Recognition of Handwritten Character by Fuzzy Neighbor Mesh Feature

Xiaowen WANG † and Reijj HASHIMOTO ‡
† Graduate School of Science, Okayama University of Science
‡ Depertment of Electronic Engineering, Okayama University of Science
1-1, Ridai-cho, Okayama 700, Japan
(Received September 30, 1993)

Abstract

The fuzzy mesh feature (FM-feature) which is proposed in our previous work has been proved that it can absorb some handwriting variation. But the recognition rate got there is still not sufficient, one reason of which may be that this feature includes limited structural information about the character. In this work, we consider a modified fuzzy feature of mesh pattern (FNM-feature) by utilizing the neighbor meshes. And by the experiment about that, we have got the result that FNM-feature improves the recognition rate about 6.6% compared with FM-feature, which shows that FNM-feature with information of neighbor meshes is more effective for recognition.

1. Introduction

There are two ways in utilizing fuzzy theory to handwritten character recognition. One uses the fuzzy theory at the stage of feature extraction, or to fuzzify extracted feature[1)-3)] (called fuzzy feature method bellow). Another one is based on the fuzzy measure, which uses fuzzy theory to decide the similarity between the features extracted from two patterns[4)5)] (called fuzzy measure method). We think that the fuzzy feature method should be paid more attention according to the following reasons :

1) Since our recognition objects are Handwritten Chinese Characters (HCC), the most features of them, say the density of black pixels in the mesh, the location of the end of a stroke and so on implicate somewhat fuzziness in nature.

2) Fuzzifying these features can absorb some handwritten variations and how to fuzzify the features would have an effect on the result of recognition.

In our previous work[2)], we considered the fuzzy mesh features (abbreviated as FM-feature hereafter) and have got the result that some handwriting variations can be absorbed by that, But the recognition rate got there is still not a sufficient one. We guess one reason of that would be the fact that a mesh involves quite limited information about the structure of the character.

In this paper, we propose a modified fuzzy features of mesh pattern to overcome this defect, which takes the neighbor meshes into consideration. We call this feature the fuzzy neighbor mesh feature and denote it FNM-feature from now on.

This paper is organized as follows: the next section briefly discribes the discriminant function used in the recognition of this work, section 3 defines the FNM-feature and shows the experimental results performed. The last section gives the conclusions.

2. Recognition Approach

2.1 Fuzzy Feature Matrix

As the character has two dimensional fnformation in itself, the feature extracted from it can also be expressed by, say $k \times k$ matrix (referred on the feature matrix). And the fuzzy feature matrix is such that the elements of which have the values fuzzified by some membership function. Now, we denote the fuzzy features matrix for the referene patten D as $F_D = [d_{ij}]$ and one for the unknown pattern T as $F_T = [t_{ij}]$ respectively.

2.2 Discriminant Function

In this work, we take "near degree" as the discriminant function, which was proposed in our previous paper[2]. Here we describe this function briefly.

At first, the near matrix $N_{D,T}$ is defined by equation (1)

$$\mathrm{N}_{D,T} = (F_D \wedge F_T) + \{I - (F_D \vee F_T)\} \tag{1}$$

where $\wedge$ and $\vee$ mean "min" and "max" operations, respectively, and I is the $k \times k$ matrix in which all elements are 1. It can be seen that the values of all elements in $N_{D,T}$(denoted by $n_{D,T}(i,j)$)are confined in the closed interval [0,1] and as the values of corresponding elements in F_D and F_T become nearer, the value of that element in $N_{D,T}$ increases to unity.

Sometimes the great variation in a mesh of HCC generates very small value of the corresponding element in $N_{D,T}$ which causes the misrecognition (we call such an element as "accidental element"). For improving the matter, we consider the cutting near matrix $N^x_{D,T}$. For each element $n^x_{D,T}(ij) \in N^x_{D,T}$, it satisfies:

$$n^x_{D,T}(i,j) = \begin{cases} n_{D,T}(i,j) & \text{if } n_{D,T}(i,j) \geq x \\ 0 & \text{if } n_{D,T}(i,j) < x \end{cases} \tag{2}$$

where x is the cutting value and if it is set suitably, the misrecognition can be avoided[2]. In the experiment, we use the dichotomizing search to decide the optimal cutting value.

Now we difine "near degree" (denoted as $N(D,T)$)as follows:

$$N(D,T) = \frac{1}{k^2} \sum_{i=1}^{k} \sum_{j=1}^{k} n^x_{D,T}(i,j) \tag{3}$$

Lastly, the category of reference pattern which has the largest near degree to the unknown pattern is decided to be the category of the unknown one.

3. Experiment of Recognition by Fuzzy Neighbor Mesh Feature

3.1 Experimental Approach

Let the character have $N \times N$ pixels with binary values. At first, we divide the binary character plane into $k \times k$ meshes. Each mesh is denoted by $b_{i,j}(i,j = 1,2,\cdots,k)$ and has $l \times l(= M)$pixels(l = INT[N/k], where INT[$\cdot$] is the largest integer less than $\cdot$),and its value $x_{i,j} \in X$,where $X = \{x|0 \leqq x \leqq M\}$,is the number of black pixels in $b_{i,j}$.

