Character Recognition Based On Maximum Membership Principle

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Abstract─Text recognition is one of the key technologies in an intelligent system. By means of highly effective extraction of the 7 typical features of characters, we dramatically shorten the time spent on feature extraction in this research. Then we built a membership function based on multidimensional normal distribution by utilizing normalized eigenvalue; and finally, we applied maximum membership principle (MMP)-based recognition technology to character recognition. The result indicates that this approach has evidently reduced the time and complexity of calculation while it was still able to maintain high accuracy of recognition.

Keyword-Character recognition; fuzzy sets; feature extraction; maximum membership principle

I INTRODUCTION

Text recognition is one of the key technologies in an intelligent system. Character recognition has been widely employed in On-line Handwritten Chinese Recognition, Off-line Handwritten Chinese character/number recognition, check recognition and table recognition etc. Furthermore, it also has extensive usage in emerging application domain such as business card recognition, ID card recognition, and vehicle license plate recognition, face recognition as well as OCR. Text recognition is usually composed of image input, image preprocessing, and character segmentation and character recognition post processing. Technologies like image input and image preprocessing is relatively mature while character recognition remains a bottleneck. Besides, character recognition is really time-consuming. So it is the key. The research mainly focuses on the application of MMP-based recognition technology in single character recognition during fuzzy information processing.

II MAXIMUM MEMBERSHIP PRINCIPLE-BASED CHARACTER RECOGNITION

Character set contains all the target characters which remain to be identified and the number of characters in this set is n. So we use X_i to represent each character in set U and the eigenvector is then defined as $\{x_1, x_2, ..., x_n\}$. x_i is the i_{th} eigenvalue of character. Let A_i be the corresponding fuzzy set of x_i and define $\mu_{A_i}(X)$ as the corresponding membership function of fuzzy set A_i. So we can identify any given character x_i in character set U based on the following maximum membership principle [0], that is, if we have:

$$\mu_{A_k}(X) = \max\{\mu_{A_1}(X), \mu_{A_2}(X), ..., \mu_{A_n}(X)\}$$

Then this character is maximally subordinated to fuzzy set A_K, and this character is recognized as the target character. We also pick a threshold $\lambda \in [0,1]$ according to the real properties of U.

Define $\alpha = \max\{\mu_{A_1}(X), \mu_{A_2}(X), ..., \mu_{A_n}(X)\}$, so if $\alpha < \lambda$, then reject recognizing this character, otherwise, it shall be recognized as X_k.

A The choice of character's recognition features

Taking various factors into comprehensive consideration, we give the following explanations to 7 eigenvalues we used to describe the character, including four complexity indexes of character strokes, area, complexity and duty ratio in this character recognition algorithm.

Define $f(i, j)$ as $M \times N$ binary dot matrix image; i_c, j_c represent centroid coordinates in $0°$, $90°$ direction respectively; S_1, S_2, S_3, S_4 represent the number of black pixels in $0°$, $45°$, $90°$, $135°$ directions:

$$S_1 = \sum_{i=0}^{N-1} f(i, j_c)$$

$$S_2 = \sum_{j=0}^{M-1} f(i_c, j)$$

$$S_3 = \sum_{k=0}^{N/2} [f(i_c+k, j_c-k) + f(i_c-k, j_c+k)]$$

$$S_4 = \sum_{k=0}^{M/2} [f(i_c+k, j_c+k) + f(i_c-k, j_c+k)]$$

While M_1, M_2, M_3, M_4 is the corresponding second central moment:

$$M_1 = \sum_{i=0}^{N-1} (i - i_c)^2 f(i, j_c)$$

$$M_2 = \sum_{j=0}^{M-1} (j - j_c)^2 f(i_c, j)$$

$$M_3 = \sum_{k=0}^{N/2} 2K^2 [f(i_c + k, j_c - k) + f(i_c - k, j_c + k)]$$

$$M_4 = \sum_{k=0}^{M/2} 2K^2 [f(i_c + k, j_c + k) + f(i_c - k, j_c + k)]$$

So the four complexity index is: $t_i = \dfrac{M_i}{S_i}$, i=1, 2, 3, 4

Eigenvalue area is the amount of pixels contained in the character target area:

$$t_5 = A = \sum_{i=0}^{N-1} \sum_{j=0}^{M-1} f(i, j)$$

Complexity C is a measure of target area's dispersion when compared with circle:

