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One Hybrid Feature Set Filtering Localization Approach for Iris Recognition

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Abstract

In this paper we propose one hybrid feature set filtering localization approach (HFSFLA) for iris recognition. Our HFSFLA method is different from the traditional iris localization method. Firstly we combine the advantages of both linear filtering method and non-linear filtering method, which can not only remove the noise and unwanted area but also keep the useful edge information of the iris image. Secondly, we propose feature set filtering localization to locate the iris precisely. Finally, we adopt one template matching method based on hamming distance deviation to recognize the iris information. Comparison experiments between the traditional localization method and the proposed HFSFLA are conducted on three iris databases. The experimental results show that the equal error rate and the correct recognition rate of the HFSFLA are better than those of the traditional localization method consistently in all iris data sets. And HFSFLA has high correct localization rate in the all three iris databases. It is a robust and rapid localization method.

Keywords: *Hybrid Feature Set Filtering, Iris Localization, Iris Recognition, Template Matching*

1. Introduction

In recent years, iris recognition technology is becoming more and more significant to the operation of security system. It is an excellent identification method because the texture of the iris is stable and unique. With the two typical advantages of high accuracy and high security, it has important application prospects [1-2]. Iris recognition technology has been used in the bank, the hospital, the police station, and the mine. Now the researchers even plan to use it in the mobile phone.

Iris localization or segmentation is the first step in an iris recognition system. Also it is one of the most important step. From an image of the eye segmentation involves detecting and isolating the iris structure. The iris located in the vicinity of the pupil, the eyelids and the sclera. Therefore the segmentation process has to precisely detect the boundaries separating the iris from these other components.

Many methods have been proposed to enhance the performance by many researchers. 2D Gabor filter based approach was proposed by Daugman [3] for the iris identification system and he adopted traditional hamming distance approach to do the iris matching. Wildes *et al.* [4] adopted Laplacian pyramid for efficient implementation of gradient-based iris segmentation. Based on zero-crossing representation from the wavelet transform decomposition, Boles [5] has proposed fine-to-coarse approximation at diverse

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resolution levels. European distance approach is used for iris matching in his system. Ma *et al.* [7] utilized multi-scale band-pass decomposition and evaluated comparative performance from prior methods.

2. Iris Pre-Processing

At pre-processing step, our task is to remove noise and unwanted area in the iris image. The iris image quality is not so good for the influence of image acquisition environment. In order to reduce the image noise and improve quality of iris image, we must use the noise reduction algorithm in pre-processing step. There are a lot of noise reduction algorithms. The typical algorithms include the linear low pass filter algorithm(such as neighborhood averaging filter algorithm, minimum mean square filtering algorithm) and nonlinear low pass filter algorithm(such as median filter algorithm [8]). Neighborhood averaging filter algorithm can select the center window template. And then we calculate the average gray value of all these pixels covered by the center window template to replace the current pixel gray value. Next we can remove the image noise point mutation. However, it smoothed iris image edge and made it become indistinct. Therefore it is difficult to extract the iris boundary information. The median filter algorithm mainly processes the noise in an isolated point form. A proper window template scans on the image. The gray window covering the image pixel values are sorted in ascending or descending order, and then we choose the intermediate gray rank value as the output current of pixel gray value. The drawback is that may damage the details of iris image and it is not conducive to extract the subsequent feature and recognize the subtle. Requirement of iris image denoising includes not only effectively eliminating noise but also effectively protecting the iris boundary information. To the practical application, this paper combines the advantages of the neighborhood average filtering and median filtering algorithms to get the purpose of noise reduction.

