Iris Detection Techniques: Daugman's Integro-Differential Operator and Ellipse fitting

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Abstract— **Authentication using biometrics has been associated generally with costly top secure applications. Iris recognition is fast emerging highly secure biometric. Efficiency of recognition stage highly depends on Iris detection and localization. In this paper, we evaluate different iris localization and detection techniques: Daugman's Integro-Differential operator and direct least square fitting of ellipse. CASIA-Iris-Interval-v3 database is used for evaluation. Iris's inner and outer boundaries where found using Daugman's Integro-Differential Operator in first case. Iris's inner boundary was found using direct least square fitting of ellipse in second case. Improper illumination, eye lashes and spotlight effects are major occlusions. Detection stage accuracy was highly affected by these occlusions. Non-circular pupil portion was properly segmented using direct least square fitting of ellipse.**

***Keywords*— Iris Localization, Iris Detection, Segmentation, Daugman Integro-Differential operator, Least Square fitting of ellipse**

I. Introduction

Biometrics is a science that involves the statistics related to biological characteristics. Biometrics is used in for analysing human characteristics and recognition for security, machine vision, and ease of work. Security based on personal identification is crucial factors in the field of business, IT, e-commerce, internet banking and military etc. Some previous methods of identification such as PIN, ID cards, signatures and password are less reliable. They can be stolen, may be forgotten and can be imitated. To overcome this problem biometric characteristics are used Biometric based personal identification technique is secure, reliable and easier than previous techniques. These patterns are well protected than previous methods. The iris texture is unique from one person to others as the degree of freedom of iris texture is extremely high [13]. The probability of two irises being identical is close to zero. We can capture iris image from distance using high resolution camera without physical contact. Iris features are stable during the life. As shown in Fig. 1, the iris of a human eye is the annular part between the black pupil and white sclera.

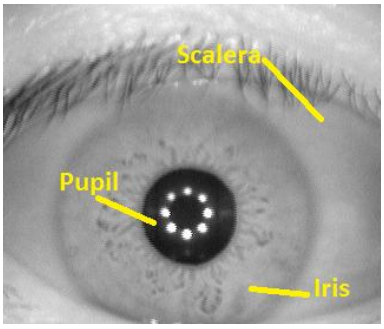

Fig. 1 a Front-on View of Human Eye

Table 1 shows comparison of several biometric technologies [1]. We can see that all the parameters are very well satisfied by iris recognition system. Only acceptability of this techniques is low. This is traded off for higher security applications. Further advancements are going on for iris localization and detection of face captured image [2] [9] [10]. This will improve acceptability as the users do not need to put their eyes in front of the camera. We can use this technique for 'Drowsy Driver Alert' system by continuously detecting iris from camera and alerting when iris is not found on face.

TABLE I
COMPARISON OF SEVERAL BIOMETRIC TECHNOLOGIES

Biometric	Fingerprint	Face	Hand Geometry	Iris	Voice
Barriers to universality	Worn ridges; hand or finger impairment	None	Hand impairment	Visual impairment	Speech impairment
Distinctiveness	High	Low	Medium	High	Low
Permanence	High	Medium	Medium	High	Low
Collectability	Medium	High	High	Medium	Medium
Performance	High	Low	Medium	High	Low
Acceptability	Medium	High	Medium	Low	High
Potential for circumvention	Low	High	Medium	Low	High

II. DAUGMAN'S ALGORITHM

In [4], Daugman introduced a circular edge detection operator for iris localization, as follows:

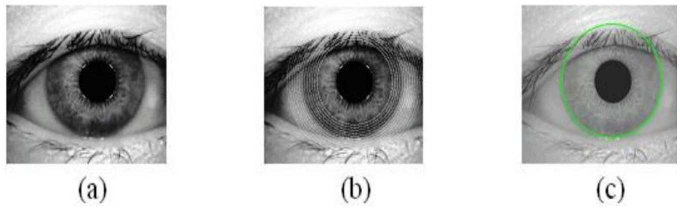

Fig. 2 (a) Contrast enhanced image
(b) Concentric circles of different radii
(c) Localized Iris image

$$\max_{(r,x0,y0)} \left| G_\sigma(r) * \frac{\partial}{\partial r} \oint_{r,x0,y0} \frac{I(x,y)}{2\pi r} ds \right| \qquad \textbf{(1)}$$

As shown in Fig. 2. for a given centre of iris, average intensity value of pixels falling on circles of given radius range are calculated. The difference of that average intensity is Gaussian smoothed. The max value of that corresponds to radius of the iris outer boundary.

In [5], Daugman Circular Differential Operator is proposed to search by assuming that the centre of the image is pupil. Average Square Shrinking (ASS) is then used to refine the pupil search. There is a possible contribution to failed detection if the assumed centre is not the pupil.

A. *Daugman's Integro-Differential Operator*

Daugman's operator is based on the fact that the intensity difference between inside and outside of pixels in iris edge circle is maximum. It means that if you calculate the difference values of pixels' gray level in iris circle, this value is higher than any other circles in images. This fact turns to colour of iris and colour of sclera. Sclera is the white region outside of iris. See Fig. 3 [5].

