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3—32 An Active Search of Local Individualities for an Off-line Signature Verification

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Abstract

We propose a new verification method that extracts local individual writing habits from signatures. In registration process, correspondence estimation is done with the reference signatures and strong parts of individual writing habits are extracted in the plural. In verification process, a questioned signature is checked by using the local individualities that is extracted from reference signatures after correspondence estimation. As for the correspondence estimation multi-scale regularization is made use of, and genetic algorithm is used for the extraction of strong parts of individual writing habits. As indexes that show the strength of individual writing habit, we use magnitude of movement when it was written repeatedly and complexity of pen stroke. Result of average error rate was 2.63% when verification experiment was done toward Japanese signatures of 20 subjects (800 examples).

1. Introduction

Individual automatic verification takes on importance with development of information-oriented society all the more, and a signature is lately reconsidered as one means of the individual verification. It is because signatures has individual characteristics to person in the same way as a face, a fingerprint, and so on, and it doesn't have a danger like "loss", "theft", "oblivion" which becomes a problem with a seal and a password. In off-line signature verification that made a target of this research, the signature written in the paper in advance is taken in computer with a scanner and the verification is done. Information such as writing speed, writing order, writing pressure is lost in comparison with an on-line form in which a signature is written on a tablet connected with computer and input, therefore the off-line form is more difficult than the on-line form in the verification. But in the off-line form there are various advantages that a burden of user is small by not minding a special machine in taking notes, the taking notes are stable, and the introduction of the system is comparatively easy in a viewpoint of cost.

Although various techniques were proposed to the off-line form, a flow of processing was almost common. In other words, encoding (feature extraction) is done on the entirety of the signature after the preprocessing, and the verification is done by statistics treatment in feature space. Then, it is a main theme how to encode a signature to check well further. But, some problems are contained in this series of flow. First problem is that many sample data that statistics treatment works effectively can't be gotten realistically. Second, it shows a tendency to make light of details of the signature. In the human visual observation, the information on the details is very much used, for example, the direction of first writing and final writing, the form of bending, the inclination of the partial stroke, and so on. To draw near to the way of checking that a human being goes, the algorithm in which little part feature can also be attached importance must build.

So, we propose a new off-line signature verification method based on local individualities. Some parts in which individual writing habits are strong are picked out from the reference signatures in advance. And verification is done only using some sub-patterns that it was extracted. In other words, all information in the reference signatures isn't used, and unnecessary parts are actively thrown away in our method.

The concrete procedural way is presented in Sec. 2 and verification experiment results are given in Sec. 3.

2. Proposed Method

This method is configured in registration process and verification process. In the registration process, (1) preprocessing, (2) correspondence estimation and (3) local individualities extraction by GA are disposed of. In the verification process, (1) preprocessing, (2) correspondence estimation and (3) verification using the local individualities are disposed of. Registration process is done only once when registration of reference signatures is done. When input signature is actually verified, only

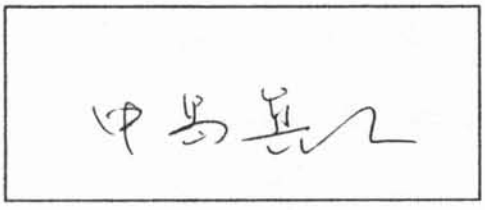

Fig.1. An example of signature data.

verification process is done. In the following, contents of each process are referred.

2.1. Preprocessing

Signature data are written in rectangular box as Fig. 1. Size of the box is 3.7cm by 9.0cm. Image pattern in this box is taken in computer with the scanner, and turns into binary image. And then, normalization of image scale is done. And the signature pattern was shifted so that center of gravity of it might become in center of the image. Finally, the image scale was normalized into 290×100 pixels.

2.2. Correspondence Estimation

The method which Mizukami et. al.[3] proposed was used to estimate correspondence of each part of two signature images with pixel measure. As Fig. 2, it is thought that signature image *g(x, y)* fits another signature image *f(x, y)* if the signature image *g(x, y)* is deformed so that amount of displacement in each location *(x, y)* may be *DX(x, y)* in *x* direction and *DY(x, y)* in *y* direction. Then, correspondence estimation returns in optimization problem that *DX* and *DY* that energy function *E(DX, DY)* in the following become the smallest are looked for.

$$E(DX,DY) = P(DX,DY) + \lambda S(DX,DY) \quad (1)$$

$$P(DX,DY) = \sum_{x,y} (f(x+DX(x,y), y+DY(x,y)) - g(x,y))^2 \quad (2)$$

$$S(DX,DY) = \sum_{x,y} \left(\left(\frac{\partial DX(x,y)}{\partial x}\right)^2 + \left(\frac{\partial DX(x,y)}{\partial y}\right)^2 + \left(\frac{\partial DY(x,y)}{\partial x}\right)^2 + \left(\frac{\partial DY(x,y)}{\partial y}\right)^2 \right) \quad (3)$$

Where *P(DX, DY)* is correspondence error between two images when displacement *DX* and *DY* are added, and *S(DX, DY)* is smoothness of the correspondence, and λ is parameter for significance.