The basic algorithm is shown in Figure 1. We take appropriate size of the window for each pixel in the gray image(Here we use the 3*3 window, and the window size can be changed according to the requirement). We calculated the upper left corner all gray 3*3 sub neighborhood, the lower left corner of the 3*3 sub neighborhood, the upper right angle of 3*3 sub neighborhood and the lower right corner of the 3*3 sub neighborhood window for the current pixel(we use [x,y] to represent it)]. We got the mean gray value of each sub neighborhood respectively:

$$M_1 = \frac{1}{N^2}\sum_{i=0}^{N-1}\sum_{j=0}^{N-1} f(x-i, y-j) \tag{1}$$

$$M_2 = \frac{1}{N^2}\sum_{i=0}^{N-1}\sum_{j=0}^{N-1} f(x-i, y+j) \tag{2}$$

$$M_3 = \frac{1}{N^2}\sum_{i=0}^{N-1}\sum_{j=0}^{N-1} f(x+i, y-j) \tag{3}$$

$$M_4 = \frac{1}{N^2}\sum_{i=0}^{N-1}\sum_{j=0}^{N-1} f(x+i, y+j) \tag{4}$$

Where $f(x, y)$ means the current pixel value for the pixel [x,y], N means the selected window size, M_1, M_2, M_3, M_4 independently represents the mean gray values of the upper left corner, the lower left corner, the upper right corner and the lower right corner of the 3*3 sub neighborhood window covering area.

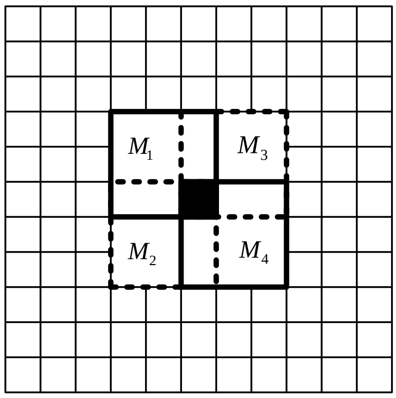
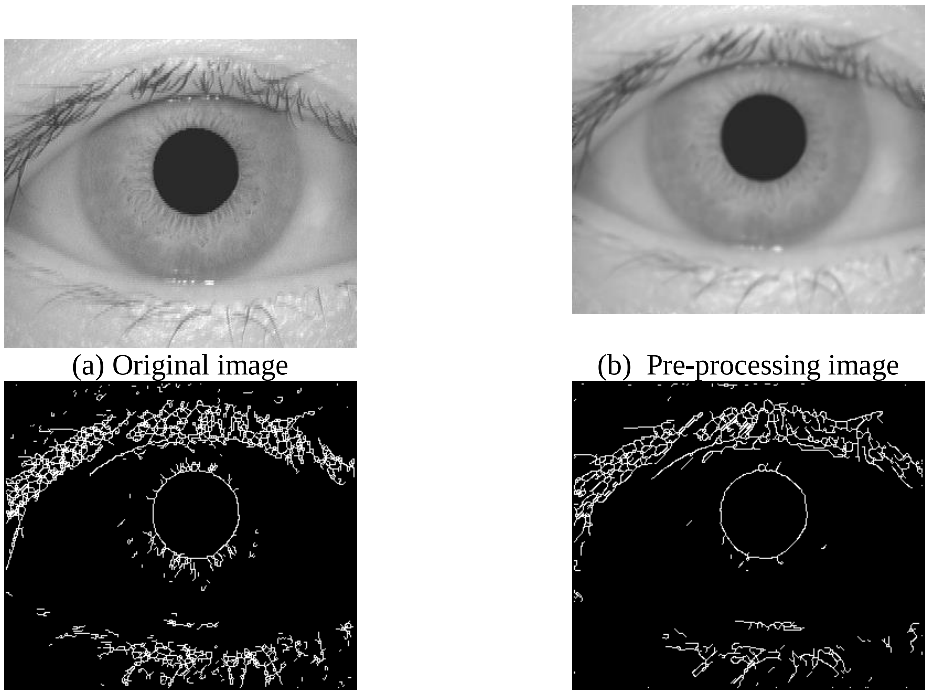


Figure 1. Sub Neighborhood Window

According to the median filter and mean filter algorithm, we take the 4 sub field of median gray mean-- $mid\{M_1, M_2, M_3, M_4\}$, and then we take an average of two median and mean gray values in the field. They act as the current pixel gray value after the noise reduction. We observe Figure 2(b) is the iris image after denoising. It obviously suppresses noise in iris image and protects the iris edge. From Figure 2(c) and Figure 2(d), the edge extraction experiment results show that the noise reduction method can effectively restrain noise and keep the iris edge information better [13]. At the same time it gets good detection effect of edge for the subsequent iris precise localization.



