On-line Recognition of Handwriting Japanese Katakana Characters

HIDEKAZU TERAI* AND KAZUO NAKATA*

Abstract

This paper describes two subjects regarding the on-line recognition of handwriting characters.

First, the bandwidth required to transmit handwriting is studied. It concludes that handwriting process can be transmitted through 320 bits/sec or less, and it implies that seven or eight input terminals of handwriting can be simultaneously transmitted with a telephone line of 2,400 bands.

Secondly, an algorithm of the on-line recognition of handwriting Japanese syllabic characters (katakana) is developed mainly based on the extraction of numbers, types, and certain characteristics of strokes. The recognition experiments indicate more than 95% correct recognition is achieved without prior instructions. A recognition time is estimated at less than 50 msec/character using a minicomputer.

1. *Introduction*

By the opening of data communication lines to commercial and private use, on-line information processing systems have been becoming increasingly popular. For information inquiry terminals, a handwriting character input device [1], [2] will become much more necessary, because it can offer valuable service through simple operation as well as being highly flexible.

This paper deals first with the transmission bandwidth required for handwriting character information, and secondly, certain algorithms of handwriting Japanese syllabic character (katakana) recognition, and the result of our experiment is described.

2. *Pen Motion in Handwriting and Estimated Transmission Bandwidth*

Fig. 2. 1 shows the plotting of penpoint motion in handwriting of the character R, obtained as a function of time sampled at 1 kHz. At the point where the tangent vector of penpoint motion change discontinuously without being lifted from the tablet (a "sharp turn"—for example, points marked with a circle 0 in Fig. 2. 2), the penpoint remains relatively still in considerable time. It takes

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* Central Research Laboratory, Hitachi, Ltd.

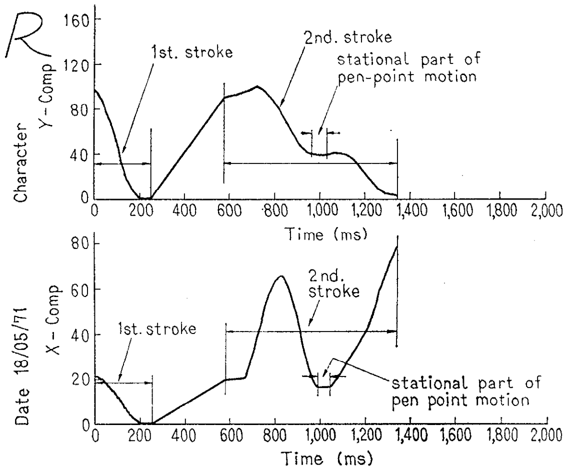


Fig. 2. 1 An example of X, Y component of strokes of character "*R*"

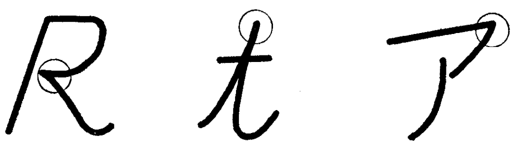


Fig. 2. 2 Examples of "sharp turn"

longer time to stop the pen, since the direction of movement changes to a sharper angle.

We analyzed these waveform $X(t)$ and $Y(t)$ by using fast Fourier transformation (FFT). Fig. 2. 3 shows the analyzed spectrum. As is evident from those spectrums, major components are concentrated at below 10 Hz. In general, high-frequency components are generated in the sharp turns of a character by scanning; however, penpoint motion in handwriting becomes very slow at these sharp turns, making its time waveform smoother. As a result, no high-frequency component is generated at those points. This is advantageous when viewed from the point of data transfer.

We were able to confirm this particular effect in handwriting characters in the course of the following experiment. The $X(t)$ and $Y(t)$ signals obtained from the character are filtered by low-pass filters before they were displayed on a CRT. Effect of the cut-off frequency on the distortion of the regenerated character is shown in Fig. 2. 4. There was no significant distortion when we lowered the cutoff frequency to 12 or 8 Hz.