By solving Euler equation in each discrete location conducted by this expression by using iteration formula of Gauss - Seidel type, the approximated *DX*, *DY* can be calculated.

Furthermore, multi-resolution images are employed to avoid fall to the local minimum in the iterated calculation. Correspondence is taken loose at first in the image of low resolution, and correspondence is gradually taken close by increasing resolution from the viewpoint of stage.

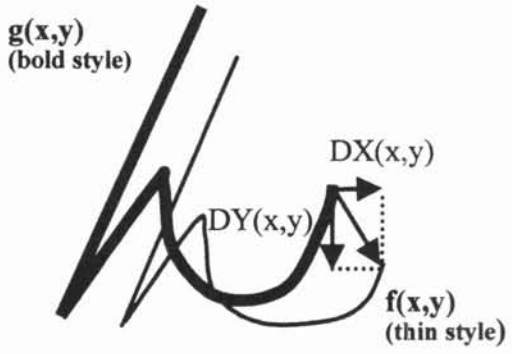

Fig.2. Correspondence estimation (definition of displacement amount DX, DY).

2.3. Local Individualities Extraction by GA

GA (Genetic Algorithm) is optimization method, which is modeled adaptation process due to natural selection paradigm with heredity of biological system of nature. Some strong parts of individual writing habits are chosen and extracted from the reference signature by GA. Before automating this process, you must decide two things. It is how to express the local characteristics as gene and how to evaluate. It is stated first about these, and how to apply GA is explained after that.

2.3.1. Genetic Expression of Local Individualities

To limit a certain part from the signature, it is sufficient if the location of the part and area are described. So one signature part can be expressed with three parameters as the following.

- *po* : position parameter
- *wid* : width parameter
- *hei* : height parameter

Each black pixel in the reference signature is given numbers in advance, and the *po* parameter indicates location by the number. *Wid* parameter and *hei* parameter show scale of area. It is the indicated signature part where the area of the rectangle whose length of width depends on *wid* parameter and length of height depends on *hei* parameter around the location decided with *po* parameter (Fig.3). To express some signature parts, you have only to put three parameters of each part side by side as the gene. Before applying GA, this is thought to be one gene.

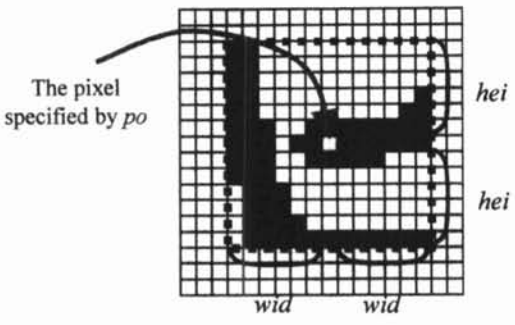

Fig.3. Relationship of Three parameter and signature part.

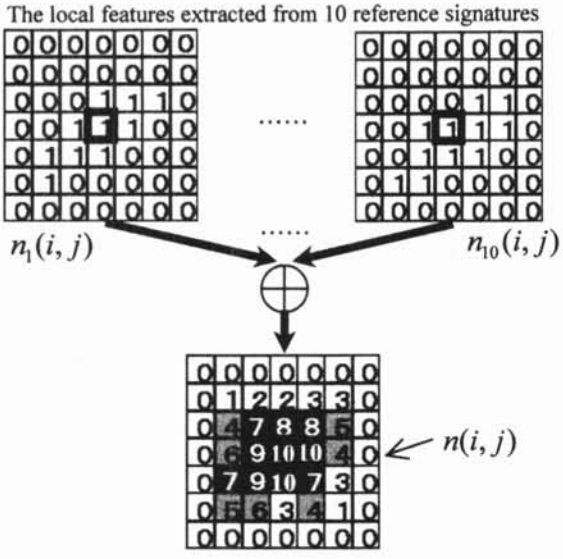

Fig.4. How to Evaluate Local Individuality, part 1

2.3.2. How to Evaluate Local Individuality, part 1

The strength of writing habit is calculated in the proposed method by using two ways of evaluating. As the first way of evaluating, Quantification of evaluation is done by similarity of writing pattern. In the proposed method, variation entropy proposed by Hase et. al.[4] is used as evaluation method. Variation entropy h is defined as the following.

$$h = -\sum_{i,j} \frac{n(i,j)}{N} \log \frac{n(i,j)}{m} \quad (4)$$

Where $n(i, j)$ is number of black pixels in each location (i, j) when signature parts extracted respectively by the reference signatures (number of m) are piled up to the correspondence point (Fig.4). Moreover, N is the total number of the black pixels,

