectorized straight line element as in Fig.1. Depending on whether a turning is clockwise or anticlockwise at a portion of direction change of a stroke contour line (a connected line), some idea is necessary to detect and process a turning point correctly. An end point, or a turning point of the stroke, or a clossing point of two strokes is an example of turning point. Two adjacent strokes must be sometimes drawn connected with respect to some kanji. At any turning point obtained above, that particular contour is once separated into two pieces, taking such possibility into account. But as already mentioned, a stroke is broken down into some straight lines. They must be connected back again if it is reasoned that they originally form a stroke together. To do this, two straight lines are connected again, if line elements at the ends of both of the two straight lines to be connected have the same direction and can be superposed if one of them is shifted, and if the original contour is found to be continuous at that connection point by checking if all the pixels constituting a new line element connecting the two elements are on the original stroke. Straight line segments thus obtained are classified into vertical, horizontal, declining to the right, and declining to the left from their inclination.

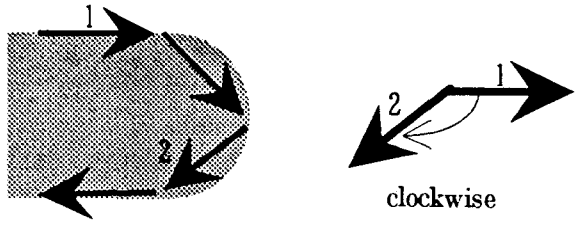

Fig.1a

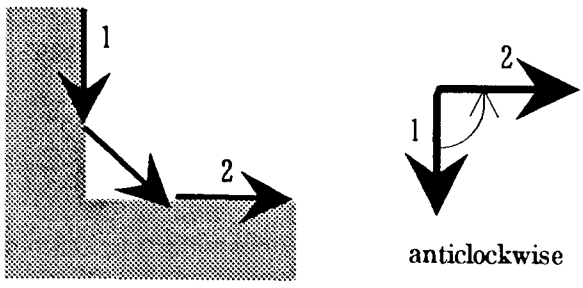

Fig.1b

Fig.1 Tracing a contour line.

3.2 Identification of Strokes

A stroke can be identified from the above procedure of extracting line segments. As already mentioned, some strokes are a single straight line. Some have turning points so as to form a sectionally straight figure. Hence some processing is necessary to extract real strokes, combining adjacent straight lines obtained above. This identification procedure is as follows. All the kinds of strokes are examined in advance and their shapes are implemented into the system as pieces of linguistic knowledge. Matching the lines with this knowledge determines if a particular line obtained in the above process is a stroke or not. Fig.2 shows an example of a stroke. And the knowledge describing this stroke shape is:

This is formed by three lines. Horizontal line comes first and it is followed by a vertical line which is further connected to a line declined to the right.

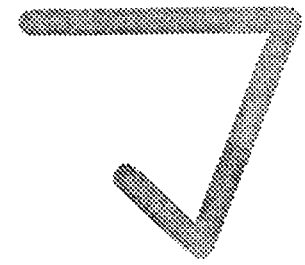

Fig.2 An example of stroke.

Any combination of adjacent straight lines are examined if that combination hits one of the prescribed conditions.

4.Relations between Strokes

Strokes are identified by the procedure in the preceding section. Now, the shape of a particular letter inputted are examined. There are location relation, crossing relation, and length relation which describe the characterstics of the shape of a letter.

4.1 The Location Category

Strokes constituting a letter are listed

applying the (order) relation in which a stroke located left to and upward from the rest of strokes comes first. Then all the strokes are symbolized by prescribed symbols which represent kinds of strokes. This symbolized list describes the characteristic of a letter as the layout of strokes. This list will be called "location category."

4.2 The Crossing Category

There are letters which can not be recognized by only location relation of that particular letter. Some of those letters can be distinguished by applying the notion of crossing relation. Whether a crossing exists or not between a pair of strokes are coded by 1 and 0, respectively. Examination of this relation with respect to every pair of strokes of a letter forms a matrix of 1 and 0 as Fig.3 shows. This matrix is reorganized by negrecting any crossing from a stroke of lower order in the location relation to a stroke of higher order. From the way of choosing crossings, the result can be described as a sequence of coded stroke names, which will be called "crossing category," as is shown in the right of Fig.3.