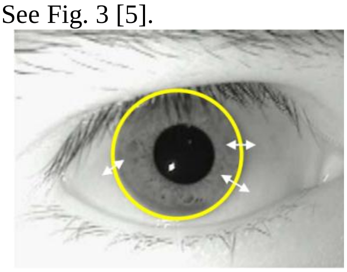

Fig. 3 Difference between inside and outside of iris edge

The equation (1) suggests that intensity value normalized by closed contour's (e.g. circle's) perimeter 2πr, with radius r and centre (x_0, y_0), is differentiated with previous value of radius r. It is convolved with Gaussian smoothing filter for noise and probable eye lashes removal. The maximum difference between previous and current normalized intensity values is found which is either inner circle or outer circle depending on the range of radius. The pre-requisite for this algorithm is centre of the pupil and radius range.

It is impossible to calculate Daugman Operator for all feasible circle of an image. For example, in many research, it is assumed that the centre of iris is near to centre of image. Also they spot a range of radius based on size of image.

We have used morphological processing to find centre candidates as shown in Fig. 4. The centre with maximum value of Integro-differential operator output value is selected as centre of the iris outer boundary.

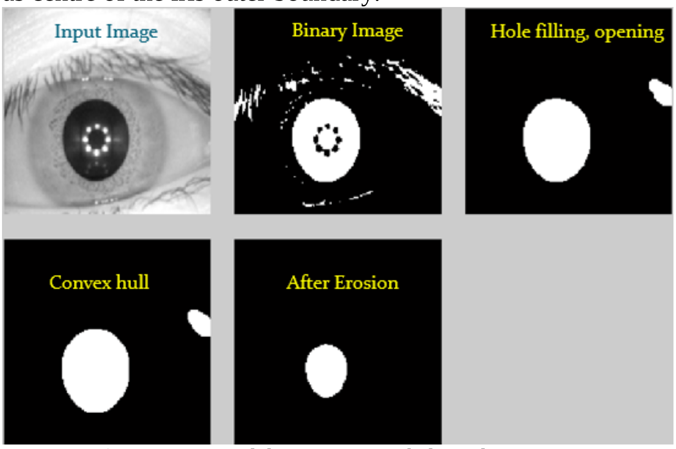

Fig. 4 Centre Candidates using morphological processing

B. *Centre Candidates in neighbourhood of pupil-centre*

In this approach after successfully segmenting pupil using hole filling, morphological opening, edge detection and convex hull we find extremity points and its centre as shown in Fig. 5. Pixel in neighbourhood (here 5x5) of centre are taken as centre candidates. This significantly reduces processing time.

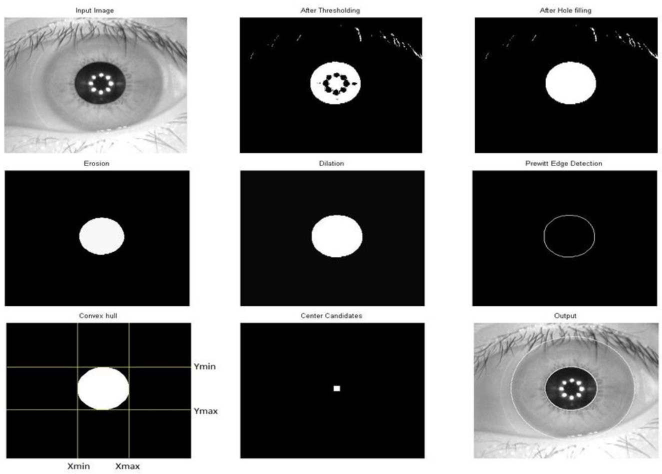

Fig. 5 Centre Candidates in neighbourhood of pupil centre

III. Least Square Fitting of Ellipse

A. Yahya and M. Nordin suggests following remarks [6]:

1. Usually, the inner boundaries are detected by circle fitting techniques. This is a source of error, since the inner boundaries are not exactly circles.
2. In noisy situations, the outer boundary of iris does not have sharp edges.

They have introduced new method based on Direct Least Squares fitting of ellipse to detect the inner boundary of the iris. Theoretically, the ellipse model also fits a circular shape.

A. Direct Least Square fitting of ellipse

Direct Least Square fitting of ellipse was proposed by Fitzgibbon et al. [7]. His method has advantages like it is ellipse-specific, so that even bad data will always return an ellipse. It can be solved naturally by generalized Eigen system. The method works on segmented data (i.e. all data points are assumed to belong to one ellipse).

An ellipse is a special case of a general conic which can be described by an implicit second order polynomial

$$F(x,y):\ ax^2 + bxy + cy^2 + dx + ey + f = 0 \quad \textbf{(2)}$$

With an ellipse-specific constrain

$$b^2 - 4ac < 0 \quad \textbf{(3)}$$

Where a, b, c, d, e, f are coefficients of the ellipse and (x, y) are coordinates of points lying on it. The polynomial F(x, y) is called the algebraic distance of the point (x, y) to the given conic. The result of this algorithm is an ellipse with parameters major axis, minor axis, orientation and the centre of the ellipse.

