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A New Localization Method for Iris Recognition Based on Angular Integral Projection Function

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***Abstract*—Iris recognition is one of the most reliable and accurate biometric technologies. Iris localization is crucial for the performance of an iris recognition system, it includes finding the iris boundaries (inner and outer) and the eyelids (lower and upper). In this paper, we propose an efficient iris localization method based on the angular integral projection function (AIPF) to detect the iris boundaries in iris images. The proposed algorithm adopts boundary points detection and curve fitting. First, the approximate pupil center is obtained. Then, two sets of radial boundary points are detected for the iris inner and outer boundaries using AIPF method. Finally, we get the iris boundaries by fitting a circle for each of the above boundary points set. In the recognition stage, we used 2D Gabor filter to extract the iris code for the normalized iris image. At last, the proposed algorithm was tested on CASIA V1.0 iris images database. We evaluate the performance based on the analysis of both False Accept Rate(FAR) and False Reject Rate(FRR) curves. Experimental results show that the proposed iris localization algorithm is efficient and improves iris recognition.**

Keywords-iris localization; iris recognition; boimetrics; integral projection function; Gabor filter

I. INTRODUCTION

Biometrics technologies have received great attention in resent years. For personal recognition, different biometrics technologies use different biometrics features such as fingerprint, face, voice, hand geometry and iris. Among the all these biometrics, iris has achieved highest recognition accuracy. The human iris is the annular part between the dark pupil and the white sclera, it is unique and stable throughout life [1][2]. In an iris recognition system, iris localization is one of the most important steps, and has great influence on the subsequent feature extraction and classification. It aims to find the parameters, the centers and radii, for both the iris inner and outer boundaries. There are two classical iris localization methods, one is the Daugman's integrodifferential operator [1][2], the other is proposed by Wilds [3], who adopts Hough transform to get iris boundaries after edge detection. Later on, more algorithms were developed to improve the performance of iris localization [4][5][6][7]. More recently, other algorithms have been presented [8][9][10][11][12][13]. However, although these methods have promising performance, they need to search the iris boundaries over large parameter space exhaustively, which takes more computational time. Moreover, they may result in circle detection failure, because some chosen threshold values used for edge detection cause critical edge points being removed. In this paper, we propose a new algorithm for iris localization in iris images. The proposed algorithm focuses on the improvement of accuracy and speed. Since both iris boundaries can be approximated as circles, we isolate iris region by finding the parameters (centers and radii) for both the circles. The proposed algorithm adopts boundary points detection followed by curve fitting. It does not need to find all the boundary points, so its localization speed is very fast.

In our earlier work [14], the angular integral projection function (AIPF) has been developed as a general function to perform integral projection along angular directions, both the well known vertical integral projection function (IPF_v) and horizontal integral projection function (IPF_h) can be viewed as special cases of AIPF. In our approach, AIPF is used to localize both iris inner and outer boundaries, as we mentioned in our previous works [14][15]. First the approximate pupil center is detected by calculating the center of mass for the binarized eye image. Then, using AIPF, two sets of radial boundary points are detected for the iris inner and outer boundaries. Finally, we localize both boundaries precisely by fitting a circle for each of the above boundary points set using the least squares method. The other iris recognition steps that include normalization, feature extraction and matching are based on the groundwork of Daugman [1]. Experimental results on CASIA V 1.0 iris images database [16], indicate that our method has better performance and provides more accurate matching results.

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Performance evaluation was based on the analysis of both False Accept Rate(FAR) and False Reject Rate(FRR) curves.

The rest of this paper is organized as follow. Section 2 describes integral projection functions and the AIPF method. Section 3 introduces the algorithm of iris boundaries localization based on AIPF. Other iris recognition steps include iris normalization, feature extraction and matching are given in Section 4, Section 5 and Section 6, respectively. Section 7 shows the experimental results, and Section 8 concludes the paper.