(a) Original image (b) Pre-processing image

(c) Canny edge detection of original image (d) Canny edge detection of pre-processing

Figure 2. Iris Pre-processing Image

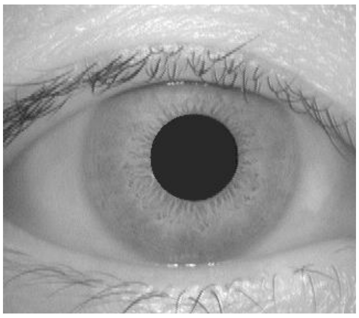
3. Iris Localization

Iris localization is to determine boundary of the iris and pupil, the boundary of the iris and sclera in eye images. The main purpose is to determine the iris inner boundary and outer boundary. The edge of iris is extracted from acquiring iris image. Then the follow-up feature extraction can be done for iris recognition. There are two classical iris location algorithms. One is calculus method. The other one is two step method based on the combination of edge detection and Hough transformation. We propose one novel method based on the advantages of two methods. Here we take the two step strategy which is from coarse to fine localization. The first step is inner edge localization of iris image, and the second step is outer edge localization of iris image.

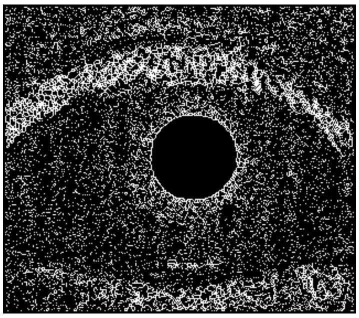
3.1. Iris Inner Edge Localization

The inner edge of the iris mainly refers to the limbus part at the junction of pupil and iris. The gray of iris inner edge change obviously. The eyelid and eyelash occlusion problem exists when the person does not blink. In the infrared illumination condition, the contrast of iris image is higher than other parts. It is easy to locate the inner edge of the iris. In the first step we use the classical edge detection algorithm for iris inner edge detection of image after pre-processing. In the second step we adopt the connected domain characteristics of multistage denoising method to remove the eyelid, eyelash and other interfering parts. In the third step we use the circle fitting method based on the precise location of the inner iris edge to locate the circle center. Finally we finish the localization of the iris inner edge.

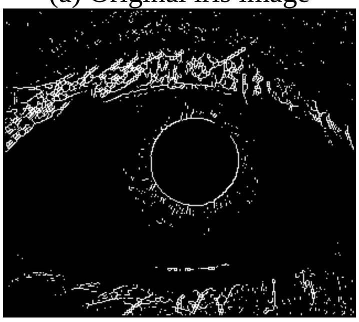
3.1.1. Canny Iris Edge Extraction:



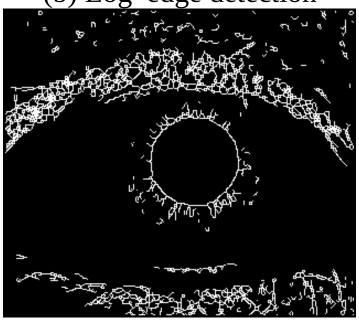
(a) Original iris image



(b) Log edge detection



(c) Prewitt edge detection



(d) Canny edge detection

Figure 3. Iris Image Inner Edge Detection

The commonly edge detection operator includes Canny operator, Roberts operator, Sobel operator, LOG operator and Prewitt operator. They each have advantages and disadvantages for edge detection. According to the characteristics of iris image, we select Canny operator to extract the iris inner boundary. At the same time we use the pre-processing algorithm to remove the noise in iris image before the edge feature extraction of iris image. Due to the easy extraction of the iris inner edge, the Canny operator can extract the inner edge of iris precisely. The Figure 3 shows the detection results of several kind of edge detection operators. Figure 3(a) presents the original iris image Figure 3(b) shows the detection result of the Log operator. We observe the details of feature extraction is not obvious but the noise is serious. Figure 3(c) shows the detection result of the Prewitt operator. We find that the

