Continuous Recognition Method for Japanese Finger Letters Using Contour Feature*

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This paper deals with a continuous recognition method for finger signs used to express some numerals in Japanese sign language by image processing technology. There have been some reports about recognition methods for finger letters; however, these were concerned with the finger letters which could be recognized from only the hand shape. Some finger letters are expressed by both hand shape and motion; therefore, it is necessary to use sequential hand images to recognize such finger letters. We propose a new continuous recognition method for sequential hand images and their contour curves. First, we define some properties of the hand image with its contour curve. Next, we determine a judgement rule for discrimination of the hand shapes based on the above properties. Finally, we describe a recognition rule to apply the judgement rule to some sequential hand images, and show some examples to demonstrate the feasibility of the continuous recognition method.

Key Words: Human Engineering, Measurement, Image Processing, Pattern Recognition, Sign Language, Motion Study

1. Introduction

Heretofore, body actions have been used as a means of communication among auditory-impaired persons. In industry, communications with body actions have often been employed in a noisy place or in a clean room. Sign language is the typical means of communication, but there are only a few people who can understand it. Therefore, a method that assists in such communication has been expected for a long time.

Recently, some reports^{(1),(2)} about recognition or

expression of body actions by a machine have been published to meet such an expectation. As regards recognition of finger letters, some papers⁽³⁾⁻⁽⁷⁾ have reported the use of image processing technology. However, in practical applications, as some of the finger letters are expressed by both hand shape and motion, it is necessary to consider the sequence of changes hand shape.

In this paper, we propose a new recognition method which can be applied when finger letters are presented consecutively such as in usual conversations, including the case in which a finger letter is expressed by means of not only the hand shape but also its motion. This method consists of a judgement rule for discriminating a hand shape based on the properties extracted from the hand image data and a recognition rule for recognizing a finger letter from a combination of some sequential hand shapes.

In section 2, we describe the properties of the hand shapes extracted from hand image data with their contour curves. In section 3, we outline our proposed method, and in section 4, we show some examples to demonstrate this method.

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2. Properties of Finger Letters and Hand Shapes

2.1 Finger letters

In this paper, we deal with numerals⁽⁸⁾ expressed using the right hand shown in Fig. 1 as the finger letters to be recognized. We call the set of these finger letters L_{group} . In L_{group} , the numeral "0" is expressed by changing the hand shape from the Japanese alphabet "ME" to numeral "9". This is one of the reasons why it is necessary to consider some sequential hand image data. Also, we include a finger letter "ME" in L_{group} . Moreover, since we use the finger letter for the syllable "SA" as a punctuation sign and the finger letter for the Japanese word "WARUI"... English as a corrective sign, we include "SA" and "WARUI" in L_{group} . "WARUI" is expressed by moving the hand with the hand shape of numeral "1".

2.2 Properties of hand shape

The hand shapes of the finger letters in L_{group} are classified as shown in Table 1 according to the state (bent or stretched) of each finger. The finger letters in this table can be divided into two groups according to the thumb's state. The hand shapes of the finger letters in the two groups can be discriminated from the other four fingers' state.

Generally, when we pay attention to the contour curve of the hand image, the fingertips and interdigital webs correspond to the convex and concave points of the contour curve, respectively. Then, we adopt the following four properties in order to discriminate the hand shapes, referring to Fig. 2.

- (1) Wrist width W at the wrist center $C(I_C, J_C)$.
- (2) Hand direction θ_H .
- (3) Finger length L_i and its direction θ_{Fi} ($1 \leq i \leq 5$).
- (4) Interdigital web angle θ_{Si} ($1 \leq i \leq 4$).