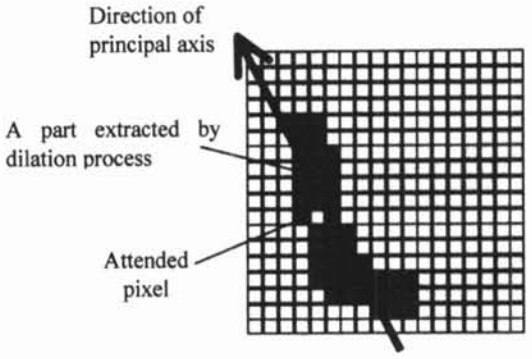

Fig.5. Detection of stroke direction

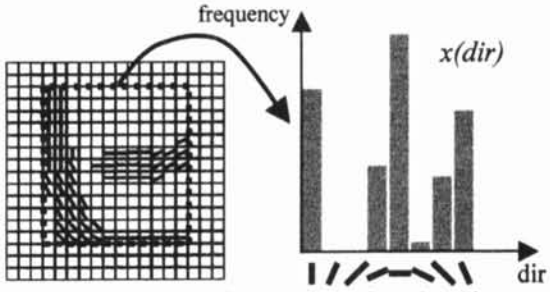

Fig.6. Drawing histogram *x(dir)* based on frequencies of stroke directions.

which construct all signature parts piled up. Evaluation quantity R_I is calculated in the following expression.

$$R_1 = (1 - \frac{h}{h_{\max}})(1 - \frac{1}{\sqrt{wid \times hei}}) \quad (5)$$

Where hmax is the maximum value which variation entropy can be taken, and equal to *-log (1/m)*. There are few variations in the pattern as much as R_I's value is high. Therefore, when R_I is high, the part is thought high repeatability in the case of said person.

2.3.2. How to Evaluate Local Individuality, part 2

Here, detection of stroke direction is done using principal axis, and distribution of histogram based on frequencies of stroke direction was employed. First, it explains about the detection of stroke direction. To examine stroke direction, dilation process is given to attended pixel constant number of times as Fig. 5. On that occasion, dilation process is done only in the black pixels. The stroke direction is detected to all black pixels of signature image.

Then, stroke direction histogram is made by all black pixels in the signature part specified by the three parameter, *po*, *wid* and *hei* (Fig.6). Each stroke direction is done quantization in 8 directions. Distribution of this histogram becomes the index that

Table.1. Verification results

Type I error	Type II error	average error
2.50%(10/400)	2.75%(11/400)	2.63%(21/800)
1.00%(4/400)	7.75%(31/400)	4.38%(35/800)

shows the writing complexity of the signature part. The complexity of writing pattern can be found quantitatively by examining the entropy of the stroke direction histogram. Formula of the evaluation quantity R_2 is as the following.

$$R_2 = -\sum_{dir} \frac{x(dir)}{N} \log \frac{x(dir)}{N} \quad (6)$$

Where, *x(dir)* is frequency in each direction *dir*, and N is total black pixels of signature part.

2.3.3. Application of GA

To apply GA to the local individualities extraction problem, adaptation degree fitness is defined as the following.

$$fitness = \sum_{Each\_part} R_1 + \mu_1 \times \sum_{Each\_part} R_2 - \mu_2 \times \sum_{Each\_part} K \quad (7)$$

Where, R_1, R_2 are the amounts of evaluation stated before, and K is the amount of pile between the extracted signature parts, μ_1, μ_2 are the parameter for significance. Purpose is to look for gene of high fitness value.

2.4. Verification Using Local Individualities

Verification is done by using the local individualities picked out in the registration process. Degree of similarity is examined in each local individualities, and said person's signature or forgery is judged. Local individuality of input signature is laid on that of one of reference signatures, and degree of similarity is calculated. The degree of similarity S is calculated as the following.

$$S = \max_{Each\_reference} \left\{ \left(1 - \frac{s_{12}}{s_1 + s_2}\right)\left(1 - \frac{1}{\sqrt{wid \times hei}}\right) \right\} \quad (8)$$

Where, s_1 is number of black pixels of the pattern in one of reference signatures, s_2 is number of black pixels of the pattern in input signature, and s_{12} is number of black pixels of part which two patterns don't pile up to. It is calculated respectively with each reference signature, and the maximum value of that is used. Then, the product of S calculated each part is S_{Total} as the following.

$$S_{Total} = \prod_{Each\_part} S \quad (9)$$

If S_{Total} is louder than the threshold T, judgment is said person. If S_{Total} is smaller than T, judgment is the stranger. The threshold T is calculated by using the evaluation quantity R_1 as the following.

$$T = th \times \prod_{Each\_part} R_1 \quad (10)$$

Where, *th* is threshold coefficient.

3. Verification Experiment

Signature verification experiment by 20 subjects was done with purpose of ascertaining effectiveness of the proposed method. As for the collected signature data, number of reference signatures is 10 per 1 person (total 200), number of said person's input signatures is 20 per 1 person (total 400) and number of forgeries is 20 per 1 person (total 400). The forgery data were written by students of our laboratory. First, the said person's signature was used as model, some minutes of training was done. Just after that, they took notes without seeing model.

The result is as mentioned in Table 1. The 1st row in Table 1 are the error rates when both Type I error and Type II error are small, and the 2nd row are the error rates when Type I error is lower than 1%.

4. Conclusion

In this paper, we proposed a new signature verification method that extracts local individual writing habits from reference signatures and verifies only by using the local individualities, and the performance was evaluated. Verification experiment was done toward Japanese signatures of 20 subjects (800 examples) and result of average error rate was 2.63%.

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