Prewitt operator damages the inner edge features and don't kept the inner edge features well. Figure 3(d) shows the detection result of the Canny operator. The Canny operator can not only extract the iris inner edge but also preserve the iris inner edge very well. And the detail characteristics are suitable for the follow-up precise localization.

3.1.2. Connected Domain Feature Denoising: In order to ensure the accuracy of the inner edge location of the iris, we must extract the iris inner edge information completely based on edge detection of iris image. There are two ways to effectively enhance the iris inner edge information:

- Extracting edge features different from the background region. First removing the background region uncoordinated with the inner edge character, and then highlighting the iris inner edge region;
- According to the characteristics of iris inner edge, first searching the target region in accordance with the iris inner edge character, then using clustering method to extract the inner edge. Because the nature of the iris inner edge image is weak after iris edge detection, it is not easy to accurately extract the characters of the iris inner edge information. We adopt the first approach to extract iris inner edge information. And we gradually reduce the background interference and highlight the iris inner edge information by ways of using feature set filtering method. The process of feature set filtering is shown in Figure 4.

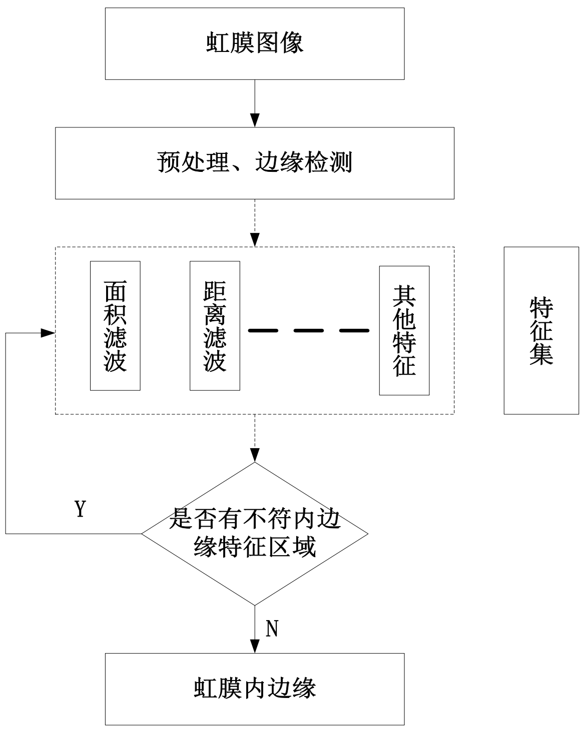


Figure 4. Connected Domain Denoising Process of Multiple Features

(1) Area Feature Filtering:

Here we adopt 8-connected algorithm to label all the connected region of the iris edge detection image of the iris image in the first step. Then we extract the area, width and height of each region in the second step. Finally we filter part of interference of the background region in the third step. The iris inner edge has a certain area, height, width and region and aspect ratio. We use these characters to do the filtering work and the results are shown in Figure 5 (c) and Figure 5 (d).