Let the wrist joint point at the ulnar side be the point $P_U(I_U, J_U)$, and one at the radial side be the point $P_R(I_R, J_R)$ on the contour curve as shown in Fig. 2. Then, the wrist width W and the wrist center $C(I_C, J_C)$ are calculated with Eq. (1) and Eq. (2), respectively.

$$W = \{(I_U - I_R)^2 + (J_U - J_R)^2\}^{1/2}. \quad (1)$$

$$\begin{cases} I_C = (I_U + I_R)/2, \\ J_C = (J_U + J_R)/2. \end{cases} \quad (2)$$

Calculation of the wrist center will be discussed in more detail in section 3.3.

Let the hand direction be the direction of the straight line that passes through the wrist center C and the center of gravity G of the hand image as shown in Fig. 2. Let the coordinate of a point on the contour curve be $P(I_K, J_K)$, where the variable K indicates the position of a point on the contour curve, and $U \leq K \leq R$. Then, the center of gravity $G(I_G, J_G)$ of the hand is calculated using the points $P(I_K, J_K)$

Table 1 Classification of L_{group}

Finger Letter	Thumb	Index	Middle	Ring	Little
SA	×	×	×	×	×
ME	×	×	×	×	×
1	×	×	×	×	×
2	×	○	×	×	×
3	×	○	×	×	×
4	×	○	×	×	×
5	○	×	×	×	×
6	○	×	×	×	×
7	○	×	×	×	×
8	○	×	×	×	×
9	○	○	○	○	○

○ : Stretched × : Bent

Fig. 1 Finger Letters: L_{group}

Fig. 2 Properties of hand shape

from $P_U(I_U, J_U)$ to $P_R(I_R, J_R)$ as follows:

$$\begin{cases} I_G = \frac{\sum_{K=U}^{R-1} IM_K \cdot JP_K \cdot IP_K + (I_U - I_R)(J_U + J_R)(I_U + I_R)}{2 \cdot \sum_{K=U}^{R-1} IM_K \cdot JP_K + (I_U - I_R)(J_U + J_R)} \\ J_G = \frac{\sum_{K=U}^{R-1} IP_K \cdot JM_K \cdot JP_K + (I_U + I_R)(J_U - J_R)(J_U + J_R)}{2 \cdot \sum_{K=U}^{R-1} IP_K \cdot JM_K + (I_U + I_R)(J_U - J_R)}, \end{cases} \quad (3)$$

where $IP_K = I_K + I_{K+1}$, $IM_K = I_K - I_{K-1}$, $JP_K = J_K + J_{K+1}$ and $JM_K = J_K - J_{K-1}$. Hereby, the hand direction θ_H is given by Eq. (4).

$$\theta_H = \tan^{-1}\{(I_C - I_G)/(J_C - J_G)\} \quad (4)$$

The finger length L_i in Fig. 3 is defined as the length of the line segment l_i normalized by the wrist width W as follows:

$$L_i = l_i/W, \quad i = 1, \dots, 5 \quad (5)$$

where l_i is the line segment which joins the fingertip

Fig. 3 Distances of contour pixels from wrist center

points $P_{Fi}(I_{Fi}, J_{Fi})$ to the wrist center $C(I_C, J_C)$, and is given by

$$l_i = \{(I_{Fi} - I_C)^2 + (J_{Fi} - J_C)^2\}^{1/2}.$$

Thus, by dint of normalization by the wrist width, individual difference is sufficiently reduced. The finger direction θ_{Fi} is defined as the directional angle of the line segment l_i normalized by the hand direction θ_H as follows:

$$\theta_{Fi} = \tan^{-1} \frac{I_{Fi} - I_C}{J_{Fi} - J_C} - \theta_H, i = 1, \dots, 5. \quad (6)$$

By this normalization, the direction of each finger is given as the angle based on the hand direction. For example, since both the syllable "ME" and the numeral "3" are expressed by the shapes of the hand of which three fingers are stretched, we adopt as the value of θ_{FA} , defined by Eq. (7), the value of θ_{Fi} , defined by Eq. (6) in order to discriminate these two hand shapes.

