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A New Localization Algorithm for Iris Recognition

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Abstract: This study presents a new localization algorithm for iris recognition. Iris recognition systems have received increasing attention in recent years. Iris localization is very important for an iris recognition system. The proposed algorithm localizes both iris boundaries (inner and outer) and detects eyelids (lower and upper). In the localization of the iris inner boundary, the approximate pupil center is detected then Daugman's integrodifferential operator is applied. While for localizing the iris outer boundary, an approach based on boundary points detection and curve fitting is adopted. First, a set of radial boundary points is detected by performing image integral projection along angular directions within specified image blocks, then a circle is fitted to these points. Steps after localization are based on Daugman's iris recognition system. Thus, the 2D Gabor filter is employed for extracting iris code for the normalized iris image. Experimental results on CASIA V 1.0 iris image database and performance evaluation based on the analysis of recognition results, indicate that the proposed method has better performance in both iris segmentation and recognition.

Key words: Iris localization, biometrics, integral projection function, Gabor filter

INTRODUCTION

Iris recognition as one of the most accurate and reliable biometric methods has received increasing attention in recent years. Compared with other biometric features such as face, finger, hand geometry, palm print and voice, iris can obtain high accuracy due to the rich texture of iris patterns. The human iris is the annular part between the dark pupil and the white sclera, it is unique and stable throughout life (Daugman, 1993, 2003). Iris localization aims to isolate the iris region from the original eye image, it includes finding both iris boundaries and detecting eyelids. The localization accuracy is very important for later iris normalization, feature extraction and patterns matching. It costs nearly more than half of the recognition time, therefore, iris localization is crucial for the performance of an iris recognition system. Daugman (1993) built a recognition system, the system used an integrodifferential operator to locate the iris boundaries. Wildes (1997) used Hough transform method and a voting procedure in order to locate the iris boundaries. Besides the above two classical methods, many other iris localization algorithms are there, such as (Kong and Zhang, 2001; Ma *et al*., 2002, 2003). In the recent years, more algorithms for iris localization have been presented (Feng *et al*., 2006; He and Shi, 2007; Al-Zubi and Abu-Al-Nadi, 2007; Zuo *et al*., 2008; Huan and Kim, 2008). Most of the previous localization methods, however, require to search the iris boundaries over large parameter space exhaustively. 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 study, a new algorithm for iris localization in iris images is presented. First, the approximate pupil center is detected by calculating the center of mass for the binarized eye image. Then Daugman's (1993) integrodifferential operator is applied to localize iris inner boundary. And to localize the iris outer boundary, an approach based on boundary points detection and curve fitting is adopted. First, a set of radial boundary points are detected for the iris outer boundary by applying image integral projection along angular directions within specified image blocks. Then, the precise iris outer boundary is localized by fitting a circle for the above boundary points set using the least squares method. The following iris recognition steps including normalization, feature extraction and matching are based on Daugman's (1993) iris recognition system. Experimental results on CASIA V 1.0 iris image database (CASIA, 2003) and analysis of recognition results, indicate that the proposed method is efficient and accurate.

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IRIS LOCLIZATION

Iris localization is crucial for the performance of an iris recognition system. It aims to find the parameters, centers and radii, of the two iris boundaries, detecting the lower and upper eyelid and isolating eyelashes. The proposed iris localization algorithm includes three steps, inner boundary localization, outer boundary localization and then eyelids and eyelashes detection.

Inner boundary localization: In order to determine the iris inner boundary, the location of the pupil center is required. First the gray levels histogram for the eye image is plotted and analyzed. Then, 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:

$$\begin{aligned} &g(x, y) = 255, \text{ if } I(x, y) > T \\ &g(x, y) = 0, \quad \text{otherwise} \end{aligned} \tag{1}$$

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. 1b. However, morphological processing is still necessary to remove pixels that located outside the pupil region. Figure 1c shows the clear pupil region obtained from Fig. 1b after noise removing by using dilate operator. Basing on (Baxes, 1994), the approximate pupil center $P(x_p, y_p)$ can be easily determined as the center of mass for the segmented pupil region, where the center of mass for an object refers to the balance point where there is equal mass in all directions. The pupil center detection process is shown in Fig. 1a-c.