(2) Distance Feature Filtering:

Through a lot of observation, the inner edge of iris image is usually located in the middle of the image. Therefore the distance filter method is adopted to remove the interference region of the iris inner edge, which shows the distance of the regional center gravity to the iris image center gravity. Just as shown in Figure 5 (e). Assuming the target region feature image pixels in the binarization after area feature filtering are (x_i,y_i) , and here i=1,2,...,n. There are n pixels and the gravity formula is as the following:

$$\begin{cases} x_c = (x_1 + x_2 + \cdots + x_n)/n \\ y_c = (y_1 + y_2 + \cdots + y_n)/n \end{cases} \tag{5}$$

Similarly, we collect the statistics of the number of connected pixels, coordinate region and calculate the gravity for each connected region center. Then the Manhattan distance is used as index of the different regions in iris image position. Just as the following formula:

$$d = \left| x_c - x_{c_k} \right| + \left| y_c - y_{c_k} \right| \tag{6}$$

Where x_c and y_c represent the gravity of the iris image. x_{c_k} and y_{c_k} represent the gravity of each connected region. k is the number of the connected region and d is the Manhattan distance.

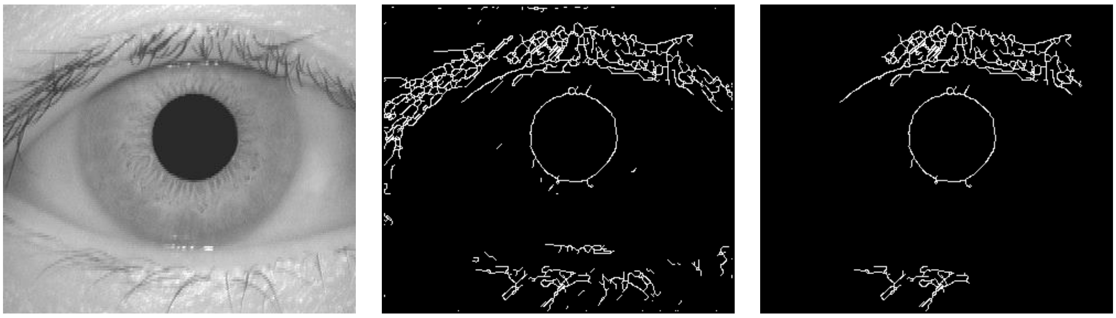
(3) Deburring:

For the burr interference in the iris edge, the iris inner edge fitting precise location is affected. In order to eliminate the burr interference, we use the depth search algorithm and marking rules to remove it. It is shown in Figure 5 (f). The working process are listed as follows:

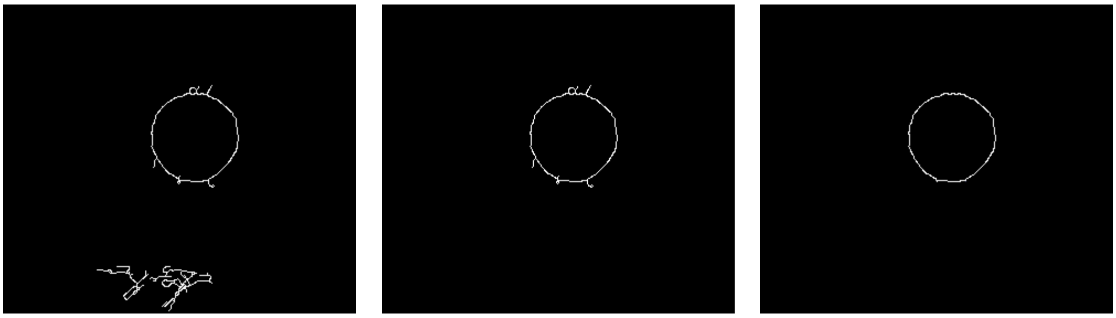
i. Mark the iris target point after denoising with the depth search algorithm;
ii. If the neighborhood target points of current marked point (x, y) are less than 2, respectively mark them and search their branch;
iii. If the branch cannot form one closed loop, then delete the marked branch, else keep it.
iv. If the branch has several closed loop, we collect the perimeter of each closed loop. If the perimeter is less than the threshold, we remove the closed loop.

(4) Other:

If other interference region still exists in the inner edge of the iris image, we can extract the characteristics of the interference region. And then we can remove it using the filter method above again.



