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A Quality Assessment Method of Iris Image Based on Support Vector Machine*

Si Gao [a], Xiaodong Zhu [a], Yuanning Liu [a,*], Fei He [a], Guang Huo [a,b]

[a] *College of Computer Science and Technology, Jilin University, Changchun 130012, China*
[b] *Informatization Office, Northeast Dianli University, Jilin 132012, China*

Abstract

The quality of iris image is one of the key factors influences the performance of iris pattern recognition. Based on the existing quality assessment measures of iris image, and in consideration of the most prominent factors that lead recognition to fail, we firstly put forward iris rotation which is a new quality assessment measure. Then iris rotation, iris visibility, iris eccentricity and iris definition are together as quality assessment measures of iris image and the quality assessment of iris image is done by Support Vector Machine (SVM) classifier. The experiment results express that the method we propose can select the images with good quality and has strong predictability for the performance of iris pattern recognition.

Keywords: Iris Recognition; Quality Assessment; Iris Rotation; SVM Classifier

1 Introduction

As a key step of iris recognition, the quality assessment of iris image has a great influence on the performance of iris pattern recognition and it exists a variety of methods that qualify iris images. Daugman [1] evaluated iris image quality by calculating high-frequency energy of the two-dimensional Fourier spectrum of the iris image. Wildes [2] qualified iris image by determining the gray scale gradient of boundary between iris and sclera. Ma [3] proposed a method that first calculated the different frequency band energy of the two-dimensional Fourier spectrum of iris image and then used SVM classifier to select qualified images. J. Chen [4] used the high frequency energy of iris texture extracted by using wavelet packet decomposition as evaluation standard. L. Xing [5] combined three factors, image definition, eccentricity of inside and outside, and iris visibility to qualify iris image comprehensively.

In summary, the main quality assessment measures includes definition, visibility and eccentricity. However, from the experiment, we found that these quality measures could cause false rejection in recognition stage when it comes to iris rotation in the process of acquisition.

Therefore, in this paper, we propose a compositive quality assessment method of iris image by

*Project supported by State Important Achievements Transfer Projects of China (No. 2012258).
*Corresponding author.
Email address: lyn@jlu.edu.cn (Yuanning Liu).

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combining the existing quality measures and iris rotation, a new quality measure we put forward. First, we roughly evaluate the definition and visibility of iris image so that the low quality images can be removed quickly and ensure the subsequent location of iris and eyelid is correct. Then according to the localization results, iris rotation, iris visibility, iris eccentricity and iris definition are calculated respectively and the quality assessment of iris image is done by the SVM classifier.

2 Rough Assessment

2.1 Definition

Although the gradient function is not sensitive to small changes of image definition, it is fast in real-time and can effectively eliminate the strong bright and strong dark images. So the gradient function is enough to be a rough assessment method of image definition.

If *Width* and *Height* represent the width and height of input image respectively, then the steps are as follows:

(1) G_x and G_y that represent the lateral and longitudinal directional derivative respectively are given in Eq. (1).

$$\begin{cases} G_x = I(x-1,y) - I(x+1,y) \\ G_y = I(x,y-1) - I(x,y+1) \end{cases} \tag{1}$$

where $x \in$(0, Width-1], $y \in$(0, Height-1]. $I(x,y)$ is the gray value at the point (x,y).

(2) The cumulative sum of gradient magnitude is calculated, then the rough assessment index of the image definition Q is defined in Eq. (2).

$$Q = \frac{\sum_x \sum_y \sqrt{G_x^2 + G_y^2}}{Width \times Height} \tag{2}$$

the bigger Q is, the clearer image would be.

2.2 Visibility

Based on the rough assessment method of visibility that Luo et al. [6] proposed, we first retain the pupil by image binarization and then eliminates the influence of image spots by using opening operation based on morphological knowledge. Finally the area of visible pupil S is calculated according to the pixels of visible pupil. We take the mean of the pupils' radius in sample as R. If it satisfies Eq. (3), the iris visibility would be good.

$$S > 0.8\pi R^2 \tag{3}$$

3 Localization

3.1 Iris Localization

In this paper, we adopt iris coarse localization algorithm for both boundaries [7]. According to the localization results, we suppose $PupilX$ and $PupilY$ represent x-coordinate and y-coordinate of the pupil center respectively and $IrisX$ and $IrisY$ represent x-coordinate and y-coordinate of the iris center respectively. $PupilR$ and $IrisR$ indicate the pupil radius and iris radius separately.