$$\theta_{FA} = |\theta_{F1} + \theta_{F2} + \theta_{F3}|. \quad (7)$$

In order to judge how widely two adjacent fingers are opened, we adopt the interdigital web angle⁽⁹⁾ θ_{Si} defined by Eq. (8) with the two adjacent fingertips and the interdigital web point $P_{Wi}(I_{Wi}, J_{Wi})$.

$$\theta_{Si} = \left| \tan^{-1} \frac{I_{Fi} - I_{Wi}}{J_{Fi} - J_{Wi}} - \tan^{-1} \frac{I_{Fi+1} - I_{Wi}}{J_{Fi+1} - J_{Wi}} \right|, i = 1, \dots, 4. \quad (8)$$

2.3 Evaluation of hand motion

Since a finger letter such as that for the numeral "0" is expressed by not only the hand shape but also its motion, it is necessary to evaluate the motion of the hand. In case of the finger letter for the numeral "0", we can recognize it by understanding the change of the hand shape from the finger letter for the syllable "ME" to that for the numeral "9" using some sequential hand image data obtained at short intervals. Also, in the case of the finger letter for the word "WARUI", we can recognize it by evaluating the distance the index fingertip moves from the starting point $P_S(I_S, J_S)$ to the end point $P_E(I_E, J_E)$, which is obtained from the sequential hand image data. The distance MD is normalized by the wrist width W , and is calculated as follows:

$$MD = \{(I_E - I_S)^2 + (J_E - J_S)^2\}^{1/2} / W. \quad (9)$$

Practically, we recognize the finger letter for the

Fig. 4 Word "WARUI"

Fig. 5 Pixel value on I axis

word "WARUI" when the distance MD is greater than the length IL of the index finger, where IL is calculated with the contour curve as shown in Fig. 4.

3. Outline of Recognition Method

3.1 Input image data

We take one hand image datum after another at short intervals, setting up a CCD camera so that the hand and a part of the forearm can be imaged on the screen of a video monitor connected to the camera. Here, the beam axis of the CCD camera is set perpendicular to the tangential plane of the hand at its center of gravity. A black curtain is used as background to eliminated the need for any auxiliary image processing.

A hand image datum obtained by the above procedure has 256 pixels on the horizontal axis (I axis) and 200 pixels on the vertical axis (J axis) with 64 levels, and is saved in the frame memory of the image processing unit as the image $D(I, J)$, ($0 \leq i \leq 255, 0 \leq j \leq 199$).

3.2 Contour curve of hand image data

We determine a threshold value TH to separate the area of the hand and the background from the image $D(I, J)$. This procedure is carried out using Eq. (10) with image data $D(i, 0)$ on the I axis as shown in Fig. 5.

$$\begin{aligned} I_{\min} &= \{i | \min(D(i, 0) - D(i+1, 0))\}, \\ I_{\max} &= \{i | \max(D(i, 0) - D(i+1, 0))\}, i = 0, \dots, 254, \\ TH &= \frac{1}{2} \left(\sum_{i=0}^{I_{\min}} \frac{D(i, 0)}{I_{\min} + 1} + \sum_{i=I_{\min}+1}^{I_{\max}} \frac{D(i, 0)}{I_{\max} - I_{\min}} \right). \end{aligned} \quad (10)$$

We will describe a method to extract the pixels

on the boundary between the hand area and the background area from the image $D(i, j)$ in the following, with reference to Figs. 2 and 5.

First, by scanning the image $D(i, 0)$, ($0 \leq i \leq 255$) along the I axis from the origin, we extract the first pixel of which value becomes larger than the threshold value TH mentioned above, and call it the contour pixel. Next, we extract one contour pixel after another in the counterclockwise direction so as to observe the high-level contour pixel to the left side on the eight neighborhood pixels⁽¹⁰⁾.

Let the set of contour pixels obtained in this manner be the contour $P(I_K, J_K)$, ($0 \leq K \leq N_c$) where N_c is the number of pixels on the contour curve.

