

Human Iris Segmentation for Iris Recognition in Unconstrained Environments

Mahmoud Mahlouji¹ and Ali Noruzi²

¹ Department of Electrical and Computer Engineering, Kashan Branch, Islamic Azad University
Kashan, Iran

² Department of Electrical and Computer Engineering, Kashan Branch, Islamic Azad University
Kashan, Iran

Abstract

This paper presents a human iris recognition system in unconstrained environments in which an effective method is proposed for localization of iris inner and outer boundaries. In this method, after pre-processing stage, circular Hough transform was utilized for localizing circular area of iris inner and outer boundaries. Also, through applying linear Hough transform, localization of boundaries between upper and lower eyelids occluding iris has been performed. In comparison with available iris segmentation methods, not only has the proposed method a relatively higher precision, but also compares with popular available methods in terms of processing time. Experimental results on images available in CASIA database show that the proposed method has an accuracy rate of 97.50%.

Keywords: *Biometric, Hough Transform, Segmentation, Normalization, Iris Tissue Encoding, and Matching.*

1. Introduction

Iris recognition is a biometric recognition technology that utilizes pattern recognition techniques on the basis of iris high quality images. Since in comparison with other features utilized in biometric systems, iris patterns are more stable and reliable, iris recognition is known as one of the most outstanding biometric technologies [1]. Iris images could be taken from humans eyes free from such limitations as frontal image acquisition and special illumination circumstances. Daugman's [2] and Wildes' [3] systems are the two earliest and most famous iris recognition systems including all iris recognition stages. In Daugman's algorithm, two circles which are not necessarily concentrated form the pattern. Each circle is defined by three parameters (x_0 , y_0 , r) in a way that (x_0 , y_0) determines the center of a circle with the radius of r . An integro-differential operator is used to estimate the

values of the three parameters for each circular boundary and the whole image is searched in relation to the increment of radius r . In Wildes' system, gradient based Hough transform has been used to localize two iris circular boundaries. This system consists of two stages. At first, a binary map is produced from image edges by a Gaussian filter. Then, the analysis is performed in a circular Hough space in order to estimate the three parameters (x_0 , y_0 , r) for a circle.

In segmentation step of the algorithm proposed in [4], a set of one-dimensional signals is extracted from iris image using the values of illumination intensity on a set of pupil-centered circular contours which have been localized through use of edge detection techniques. In [5] iris images are projected vertically and horizontally to estimate the center of the iris. Also, this method has been utilized for eyelash segmentation and lightening reflection removal in [6]. The algorithm proposed in [7] predicts the optimization of iris biometric system on a bigger set of data on the basis of Gaussian model obtained from a smaller set of data. Also, an iris recognition system has been proposed in [8] which is used for frontal iris images and for an iris image which is not taken from frontal view. When frontal iris image is not available for a particular individual, in this system the issue is considered through maximizing Hamming distance between the two mentioned images or through minimizing Daugman's integro-differential operator. Next, the image is transformed to a frontal image. An algorithm is presented to find eyelash and eyelids occlusions on iris in a completely close up image similar to Daugman's method in [9]. In 3D environment, this algorithm searches for three parameters as with (x , y) in center and radius of z . The remainder of present paper is organized as follows. In section 2, the proposed method of iris recognition is

introduced and next in section 3, experimental results of the proposed method on several databases are presented, and finally in section 4, conclusions are drawn.

2. Proposed method for iris recognition

Fig. 1 shows block diagram for a biometric system of iris recognition in unconstrained environments in which each block's function is briefly discussed as follows:

1. Image acquisition: in this stage, a photo is taken from iris.
2. Pre-processing: involving edge detection, contrast adjustment and multiplier.
3. Segmentation: including localization of iris inner and outer boundaries and localization of boundary between iris and eyelids.
4. Normalization: involving transformation from polar to Cartesian coordinates and normalization of iris image.
5. Feature extraction: including noise removal from iris image and generating iris code.
6. Classification and matching: involving comparing and matching of iris code with the codes already saved in database.

Regarding the fact that in an unconstrained environment iris may have occlusions caused by upper or lower eyelids or eyes may roll left and rightwards, as the paper goes on, these blocks are introduced and such issues are solved.