3.2 Eyelids Localization

In order to reduce the interference of the upper eyelash and consider the results of iris localization, we firstly preprocess the original image to get the contour of the lower eyelid and upper eyelash and then fits the contour to parabola. The steps of image preprocessing are as follows:

(1) Use morphological method to enhance the original image. The original image and enhanced image are shown in Fig. 1 (a) and Fig. 1 (b) respectively.

(2) Equalize the enhanced image. The equalized image is shown in Fig. 1 (c).

(3) Use threshold method for binarization of the equalized image. If the minimum gray value of the equalized image is I_{min} and its mean gray value is $\bar{I}$, the threshold of binarization is given as $T = I_{min} + \frac{\bar{I}}{3}$. The binarization image is shown in Fig. 1 (d).

(4) Remove the pupil. According to the results of iris localization, each pixel is set to white at the range of the circle whose center is the point ($PupilX$, $PupilY$) and radius is ($PupilR + 5$). The image removed the pupil is shown in Fig. 1 (e).

(5) Use median filtering method to weaken the noise of the image. The result is shown in Fig. 1 (f).

(6) Use region growing denoising method [8] to remove noise. The result is shown in Fig. 1 (g).



(a) (b) (c) (d) (e) (f) (g) (h)

Fig. 1: Image preprocessing

Firstly, we would get the contour of the lower eyelid and upper eyelash based on the preprocessed image and then uses least square method to fit the contour to parabola on the basis of the edge points of the contour we detected. Parabolic formula is defined in Eq. (4).

$$y = ax^2 + bx + c \tag{4}$$

The steps of solving the parameters including a, b and c are as follows:

(1) According to Eq. (5), calculate the sum of squares of deviations between the theoretical values and the experimental values based on the edge points (x_i, y_i) we detected.

$$d^2 = \sum_{i=1}^{N} (ax_i^2 + bx_i + c - y_i) \tag{5}$$

where N is the width of the image.

(2) According to the sum of squares of deviations, the partial derivatives of three parameters are set to zero respectively, namely $\frac{\partial d^2}{\partial a} = 0$, $\frac{\partial d^2}{\partial b} = 0$, $\frac{\partial d^2}{\partial c} = 0$. Thus, the ternary equations we obtained are in Eq. (6).

$$\begin{cases} a\sum_{i=1}^{N} x_i^4 + b\sum_{i=1}^{N} x_i^3 + c\sum_{i=1}^{N} x_i^2 - \sum_{i=1}^{N} x_i^2 y_i = 0 \\ a\sum_{i=1}^{N} x_i^3 + b\sum_{i=1}^{N} x_i^2 + c\sum_{i=1}^{N} x_i - \sum_{i=1}^{N} x_i y_i = 0 \\ a\sum_{i=1}^{N} x_i^2 + b\sum_{i=1}^{N} x_i + cN - \sum_{i=1}^{N} y_i = 0 \end{cases} \tag{6}$$

(3) Solve the above equations and get the values of three parameters. The result is shown in Fig. 1 (h).

4 The Quality Assessment Indexes of Iris Image

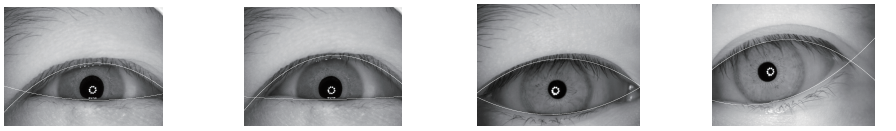
4.1 Iris Rotation

According to the physiological characteristics of human itself, iris rotation can be determined by calculating the angle between the vector made up of two intersections of the upper and lower eyelids (two corners of the eye) and the horizontal vector. In this paper, the intersections of two parabolas gotten by fitting the lower eyelid and upper eyelash are considered to be two intersections of upper and lower eyelids.

If the intersections of two parabolas are $A(x_1, y_1)$ and $B(x_2, y_2)$ respectively, where $(x_1 < x_2)$, and the coordinate of the horizontal vector is set to $\vec{a} = (1, 0)$, then the direction vector coordinate of $\overrightarrow{AB}$ is $\vec{b} = (x_2 - x_1, y_2 - y_1)$ and the angle between $\vec{a}$ and $\vec{b}$ is considered to be Iris Rotation which is calculated in Eq. (7).

$$Q_{rotation} = \arccos \frac{\vec{a} \cdot \vec{b}}{|\vec{a}| \times |\vec{b}|} \tag{7}$$

the smaller $Q_{rotation}$ would be, the smaller Iris Rotation is. Iris Rotation of different images is shown in Fig. 2.