Then, the fuzzy subset A representing "blackness of mesh" in universal set X is constructed by the following equation

$$A = \sum_{x=0}^{M} \mu_A(x)/x \qquad (4)$$

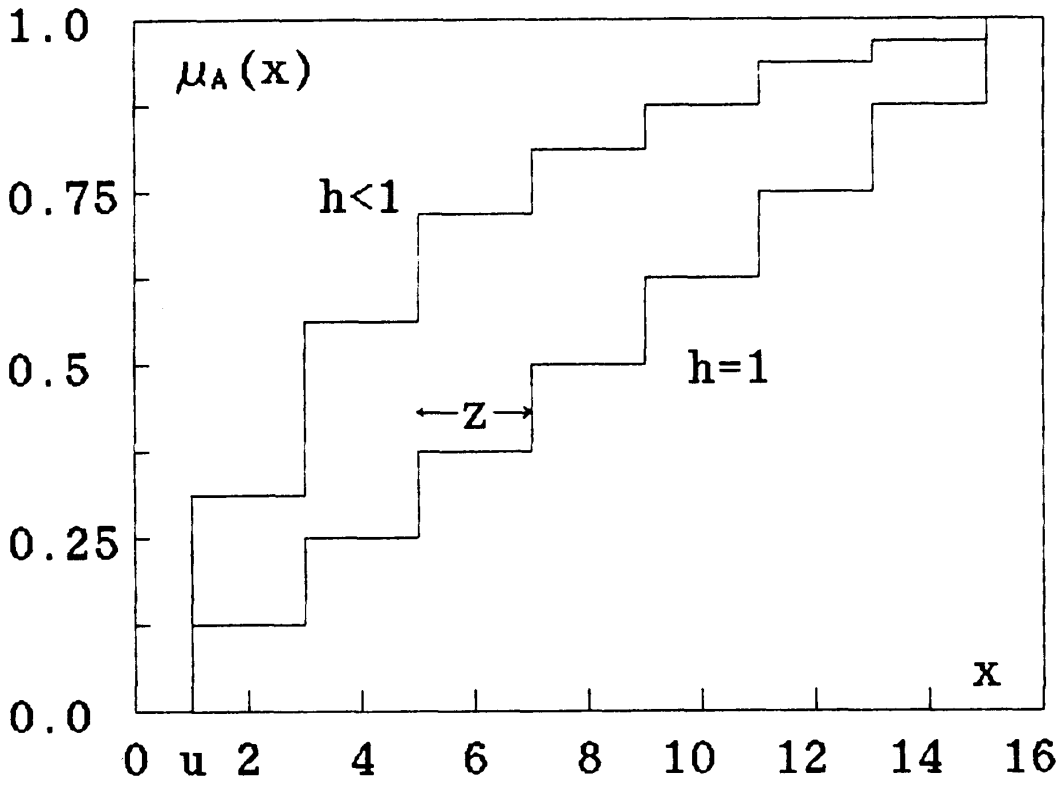

Fig. 1 The Membership Function Expressing "Blackness of Mesh"

Table 1 30 Categories Used in Experiments

愛	悪	圧	安	暗	案	以	位	依	囲
委	意	易	異	移	胃	遺	医	育	一
壱	印	員	因	引	飲	院	右	雨	運

where the membership function μ_A is defined as

$$\mu_A = \mathrm{INT}[(x+u)/z]/v \tag{5}$$

and μ is an integer less than z that makes $\mu_A(x) = 0$ when $0 \leqq x < u$. Further, as shown in Fig. 1, the parameter z is width of the mesh values with the same membership value($z \in \{1,2,3,4,5,8\}$). Some of the handwriting variations can be absorbed by choosing it properly[2]. The parameter v is the number of different membership values and $v = \mathrm{INT}[M/z]$.

Based on this membership function, the fuzzy feature matrices F_D and F_T are generated according to equations (6) and (7), respectively. The detail of it will be described in section 3. 2.

$$d_{ij} = \frac{1}{S}\sum_{s=1}^{S} \mu_A(x_{ij}^{D,s}) \tag{6}$$

$$t_{ij} = \mu_A(x_{ij}^{T}) \tag{7}$$

where $x_{ij}^{D,s}$is the value of mesh b_{ij} in sth sample of the reference category D,S is the number of the samples, and x_{ij}^{T} is the value of mesh b_{ij} in the unknown pattern T.

Lastly, the recognition is performed by applying the near degree to the fuzzy feature matrices according to the maximum criterion.

The data used in the experiments are HCC which are chosen from the data base ETL8 (B2) made by Electro-technical Laboratory of Japan. This data base is composed of 965 characters (namely categories) and each category has 160 samples. 30 categories (from 76'th to 105'th category as shown in table 1, the number of categories C is therefore 30) are selected as the data for the experiments by considering the processing time and the memory capacity. The first 100 samples in each category are taken as the reference patterns ($S = 100$), and the next 60 samples are taken as the unknown ones.