2.1 Image acquisition

Taking a photo from iris is the initial stage of an iris-based recognition system. Success of other recognition stages is reliant on the quality of the images taken from iris during image acquisition stage. Images available in CASIA database lack reflections in pupil and iris areas because infrared was used for imaging. Additionally, if visible light is used during imaging for those individuals whose iris is dark, a slight contrast comes to existence between iris and pupil which makes it hard to separate these two areas [10].

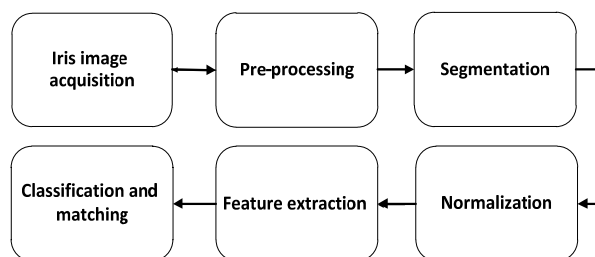


Fig. 1 Block diagram of an iris recognition system.

2.2 Pre-processing

Initially, in order to improve and facilitate later processing, a primary processing is performed on iris images. In pre-processing stage, Canny edge detection is used to enhance iris outer boundary that is not recognized well in normal conditions, and a multiplier function is used to enhance Canny iris points, also image contrast adjustment is performed to make its pixels brighter. Fig. 2 shows a sample of an eye image and the results of pre-processing stage performed.

2.3 Segmentation

Precise iris image segmentation plays an important role in an iris recognition system since success of the system in upcoming stages is directly dependent on the precision of this stage [16]. The main purpose of segmentation stage is to localize the two iris boundaries namely, inner boundary of iris-pupil and outer one of iris-sclera and to localize eyelids. Fig. 3 shows block diagram of segmentation stage. As it could be seen in this figure, segmentation stage includes three following steps:

1. Localization of iris inner boundary (the boundary between pupil and iris).
2. Localization of iris outer boundary (the limbic border between sclera and iris).
3. Localization of boundary between eyelids and iris.

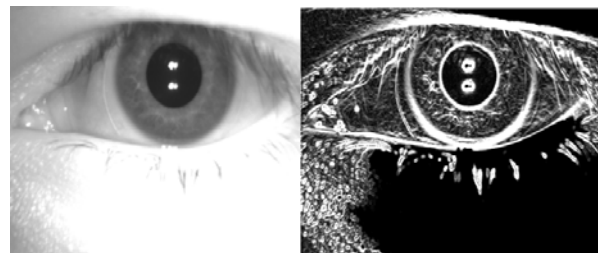


Fig. 2 An eye image from CASIA database and the results of pre-processing performed.

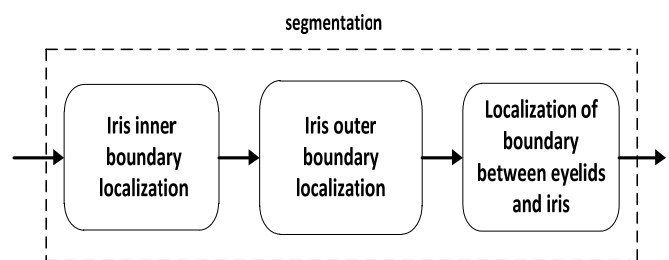


Fig. 3 Block diagram of segmentation stage.

2.3.1 Iris inner boundary localization

Regarding that illumination intensity is very different in pupillary inner and outer parts, and pupil is darker compared with iris, the use of Canny edge detection in pre-processing stage results in determining points in iris-pupil boundary. Fig. 2 shows the results of performing Canny edge detection on an eye image as pre-processing output. As it could be observed, pupillary boundary is almost completely detected. After determining edge points, by the use of circular Hough Transform, the center and radius of iris circle are obtained. Fig. 4 shows iris inner boundary which has been achieved via this method for two eye images.