After the pupil center is found, Daugman's integrodifferential operator is applied for locating the iris inner boundary. The integrodifferential operator is defined as:

$$\max_{(r, x_0, y_0)} \left| G_\sigma(r) * \frac{\partial}{\partial_r} \oint_{r, x_0, y_0} \frac{I(x, y)}{2\pi r} ds \right| \tag{2}$$

where, I (x, y) is the eye image. The operator searches iteratively over the image domain (x, y) the maximum derivative, with respect to increasing radius r, of the normalized contour integral along a circular arc ds of radius r and center coordinates (x_0, y_0). The symbol * denotes convolution and G_σ (r) is a smoothing function such as a Gaussian of scale s. Thus, Eq. 2 is used to determine the pupil boundary of the iris. The localization result is shown in Fig. 2.

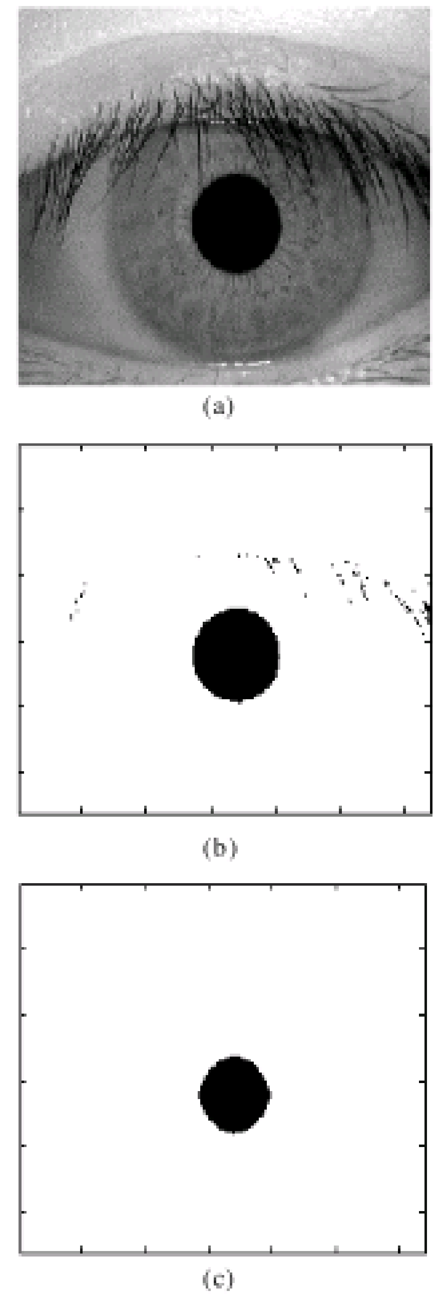

Fig. 1: Pupil center detection. (a) original image, (b) binary image and (c) Binary image after morphological dilation operation

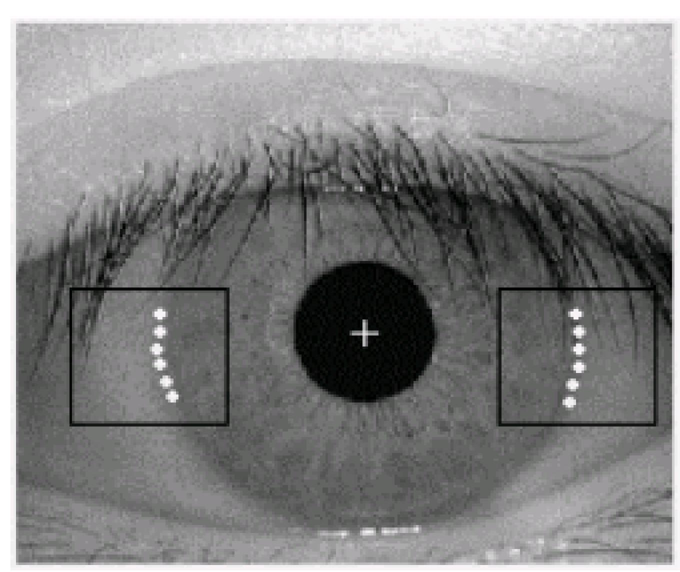

Fig. 2: Detected iris outer boundary's points. The black rectangles are for the left and right iris rectangles. White cross denotes the detected pupil center

