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Research on the Gabor Feature Extraction Methods of Online Handwritten Tibetan Characters Recognition

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Abstract

Gabor filters have a good performance for texture feature extraction of texture images from a variety of low-quality handwritten character images. Therefore, this article proposes an online handwritten Tibetan character feature extraction methods which is based on the Gabor filter. The Gabor filter is used to process the Tibetan character image, block the image, extract the Gabor energy value of each block, and combine the energy values into the energy matrix, obtain the feature vector of the characters after feature dimension reduction, and then recognize the feature vector through the MQDF classifiers. The experiment shows that: the recognition of the samples in the data base of the handwritten Tibetan characters which is based on Gabor energy feature is simple and effective.

Keywords: Online handwritten Tibetan characters; Gabor filters; MQDF classifiers; Samples

1 INTRODUCTION

Handwriting recognition is the process of changing the written handwriting from the space graphics into the semantic symbols. On-line handwritten input is in line with people's natural way of writing, with the popularity of portable devices like mobile phones, tablets, the use of online handwriting has huge value, cause the extensive concern of more and more researchers, which leads to the sustainable development.

Tibetan is one of the world's best mature characters, it is a special kind of alphabet writing, which has a changing font structure. Currently, online handwritten Tibetan recognition is still in the research stage [2-5], so far there are still no mature products. In recent years the development of Chinese character recognition technology is more mature, we can learn from the Character recognition to recognize Tibetan characters.

Gabor filter is a narrow band-pass filter with a clear direction selection and frequency selection characteristics which can effectively extract structural features from characters. Gabor filter is first applied to image analysis, image compression and image feature extraction, In recent years in many areas of the handwritten character recognition [9-11], Gabor filter is thought as a method of feature extraction for various binary and grayscale images printed and handwritten characters texture feature extraction of handwritten character images, achieves a good recognition effect.

This paper proposes a method for extracting energy feature from online handwritten Tibetan characteristics recognition based on Gabor filters. This method is trying to use the real value of the Gabor filter to process the character image which is normalized to 48×96 size, the filtered image is divided into 72 8×8 non-overlapping pieces, and extracting energy characteristics from each piece to form an energy matrix, and use the LDA(Linear Discriminant Analysis) method and dimension reduction to obtain the feature vector from the energy matrix, then recognize the samples of handwritten Tibetan characters through the MDQF (Modified Quadratic Discriminant Function) classifier.

2 THE BASIC PRINCIPLE OF GABOR FILTERS

In the 1980s, Daugman was the first to propose a two-dimensional Gabor filter in computer vision [1], which is a local narrow band-pass filter, it is possible to obtain the joint information from the two-dimensional spatial domain and frequency domain (2D Fourier domain), Daugman applied it to image analysis and image compression. And he has given the function form of the two-dimensional Gabor filter, in the spatial domain, Gabor filter is a Gauss kernel function which is modulated by a sinusoidal plane wave, such as formula (1) and (2) below.

$$g(x,y) = s(x,y)w(x,y) \tag{1}$$

(x,y) is the spatial domain pixel position coordinates, $s(x,y)$ is the sinusoidal plane wave, $w(x,y)$ is a two-dimensional Gauss kernel function.

The general form of the sinusoidal plane wave is:

$$s(x,y) = \exp(i2\pi(u_0 x + v_0 y) \tag{2}$$

Parameter (u_0, v_0) is the spatial frequency of the Sinusoidal plane wave (spatial frequency), formula (2) can be represented in the form of polar coordinates (f_0, θ_0), f_0 is the frequency (or scale), θ_0 is the direction, such as the formula (3) below.

$$\begin{gathered} s(x,y) = \exp(i2\pi f_0 (x\cos\theta_0 + y\sin\theta_0) \\ f_0 = u_0{}^2 + v_0{}^2, \tan\theta_0 = \frac{v_0}{u_0} \end{gathered} \tag{3}$$

2D Gauss kernel function called Gabor filter envelope, its general form is as follows:

$$w(x,y) = K\exp(-\pi(\frac{(x-x_0)_r{}^2}{a^2} + \frac{(y-y_0)_r{}^2}{b^2})) \tag{4}$$

(x_0, y_0) is the peak value of the kernel function, a and b are mean square errors of the Gauss function along the x-axis and y-axis directions, K is coefficient which Gaussian envelopes, the subscript r represents a rotation angle β.