2.3.2 Iris outer boundary localization

The most important and challenging stage of segmentation is detecting the boundary of iris and sclera. Firstly, because there is usually no specific boundary in this area and illumination intensity distinction between iris and sclera is very low at the border. Secondly, there are other edge points in eye image in which illumination intensity distinction is much more than that of the boundary of iris and sclera. As a result, edge detection algorithms which are able to detect outer iris edges identify those points as edge. Therefore, in order to detect iris outer boundary, these points have to be identified and eliminated. In this paper, available boundaries are initially enhanced and then extra edge points are identified and eliminated. At the end, through circular Hough transform, outer iris boundary is obtained. In order to enhance iris outer boundary edges, Canny edge detection is performed on eye image in pre-processing stage. By performing such edge detection, a matrix is obtained with the same dimensions as of the image itself which its elements are high in areas where there is a definite boundary and the elements are low in areas where there is no perfectly definite boundary, such as iris outer boundary. Through multiplying of 2.76 in the matrix of pixel values of iris image and intensifying light in eye image, the edges are enhanced. Applying Canny edge detection and multiplying that to the constant value of 2.76 result in better revelation of iris outer boundary edge points. Results of such application on two eye images are shown in Fig. 5.

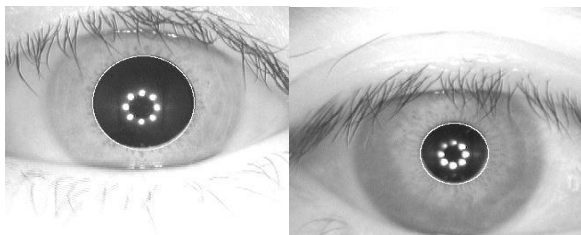


Fig. 4 Iris inner boundary localized for two eye images.

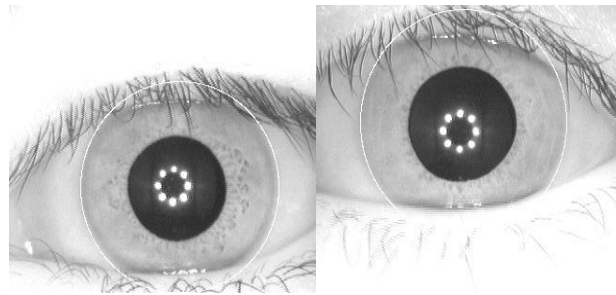


Fig. 5 Iris outer boundary localized for two eye images.

The only issue of this method is sclera boundary not being circular which is the result of angled or sideward imaging and in these cases, some information are lost or clutter comes to existence. In this stage, after identifying iris inner and outer boundaries, the results of these two stages are combined. Fig. 6 shows the results obtained. As it could be seen in this figure, iris inner and outer boundaries are correctly identified in CASIA Iris Image-Interval database.

2.3.3 Localization of boundary between eyelids and iris

As could be seen in Fig. 2, one can consider the boundary between eyelids and iris as two lines with first order estimate. To localize them, after detecting edges and by the use of linear Hough transform, the properties of the line could be obtained. To do this, initially eyelids boundary should be detected by using of Canny edge detection. As could be seen in Fig. 2, there are only pupillary edge points between the two eyelids and since pupillary boundary has been already obtained, these points are eliminated. Fig. 7 shows few boundaries localized through this method for some eye images. This method could result in a false outcome only for some images which have too many patterns in iris tissue when the edges of these patterns are detected by Canny edge detection. As they are observable in Fig. 7, the method localizes eyelids with relatively high precision.

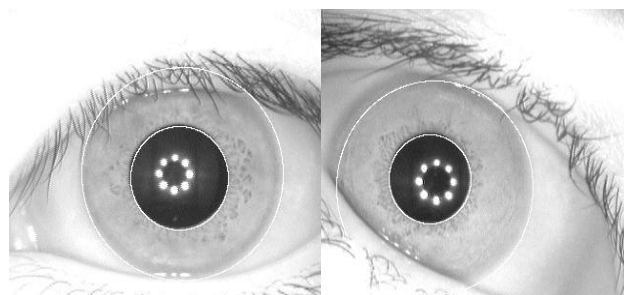


Fig. 6 Iris inner and outer boundaries localized for two eye images.