From these experiments we were able to determine the speed of data transfer required for transmission of handwriting character data being written in ordinary size at normal speed under the following conditions.

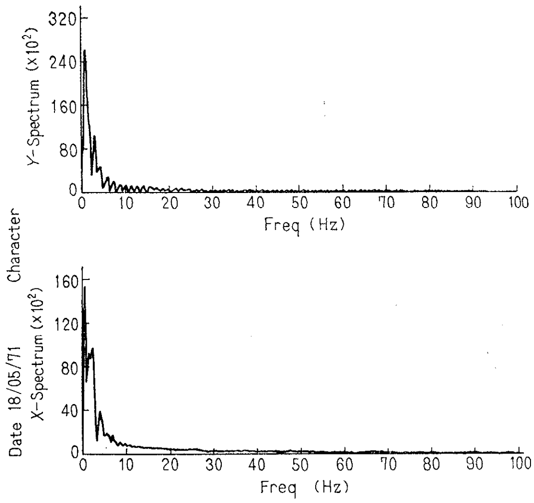
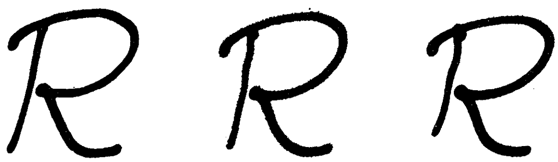


Fig. 2.3 Frequency spectrum of X, Y component of strokes of "R"



(a) original pattern (b) cut off freq. 12 Hz (c) cut off freq. 8.5 Hz

Fig. 2.4 Examples of regenerated pattern "R" by high frequency cut off

(1) Digital transmission (2) Sampling freq.—20 Hz

(3) Size of character—1 in. (4) Resolution of mesh—0.01 in.

(5) Pen UP/DOWN—1 bit

Thus, the time required for data transfer from a terminal at 20 samplings per second would be:

$$8 \text{ bit} \times 2 \times 20 = 320 \text{ bits/sec.}$$

If we transmit the same character by using a black-and-white dot pattern (0, 1 pattern) of 100×100 mesh scanned by simple horizontal scanning, and assume transmitting the data at four seconds per character (this is approximately equal to the average time required to write a character), the transmission speed would be:

$$100 \times 100/4 = 2500 \text{ bits/sec.}$$

By transmitting the data at 320 bits/sec., up to seven terminals can utilize a 2400-baud data line in the multiplex transmission basis.

3. *On-line Recognition of Handwriting Katakana Characters*

3.1 *Fundamental Stroke*

We employ the structural analysis method for the recognition of handwriting characters.

First of all, terms used in this paper are difined here.

Definition 1 Fundamental stroke

Strokes necessary for basic composition of a character.

Definition 2 Sharp turn

A particular point in the handwriting process at which the tangent vector of penpoint motion changes discontinuously without lifting from the tablet.

Definition 3 Simple stroke

A fundamental stroke in which no sharp turns exist.

Definition 4 Complex stroke

A fundamental stroke having one or more sharp turns.

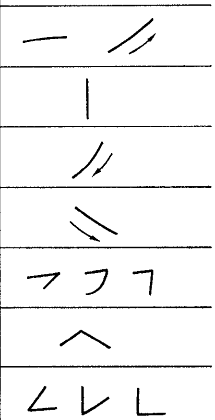
Definition 5 Segment

A portion of a handwritten character which starts from or ends at a sharp turn. The simple stroke is composed of a segment.

The fundamental strokes we defined for katakana characters are listed in Table 3. 1.

Table 3. 1 Fundamental strokes of katakana characters

			stroke pattern
fundamental strokes	simple strokes	A	
		B	
		C	
		D	
	complex strokes	F	
		G	
		H	



3. 2 *Extraction and Classification of Stroke*

The number of strokes forming a character being written can be easily verified by testing the pen UP/DOWN data from time to time. The extracted and separated strokes must then be examined as to whether they are simple strokes or complex strokes.