In order to simplify the functional form of the Gabor filter, it can be assumed:

1) Angle of rotation of the Gaussian kernel function has the same direction with the Sinusoidal plane wave, that is $\theta_0 = \beta$.
2) The center of the Gaussian kernel function is at the origin (0, 0) and the mean square error $a = b = \delta$ of the x axis and the y axis.

The sinusoidal component of the exponential function (i.e., Sinusoidal plane wave)debugged by the Gaussian function is with zero mean, and the cosine function does not have zero mean. So we can minus $\exp(-w^2\delta^2/2)$ to make the Sinusoidal plane wave with zero mean. The 2 dimensional Gabor filter which simplified is defined as:

$$g(x,y,w,\theta) = \frac{1}{2\pi\sigma^2} e^{-(\frac{x'^2+y'^2}{2\sigma^2})} [e^{-iwx'} - e^{-\frac{w^2\sigma^2}{2}}] \tag{5}$$

The 2 dimensional Gabor filter includes all frequency, amplitude values and phase values. When extracting the feature through from the character images through Gabor filters, we need to do convolution integral calculation on the input image and the filter, and extract the pixel energy as the feature of the characters.

3 THE ENERGY FEATURE EXTRACTION METHOD BASED ON THE GABOR FILTER

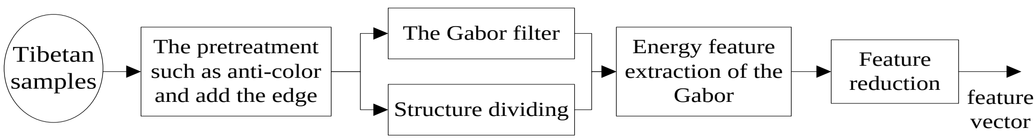

FIG. 1 THE FLOWCHART OF THE FEATURE EXTRACTION METHOD BASED ON THE GABOR FILTER

As shown in FIG. 1, the main step of the method of extracting online handwritten Tibetan character feature is based on Gabor filters.

Step1. Character image anti-color processing

Before the filtering operation with the the Gabor filter, the Tibetan character images after pretreatment need to be anti-color processing.

$$h(x,y)=1-I(x,y) \tag{6}$$

$I(x,y)$ is the gray of the normalized binary image, $h(x,y)$ is the gray of the anti-color image.

As shown in FIG. 2, after the adoption of anti-color processing, the character handwriting part of the character image change into white from black, and the white of the background portion change into black. The aim of the anti-color processing is to reduce the computation of the character image feature extraction.

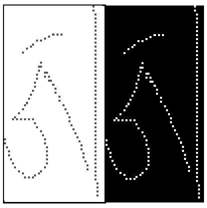

FIG. 2 THE IMAGE OF CHARACTER BEFORE AND AFTER THE ANTI-COLOR

Step2. Character image bordered processing

According to the height and width of the Gabor filter window, add the edge of the character image. all the character information in the internal of the image after adding the edge processing, and avoid the loss of image edge information after filtering. Assuming that the width and height of the Gabor filters filter window were GaborHeigh and GaborWidth, then put on the character image, the edge (GaborHeigh - 1) / 2 rows, left and right edge (GaborWidth - 1) / 2 columns, the pixel value of the bordered area is 0.

Step3. The Gabor filter designing

Two-dimensional Gabor function is a complex function which consists of the real part and imaginary part. Since the Gabor function is an even symmetric function, the calculation process is complicated. Therefore, we generally use the real part of the two-dimensional Gabor function as the filter to process the character image. In the literatures [6~8] extracting the feature of characters by using the Gabor filter has achieved good results. The real value of the Gabor filter expressions is shown in formula (7) below.

$$g(x,y,\lambda,\theta)=\exp\{-\frac{1}{2}[\frac{x'^2}{\sigma_x{}^2}+\frac{y'^2}{\sigma_y{}^2}]\}\cdot\cos(i\cdot\frac{2\pi x'}{\lambda}), \quad , \tag{7}$$

Among them, the expressions of x' and y' are shown by formula (8)and formula (9) as below.