(a) $Q_{rotation}$=0.006 (b) $Q_{rotation}$=0.013 (c) $Q_{rotation}$=0.053 (d) $Q_{rotation}$=0.184

Fig. 2: Iris rotation

4.2 Iris Visibility

The impact factors of iris visibility mainly include eyelashes and eyelids occlusion and pupil scaling. According to the results of localization, we made these definitions:

Pupil scaling factor:

$$K_1 = 1 - \frac{PupilR}{IrisR} \tag{8}$$

Iris shielding factor:

$$K_2 = \frac{d_{up} + d_{down}}{2IrisR} \tag{9}$$

where d_{up} and d_{down} represent the distance between the iris center and the upper eyelash and the distance between the iris center and the lower eyelid in vertical direction respectively. According to Eq. (8, 9), Iris Visibility is defined in Eq. (10).

$$Q_{Visibility} = K_1 \times K_2 \times 100\% \tag{10}$$

the higher $Q_{Visibility}$ is, the greater Iris Visibility would be.

4.3 Iris Eccentricity

In the process of iris image acquisition, the iris images which are off-angle and beyond acquisition region will bring great difficulty to subsequent normalization processing. Therefore, we propose Iris Eccentricity.

Based on the "Inside and outside eccentricity" that Luo et al. [6] put forward, we first define iris eccentric factor:

$$K_3 = \frac{\sqrt{(IrisX - PupilX)^2 + (IrisY - PupilY)^2}}{PupilR} \tag{11}$$

the smaller K_3 is, the closer to the concentric circle the inside and outside boundaries of iris would be. And then we define iris centrifugal factor:

$$K_4 = \frac{\sqrt{(x - PupilX)^2 + (y - PupilY)^2}}{d_{max}} \tag{12}$$

where (x, y) is the center coordinate of image. d_{max} is half length of the image diagonal. The smaller K_4 is, the closer to image center the iris center would be. According to Eq. (11, 12), Iris Eccentricity is defined in Eq. (13).

$$Q_{eccentricity} = (\alpha_1 K_3 + \alpha_2 K_4) \times 100\% \tag{13}$$

where α_1 and α_2 are the weight values of two factors respectively, $\alpha_1 + \alpha_2 = 1$. This paper takes $\alpha_1 = 0.7$, $\alpha_2 = 0.3$. The smaller $Q_{eccentricity}$ is, the more favorable to recognition the image would be.

4.4 Iris Definition

This paper proposes a method with multi-directional fusion of Gray Level Co-occurrence Matrix (GLCM) based on the Region of Interest (ROI). Firstly, sub-image is segmented on the right side of the pupil as ROI. Then the GLCMs of ROI with 0°, 45°, 90° and 135° are solved and normalized respectively. Finally, the root-mean-square of four entropy values evaluated based on the GLCMs is considered to be Iris Definition. Entropy is calculated in Eq. (14).

$$E(n) = -\sum_{i=1}^{K}\sum_{j=1}^{K} p_\lambda(i,j,n)\lg p_\lambda(i,j,n) \tag{14}$$

where $n \in [1,4]$, which represents four directions. K is the gray quantization level. λ is statistical distance. $p_\lambda(i,j,n)$ represents pixels frequency whose gray value is j with starting with gray value i at the range of λ in the direction of n. According to Eq. (14), Iris Definition is given in Eq. (15).

$$Q_{definition} = \sqrt{\frac{\sum_{n=1}^{K} E^2(n)}{4}} \tag{15}$$

the bigger $Q_{definition}$ is, the clearer iris would be.

4.5 Comprehensive Quality Assessment of Iris Image

The assessment steps of algorithm proposed in this paper are as follows:

(1) Evaluate the definition and visibility of iris image roughly. If passed, then go on the next step. Otherwise, discard the image and reacquire;

(2) Calculate four Quality Assessment Factors (QAF) of the iris respectively according to the localization results.

(3) Use 2-class SVM to determine if the image quality is satisfactory based on QAF.

5 Experimental Analysis and Results

For the purpose of validating the effectiveness of the method we propose, the database we use has 50 different image sequences and each contains 30 images, where include 10 images with different Rotation to validate the Iris Rotation algorithm we propose. We select randomly half of the images in each sequence as the training set Data 1, and the other as test set Data 2.