3.2 Fuzzy Neighbor Mesh Feature

In this section, we consider the fuzzy neighbor mesh feature (FNM-feature) for enhancing the recognition rate.

The FNM-feature is produced according to the following steps. Firstly, as mentioned in section 2, a character having $N \times N$ pixels with binary values is divided into $k \times k$ subpatterns. x_{ij}, the value of the mesh b_{ij}, is the number of black pixels in that mesh and the neighbor of b_{ij} mesh is expressed by equation (8), which is so called 4-neighbor of the center point (i,j).

$$neib(i.j) = \{(i-1,j),(i,j-1),(i+1,j),(i,j+1)\} \tag{8}$$

Then, mesh bij's fuzzy neighbor feature is defined by the following equation.

$$v_{ij} = w_1\mu_A(x_{ij}) + \sum_{(p,q)\in neib(i,j)} w_2\mu_A(x_{pq}) \tag{9}$$

Table 2 Experimental Results of Recognition Rate

	cutting value	Accumulative Recognition Rate (%) A(1)	A(2)	A(5)	A(7)	A(10)
FM-feature	0	79.8	88.4	94.4	95.8	97.1
	0.4175	84.3	92.8	96.2	97.3	98.4
FNM single method	0	86.4	93.1	96.1	97.2	98.3
	0.425	86.8	93.3	96.5	97.5	98.5
FNM multi-template	0	95.1	97.4	99.1	99.2	99.3
	0.425	95.2	97.5	99.2	99.3	99.4

where w_1 and w_2 are the weights given to the mesh b_{ij} and its neighbor meshes, respectively. These weights should satisfy the followiding two conditions.

1. $w_1 > w_2$. This is because information involved in the center mesh should be paid more attention than that of the neighbor meshes.
2. $(w_1+4w_2) = 1$.

3.3 Experiment of Recognition and the Results

In the experiment, we apply the near degree to the FNM-feature,where the difference of the reference pattern D and the unknown one T is evaluated by equation (10).

$$N(T,D) = \sum_{i=1}^{k} \sum_{j=1}^{k} | V_{ij}^{T} - V_{ij}^{D} | \tag{10}$$

where V_{ij}^{T} and V_{ij}^{D} are the V_{ij} values in equation (9) for the unknown and the reference patterns, respectively. The mesh's parameter k was set to be 16, so $l = 4$ and $M = 16$, and as N is 64, the number of meshes is 64. The simple matching method as well as the multi-template method in which the number of templates is 100 were treated. Moreover, the membership function parameter z was set to be 2, which had been decided to be optimal in the paper[2].

Some experiments to test the weights were carried out, as the result of which $w_1 = 0.4$ and $w_2 = 0.15$ were found to be optimal.

The results of recognition achieved by simple and the multi-template matching method are shown in Table2. In this table, $A(k)$ represents the k'th correct accumulative classification rate. Optimal cutting values were detemined by the dichotomizing search as mentioned before.

4. Conclusion

From the results of recognition shown in table 2, we have got following conculsions.

1. Compared with non-fuzzy mesh feature method (it's recognition rate was about 78%[2]), the rate of recognition in FNM was enhanced 8.0%, and using multi-template matching method, it was additionaly improved about 8.5%, so totaly it was increased about 16.5%. This result confirms that fuzzifying the mesh feature is an effective

approach to absorb the handwriting variation.

2. Compared with FM-feature method, the rate of recognition in FNM is enhanced 6.6%, and when applying the multi-template matching method, it is totally increased about 15.3%. This result shows that the neighbor meshes contribute for improving the correct recognition.

3. Compared with FM-feature method, the cutting value did not influence so much, though a little good effect remains to be. The reason could be that the large part of variations has already be removed by the FNM-feature itself.

4. The correct accumulative classification rate of 5'th rank surpasses 99% in FNM-feature method, which also shows the effectiveness of this method.

References

1) Ohmori K.: "Online handprinted characters recognition by fuzzy inference", Trans. IEICE Japan, 172-D, 3, pp. 369-379 (1989).

2) Wang X. W., Hashimoto R. and Miyagaki Y. : "An approach to recognition of handwritten Chinese characters by using fuzzy theory", Proc. Sino-Japan joint meeting on fuzzy set and system, Beijing, E2-4(1990).

3) Wang X. W., Hashimoto R. and Miyabaki Y. : "Recognition of handwritten Chinese character by fuzzy mesh black density feature,"The 42'th national conf. IPSJ, 5D-5, march (1989).

4) Cheng F. H. and Chen C. A. : "Fuzzy approach to solve recognition problem of handwritten Chinese characters", Pattern recognition, 2, pp. 133-141 (1989).

5) Ohkura M. and Shiono M. : "On discrimination of similar hand printed KANJI character by the measure of fuzziness", Proc. Sino-Japan joint meeting on fuzzy set and system, Beijing, E2-2 (1990).

6) He Zh. X. : "Fuzzy theory and its application ", TST Press, Tianjin (1983).