(a) iris image (b) edge detection (c) first region feature filtering



(d) 2nd region feature filtering (e) distance feature filtering (f) defurring

Figure 5. Connected Domain Feature Filtering

3.1.3. Iris Inner Edge Localization: After feature set filtering, the iris inner edge has been accurately extracted. We use the method of circle fitting to get the center of inner edge. Then we locate the iris inner edge in the original iris image. The iris inner edge localization processes are listed as follows:

(1) Assuming there are n points, we use neighborhood marking method to mark (x_i, y_j) of the inner edge in iris image. Here the range of i is from 1 to n.;

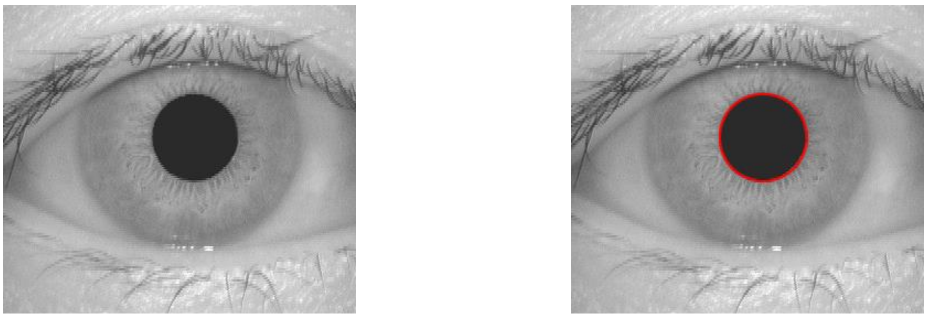
(2) Search the point (x_i, y_j) in the iris image ($i \in [0, col), j \in [0, row)$), then calculate the distance and the mean square error from the point (x_i,y_j) to the target point.

$$d_k = \sqrt{(x_i - x_k)^2 + (y_j - y_k)^2}\ ,\quad k \in [1, n] \tag{7}$$

$$u_{i,j} = \frac{\sum_{k=1}^{n} d_k}{n} \tag{8}$$

$$\sigma_{i,j} = \sqrt{\frac{\sum_{k=1}^{n} (d_k - u_{i,j})^2}{n}} \tag{9}$$

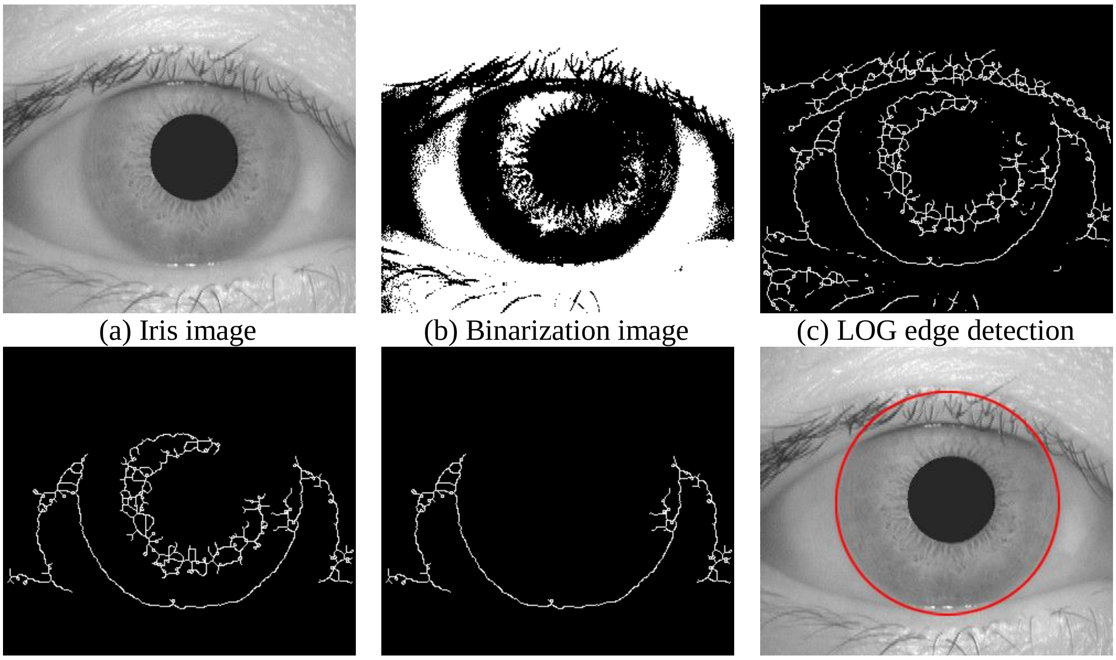
(3) From $\sigma_{i,j}$, ($i \in [0, col), j \in [0, row)$) we select the point ($x_i$, y_j) as the center of iris inner edge which has the minimum value of the mean square error.Then we locate the inner edge of iris image and we show the localization result in Figure 6.