(1) Descrimination of simple or complex stroke

This test is conducted in the following three steps:

(a) Length of a stroke

The type of a stroke, simple or complex, can be determined by comparing length of the stroke with the total length of strokes in the character. If it does not reach a predetermined threshold value, the stroke is unconditionally regarded as a simple stroke. If it is larger than the threshold level, no conclusion is given at this step and enters the next step.

(b) Variation in X and Y components of the stroke

X and Y components of a simple stroke vary smoothly as shown in Fig. 3. 1, while the X or Y component of a complex stroke takes a maximum or minimum value at the junction of two segments (at a sharp turn) as shown in Fig. 3. 2.

Thus, a stroke can be defined as a complex stroke if a maximum or minimum point exists in the variation of waveform of X and Y components of the stroke.

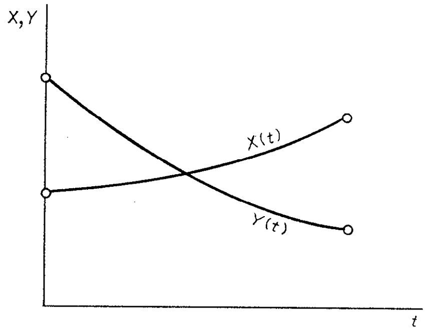


Fig. 3. 1 $X(t)$, $Y(t)$ of simple stroke; stroke "\"

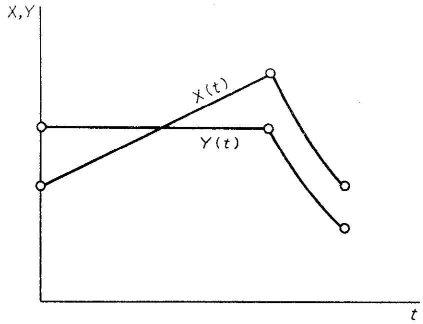


Fig. 3. 2 $X(t)$, $Y(t)$ of complex stroke; stroke "フ"

(c) Test of penpoint motion stop

The test of maximum or minimum value in a coordinate train (test b above) cannot render correct judgment if a complex stroke is somewhat obtuse as shown in Fig. 3. 3 (broad turning at the corner).

As already described, the writer's penpoint motion stops when he comes to a sharp turn, and the presence of a sharp turn can be easily examined by testing the time coordinates of the stroke for stopping. In this sense, we defined a

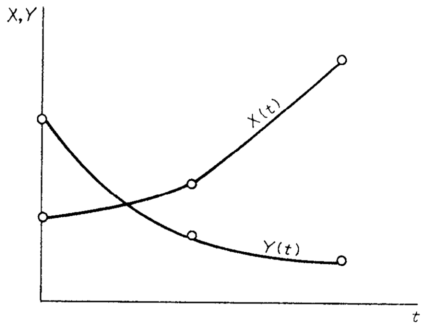


Fig. 3. 3 $X(t)$, $Y(t)$ of distorted complex stroke; stroke "\"

complex stroke to have a time relation;

$$\Delta T_{\max} \geqq T_{\theta} \qquad (1)$$

where T_{θ}: threshold level

$\Delta T_{\max}$: maximum value of time difference between sampling points.

(2) Processing of ambiguous characters

By combining tests (a), (b), and (c) above, all complex strokes can be recognized, as long as the character being tested is written in the correct style. However, these tests are insufficient if the character is somewhat ambiguous. For example, stroke "\" of the character in Fig. 3.4 is the key to recognition of this character. If we read the stroke as a D stroke, the character will be recognized as a "ヤ". If we read it as an H stroke, the character will be read as a "セ".