Outer boundary localization: As both iris boundaries are approximately circular and the intensity of the iris is limited between pupil and sclera, an approach based on image integral projection is decided to localize the iris outer boundary. Due to their simplicity, image integral projection functions have been used widely for the detection of the boundary between different image regions. Among them, the vertical integral projection function $IPF_v(x)$ and horizontal integral projection function $IPF_h(y)$ are most popular, they can be defined in intervals $[y_1, y_2]$ and $[x_1, x_2]$, respectively as:

$$IPF_v(x) = \int_{y_1}^{y_2} I(x, y)dx \qquad (3)$$

$$IPF_h(y) = \int_{x_1}^{x_2} I(x, y)dx \qquad (4)$$

where, I (x, y) is the intensity of a pixel at location (x, y) (Zhou and Geng, 2004).

Meanwhile it has been noticed, that the application of image integral projection along angular directions produces new radial boundary points, also localizing the area in which the integration takes place will result in more accurate boundary points detection. Thus in the present study, image integral projection is performed along θ directions each within a specified rectangle block with fixed dimensions. Here, iris outer boundary is localized in two steps. First iris outer boundary's points detection then curve fitting.

Outer boundary's points detection: In order to find a set of radial boundary points for the iris outer boundary, two steps are required prior the application of image integral projection. First, to avoid regions which are potentially occluded by eyelids and eyelashes and to reduce computational time, two rectangles are established on both the left and right sides of the iris basing on the detected location of the pupil center. Second, image filtering is performed within both the iris rectangles to minimize the influence of eyelashes. Then, image integral is applied for θ runs within the range -30~5° and 175~210° for the right and left iris rectangles, respectively (Fig. 2). Here, to improve the accuracy of the later circle fitting, all integration blocks are selected to be equally spaced around the iris outer edge. After that, a radial boundary point for each integration block on θ direction is found. This is accomplished by computing the gradient of the projection curve resulted from each integral block. Then, a boundary point is detected by searching the gradient curve for its corresponding local maximum. Clearly, the more integration blocks, thus boundary points, the finer iris outer boundary localization.

Curve fitting: Finally, the precise iris center I (x_i, y_i) and radius R_i are obtained by fitting a circle to the outer boundary's points detected in the previous step. As a

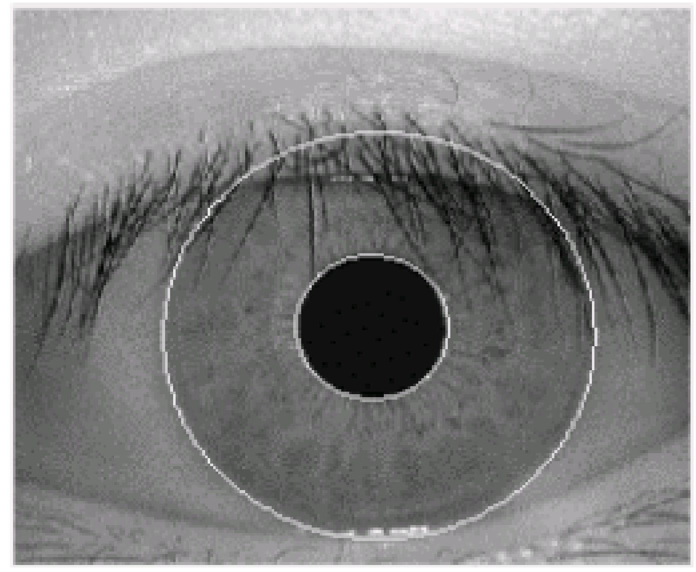

Fig. 3: Localized iris boundaries

method for curve fitting, the least square method which minimizes the summed square of errors, is applied in present study. Figure 3 shows the localized iris outer boundary.

Eyelids and eyelashes detection: To localize the lower and upper eyelids, a Canny edge detector is applied to generate edge map, then a line is located using a linear Hough transform, since eyelids were modeled here as two horizontal lines. 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.