B. Iris inner boundary localization

Here, to segment the pupil threshold value 79 is used to binaries the image and then we have used morphological operators to remove eyelashes and reflections. Fig. 6(A) shows original image, Fig. 6(B) is binaries image with hole filling, Fig. 6(C) largest object in binary image i.e. pupil, and Fig. 6(D) shows boundary of pupil region in the binaries image. Finally we apply the direct least squares fitting of ellipse to get the ellipse parameters. For outer boundary of iris Daugman's Integro-differential operator is used.

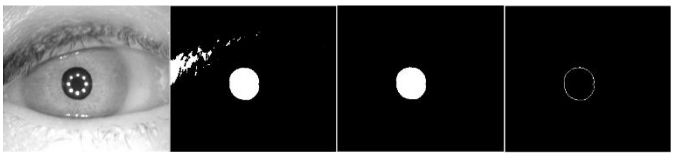

Fig. 6 (A) Original Image, (B) Binaries and hole-filled Image, (C) Pupil region in binaries image, (D) Edge Detected Image

Fig. 7(a) shows result from Daugman's Integro-differential operator and Fig. 7(b) shows results from direct ellipse fitting and we can see that second method outperforms the first one.

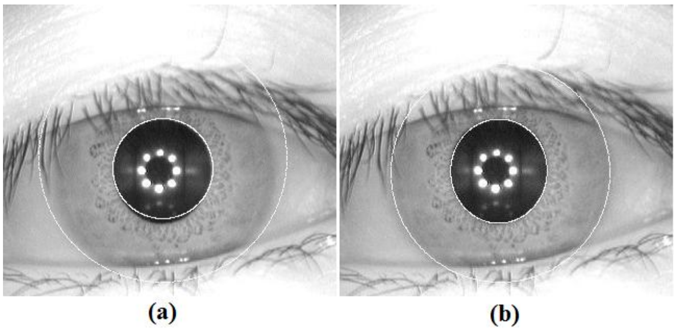

Fig. 7 Iris localization using, (A) Daugman's Integro-Differential operator (B) Direct ellipse fitting

IV. Experimental Results

Both techniques where applied on CASIA-Iris-Interval-v3 1332 left eye images with machine configuration as Intel® Core™ 2 Duo CPU T6500 @ 2.10GHz, 3 GB DDR-II RAM. Image database is affected by occlusions like eyelashes and spotlight in pupil region. We can see that second method outperform the first one.

TABLE II

COMPARISON OF BIOMETRIC TECHNOLOGIES

Technique	Daugman's Integro-Differential	Direct Least Square fitting of Ellipse
Pupil Detection	85.51 %	86.19 %
Iris Detection	80.93 %	77.03 %

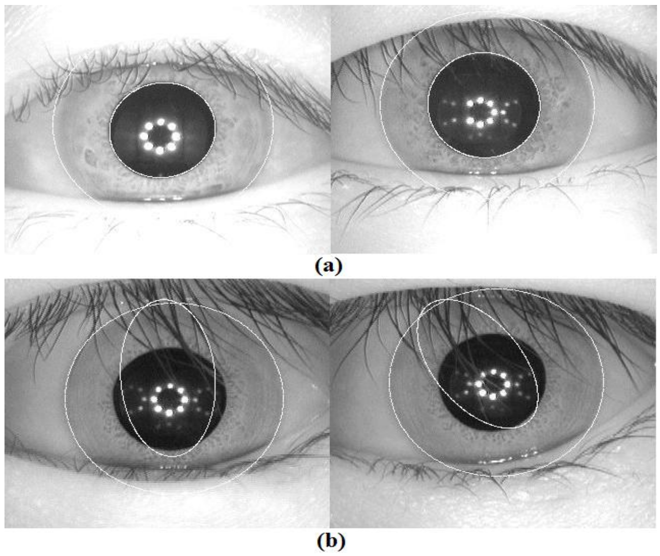

Fig. 8 Pupil detection using ellipse (a) successful case (b) failed case

Fig. 8, shows localized image results for non-circular irises. From Fig. 8. (b) we can say that threshold value must be carefully selected for avoiding occlusions (i.e. eye lashes). Direct least square fitting of ellipse successfully localizes iris.

V. CONCLUSIONS AND FUTURE-WORK

Different techniques for iris localization are reviewed and experimented. We found that iris is most preferred biometric. Its acceptance can be improved for face captured images. Method used in Daugman's Integro Differential operator detects inner circle and outer circle boundary using the fact that there is sudden change in intensity at pupil-iris and iris-sclera boundary. Daugman's Integro-Differential Operator requires centre and radius range as argument. For that we have used pupil segmentation and finding the centre of that object. The pixel in neighbourhood of centre are considered as centre candidates. Direct Least Square fitting of ellipse is used which successfully localizes iris in most of the case. However severe occlusion of eye lid and eye lashes fail the algorithm. For future work, adaptive thresholding can be used to avoid occlusion.

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