II. PROJECTION FUNCTIONS

A. *Integral Projection Functions*

Due to their simplicity and robustly, image integral projection functions have been used widely for the detection of the boundary between different image regions. Among them, the vertical and horizontal integral projection functions are most popular. Here, suppose $I(x,y)$ is the intensity of a pixel at location (x,y), the vertical integral projection function $IPF_v(x)$ and horizontal integral projection function $IPF_h(y)$ of $I(x,y)$ in intervals $[y_1, y_2]$ and $[x_1,x_2]$ can be defined respectively as

$$IPF_v(x) = \int_{y_1}^{y_2} I(x,y)dx, \tag{1}$$

$$IPF_h(y) = \int_{x_1}^{x_2} I(x,y)dx. \tag{2}$$

The above two functions are used to detect the boundary of different image regions in the vertical and horizontal directions. Assuming PF is a projection function and ξ is a small constant. Thus, if the value of PF rapidly changes form z_0 to $(z_0+\xi)$, it indicates that z_0 lie on the boundary between two homogeneous regions. More details are in [17].

B. *Angular Integral Projection Function*

Besides the sets of vertical and horizontal boundary points that can be detected using IPF_v and IPF_h respectively. Other boundary point sets can be identified on other directions rather than those are on the vertical and horizontal directions. Considering this fact and in order to capture the boundary point sets along all directions within an image, the AIPF has been proposed in [14] as a general function to perform integral projection along angular directions. Specifically, the application of AIPF on θ direction carries out within an integration rectangle with $w\times h$ dimensions, it extends along a central line irradiated from the image center and having θ with x-axis. Here, it is worth to mention that even the most commonly used projection functions IPF_v and IPF_h can be implemented using AIPF by assigning θ=0,180º and θ=90,270º respectively.

III. IRIS LOCALIZATION

Iris localization is very important for iris recognition, it aims to isolate the iris region, thus it includes not only locating the circular inner and outer boundaries of iris, but also detecting the lower and upper eyelids. From the iris image shown in Fig. 1(a), it is clear that the iris is circular and brighter than pupil but it still darker as compared to sclera. We, therefore decided to apply AIPF to detect iris boundaries' points. The algorithm performs faster than the traditional methods based on the circular Hough transform and the integrodifferential operator. The iris boundaries are localized, and both eyelids are detected. The details will follow.

A. *Iris Boundaries Localization*

To localize iris boundaries, the pupil and iris centers with respected radii are calculated. The whole process includes three steps as follow.

1) Approximate Pupil Center Detection: The application of AIPF to detect iris boundaries' points requires the pupil center. Thus, the approximate pupil center has to be detected first. To do that, the gray levels histogram is plotted and analyzed. Fig. 1(b) shows the histogram of gray levels for the image in Fig. 1(a). Depending on the eye image histogram, a threshold value T is determined as the intensity value associated with the first important peak within histogram. Then, all intensity values in the eye image below or equal T are changed to 0(black) and above T are changed to 255(white),as

$$\begin{aligned} &g(x,y) = 255, \text{ if } I(x,y) > T \\ &g(x,y) = 0, \text{ otherwise} \end{aligned} \tag{3}$$

where $I(x,y)$ is the intensity value at location (x,y), $g(x,y)$ is the converted pixel value and T represents threshold. This process converts a gray image to binary image and efficiently segments the pupil from the rest of the image as shown in Fig. 1(c). However, morphological processing is still necessary to remove pixels that located outside the pupil region. Fig. 1(d) shows the clear pupil region obtained from Fig. 1(c) after noise removing by using dilate operator. Now, the center of the segmented pupil can be easily determined. Basing on [18], the center of a simple object like circle and square coincides with its center of mass. The center of the mass refers to the balance point $(\overline{x}, \overline{y})$ of the object where there is equal mass in all directions as

$$\overline{x} = \frac{1}{\sum g(x,y) \in F} \sum_{g(x,y)\in F} x \tag{4}$$

$$\overline{y} = \frac{1}{\sum g(x,y) \in F} \sum_{g(x,y) \in F} y \quad (5)$$

where $g(x,y)$ is a pixel in the position (x,y), and F is the object under consideration. We make use of (4) and (5) to find the center of mass for the segmented pupil region which represents the approximate pupil center $P(x_p,y_p)$.The pupil center detection process is shown in Fig. 1.