IRIS NORMALIZATION

In order to compensate for the differences in the located iris regions due to different iris sizes and to improve the precision of matching, iris normalization is necessary. For this purpose, Daugman's (1993) rubber sheet model which projects the segmented iris disk into a rectangle block with fixed size, is applied. In the experiments, the size of 20×240 pixels is selected for the unwrapped iris. The following formulas perform the transformation.

$$\theta \in [0, 2\pi],\ r \in [0,1],\ I(x(r, \theta), y(r, \theta)) \longrightarrow I(r, \theta) \qquad (5)$$

$$x(r, \theta) = (1-r)x_p(\theta) + rx_i(\theta) \qquad (6)$$

$$y(r, \theta) = (1-r)y_p(\theta) + ry_i(\theta) \qquad (7)$$

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.

FEATURE EXTRACTION AND MATCHING

Feature extraction is very important part in recognition systems. It is crucial to choose the suitable filter. Considering the Gabor has many excellent attributes which are very suitable to extract iris information, the 2D Gabor filter is adopted in this work for iris features extraction, as in (Daugman, 1993). A 2D Gabor filter is represented as:

$$G(x,y) = e^{-\pi\left[x^2/\sigma_x^2 + y^2/\sigma_y^2\right]} e^{-2\pi i[\mu x + \nu y]} \quad (8)$$

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.

However, using 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 experiments and analysis based on the inter-class and intra-class curves produced from various filter parameters, satisfactory parameters were found and applied.

For matching, the Hamming Distance (HD) between two iris codes is employed to determine whether they belong to the same class or not. It is based on 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:

$$HD = \text{Min}\left\{\frac{1}{N}\sum_{i=1}^{N} A(i+\varphi) \oplus B(i)\right\} \quad (9)$$

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 Eq. 9 represents the HD of the two iris codes without rotational error.

EXPERIMENTAL RESULTS

The proposed system is implemented in Matlab (version 6.5) on a PC with P4 3 GHz processor and 512 M of DRAM. Iris images are obtained from CASIA V 1.0 iris image database (CASIA, 2003). It contains 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 (Philips *et al*., 2007). However, it does not affect the application of the proposed localization algorithm so much due to two reasons. First, the editing of the database was limited to the pupil region. Second, the localization of the iris inner boundary is originally more easier compared with the outer boundary due to the high contrast between the pupil and iris.

