Individuals Authentication from Both-Eye Images using Dempster-Shafer Fusion

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Summary
In this paper, an efficient method that allows us to authenticate individuals from both-eye images is presented. The proposed method consists of three main steps: In the first one, the iris images are segmented in order to extract the iris disc. The segmented images are normalized by Daugman rubber sheet model. In the second step, the normalized images are analyzed by a bench of two 1D Log-Gabor filters to extract the texture characteristics. The encoding is realized with a phase of quantization developed by J. Daugman to generate the binary iris templates. In the third step, for the authentication and the similarity measurement between both binary irises templates, the hamming distances combined using Dempster Shafer rule are used with a previously calculated threshold. The proposed method has been tested on a subset of iris database CASIA-IrisV3-Interval which achieves a good performance with accuracy of 99.97%, FPR of 0% and FNR of 3.58%.

Keywords:
Both eye, authentication, Dempster Shafer rule, performance.

1. Introduction

Iris is claimed to be one of the best biometrics. It is the only internal organ which can be seen outside the body. Iris texture patterns are believed to be different for each person, and even for the two eyes of the same person [1][2][3]. Texture feature matching as demonstrated by Daugman [4] has been shown to be a viable approach to iris recognition.

Daugman's algorithm [5][6] is the best known iris algorithm. In this system, the iris image is segmented using an integrodifferential operator and is normalized and converted from Cartesian image coordinates to polar image coordinates. Then a 2D Gabor filters [4,7] is used to encode the iris image to a binary code of 256 bytes in length. This system also uses hamming distance (HD) [5] between the IrisCodes as the similarity measure and takes the decision upon the condition of HD from two different irises being greater than a criterion. The True Positive Rate versus False Positive Rate Curve shows that the decision becomes more conservative for lower HD criterion, while it becomes more liberal for higher HD criterion.

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Richard P.Wildes [8] introduced another approach for iris recognition using a diffuse source and polarization [8] in conjunction with a low-light-level camera and Hough Transform for image pre-processing. Camus and Wildes [9] presented a more similar method to Daugman's algorithm for iris segmentation, which is faster than Daugman's 2001 algorithm [6].

Ma et al. [10] represented a different approach for iris features using a bank of spatial filters. Noh et al. [11] adopted an efficient method based on Haar wavelet decomposition to obtain iris features. These methods obtain a similar performance compared to Gabor filters [4,7]. L. Masek [12] used an alternative method based on Log-Gabor filters for iris feature extraction. A disadvantage of the Gabor filter is that the even symmetric filter will have a DC component whenever the bandwidth is larger than one octave [12]. However, zero DC component can be obtained for any bandwidth by using a Gabor filter which is Gaussian on a logarithmic scale (Log-Gabor filter). Some researchers have tried to incorporate features from more than one biometric trait on motivation to increase the overall performance, and hence, the multi-biometric security systems were introduced. Rattani et Tistarelli [13] fused information from face and iris. Elmadani [14] presented the "fingerIris" algorithm for combination of iris and fingerprint. It has been proven that multi-biometric system show better performance while Nagar et al. [15] reported on multi-biometric research involving face, iris, and fingerprint for better performance. Nevertheless, fusion information from two irises gets also better performance due to its unique textures and as the distinguishable biometric identity, the probability of two irises producing the same IrisCode™ (the biometric code obtained from Daugman's technique) is approximately 1 in 1078 [16]. Moreover, both irises require the same algorithm which reduces the system complexity.

This paper proposes a dual iris authentication system that follows these main phases:

(i) Segmentation based on circular Hough transform to delineate iris and pupil circles, and linear Hough transform to define the high and low parts of the eyelids.

(ii) Normalization stage was applied to compensate the non-concentricity of the two borders and the varying size of the iris caused by the dilation/contraction of the pupil.
(iii) A bench of two 1D Log-Gabor filters is used for extracting information from iris texture, and then the encoding is realized with a quantization phase developed by J. Daugman [5].

This work presents two main contributions related to iris segmentation phase. First, the upper and lower parts of the eyelids are detected by two segments in order to exploit efficiently the interest region of the iris. Second, only the interior half of the iris disc is considered that since it contains the most relevant information [17], and it is less affected by noise. In addition, a dual iris authentication system is developed by using a fusion method based on Dempster Shafer Theory. The proposed system based on fusion method using Dempster Shafer rule was compared to Iftakhar and Ashraful system [24] which uses fusion method based on AND rule.

The remainder of this paper is organized as follows. The iris pre-processing is presented in section 2. The iris feature extraction and encoding is detailed in section 3. The authentication mode is devoted in section 4. Finally, conclusions are drawn in section 5.

2. Iris pre-processing

Before extracting distinguishable features from the eye images for creating binary iris templates, the images need to go through the pre-processing phase including: segmentation and normalization.