2) Iris Boundaries' Points Detection: As we mentioned earlier, both iris boundaries are circular, and the intensity of the pupil is lower than the surrounding area, also the intensity of the iris is limited between pupil and sclera. Owning to these facts, and by considering the approximate pupil center detected in the previous section as the image center, the AIPF method can be applied to find a set of radial boundary points for each of the iris inner and outer boundary.

For the detection of the inner boundary's points, θ runs within the range [0, 2π]. While for the detection of the outer boundary's points, two steps are required prior the application of AIPF. First, to avoid regions which are potentially occluded by eyelids and eyelashes and to reduce computational time, two rectangles are established on both the sides of the iris basing on the estimated location of the pupil center. Second , image filtering is performed within both the iris rectangles to minimize the influence of eyelashes. Here, AIPF is applied for θ runs within the range -30~5º and 175~210º for the right and left iris rectangles respectively. Here, in order to improve the accuracy of the later circle fitting, we select all the integration rectangles being equally spaced around both the pupil's and iris' edges. Once AIPF has been applied, a radial boundary point for each integration rectangle on θ direction is found. This is accomplished by computing the gradient of the projection curve resulted from each application of AIPF. Then, we get the boundary point by searching the gradient curve for its corresponding local maximum. Clearly, the more integration rectangles ,thus boundary points, the finer iris boundaries localization.

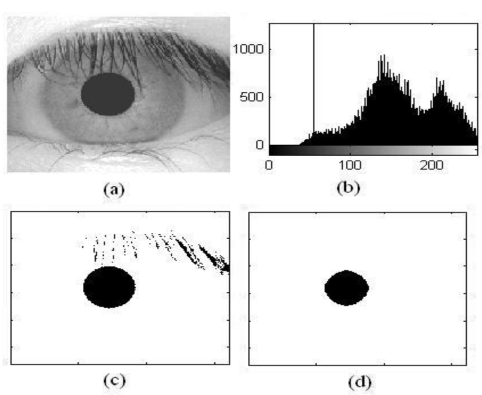

Figure 1. Pupil center detection.(a) Original image. (b)Gray levels histogram. (c) Binary image. (d) Binary image after morphological dilation operation.

3) Curve Fitting: We get the precise pupil center $P(x_p,y_p)$ and radius R_p through fitting a circle to the above detected inner boundary's points. Similarly, the precise iris center $I(x_i,y_i)$ and radius R_i are obtained by fitting another circle to the above detected outer boundary's points. Here in order to obtain a best circle fit, we make use of the least square method which minimizes the summed square of errors. Fig. 2 displays localized iris boundaries.

B. Eyelid Detection

Eyelids where modeled as two horizontal lines as in Masek's algorithm[4]. Thus when detecting the lower eyelid and the upper eyelid, a Canny edge detector is used to generate the edge map, then a line is searched using a linear Hough transform. This approach is fast, since lines localization is performed within two relatively small iris portions, one for the lower eyelid and the other for the upper eyelid, also linear Hough transform requires less computation time. After that, to isolate eyelashes a simple thresholding technique was applied within the segmented iris region since eyelashes are darker than the rest of iris region.

IV. IRIS NORMALIZATION

Normally, irises from different people vary in size, even the irises from a single person, and this change in size is due to illumination variation, pupil size and distance of the eye from the camera. To compensate for these different conditions and improve the precision of matching. We used Daugman's rubber sheet model which projects the segmented iris disk into a rectangle region with fixed size. In our experiments, we selected the size of the unwrapped iris as 20×240 pixels. The following formulas perform the transformation.

$$\theta \in [0,2\pi],\ r \in [0,1],\ I(x(r,\theta), y(r,\theta)) \longrightarrow I(r,\theta) \quad (6)$$

$$x(r,\theta) = (1-r)\,x_p(\theta) + r x_i(\theta) \quad (7)$$

$$y(r,\theta) = (1-r)\,y_p(\theta) + r y_i(\theta) \quad (8)$$

Where $I(x,y)$ is the iris region image, (x,y) and (r,θ) are the Cartesian and normalized polar coordinates respectively, and (x_p,y_p) and (x_i,y_i) are the coordinates of pupil and iris boundaries along θ direction.