5.1 Design of SVM Classifier

In this paper, we adopt SVM with the Radial Basis Function (RBF). The key of the design of SVM classifier is confirming the penalty coefficient of SVM classifier C and radius of RBF γ. These are the steps we follow:

(1) Normalize the data set composed of four characteristic values of the images in Data 1.

(2) Calculate the misclassification rate by using 10-Fold Cross Validation at the given range of C and γ.

(3) Use the grid searching method to find the optimal C and γ under the minimum misclassification rate.

5.2 Performance of Algorithm Testing

5.2.1 Accuracy Testing

We would obtain the optimal parameters of SVM based on the above steps and conducts SVM training for Data 1 to access SVM model, and then classify Data 2. The Correct Classification Rate (CCR) of this paper is shown in Table 1. It follows that the assessment method we propose has great classification ability.

Table 1: The CCR of assessment indexes

Index	Rotation	Visibility	Eccentricity	Definition	SVM Classifier
CCR (%)	99.2	99.6	98.0	98.3	97.7

5.2.2 Prediction Testing

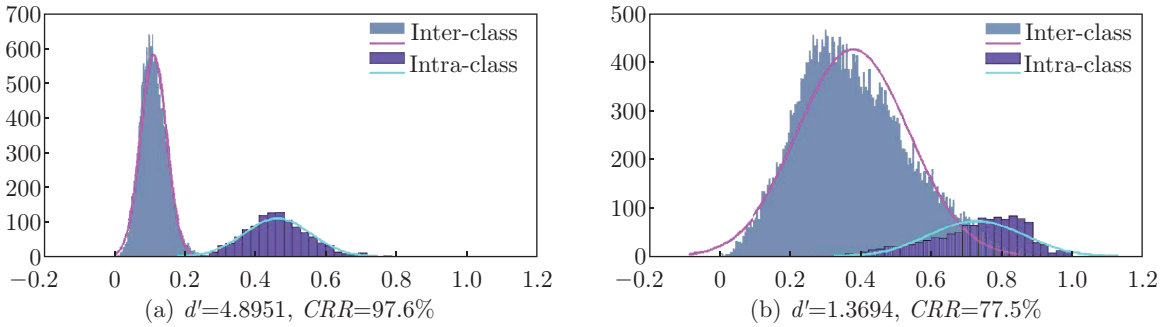
Data 2 is divided into two image sets by the method we propose, and one with good quality is marked for High, the other with poor quality is marked for Low. In this paper, the distinguishing factor d' and Correct Recognition Rate (CRR) are used as indexes to measure recognition performance. The greater performance gap of two image sets is, the better prediction of the algorithm would be [9]. d' is defined in Eq. (16).

$$d' = \frac{|\mu_1 - \mu_2|}{\frac{\sqrt{\sigma_1^2 + \sigma_2^2}}{2}} \tag{16}$$

where μ_1 and σ_1^2 represent the mean value and variance of intra-class respectively, and μ_2 and σ_2^2 are the mean value and variance of inter-class separately. We use the method Daugman [10] proposed to eliminate the influence of the algorithm itself when testing. Fig. 3 shows the distinction degree of intra-class and inter-class of High and Low. As shown in Fig. 3, the distinction degree gap and CRR gap of two image sets are $\triangle d = 3.5257$ and $\triangle CRR = 20.1\%$ respectively. Besides, as shown in Table 2, it has higher CCR compared with Daugman [1], Wildes [2] and Xing L. [5] in terms of Data 2. Thus it can be seen that the method we propose has good prediction performance.

Table 2: Testing results and performance comparison

Method	Daugman [1]	Wildes [2]	Xing L. [5]	Proposed
CRR (%)	87.8	83.9	86.5	97.6



(a) d'=4.8951, CRR=97.6% (b) d'=1.3694, CRR=77.5%

Fig. 3: The distinction degree and CRR of intra-class and inter-class

6 Conclusion

Because of limitation of iris images on recognition, we propose a new quality measurement, iris rotation, which combines the existing quality measures with SVM classifier. Experimental results show that our algorithm has better classification ability and higher CRR than other algorithms. In the future work, we will continue to research more efficient and accurate localization algorithms of iris and eyelid. From the perspective of the effects on recognition performance, more characteristics of iris image with low quality will be researched so that the quality assessment method of iris image can be more accurate.

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