3.3 Extraction of properties

The positions of the two wrist joints, five fingertips and four interdigital webs can be determined with the curvatures which are calculated using three points $P(I_K, J_K)$, $P_1(I_{K-d}, J_{K-d})$ and $P_2(I_{K+d}, J_{K+d})$ on the contour curve by Eq.(11).

$$\theta_K = \tan^{-1} \frac{I_{K-d} - I_K}{J_{K-d} - J_K} - \tan^{-1} \frac{I_K - I_{K+d}}{J_K - J_{K+d}}, \quad (11)$$

$$K = d, d+1, \dots, N_c - d$$

Let the sign of the curvature be positive when the point $P(I_K, J_K)$ turns to the left along the contour curve. We show an example of the curvatures along the contour curve in Fig. 6. From Fig. 6, we can understand the following facts.

The first minimum and the last minimum of which the values are between θ_w and θ_L indicate the wrist joints $P_U(I_U, J_U)$ and $P_R(I_R, J_R)$, respectively. Also, five maxima of which the values are larger than θ_H indicate the positions of the fingertips, and four minima of which the values are smaller than θ_L show the positions of the interdigital webs. (Here θ_w , θ_L and θ_H are threshold values which are determined from experimental data.)

We will discuss the practical values of θ_w , θ_L and θ_H in section 4.1.

3.4 Judgement rule of hand shape

We describe three conditions to determine the state of fingers, i.e., "bent", "stretched", and "interdigital angle".

<Condition 1> : Thumb's Status

The thumb is judged to be stretched if the i th element that $L_{T1} \leq L_i < L_{T2}$ and $\theta_{IW} \leq \theta_{Si}$ exists, and to be bent otherwise.

<Condition 2> : Four Fingers' Status

The i th finger is judged to be stretched if $L_i \geq L_{T2}$, and to be bent otherwise.

<Condition 3> : Three Stretched Fingers' Status

It is judged that the middle, ring and little fingers are stretched if $\theta_{FA} \geq \theta_T$; otherwise the index, middle and ring fingers are stretched. Here, L_{T1} , L_{T2} , θ_{IW} and

Table 2 Recognition rule of L_group

Status of Thumb	Condition		Discrimination	
	Number of Stretched Fingers	Sum of Three Finger Directions	Stretched Fingers	Finger Letter
Bent	0	—	None	SA
	1	—	I	1
	2	—	I, M	2
	3	$\theta_{FA} \geq \theta_T$ or $\theta_{Si} < \theta_{IW}$	M, R, L I, M, R	ME 3
Stretched	4	—	I, M, R, L	4
	0	—	T	5
	1	—	T, I	6
	2	—	T, I, M	7
If $L_{T1} \leq L_i < L_{T2}$ and $\theta_{Si} \geq \theta_{IW}$	3	—	T, I, M, R	8
	4	—	All	9

Fig. 6 Curvature of contour curve

θ_T are determined from experimental data, and will be shown as practical values in section 4.1.

Using the above three conditions, we set up the judgement rule to determine the kind of finger letters from a hand image as shown in Table 2.

<Judgement Rule>

(1) If the thumb is bent in condition 1 and the number of stretched fingers in condition 2 is 0, 1, 2 or 4, the image is judged to be "SA", "1", "2" or "4", respectively.

(2) If the thumb is stretched in condition 1 and the number of stretched fingers in condition 2 is 0, 1, 2, 3 or 4, the image is judged to be "5", "6", "7", "8" or "9", respectively.

(3) When the thumb is bent in condition 1 and the number of stretched fingers is 3 in condition 2, the image is judged to be "ME" if $\theta_{FA} \geq \theta_T$, and to be "3" otherwise.

3.5 Recognition rule

Assume the time interval, in which an image $D(i, j)$ is taken into the image processing unit through the CCD camera, to be S . Also assume the image at time t to be $P(t)$, and the one at time $t+1$ to be $P(t+1)$.

In practical recognition, a finger letter is not recognized until a hand shape corresponding to the finger letter in section 3.4. Therefore, it is necessary to use some sequential image data in order to recognize a finger letter. Moreover, in the case the same finger letter is presented more than two times, the punctuation finger letter for "SA" must be used each time.