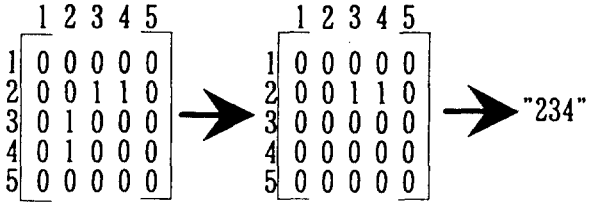

Fig.3 An example of the crossing category.

4.3 The Length Category

There exist some letters for which the above two categories are not sufficient enough to specify. For those letters, the length relation category is applied. Strokes of the same kind constituting a single letter are compared with each other in their length. As in Fig.4, if the "longer than" relation holds, then the value 1 is assigned to the corresponding element of the length relation matrix. In the figure, the stroke 3 is longer than the stroke 4.

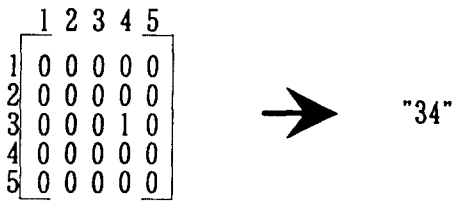

Fig.4 An example of the length category.

5. Discussion

To evaluate the effect of the crossing category, kanji characters

甲 and 田

are employed. Each of them were inputted 20 times. The location category took the same pattern with respect to both of

甲 and 田

The patterns of the crossing category were different between these letters as is shown in Table 1. As these examples show, the crossing category differentiates letters which take the same location category patterns. Kanji characters

未 and 末

were employed to evaluate the effect of the length category. It took definite values, 34 and 43, respectively as shown in Table 2. The value 43 means that the fourth stroke has longer length than the third stroke. In writing

未 and 末,

this fact with respect to those letters are consciously maintained by the writer, and this category is always successful in

Table 1

Letter	Location category	Crossing category	No.of times
甲	22117	234	19
	22118	234	1
田	22117	23	19
	22118	23	1

Table 2

Letter	Location category	Length category	No.of times
未	32114	34	20
末	32114	43	20

differenting the difference in lengths of strokes.

Then next, the following letters which are of some special strokes,

強 細 誤 予 字 同 式 秀

are employed for examination of the present system. From Table 3, for more than half

Table 3

Letter	Location category	No.of times	Letter	Location category	No.of times
強	17B4N221714	10	秀	332142P	12
	17BN2241714	5		332145P	4
	17N22B41712	3		112143P	2
	17B4N221814	1		132143P	2
	18N22B41714	1			
細	CB422117324	12	字	4288G1	14
	CB422132147	3		2288G1	3
	CB432422117	2		4388G1	2
	CB432221417	2		2388G1	1
	CB422113274	1			
誤	41211I71121734	13	予	848E	20
	21217111121734	4			
	41211I71217134	3			
同	21217J	17	式	41121F	16
	21218J	3		41121D	4

times of 20 inputs, each letter is categorized into the same location category. existence of category patterns other than those are because of the difference in line inclination of a stroke. Line inclination can often be slightly disturbed even if the writer is conscious of that point. And moreover, individual difference or the writer's habit can be involved in the difference in inclination.

6. Conclusion

The present paper described the application technique of relations which hold between strokes constituting a (handwritten) letter. Strokes are extracted as a combination of line segments. Their features were categorized as the location, the crossing, and the length categories. The crossing category was effective in distinguishing a letter from another which are the same in the way of crossing between strokes. The length category was effective in differentiating stroke lengths. The location category was also effective usually, but it is not so effective for letters which can be separated into left and right parts each of which is a chunk of strokes and is sometimes a letter in its own right. In such a case, it is better to identify part by part and then to unite those results.

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