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Handwritten Letter Recognition for the Visually Handicapped

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Abstract: The authors' automatic skill acquisition methodology is applied to handwritten letter recognition for the visually handicapped.

Keywords: handwritten letters, letter recognition, the visually handicapped, on line data reading, man-machine interface

1. Introduction

Computers and other information devices can be good tools to support the handicapped's communication. In order to improve those tools, there are a variety of researches and developments.[1] In the present paper, handwritten letters recognition will be discussed as a communication aid for the visually handicapped to input characters and data. A visually handicapped person usually uses a Braille keyboard or an ordinary kind of keyboard by remembering the key laypout to use it blindfold. In these cases, some additional loads are to be assigned to the user. For a Japanese, it is a serious defect with respect to the ordinary keyboards that Japanese "kanjis" are not directly available. In order to input those characters, it is necessary to first input alphabet or "hirakanas" and then to convert them into a kanji. There are homophones, and the correct kanji for the meaning of the sentence to be formed must be chosen by seeing the computer screen. So instead of this conventional system, a handwritten letter recognition method is proposed here for the visually handicapped. The authors have developed a recognition technique for characters and general figures using PC networking and automatic skill acquisition by experiencing instances of figures and characters.[2,3,4,5] Typicality, which is called representativity from the idea's covering the notion of typicality, is deduced by this mechanism. The advantage of this mechanism is that it can be applied to learning letter writing for the visually handicapped. The operation in inputting characters are almost the same as the writing with a pencil. So, no additional load is not assumed for the user.

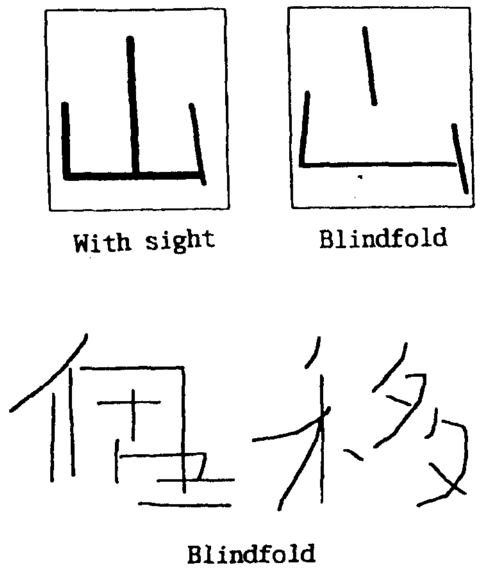

Fig.1 Instances of handwritten letters.

2. Deformation Characteristics of Handwritten Letters without Visual Confirmation

Letters written without confirming the shape of the letter writing, or the movement of the writing hand, by seeing usually becomes out of shape. Fig.1 shows some examples. The deformation, however, is not so bad that the letter written can not be identified. But this is not so simple. This comes from the fact that a human can comprehend the shape so deformed by inference based on experience. Automating recognition of such deformed letters requires the same sort of mechanism; i.e., experiencing and acquiring skill to infer the original shape of a deformed letter. By examining such deformed letters, it is found that although the whole letter is out of shape, every stroke which is written at a single movement of hand almost maintains its original shape. This comes from the facts that strokes are of rather simple shape, especially in the case of Japanese kanji, and that in drawing a stroke in one movement the writer can feel the movement of the penpoint and can control the shape. In moving the penpoint from an end of a stroke to the start of the next stroke to be drawn, the penpoint is raised and loses the contact to the paper surface. So in doing this, visual information plays the decisive role. This is the cause of the disorder in arranging strokes as a letter. This disorder leads to separation of a stroke from another which must be drawn connected with each other, and on the contrary leads to connection or crossing of more than two strokes each of which should be drawn separately.

3.Feature Extraction without Sight Check

In the present paper, the hand's motion in writing a letter is sent to the CPU on line, using a pen-type mouse. So the information about how and in what order strokes are drawn is obtained. Features of handwritten letters are thus extracted here in this paper.

3.1 Features of a Stroke Shape

The shape of a stroke is almost free from deformation in drawing, as was mentioned above. So, a node can be a good feature of the shape of a stroke to distinguishm others, in the case that the particular stroke is a combination of straight line segments as is mostly the case with kanji's strokes. [5] In detecting a node of a stroke, the fact that a node is a point of the change in direction of drawing is used. To detect such a point, the following technique is applied. The start and the end of a stroke as an objective of analysis is connected by an additional straight line to make the stroke a closed line. Every point (pixel) on the stroke line is measured the distance (signed distance) from that particular point to that additional straight line drawn from the start point of the stroke toward its end point. Listing those distances in the order from the start point to the end point can be used to see the increasing and decreasing of those values. There are turning points from increasing to decreasing or vice versa. Each of such turning points is defined to be a node. Nodes are named the positive node or the negative node according to its circumstance:

Positive node if the distance value turns from increasing to decreasing at that node.

Negative node if in the opposite tendency.

Handwritten straight lines are not exactly straight. So a threshold value is set so as to regard the line as a straight line if the degree of distortion is within that value. From the result of subjective experiments, the threshold is determined to be 8 dots (pixels). The direction of the additional line used for picking out nodes also provides information in identifying the stroke shape as a part of a letter. The direction classification is as shown in Fig.2.

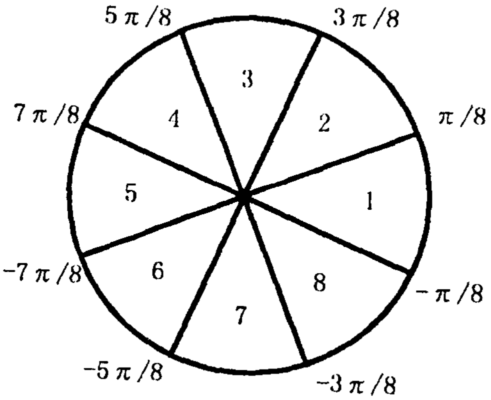

Fig.2 Direction classification.