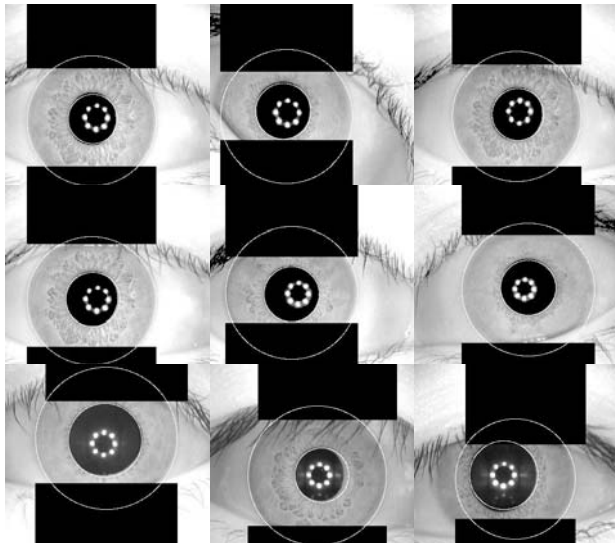


Fig. 7 Boundaries between iris and eyelids localized for some eye images.

They are obvious in Fig. 7, for those eye images in which eyelids are linearly shaped, the boundaries of eyelids and iris are recognized properly but for those images in which eyelids are parabola shaped, this boundary is recognized with slight discrepancy. The accuracy rate of the proposed method for segmentation stage on different databases is presented in Table 1. As the results presented in this table show the method has an accuracy rate of more than 97.6% for iris boundary localization.

2.4 Normalization

In normalization stage, an approach based on Daugman's method is used. Fig. 8 shows transforming iris area from polar to Cartesian coordinates. Therefore, iris area is obtained as a normalized strip with regard to iris boundaries and pupillary center. In this paper, iris area is illustrated on a rectangular strip of 8×512 [11, 12].

Table 1: Accuracy rate of iris boundary localization for three databases

Database	Accuracy rate in pupil boundary localization (%)	Accuracy rate in sclera boundary localization (%)	Accuracy rate in eyelids boundary localization (%)
CASIA Iris Image (ver. 1.0)	98.13	99	98
CASIA Iris Interval (ver.3.0)	99.73	99.19	98.63
University of Bath	99.18	99.70	97.60

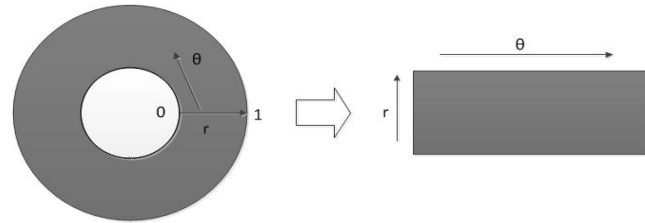


Fig. 8 Transforming polar to Cartesian coordinates.

In order to transform iris area from polar to Cartesian coordinates, 128 pupils-centered perfect circles are chosen starting from iris-pupil boundary and then the pixels located on these circles are mapped into a rectangle. As a result, iris area which looks like a circular strip is converted into a rectangular strip. Since with changes in surrounding illumination level, the size of pupil is adjusted by iris to control the amount of light entering into eyes and it is also possible that individual's distance with a camera could be different, iris is not of the same size in different images. Therefore, choosing these 128 perfect circles normalizes iris in terms of size as well. Then we adjust illumination intensity in segmented iris tissue, i.e. we applied image contrast to bring more clarity into iris tissue. Fig. 9 shows a sample of normalized iris tissue. As the figure shows, all previously mentioned recognition stages have been performed on each image. In initial stage, localization of iris circular inner and outer boundaries, then that of eyelids; later choosing 128 circles on iris area, and eventually transforming polar to Cartesian coordinates has been performed.