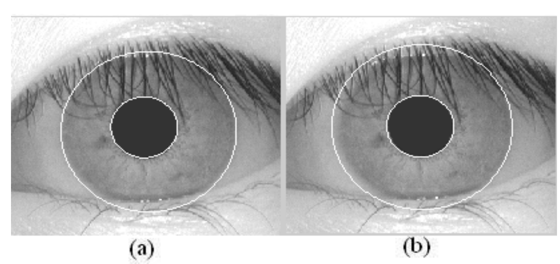

Figure 2. Localized iris boundaries.(a)Using AIPF method. (b) Using Integrodifferential operator .

V. Feature Extraction

Commonly, iris feature extraction is crucial for an iris recognition system. Gabor filters provide excellent attributes which are very suitable to extract iris features. Daugman has extracted iris features using Gabor filter successfully [1]. The 2D Gabor filter is adopted in this work for iris feature extraction. A 2D Gabor filter is represented as

$$G(x,y) = e^{-\pi\left[x^2/\sigma_x^2 + y^2/\sigma_y^2\right]} e^{-2\pi i[\mu x + \nu y]}. \quad (9)$$

It is Gaussian modulated by oriented complex sinusoidal functions. Where σ_x and σ_y are the scale parameters of the Gaussian function, μ and ν are the frequency parameters of Gabor. The convolution of the normalized iris image with 2D Gabor filter results in complex valued coefficients. Using Daugman's phase quantization method, the phase information of these coefficients are quantized into four levels, one for each possible quadrant in the complex plane. Thus to create the iris code that corresponds to iris features, each pixel in the normalized iris image produces two bits of data in the iris code. For our case, this process extracts 9600 bits iris code. Although being widely used to encode iris image, 2D Gabor filter requires several parameters be set. These include the scale parameters of the Gaussian function and the center frequency parameters. Doing a lot of many experiments and analysis based on the inter-class and intra-class curves produced from various filter parameters, satisfactory parameters were found and applied.

VI. Matching

The final step in an iris recognition system is iris code matching. Hamming distance (HD) between two iris codes is used to determine whether they belong to the same class or not. It accounts the number of mismatched bits between a pair of iris codes. Letting A and B be two iris codes to be matched. Hamming distance is calculated as follows:

$$HD = Min\left\{\frac{1}{N}\sum_{i=1}^{N} A(i+\varphi) \oplus B(i)\right\} \quad (10)$$

where $-10 \le \varphi \le 10$ is used to compensate the rotation of iris and N is the number of bits of iris code. If HD $\le$ separation point, the given two iris images belong to the same class. The lowest calculated value from (10) represents the HD of the two iris codes without rotational error.

VII. Experimental Results

To evaluate the performance of the proposed system, extensive experiments were performed. Iris images are obtained from CASIA V1.0 iris image database [16]. The experiments are done in Matlab (version 6.5) on a PC with P4 3GHZ processor and 512M of DRAM.

A. Database Characteristics

CASIA V1.0 iris image database includes 108 classes and each class has seven iris images captured in two sessions. So there are totally 756 iris images with a resolution of 320×280 pixels. Here it must be mentioned that this database has been manually edited [19]. However, it does not effect the application of AIPF so much, since this method has shown its effectiveness for the detection of the iris outer edge which is more difficult to detect as compared to the pupil edge due to the weak contrast between the iris and sclera, also the editing of the database was limited to the pupil region.