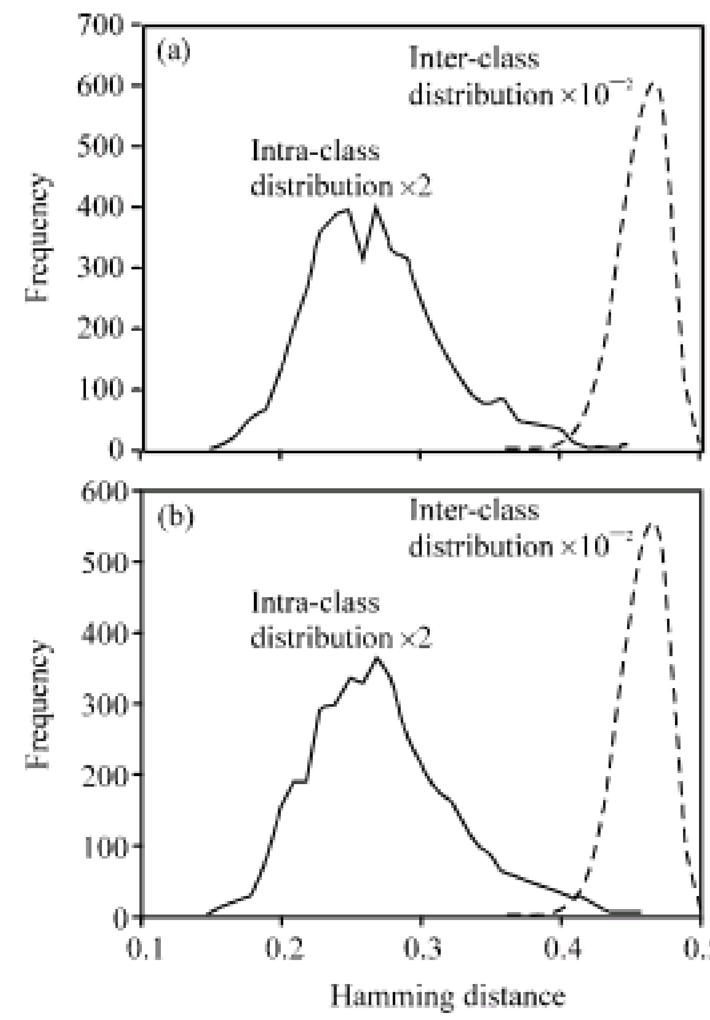

Fig. 4: Intra-class and inter-class Hamming distances (a) Using proposed method for iris localization and (b) Using Integrodifferential operator for iris localization

The performance evaluation of the proposed iris localization algorithm is based on the analysis of iris recognition results. Since Daugman's (1993) system is claimed to be the most efficient iris recognition algorithm and has best performance on the CASIA iris database. Thus, comparative results are designed by implementing Daugman's system with two different iris localization methods, one is the proposed algorithm and the other is Daugman's integrodifferential operator. The execution times for both the iris localization methods are shown in Table 1, which indicate that the proposed algorithm performs faster than that of Daugman. The recognition results based on the proposed method and integrodifferential operator for iris localization are shown in Fig. 4 and 5. The inter-class and intra-class distribution's curves of Hamming distances are shown in

Table 1: Execution time comparison for iris localization

Method	Time (sec) Mean	Min.	Max.
Daugman	1.4	1.1	1.6
Proposed	0.95	0.9	1.2

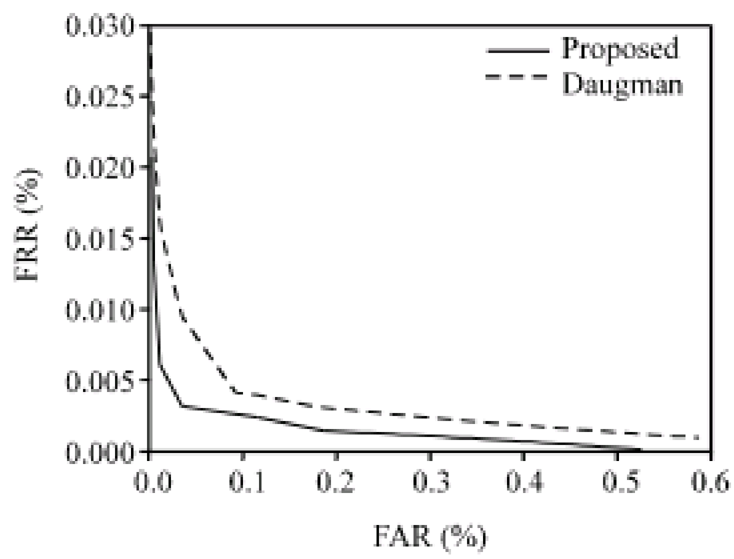

Fig. 5: Comparison of ROCs curves

Fig. 4. While the ROC (Receiver Operating Characteristic), which plots probability of False Acceptance Rate (FAR) versus probability of False Rejection Rate (FRR) for different threshold values of Hamming distance, is shown in Fig. 5. Both figures confirm that the proposed iris localization algorithm has improved the accuracy of iris recognition.

CONCISION

In this study, a new iris localization algorithm was proposed. It localizes the iris inner boundary by using Daugman's integrodifferential operator after finding the approximate pupil center. For localizing the iris outer boundary, the algorithm adopts boundary points detection and curve fitting. First, a set of radial boundary points is detected by applying image integral projection along angular directions while localizing the integration area. Then a circle is fitted to these points by making use of least squares method. Eyelids and eyelashes are also detected. As in Daugman's iris recognition system, 2D Gabor filter is employed for extracting iris code for the normalized iris image. To evaluate iris localization results, an iris recognition system is implemented on CASIA V 1.0 with two different iris localization approaches, the proposed and Daugman's algorithms. Analysis of matching results, indicates that the proposed algorithm gives better results.

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