(a) iris image (b) iris inner edge localization

Figure 6. Iris Inner Edge Localization

3.2. Iris Outer Edge Localization



(a) Iris image (b) Binarization image (c) LOG edge detection

(d) Region feature filtering (e) Scleral interference filter (f) Scleral edge localization

Figure 7. Iris Image Edge Localization

The outer edge of iris is a part of the iris and sclera limbus boundary. The part of the transition band is wide and the boundary is indistinct. What's more, with the interference of eyelashes and eyelids, it is difficult to get the accurate outer iris edge. The iris outer boundary features are fuzzy and difficult to extract directly. However, its contrast with the sclera is obvious, and firstly we adopt one segmentation algorithm which combines the contrast and OTSU to distinguish the iris and sclera. Secondly we use the LOG operator to extract the faint iris outer edge information. Thirdly we use the features set filtering method to remove the interference outside the region of iris outer edge. Finally we finish the localization of the iris outer edge.

In the iris image after features set filtering, the main interference region includes sclera, canthus, eyelid and other regions in the iris image. The characters of outer edge are different from the inner edge of iris image. For outer edge, it is not closed, and the sclera is small connected region. We can get the closed region number to remove the sclera interference. For the canthus and eyelid connected with the outer edge, we observe that most of target domains are independent neighborhood. We can fit the outer edge from the target point of the independent neighborhood. It is similar to the method in 3.1.3. We only choose the fitting target of solitary neighborhood without neighborhood. We show the results in Figure 7.

4. Iris Template Matching Method

Matching is the process of calculating the degree of similarity between the input test image and training image from database. We use zero-crossing coding approach here. We adopt the sampling approach to construct the 2048 bits code length. There are 8 bits in vertical direction and 128 bits in horizontal direction. In the matching step we use the HDDMA [12] instead of traditional Hamming Distance Matching Method. HDDMA consider the whole shift curve change and matching process. HDDMA gets the better matching ratio than traditional Hamming Distance Matching Method. At the same time, it has strong eyelid and eyelash denoise capability.

5. Experiments

5.1. Experiment Environment introduction

CASIA-V1.0, CASIA-V2.0-Device1 and CASIA-V3.0-Twins are used to evaluate the performance in our experiments (http://www.cbsr.ia.ac.cn/IrisDatabase.htm). Several typical parameters to evaluate the iris recognition system include FAR (False Acceptance Rate), FRR(False Rejection Rate), EER(Equal Error Rate) and CRR(Correct Recognition Rate). They are usually used to evaluate the recognition performance of the iris recognition algorithm. In localization step the running time and localization correct ratio are used to evaluate the localization performance of the HFSFLA. Our main target is to get low EER and high CRR at the same time. It means better performance of the algorithm.

i. False Acceptance Rate (FAR): is the ratio of the number of false acceptances divided by the total number of identification attempts.
ii. False Rejection Rate (FRR): the percentage of times the system produces a false reject.
iii. Equal Error Rate (EER): The rates at which both accept and reject errors are equal.