Now, we discuss the time interval S and the time

T_D required to present a hand shape. We measured the time required for a hand shape to be presented completely, beginning with the shape of the hand forming the finger letter for "SA", for all the finger letters in L_group. We found that the case of "1" was the shortest, and the mean time was 0.25 sec. This time corresponds to the 2 MOD time obtained by the MODAPTS method⁽¹¹⁾, which is 0.258 sec. Therefore, it is considered sufficient for the time interval S to be set up within 2 MOD (0.258 sec).

Hereby, the number N of images to be taken into consideration until a hand shape is judged completely is expressed by Eq.(12), and the processing time T_D is given by Eq.(13), because the hand shape will not be judged completely until the next new hand shape is judged.

$$N = [0.258/S] + 1, \quad (12)$$

where $[\]$ implies Gaussian sign.

$$T_D = S \cdot (N + 1) \quad (13)$$

Now, in the case in which the finger letter for the word "WARUI" is recognized successively, the time T_D has to be extended.

Thus, the continuous recognition rule is summarized as follows.

«Recognition Rule»

(1) If the hand shape expressing "ME" is judged successively at time longer than T_D , and the next hand shape is judged as "9", the sequence of images is recognized as "0".

(2) If the hand shape expressing "1" is judged successively at time longer than T_D , and the next hand shape is judged as "SA", the sequence of images is recognized as "1". If the next hand shape is expressing anything except "1", we examine the moving distance MD of the fingertip of the image. If the distance MD is greater than IL , the sequence of images is recognized as "WARUI", i. e., the corrective symbol. Then, the last finger letter is deleted.

(3) If the hand shapes expressing the numerals from "2" to "9" are judged successively at time longer than T_D , the sequences of images is recognized as from "2" to "9", respectively.

(4) If the hand shape expressing "SA" is judged successively within the time T_D , the sequence of images is recognized as "SA", i. e., the punctuation symbol. Then, the state awaiting the next input begins.

(5) If the hand shape is judged successively even after the finger letter has been recognized, the finger letter is presented continuously until the hand shape changes into a different one.

(6) If the word "WARUI" is recognized successively more than two times, the time T_D is extended until another finger letter is recognized.

Table 3 Maximum and minimum curvatures

Finger Letter	Fingertip θ_{MAX}		Interdigital Web θ_{MIN}		Wrist Joint Web θ_{MIN}	
	AV	SD	AV	SD	AV	SD
ME	139	8.8	-163	9.3	-19.5	9.4
1	153	2.7	—	—	-20.9	6.0
2	135	2.9	-124	32.4	-22.4	8.0
3	132	9.4	-157	8.9	-21.4	6.8
4	140	3.8	-156	10.0	-21.4	6.7
5	130	8.3	-114	13.5	-23.2	6.9
6	136	2.9	-104	13.4	-22.4	6.4
7	135	6.9	-137	19.8	-23.6	5.7
8	133	13.8	-143	30.7	-21.9	5.5
9	140	5.0	-164	6.8	-25.0	6.4
AV	137	—	-136	—	-22.1	—

Table 4 Interdigital web angle

Finger Letter	Interdigital Web Angle							
	Thumb - Index		Index - Middle		Middle - Ring		Ring - Little	
	AV	SD	AV	SD	AV	SD	AV	SD
ME	—	—	—	—	23.6	4.8	35.0	5.9
1	—	—	—	—	—	—	—	—
2	—	—	36.5	8.2	—	—	—	—
3	—	—	29.7	6.7	25.0	5.9	—	—
4	—	—	34.7	8.8	23.9	5.2	30.7	7.0
5	82.6	12.1	—	—	—	—	—	—
6	83.0	11.1	—	—	—	—	—	—
7	69.7	12.4	35.1	7.9	—	—	—	—
8	72.1	20.2	26.7	4.1	28.3	2.4	—	—
9	70.6	12.2	27.0	5.9	23.8	6.0	36.1	6.8
AV	75.6	—	31.6	—	24.9	—	33.9	—