3.2 Location Relation between Strokes

To draw a stroke, one put his pen down at some point of a sheet of paper and start to draw the stroke. Then he/she raise it to finish drawing the stroke. This action of raising the pen at some point and putting it down again at some other point to start drawing the next stroke needs help of vision as already mentioned. This is important to write a letter correctly, which can keep its good shape only when its strokes are well arranged on a sheet of paper. In order to guess the correct location relation between two successive strokes drawn without visual confirmation, the direction of the movement of the pen raising and lowering is taken into account, since the direction is considered to be almost correct. The direction of hand motion can be felt correctly if the writer is blindfold. The difficulty is where to put his/her pen down onto the sheet of paper. So, the cause of disorder in stroke arrangement is mainly the disorder in the starting point of a stroke. Tables 1a and 1b show examples of variance in the hand movement discussed above. The magnitue of the variance in distance shows a significant amount of variation, but the direction of motion measured in radian is not necessarily proportional to the variance in distance. It is seen that the direction of motion is rather steady. This fact can be seen in examples of handwritten letters in Fig.1. To identify the direction of this sort of movement, Fig.2 is again applied. The

Table 1 Variances in hand movwment in starting to depict a next stroke.

Table 1a

Stroke i to j	Variance Distance(dot^2)	Angle(rad^2)
(1,2)	62	0.0050
(2,3)	124	0.035
(3,4)	3024	0.011
(4,5)	2288	0.0080
(5,6)	3826	0.0040

Table 1b

Stroke i to j	Variance Distance(dot^2)	Angle(rad^2)
(1,2)	493	0.070
(1,3)	416	0.027
(1,4)	862	0.041
(1,5)	625	0.038
(1,6)	1038	0.030
(1,7)	798	0.012

category determined by this direction will be called the movement category. This category is the listing of the directions of movements from the first move to the last move, so the length of this category is $n - 1$ in the case of a letter of n strokes. In the case of a letter of single stroke, the category is null or the category is not defined.

3.3 Location Relation between Figure Centers of Strokes

Here in this section, figure-centers of two successively drawn strokes are considered as the objects of categorization. The stroke movement category described in the preceding section is a category which is not basically disturbed due to no sight check in drawing strokes. But since some probabilistic factors usually exist as is the case with a normal vision writer, this category of figure-center together with the movement category strengthen the system's recognizability. As is the case with the movement category, directions are coded into 8 directions, and the figure-center category is not defined for a single-stroked letter.

4. Experience-Based Recognition and its Accumulation

Features of letter shape are accumlated and those data are used in identifying the letter to be recognized. This is considered to be automatization of human skill acquisition. [6,7,8] The list of strokes in time order includes the order of drawing them. So also the shape, the movement, and the figure-center categories carry the information about the order of drawing strokes. With respect to each of the subjects, there was no variation in the order of drawing strokes if the writer is fixed and if a letter is printed. But such a routine is a particular writer's habit and not necessarily common to all the writer, or a general order of writing. So, experiencing one's own habit of writing is very effective in recognizing letters written without sight check as a visually handicapped person.

5. The Procedure of Recognition and the Evaluation of the System

With a pen-type mouse, on-line inputting is employed. A letter as the recognized result is shown on the CRT display. The restrictions in inputting letters are as follows:
i)"On-line" handwriting.
ii)One by one recognition.
iii)Letters inputted can be of any size if written within a prescribed area.
Under the above restrictions, letters to be recognized are processed by the following procedure:
1)A letter is inputted using a pen-type mouse.2)Features of shape, movement, and figure-center are extracted and classified. These are categorized as the shape, the movement, and the figure-center categories, respectively.
3)The above categories of the inputted letter is tried to match experienced instances of categories to find probable letters.
4)Among the probable solutions above, typicality ratings are compared and the highest one is chosen to be the correct answer. It is shown on the CRT display.
5)If the answer is correct, then the categories involved are added 1 as a piece of experience.
6)If the probable answer can not be narrowed down to a single letter, then it is judged to be the an impossible case and the data is added as manually to the correct answer as a piece of experience.
Thus the evaluation of the system performance was made. Letter writing area was width 131mm x 110mm, and the recognized letter is shown on the CRT display. Experiment was started from the state of no experience, and each result was accumulated as a piece of experience. Evaluation of recognition performance was made after processing 50 pieces of experience with respect to a single letter. Table 2 shows the results. For letters with fewer strokes, every category for features extraction described above converges to a typical cateory. For letters of many strokes, this was also the case, but the tendency was slower compared with the case of fewer strokes. The movement and the

figure-center categories were rather stable especially in the cases in which the motion is rather vertically upward or horizontal.

Table 2 Correct recognition rates for a variety of handwritten kanji without sight check.

Letter inputted	Rate of correct recognition(%)	
	With sight	Blindfold
上	98	98
下	98	98
半	98	98
古	98	96
画	98	98
東	98	96
浩	96	94
渉	94	92

With respect to the shape category, judging if the stroke is of straight line or not sometimes leads to error in recognition.

6.Conclusion

In the present paper, a handwritten-letter- recognition system was proposed as a letter inputting device for the visually handcapped. It was found that the shape of a stroke and the location relation of strokes were free from confusion in writing without sight check. Based on this finding, the shape, the movement, and the figure-center categories were defined as features inherent to a particular letter. Recognition experiments showed that this idea is successful.

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