Pre-processing including localization is the first step. Feature extraction is the second step. And the last step is the iris encoding and matching. Here we pay more attention to the first step. The traditional localization method and HFSFLA are compared in the experiments.

We used tools openCV and Visual C++6.0 for the development. The main configuration of the computer is as below: intel i5 3230@2.6GHz CPU and 4G RAM.

5.2. Localization Ratio Contrast

In three databases we observe the HFSFLA get higher accuracy in localization and the time cost for localization is less in Table I. Some low-noisy iris images in CASIA-1.0 have been pre-processed and are clear for the localization algorithms. Therefore it is easy for localization and we get the best result in three databases.

Table 1. Experimental Results of HFSFLA

Iris Lib	Sample Num	Correct Localization Ratio	Average Localization Time
CASIA-1.0	756	98.98%	0.58s
CASIA-2.0-Device1	1200	97.73%	0.92s
CASIA-3.0-Twins	3183	96.02%	1.36s

[15] approach uses one revised Hough Transform method to do the iris localization. The localization correct ratio of this approach is 98.9%. However, it need some prior knowledge and the experiment is done only in CASIA-1.0. HFSFLA get excellent correct localization rate in the three databases. In conclusion, HFSFLA is a rapid and robust localization method for iris recognition.

5.3. Recognition Ratio Contrast

The EER (Equal Error Rate) and CRR (Correct Recognition Rate) are used to evaluate several methods in contrast. We list the experimental results in table II. It is obvious that the performance of HFSFLA is better than other two methods.

Table 2. Experimental Results of EER and CRR

	Iris Lib	Sample Num	EER/%	CRR/%
Daugman	CASIA-1.0	756	2.62	97.38
Wildes			2.84	97.16

HFSFLA			1.34	98.66
Daugman	CASIA-2.0-Device1	1200	3.51	96.49
Wildes			3.64	96.36
HFSFLA			2.71	97.29
Daugman	CASIA-3.0-Twins	3183	5.36	94.64
Wildes			4.35	95.65
HFSFLA			3.68	96.32

5.4. Comparison with Other Iris Localization Methods

To analysis the HFSFLA we use CASIA-V1.0 to do the compare experiment. Database A has noise and database B has not noise or has low noise. Database A includes 756 images collected from 108 eyes and database B includes 490 images collected from 70 eyes. The compare experiment result in CASIA-V1.0 is listed the result as below:

Table 3. Experimental Results of EER and CRR in CASIA-V1.0

	Code/bits	Sample Num	EER/%	CRR/% for EER
[9]	1920	210	1.54	98.46
[10]	1536	420	1.69	98.31
HFSFLA	2048	490	0.86	99.14
HFSFLA	2048	756	1.34	98.66

[9] and [10] approaches select the low-noisy images to do the compare experiments. HFSFLA is used in both complete noisy database A and reduction low-noisy database B. HFSFLA gets better performance than other two methods in the low noisy database B. Even in noisy database A HFSFLA still gets better performance than other two methods in low noisy database B. It fully proves the superiority of HFSFLA in another way.

6. Conclusion

In pre-processing step we combine the advantages of the linear low pass filter algorithm and nonlinear low pass filter algorithm. In localization step we propose one hybrid feature set filtering localization approach(HFSFLA) to precisely locate the inner and outer edge of the iris image. HFSFLA can effectively remove the noise and interference of eyelid and canthus. Furthermore, we use the HDDMA for template matching of the iris recognition. HFSFLA not only has short run time, but also gets the good localization correct ratio. The experimental results show that HFSFLA is an excellent localization approach of iris image. At the same time HFSFLA can get higher correct recognition rate and lower equal error rate in compare with traditional recognition methods proposed by Daugman and Wildes.

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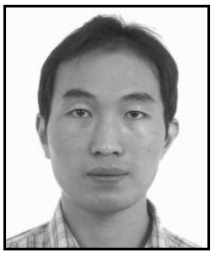

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