Table 5 Normalized values of hand

		Length from Wrist Center		Length Normalized by Wrist Width	
		AV	SD	AV	SD
Finger- tip	Thumb	124	5.61	2.18	0.08
	Index	175	8.53	3.09	0.15
	Middle	185	8.35	3.25	0.14
	Ring	176	9.39	3.09	0.17
	Little	148	8.31	2.61	0.12
Inter- digital web	Thumb-Index	79	5.74	1.42	0.09
	Index-Middle	101	7.58	1.82	0.14
	Middle-Ring	104	8.60	1.86	0.14
	Ring-Little	93	6.32	1.68	0.13
Wrist Width		56	2.35	—	—
Index Finger Length		74	4.05	1.31	0.08

4. Examples

4.1 Objects and some threshold values

We selected eighteen male students as the subjects to form the finger letters to be recognized.

First, we measured the curvatures of the fingertips, the interdigital webs and the wrist joints for all subjects. The means and standard deviations were calculated, and the results are summarized in Table 3. The results for the angles $\{\theta_{si}\}$ of interdigital webs are summarized in Table 4 in a similar way. Moreover, the results for the finger lengths $\{L_i\}$ are summarized in Table 5.

Next, we determined some threshold values to judge hand shapes using these experimental results. From Table 3, we found that $\theta_H = 90^\circ$, $\theta_L = -90^\circ$ and $\theta_W = -10^\circ$.

From Table 4, we determined that $\theta_{IW} = 48.3^\circ$. From Table 5, we found that $L_{T1} = 2.02$ and $L_{T2} = 2.38$. L_{T1} is calculated using the mean 2.18 and the standard deviation 0.08 of the thumb's fingertip as $L_{T1} = AV$

Table 6 Time and rate of recognition

Finger Letter	Rate(%)		Time(ms)	
	AV	SD	AV	SD
SA	99.5	0.46	88	12.2
ME	98.9	0.97	145	14.5
1	99.4	0.93	108	10.2
2	99.9	0.50	127	16.9
3	99.0	0.81	145	13.5
4	99.4	0.92	159	12.2
5	99.3	0.90	104	10.1
6	97.5	2.37	120	10.2
7	98.1	3.02	139	13.2
8	98.9	1.60	155	13.4
9	99.0	0.79	174	9.8
AV	99.0	—	133	—

$-2SD$. L_{T2} is calculated using the mean 2.61 and the standard deviation 0.12 of the little finger's tip in a similar way. We determined $IL=1.47$, calculating it using the mean 1.31 and the standard deviation 0.08 of the index finger length as $IL=AV+2SD$.

Finally, we measured the direction angles of fingers, and obtained the results that $\theta_{FA}=28.6\pm5.4^\circ$ for "ME", and $\theta_{FA}=2.47\pm4.4^\circ$ for "3" using Eq.(7). From these results, we determined that $\theta_T=15^\circ$.

4.2 Experiment for judgment rule

We carried out an experiment wherein for all subjects finger letters were to be judged using the proposal judgement rule. In this experiment, each of these finger letters was presented 100 times. The results are summarized in Table 6.

Here, the greater the number of fingers in the image was, the longer the processing time was because the length of the contour curve increases with increasing number of fingers.

The case of "9" was the longest, and the mean of its time was 0.174 sec. The mean time for all kinds of hand shapes in L_group was 0.133 sec. As regards the recognition rate, it was 99.0% for all kinds of hand shapes. The finger letters of which recognition rate was comparatively low were these for "ME", "6", "7" and "8". We believe that the reasons for these are that the fingers are not bent or stretched completely, the thumb is not spread enough and/or the tangential plane of the hand at the center of gravity is not kept perpendicular to the beam axis of the CCD camera.