$$x'=x\cos\theta+y\sin\theta \tag{8}$$

$$y'=-x\sin\theta+y\cos\theta \tag{9}$$

In the expression (7), $1/\lambda$ is the spatial frequency of the modulation harmonic function, θ is the direction of the Gabor filter, these two parameters values in the local range are unchanged. The σx and σy represent the variance of the two-dimensional Gaussian function whose center is located at the point of the airspace sample, their value directly affects the filtering effect. If the value is too large, it will lead to pseudo wire; if the value is too small, it will result that some frequencies can not pass a two-dimensional band-pass filter, and affected the quality of the filter. Typically, the value of σ_y should be greater than the value of σ_x, determining the appropriate σ_x and σ_y can not only enhance character features of the specified direction, but also can suppress the interference information such as noise. The character features which is extracted by the Gabor filters can effectively represent the character image of strong directional character image stroke information, so selecting the appropriate parameter values has become the key steps in the Gabor filter designing. In general, the frequency of the Gabor filter is determined by the frequency of the image, and the direction is determined by the direction of the image. The σ_x and σ_y mostly take the same value.

The Tibetan character image is discrete, Gabor filtering the image usually means to do a convolution processing on the signal function of the image and the filter function. The formula of the Tibetan characters which is Convolution operated by the Gabor filter is as shown in formula (10).

$$H(x,y)=\sum_{u=-\frac{Gh}{2}}^{\frac{Gh}{2}}\sum_{v=-\frac{Gw}{2}}^{\frac{Gw}{2}} g(x,y,\lambda,o(x,y))*h(x-u,y-v) \tag{10}$$

In formula (10), λ is the wavelength of the character image, $o(x,y)$ is the direction of the character image, $h(x,y)$ is the gray value of the character image. The character image with $h(x-u,y-v)$ represents pan handling with the window of the filtering area. Gh and Gw are the width and height of Gabor filters window.

Step4. Character image filtering processing

Filtering the character image with the Gabor filter.

$$H(x,y)=\sum_{u=-\frac{Gh}{2}}^{\frac{Gh}{2}}\sum_{v=-\frac{Gw}{2}}^{\frac{Gw}{2}} g(x,y,\theta,f)*h(x-u,y-v) \tag{11}$$

Among them, Gh=(GaborHeigh-1)/2, Gw=(GaborWidth-1)/2, $\theta = k\pi/6$, $f=1$.

In this article the k are 0,1,2,3,4,5, the anti-colored and bordered image is filtering processed with 0 degrees, 30 degrees, 60 degrees, 90 degrees, 120 degrees, 150 degrees by the Gabor filters.

Step5. Character image area dividing

Equally dividing the filtered 48×96 character image's width and height into 8×8 non-overlapping sub-image blocks, it will total achieve 6×12 pieces, as shown in FIG. 3.

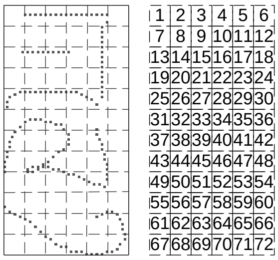

FIG. 3 TIBETAN CHARACTER STRUCTURE DIAGRAM

Step6. the character image feature extraction

After the completion of the regional division, calculate the energy of the 72 same size, non-overlapping blocks. In the k-th image blocks, assuming the value of the filtered images in the i-th pixel is p(i), the energy is $|p(i)|^2$, the expression of the k-th image block's energy is as shown in formula (12).

$$e(k)=\frac{1}{64}\sum_{i=1}^{64}\sqrt{|p(i)|^2} \quad , \quad k\in[1,72] \tag{12}$$

After calculating the energy of each sub-image block, make all the energy value of the sub-image blocks an energy matrix of 6×12. After filtering the character image in six directions with the Gabor filter. Extracting the feature of the image energy, we will get six energy matrices of six 6×12, and then combining them to obtain a 1×432 feature matrix, which is V, I.e. V (e (1), e (2), ..., e (432)). V is the feature vector of the Tibetan character image.

Step7. Feature Transforming

The feature transformation process is as shown in FIG.4 . Using the method of linear differential LDA, transforming and compressing the original characteristics through calculating the transform matrix to obtain the final recognition feature.