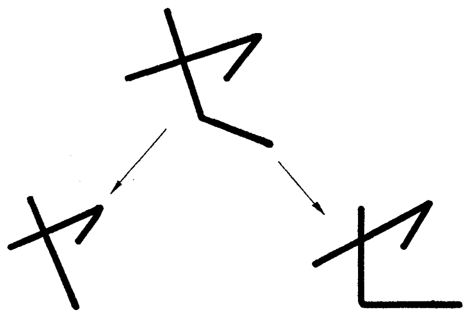


Fig. 3.4 Examples of ambiguous characters

For these strokes, equation (1) will not hold. These ambiguous strokes are recognized as simple stroke D at the first step; then, the curvature is calculated for this final descrimination.

(3) Determination of stroke code

Figs 3.5 and 3.6 show the allowable limits of inclination for simple and

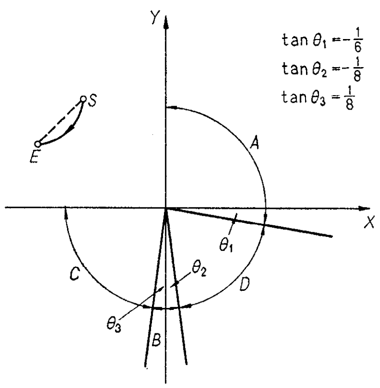


Fig. 3.5 Allowable domain for each simple stroke

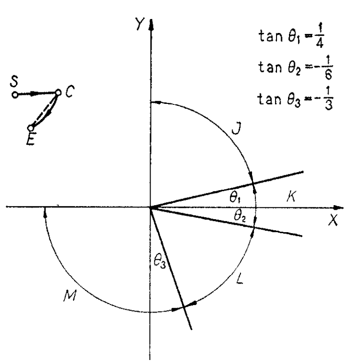


Fig. 3.6 Allowable domain for each complex stroke

complex strokes. For a stroke recognized as a simple stroke, vector $\overrightarrow{SE}$ which connects the start and end points of a stroke is checked for its relative location in the domains in Fig. 3.5. For complex strokes, vectors $\overrightarrow{SC}$ and $\overrightarrow{CE}$ (junction of two segments C has been determined in previous tests) are tested for the domains in Fig. 3.6. When the following conditions are met, the stroke is finally recognized as a complex stroke.

$$F=((K \text{ or } J) \blacktriangleright M) \text{ or } (D \text{ and ``convex''})$$
$$G=J \blacktriangleright L \qquad (2)$$
$$H=(M \blacktriangleright (K \text{ or } J)) \text{ or } (D \text{ and ``concave''})$$

(Triangle ▶ indicates that the left term—i. e. segment 1—is followed by the right term, segment 2)

4. *Rules Used for Recognition of Characters*

Most characters are written in an ordered sequence, although we found some that were written in different sequences by different writers. Most katakana characters can be correctly recognized by using the number of strokes and stroke sequence data, but certain ones have the same number of strokes and stroke code train—for example (ア and カ), (ス, ヌ, マ and ヤ), and (コ and ユ). For recognition of these characters, relative position among strokes must be checked.

5. *Recognition Experiment and Evaluation*

The recognition program required approximately 2,500 steps using an assembler language of the HITAC-10 mini-computer. A character (1 cm×1 cm) can be recognized within 50 ms.

Our handwriting character recognition system was tested by eight writers who had no experience in handwriting tests and had no preliminary knowledge of the system. The correct recognition rate was 95% for 576 characters.

6. *Conclusion*

At the first stage of our on-line recognition system of handwriting characters, a system of the recognition of Japanese syllabic characters (katakana) was developed and tested without issuing any special precautions to writers. The attained average correct recognition rate was 95%. This rate will become about 100% by giving simple precaution. This system can also be expanded for recognition of English alphabet of capital letters (A, B, C) and Chinese kanji characters.

Our experiment included an analysis of penpoint motion which led us to confirm necessary data speed for transmission of handwriting characters to be 320 bits/sec. or less. This will prove valuable in producing a very economical character input terminal in multiplexing mode.

References

[1] M. I. Bernstein : "Computer Recognition of On-Line Hand-written Characters", RAND Corp. Memorandum, Oct., 1964

[2] G. F. Groner : "Real-time Recognition of Handprinted Text", FJCC, 1964