2.5 Feature extraction and iris encoding

In order to extract features, two-dimensional Gabor Filters are utilized in this paper [13, 14]. Through performing Gabor Filters to the image from different orientations, ultimate feature vector is obtained. In this stage, the dimensions of the feature vector extracted from iris area have to be as small as possible. Regarding high dimensions of the image drawn, Wavelet transform was performed in order to decrease the dimensions in the way that important information existing in tissue can be preserved in spite of downsizing image dimensions [15]. By performing Wavelet transform twice on an image of 256×512 already obtained after pre-processing stage, we will have a smaller one of 16×32 , and later this image is used to extract features vector [8]. The encoding obtained in this stage with dimensions of 80×240 enters the next stage of the system namely matching stage. Regarding that some sections of the area chosen for feature extraction may have occlusions caused by eyelids and eyelashes and since it is possible that, because of error in segmentation stage, some parts of sclera be detected as iris area, it is required that a measure be taken to remove these points from the feature

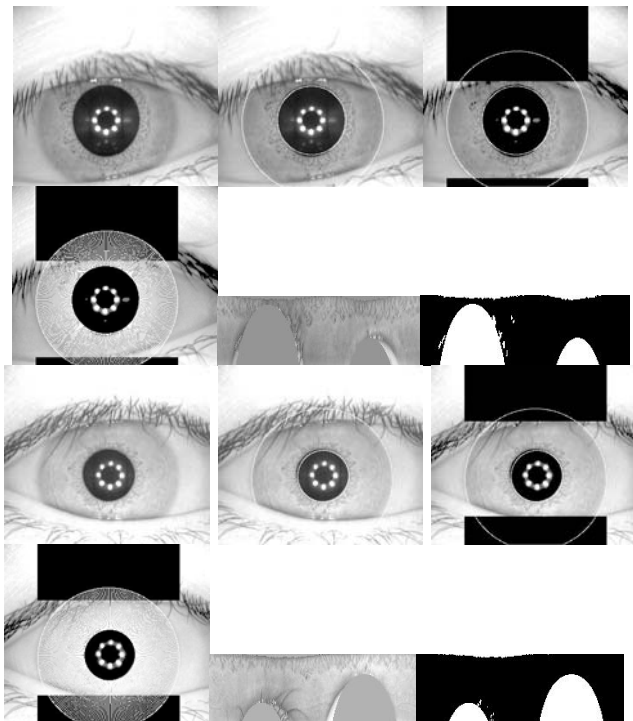


Fig. 9 Transforming iris area into normalized rectangular strip (from left to right: original image, iris inner and outer boundaries, eyelid boundaries, normalization, iris area normalized rectangular strip, eyelids area).

extraction stage. To resolve the latter issue that is caused by error when detecting iris outer boundary, 20% of the lower section of the image is eliminated and to resolve the first issue, points of the image that are placed in this section are eliminated from encoding. To do this, we produce a binary encoding which detects occlusion points. We use this encoding in matching stage and these points are eliminated in that stage. Two outputs are generated in this stage. First output belongs to transformation of iris to iris encoding and another output belongs to transforming iris noises into encodings.

2.6 Classification and matching

In the method presented in this paper, Hamming distance criterion is used. If the value of feature vector in a point is equal to the value of other feature vector in that point, digit 1 and if they are not equal, digit zero is allocated to that point and then the values allocated to the pixels are summed up and similarity criterion of the two vectors is attained by finding the best of Hamming distance accordance in following equation:

$$HD = \frac{1}{N} \sum_{i=1}^N (x_i \oplus y_i) \quad (1)$$

In this equation N is equal to total numbers of feature vector points; and x_i, y_i is values of two compared feature vectors.

3. Experimental results

In this paper, the amount of HD value threshold was supposed to be 0.4. Therefore if two irises are identical, their HD value must be below 0.4 and if two irises are distinctive, their HD value must approximate or exceed 0.4. Efficiency of a biometric system is usually evaluated by taking to account the False Rejection Rate (FRR) and False Acceptance Rate (FAR) and the lower the two error rates; the system is evaluated as more efficient. The FAR means how many people, who introduce you instead of other people, the system accept as an error. The FRR means how many people, who have entrance, allowance, and the system don't known and accept as an error.