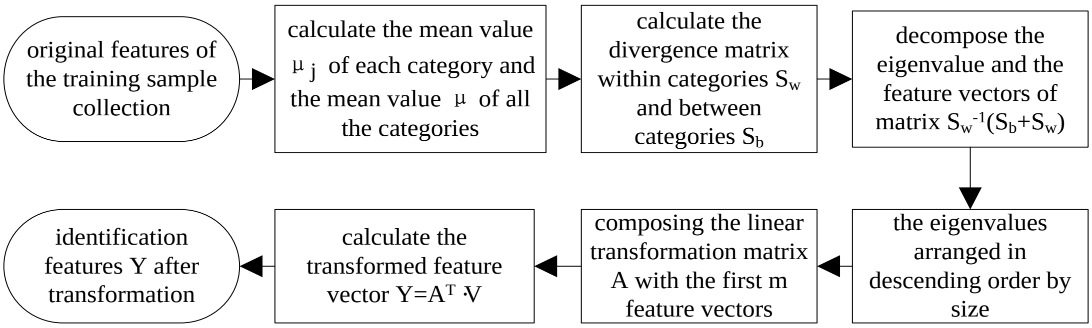

FIG. 4 FEATURE TRANSFORMING FLOWCHART

Setting $\{\{V_i^{(j)}, 1 \le i \le N_j\}, 1 \le j \le C\}$ to original set to feature vector collection, $V_i^{(j)}$ is belonging to the original feature vector which is extracted from the i-th sample in the j-th category, N_j is the number of samples of j-th category, C is the number of categories, which means 562 Tibetan characters.

Calculating the mean value of all categories and each category through formula (13).

$$\mu_j = \frac{1}{N_j}\sum_{i=1}^{N_j} V_i^{(j)}, \mu = \frac{1}{C}\sum_{j=1}^{C}\mu_j \tag{13}$$

Calculating the divergence matrix within categories and between categories through formula (14) and (15).

$$S_w = \frac{1}{C}\sum_{j=1}^{C}\left(\frac{1}{N_j}\sum_{i=1}^{N_j}(V_i^{(j)} - \mu_j)(V_i^{(j)} - \mu_j)^T\right) \tag{14}$$

$$S_b = \frac{1}{C}\sum_{j=1}^{C}((\mu_j - \mu)(\mu_j - \mu)^T) \tag{15}$$

Selecting $|(S_b + S_w)/S_w|$ as the optimization criterion, which means to strike a linear transformation matrix A to make $|A^T(S_b + S_w)A / A^T S_w A|$ the maximum.

Setting transformation matrix A to $n \times m$ matrix, n is the original feature dimension, m is the feature dimension transformed.

The calculation method of the transformation matrix is as follows: Decomposing the eigenvalue and the feature vectors of $S_w^{-1}(S_b + S_w)$, to obtain the eigenvalue $\{\gamma_i, i = 1, 2, ..., n\}$, the eigenvalues arranged in descending order by size, and feature vectors $\xi_i, i = 1, 2, ..., n$. Composing the matrix with the first m feature vectors $A = [\xi_1, \xi_2, ..., \xi_m]$, the A is a linear transformation matrix. So the original feature vector V changes into selection feature Y: $Y = A^T V$.

Step8. The classifier training and recognition

This article uses the quadratic classifier MQDF for the improved model of the Gaussian model. The training and recognition process of the classifier is as shown in FIG. 5.

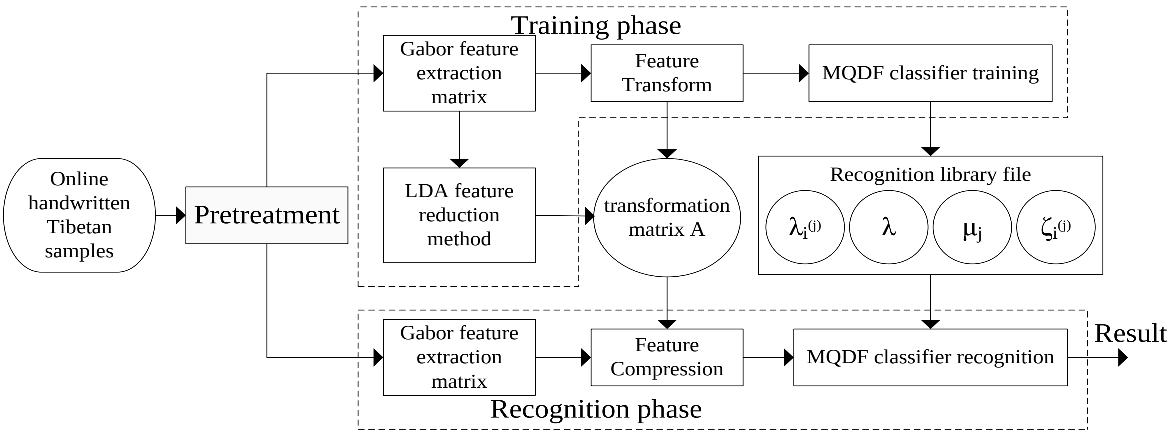

FIG. 5 THE CLASSIFIER TRAINING AND RECOGNITION

The introduction of the quadratic classifier. The decision function of the QDF is:

$$g_j(Y) = \sum_{i=1}^{m} \frac{((Y-\mu_j)^T \zeta_i^{(j)})^2}{\lambda_i^{(j)}} + \sum_{i=1}^{m} \log \lambda_i^{(j)} \tag{16}$$

In formula (16), Y is the feature vector input, m is feature dimension, μ_j is the mean vector of the j-th category, the first one is the first feature vector covariance matrix of categories, $\zeta_i^{(j)}$ is the i-th feature vector of the j-th category's covariance matrix, $\lambda_i^{(j)}$ is the i-th eigenvalue of the j-th category's covariance matrix.We can classify with the following criteria when identify input Y.

Classify Y as the i-th category, if $g_j(Y) = \min_{1 \le j \le C} g_j(Y)$, C is the number of categories.

In practice, because of the estimates of the small eigenvalues is inaccurate, it may cause the performance degradation of QDF. In order to reduce the adverse impact on classification performance, we can use the improved secondary classifier MQDF.MQDF substitutes constants determined in advance for too small eigenvalues, the discrimination function is as shown in formula (17) below. k is a positive integer less than m, and λ is a constant.

$$g_j(Y) = \sum_{i=1}^{k} \frac{((Y-\mu_j)^T \zeta_i^{(j)})^2}{\lambda_i^{(j)}} + \sum_{i=k+1}^{m} \frac{((Y-\mu_j)^T \zeta_i^{(j)})^2}{\lambda} + \sum_{i=1}^{k} \log \lambda_i^{(j)} + \sum_{i=k+1}^{m} \log \lambda \quad \lambda = \frac{1}{C} \sum_{j=1}^{C} \lambda_{k+1}^{(j)} \quad j = 1, 2, \ldots, C \tag{17}$$

In formula (17), k and m are empirical parameters, in the experiment, m is 120, k is32. When classified, the input Y is divided into the category which make $g_j(Y)$ the minimum value.

4 THE EXPERIMENTAL RESULTS AND ANALYSIS

This article uses the energy feature extraction method which is based on the real value Gabor filter and MQDF recognition classifier to do the recognition experiment with online handwritten Tibetan characters. The experiment uses the self-built handwritten Tibetan character database in the laboratory which includes 180 sets, each set contains 562 Tibetan characters, in this experiment we choose one of 120 sets as training samples, 60 sets as a test sample.

TABLE 1 30 CHARACTERS RECOGNITION TABLE

C	Top 1	Top 3	Top 5	Top 10	C	Top 1	Top 3	Top 5	Top 10
ག	67.18%	91.44%	93.51%	98.63%	ཁ	79.16%	87.19%	90.48%	94.92%
ཀ	83.96%	91.60%	91.80%	94.28%	ང	76.02%	82.36%	82.36%	90.32%
ཅ	61.05%	68.39%	74.48%	88.36%	ཆ	68.08%	71.62%	87.40%	97.03%
ཇ	65.09%	79.86%	85.56%	92.36%	ཉ	76.30%	82.03%	82.03%	92.78%
ཏ	63.96%	83.64%	89.57%	94.68%	ཐ	62.28%	72.96%	80.18%	93.64%
ད	79.08%	85.18%	93.74%	97.32%	ན	70.16%	83.62%	89.70%	92.06%
པ	58.64%	76.08%	78.72%	87.06%	ཕ	59.07%	79.69%	85.39%	93.31%
བ	61.81%	77.05%	83.18%	90.27%	མ	66.82%	78.47%	88.06%	94.46%
ཙ	66.38%	80.26%	87.69%	92.52%	ཚ	77.28%	84.93%	89.67%	95.37%
ཛ	56.52%	78.24%	85.70%	94.74%	ཝ	59.72%	70.25%	83.90%	92.30%
ཞ	84.08%	88.36%	88.36%	93.51%	ཟ	68.20%	76.88%	88.82%	91.27%
འ	52.38%	68.05%	81.64%	92.80%	ཡ	76.04%	85.32%	90.04%	94.76%
ར	72.59%	86.03%	94.27%	97.96%	ལ	62.31%	75.29%	87.13%	92.84%
ཤ	68.43%	83.20%	89.36%	92.18%	ས	60.18%	72.68%	84.60%	93.06%
ཧ	64.96%	76.32%	84.12%	91.92%	ཨ	57.03%	69.91%	82.46%	85.02%