B. Comparative Results

As mentioned earlier, iris localization is a key step in the whole iris recognition system. Thus iris localization's results should be evaluated by analyzing the changes in iris recognition algorithm. Since Daugman's method [1] is claimed to be the most efficient iris recognition algorithm and has best performance on the CASIA iris database. Our comparative results are designed by implementing Daugman's algorithm with two different iris segmentation methods, one is our proposed AIPF method and the other is Daugman's integrodifferential operator. The runtime results for the iris localization are given in Table I, which confirm that the proposed AIPF method performs faster than that of Daugman. The results of iris recognition are detailed in Fig.3 and Table II. Fig. 3 shows the inter-class and intra-class distribution's curves, while Table II provides the values of False Acceptance Rate(FAR) and False Rejection Rate(FRR) at different separation points for both AIPF and Daugman methods.

TABLE I. RUNTIME RESULTS FOR IRIS LOCALIZATION

Method	**Time**		
	Mean	***Min.***	***Max.***
Daugman	1.48s	1.1s	1.8s
Proposed	0.37s	0.33s	0.64s

TABLE II. FAR AND FRR VALUES FOR DIFFERENT THRESHOLD VALUES FOR BOTH AIPF AND INTEGRODIFFERENTIAL OPERATOR METHODS

The proposed AIPF method			**Integrodifferential operator**		
Threshold	***FAR(%)***	***FRR(%)***	***Threshold***	***FAR(%)***	***FRR(%)***
0.30	0	0.2616	0.30	0	0.3327
0.35	0	0.0864	0.35	0	0.1221
0.40	0.0044	0.0152	0.40	0.0045	0.0311
0.45	0.3535	0.0013	0.45	0.3557	0.0038
0.50	1	0	0.50	1	0

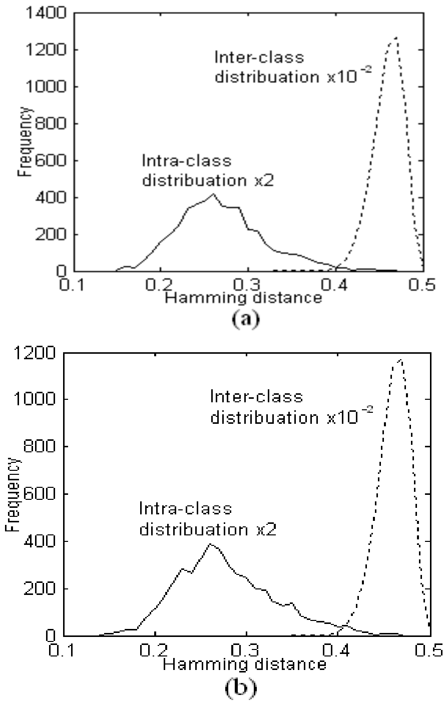

Figure 3. Intra-class and inter-class Hamming distances (a) Using AIPF method for iris localization. (b) Using Integrodifferential operator for iris localization.

The above distribution curves and FAR's and FRR's values confirm that the proposed iris localization algorithm segments iris more accurately than the integrodifferential operator, thus achieves better results in iris recognition.

VIII. CONCLUSION

In this paper, an efficient iris localization algorithm based on AIPF method was proposed, it detects the iris inner and outer boundaries in iris images. The algorithm adopts boundary points detection with curve fitting and it does not need to find all the boundary points, so its localization speed is very fast. First, the approximate pupil center is obtained. Then, using AIPF method, two set of radial boundaries points for the iris inner and outer boundaries are detected. Finally, we get the iris boundaries by fitting a circle for each of the above boundary points set. We used 2D Gabor filter to extract the iris code for the normalized iris image. Other iris recognition steps are based on the groundwork of Daugman [1]. We tested the iris recognition system on CASIA V1.0 iris images database for both the AIPF and integrodifferential segmentation methods. The evaluation of the performance for the iris recognition results was based on the analysis of both FAR and FRR curves. Experimental results show that the proposed localization algorithm is efficient and improves the accuracy of iris recognition.

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