In Table 2 the results of the proposed method is presented for two different databases. According to the table results, accuracy rate of proposed method on CASIA database is 97.5% that it is a rather good precision. The reason of being low precision for Bath university database is being very low the difference of illumination intensities in iris and pupil boundary of the database. Also, in Figs. 10 and 11, results of the proposed method for two iris databases are shown. In Table 3, the performance results of several popular algorithm of iris recognition with proposed method on CASIA database images are presented. As seen in the table, the accuracy rate of proposed method is better than Ma algorithm and it is very close to the accuracy rate of Yahya algorithm. It is better mentioned that the reason of very high precision of Daugman's method is very much limitations of this method when it is imaging. Also, linear Hough transform is used for eyelids localization; therefore, the speed of the proposed algorithm is better than the speed of other algorithms such as parabolic Hough transform in the stage of iris localization [16-17].

Table 2: False Rejection Rate (FRR) and False Acceptance Rate (FAR) for two different databases with threshold of 40%

<i>Iris Database</i>	<i>FAR (%)</i>	<i>FRR (%)</i>	<i>Overall system accuracy (%)</i>
CASIA Iris Interval (ver. 3.0)	0.5	2	97.5
University of Bath	4	0	96

Table 3: Efficiency comparison on CASIA database images for popular algorithms

<i>Algorithm</i>	<i>FAR (%)</i>	<i>FRR (%)</i>	<i>Overall system accuracy (%)</i>
Yahya [11]	2.08	0.03	97.89
Daugman [2]	0.09	0.01	99.90
Ma [6]	8.79	0.84	89.37
Proposed method	0.50	2	97.50

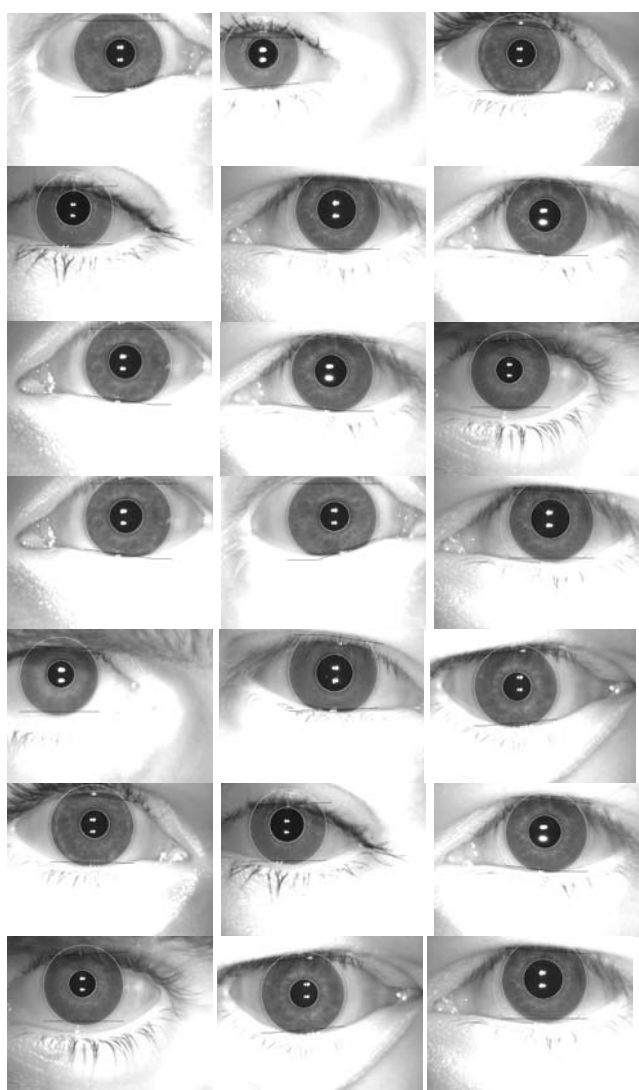


Fig. 10 Iris boundaries localized for some eye images (iris database: University of Bath).