As shown in Table 1, it lists the recognition rate of the preferred character, the top 3 elections, the top 5 and the top 10 elections of the 30characters. In the top 10 elections, The highest recognition rate is 98.63%, the lowest recognition rate is 85.02%, the mixed average recognition rate is 93.06%.

TABLE 2. THE RECOGNITION TABLE OF 10 CHARACTERS BASED ON ཀ

C	Top 1	Top 3	Top 5	Top 10
ཀ	67.18%	91.44%	93.51%	98.63%
ཀྲ	53.76%	93.60%	93.60%	95.72%
ཀི	58.24%	75.39%	86.28%	96.31%
ཀུ	68.92%	81.26%	84.67%	93.23%
ཀེ	65.67%	81.93%	81.93%	95.65%
ཀོ	70.06%	80.14%	85.72%	94.27%
ཀྱ	56.33%	73.35%	84.52%	86.06%
ཀྱུ	58.91%	69.28%	70.12%	83.33%
ཀྱེ	61.23%	65.50%	74.69%	78.92%
ཀྱོ	65.38%	70.29%	70.29%	79.63%

As shown in Table 2, it lists the recognition rate of 10 characters based on ཀ , the highest recognition rate is 98.63%, the lowest recognition rate is 75.63%, the mixed average recognition rate is 89.9%. Comparing the preferred character, the top 3 elections, the top 5 and the top 10 elections, we can find the recognition result of the characters with relatively complex structure is slightly worse than characters with relatively simple structure.

5 CONCLUSIONS

This paper adopted the MQDF classifier to classify recognition, proposed the energy feature extraction method of the online handwritten Tibetan characters which is based on the real value Gabor filter. The experiment has proved that the energy feature extraction method of the online handwritten Tibetan characters which is based on the real value Gabor filter is simple and effective. In order to improve the recognition rate, we need to optimize the design of Gabor filter and fuse other features extracted by other methods with Gabor feature.

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REFERENCES

[1] Daugman. Uncertainly relation for resolution in space,spatial frequency,and orientation optimized by two-dimensional visual cortical filters [J]. J Opt Soc Am,1985,2(7):1160-1169.

[2] Qianjun Qian,Weilan Wang.A Novel Approach for Online Handwriting Recognition of Tibetan Characters.IMECS,2010.

[3] Weilan wang, Jianjun Qian, Daohui Wang. Online Handwriting Recognition of Tibetan Characters Based on the Statistical Method. 2011 Journal of Communication and Computer 8, 2011

[4] Weilan wang, Wanjun Chen. Online handwritten Tibetan characters recognition based on strokes feature and MCLRNN model Computer Engineering and Applications,2008

[5] Daohui Wang. Online handwriting Tibetan Characters recognition research on feature extraction of statistical structure[D]. Northwest University for Nationalities,2011

[6] Xuewen Wang, Xiaoqing Ding. Changsong Liu.A robust Chinese Characters recognition based on Gabor Transform[J].Acta Electronica Sinica,2002,30(9):1317-1322

[7] Lianwen Jin, Jianzhao Qin. A handwritten Chinese characters feature extraction Algorithm based on Elastic Network Gabor Filters[J]. Application Research of Computers,2004(12):163-165
[8] Wen Jiang, Likang Liu. Handwritten Balakrishnan Character Recognition based on energy faeature of the Real Gabor. Computer Engineering and Design,2013,34(9):3273-3278
[9] Yuli Xue,Yuhua Peng,Xinhong Zhou. Palmprint recognition based on real Gabor Transform[J]. Computer Engineering and Applications,2007,43(6):216-219
[10] Tsinghua University. Character Recognition Technology based on Gabor filters: China,02117865.8[P]. 2003,12
[11] Junbao Liu, Yi Li. Gabor filter design for figerprint image enhancement[J]. Computer Engineering,2012,38(18):130-132

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