$t_6 = C = \dfrac{L^2}{4\pi A}$ (L stands for the character's perimeter; A stand for area)

Duty ratio is defined as:

$t_7 = B = \dfrac{A}{L \times W}$ (L and W represent the length and breadth of the minimum enclosing rectangle)

B   The normalization of eigenvalue

Due to the difference in dimension of each eigenvalue, there is comparability in the calculation process. So we shall normalize the eigenvalue and make it between 0 and 1:

$$x_{ij}^{'} = \frac{x_{ij} - x_{avgj}}{x_{max\ j} - x_{min\ j}}$$

III   THE ESTABLISHMENT OF MEMBERSHIP FUNCTIONS

To utilize fuzzy logic in classification and maintain recognition rate, the key lies in a well-established character model library. And in this research, it represents a good performance membership function. Suppose that character A_i in target character set U has N_i training samples and here we have 7 selective eigenvalue. We all know that normal distribution, as a kind of continuous random variable probability distribution, is ubiquitous in nature. When the training sample is big enough, all the parameters shall obey normal distribution. Considering the fact that $x_i = \{\lambda_1, \lambda_2, \dots, \lambda_7\}$ obeys normal distribution of seven dimensions:

$$x_i = \{\lambda_1, \lambda_2, \dots, \lambda_7\} \sim N(\mu, \Sigma)$$

Here, $\mu = (\mu_1, \mu_2, \dots, \mu_7)^T$ and $\Sigma = (\delta_{ij})_{7\times7}$ represent eigenvalue's mean value and covariance matrix respectively; then standardize it as standard normal distribution: $x_i^* \sim N(0, \Sigma')$

$$X_i^* = (\frac{\lambda_1 - \mu_1}{\sqrt{\delta_{11}}}, \frac{\lambda_2 - \mu_2}{\sqrt{\delta_{22}}}, \dots, \frac{\lambda_7 - \mu_7}{\sqrt{\delta_{77}}})$$

$\Sigma' = (\delta_{ij}^{'})_{7\times7}$ is a positive definite matrix. So we define

$$d = (d_1, d_2, \dots, d_7)^T = \Lambda^{-\frac{1}{2}} Q^T X_i^* \quad ;$$

$\lambda^{-\frac{1}{2}} = diag(\sqrt{i_1}, \sqrt{i_2}, \dots, \sqrt{i_7}), i_j > 0 (j = 1,2,\dots,7)$ is the eigenvalue of Σ', Q is a n*n orthogonal matrix and we have an equation: $Q^T \Sigma Q = \Lambda$. So the membership functions of $x_i = \{\lambda_1, \lambda_2, \dots, \lambda_7\}$ are the probability density functions of normal distribution of seven dimensions:

$$\mu_{A_i}(X) = f_i(X) = f(\lambda_1, \lambda_2, \dots, \lambda_7) = \prod_{j=1}^{7} \frac{1}{\sqrt{2\pi}} e^{-\frac{d_j^2}{2}}$$

After establishing the membership function of each character fuzzy set with the help of training samples, we can start recognizing characters. For any $x_i = \{\lambda_1, \lambda_2, \dots, \lambda_7\}$, it can be identified as character X_k according maximum membership principle.

IV   CONCLUSION

Thanks to the good stability and good anti-interference performance of seven eigenvalues we used in this research, and few number of eigenvalue, plus relatively low complexity of establishing membership functions and correlative calculation. It takes only one time massive calculation to get the character identified which is fast and efficient. It dramatically reduces the expenses of machine recognition as well as shortens the learning period while keeping a high accuracy of recognition rate.

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