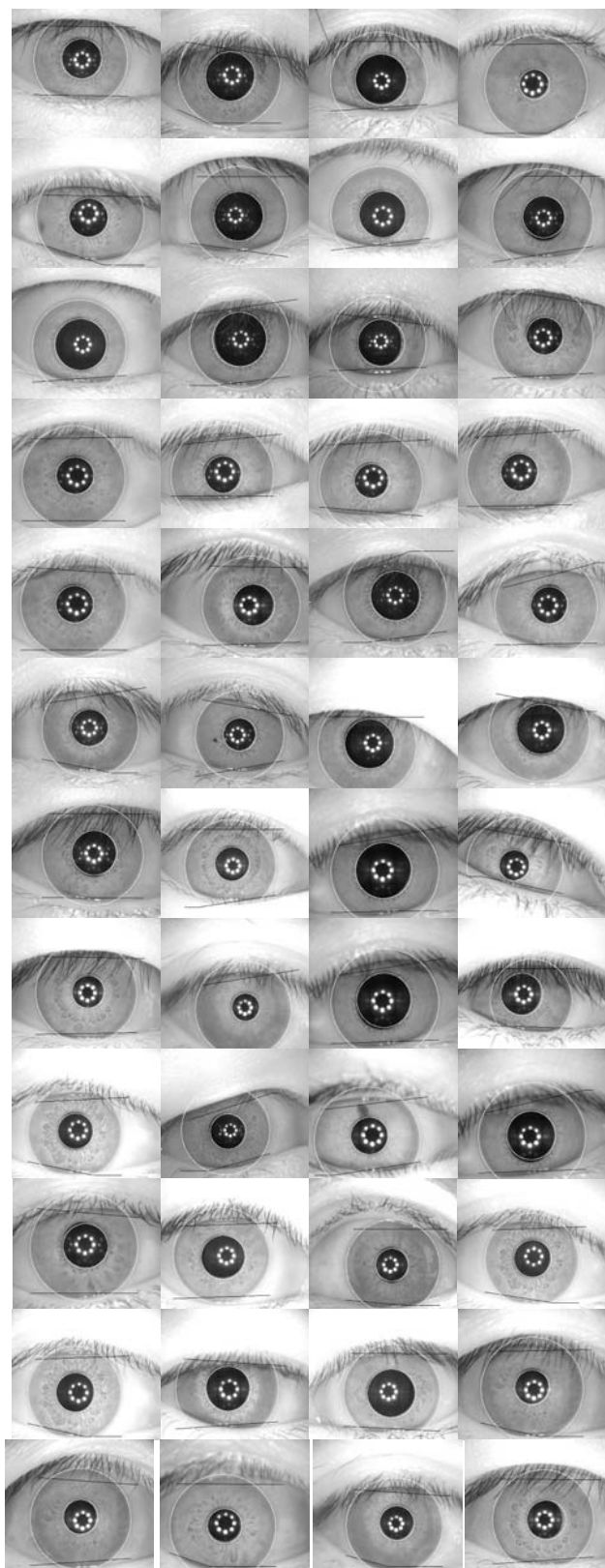


Fig. 11 Iris boundaries localized for some eye images (iris database: CASIA Iris Interval).

4. Conclusions

This paper presents an effective method to recognize iris boundaries by performing Canny edge detection and Hough transform. In this method, the boundaries were localized with high precision, and with particular attention to the issue of low variations of illumination intensity in iris outer boundary compared with other sections was achieved a fine accuracy rate for this proposed method. The results of examining the method on CASIA database images indicated the efficiency and high precision of the proposed method that are comparable with other existed methods of identity recognition by using iris images.

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Mahmoud Mahlouji received the B.S. degree in telecommunications engineering from Sharif University of Technology, Tehran, Iran, in 1990, the M.Sc. degree in electronics engineering from Sharif University of Technology, Tehran, Iran, in 1993, and the Ph.D. degree in telecommunications engineering from Science and Research Branch, Islamic Azad University, Tehran, Iran, in 2008. At present he is an assistant professor of the Electrical and Computer Engineering Department, Kashan Branch, Islamic Azad University, Kashan, Iran. His current interests are in image processing, pattern recognition, neural networks, computer vision, and iris recognition.

Ali Noruzi received the B.S. degree in computer engineering from Neragh Branch, Islamic Azad University, Neragh, Iran, in 2007, and the M.Sc. degree in computer architecture from Dezful Branch, Islamic Azad University, Dezful, Iran, in 2010. His research interests include image processing, and iris recognition.