4.3 Experiment for recognition rule

We carried out an experiment wherein for all subjects the finger letters were to be recognized with the proposed recognition rule on the condition that they were shown according to the numerals which were given at random. For each subject, the experiment was carried out 50 times.

We show the results of the recognition rate and the processing time for one finger letter in Fig.7. Here, we set $S=0.2$ sec and $T_D=0.6$ sec. Furthermore, we assumed that the word "WARUI" was not used.

From the experiment, it was found that recogni-

Fig. 7 Recognition results

tion rate improved gradually as each of the subjects learned the manner of presentation of finger letters. After the 7th experiment, the mean of the recognition rate reached 97.7%. The reasons for errors were the same as those of the judgement rule.

Furthermore, we carried out an additional experiment for all subjects on the condition that we pointed out the cause of error to the subject, and using "WARUI" in such case, the subject was requested to present the finger letter once more. The mean number of corrections was 1.69 times, with a maximum of 5 times. Also, the recognition rate for the word "WARUI" was 99.8%.

From these experiments, it was found that all the numerals from "0" to "9" could be recognized almost completely using the correcting symbol "WARUI".

5. Conclusion

We presented a continuous recognition method of finger letters in Japanese sign language. The following points were clarified.

(1) The hand form would be quantitatively evaluated using some properties of the hand image, paying attention to its contour curve. A judgement rule for discrimination of hand shapes was developed.

(2) A recognition rule to recognize finger letters presented successively was established using the judgement rule.

(3) With this method, the finger letters for all numerals from "0" to "9" could be recognized with very high accuracy.

In the future, we intend to develop a recognition method of finger letters for syllables using three dimensional image processing.

References

- (1) Kurtenbach, G. and Hulteen, E.A., Gestures in Human-Computer Communication, The Art of Human Computer Interface Design, Addison Wesley, Reading, (1990), p. 309
- (2) Kurokawa, T., Nonverbal Language and

- Introduction to the Interface, System, Control and Information, Institute of System, Control and Information Engineers, (in Japanese), Vol. 36, No. 2 (1992), p. 81
- (3) Hagiwara, N. and Waki, M., Recognition of Finger Alphabet Using Contour Features, National Convention Record, Institute of Electronics and Communication Engineers of Japan, (in Japanese), No. 114, (1985), p. 1
 - (4) Hagiwara, N. and Waki, M., Recognition of Finger Alphabet Using Projections, National Convention Record, Institute of Electronics and Communication Engineers of Japan, (in Japanese), No. 1536, (1986), p. 6
 - (5) Ochiai, K. Asai, S. and Kamata, K., Recognition Method for Japanese Manual Alphabet Using Contour Feature, Technical Report, Institute of Electronics, Information and Communication Engineers of Japan, (in Japanese), No. PRU 88-44, (1988), p. 37
 - (6) Tokunaga, S., Kaneda, M. and Osaki, H., Study of Recognition of Finger Characters Using Image Processing Techniques, Journal of Japan Industrial Management Association, Vol. 43, No. 4 (in Japanese), (1992), p. 296
 - (7) Tamura, S. and Kawasaki, S., Recognition System for Sign Language Motion Image, Computer Vision Workshop Report, Information Processing Society of Japan, (in Japanese), No. 44-1, (1986), p. 1
 - (8) Ito, M. and Takemura, S., An Introduction to the Study of Sign Language, (in Japanese), (1982), p. 234, Kousaido Publishing Co., Ltd.
 - (9) Kohara, J. Uchida, K. Ueno, Y. and Hatta, K., Data of Measured Value "A Human Body is Measured", (in Japanese), (1986), p. 85, Japanese Publication Service Co., Ltd.
 - (10) Ogami, M., Image Processing Handbook, (in Japanese), (1987), p. 316, Shokodo Publishing Co., Ltd.
 - (11) Osaki, H. Akagi, F. Fujiwara, Y. and Kikuchi, S., Production System Technique, (in Japanese), (1981), p. 94, Kyoritu Publishing Co., Ltd.
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