2.1 Iris segmentation

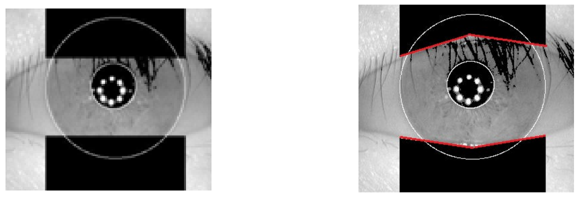
Iris segmentation consists of the iris disc extraction delimited by the circular borders of iris/sclera and iris/pupil. Thus, the detection of these boundaries in our system is based on Circular Hough Transform, which needs at the first time the generation of an edge map using Canny Edge Detector [18,19]. The Circular Hough Transform detects at first the iris/sclera boundary to locate efficiently the iris/pupil boundary.

Eyelids are isolated by fitting a line to the upper and lower eyelid using the Linear Hough Transform. For isolating eyelashes, a simple thresholding technique was used, since analysis reveals that eyelashes are quite dark when compared with the rest of the eye image. The obtained results show some anomalies that appear by the unexploited areas marked with red color, as illustrated in Fig. 1.

Original image Segmented image (1)

Fig. 1. Separation of the eyelids using Linear Hough Transform.

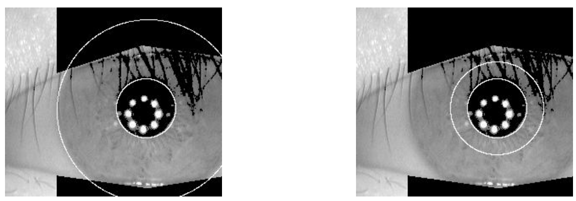
To deal with such problem, another technique is applied for delimiting the high and low eyelids with two segments by using Linear Houhg Transform [20], as shown in Fig. 2.



Original image Segmented image (2)

Fig. 2. Separation of the eyelids by two segments using Linear Hough Transform.

Furthermore, in order to obtain only relevant information, which is represented by the structural variation of the iris texture (high gradient areas), only the internal half of the iris disc is exploited, because it contains the most relevant information [17] and it is less affected by the noise, as shown in Fig. 3. Indeed, the proposed technique decreases the complexity and the computation load without losing information.



Segmented image (2) Segmented image (3)

Fig. 3. Delimitation of the structural variation of the iris texture.

The segmentation phase is described in Fig. 4.

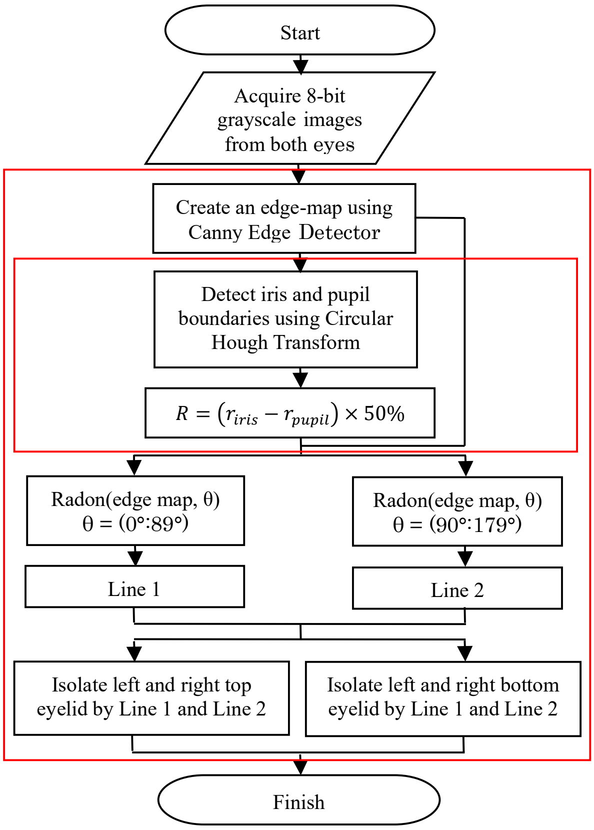


Fig. 4. Flowchart of two main contributions in iris segmentation.

2.2 Iris normalization

The iris disc does not always have the same dimension, even for eye images of the same person; this is due to various problems as follows:

(i) Different acquisition conditions of the eye images.

(ii) Dilation and contraction of the pupil due to the variation of the illumination level.

(iii) The pupil region is not always concentric within the iris.

(iv) In order to overcome these problems, a stage of normalization is applied. It consists of transforming the region of the iris disc to rectify the dimensions of all the iris discs, by using the homogenous rubber sheet model proposed by Daugman [5]. It transforms each point in the iris area to the polar coordinates (r,θ), where r is on the interval [0,1] and θ is angle [0,2π], as illustrated in Fig.5.

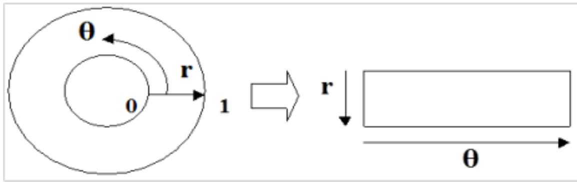


Fig. 5. Daugman rubber sheet model [5].

In our system, (20*240) points were used, but only (10*240) points corresponding to the internal half of the iris disc that contains the most relevant information [17] and it which is less affected by noise, are retained for the next steps of the processing, as shown in Fig. 6.

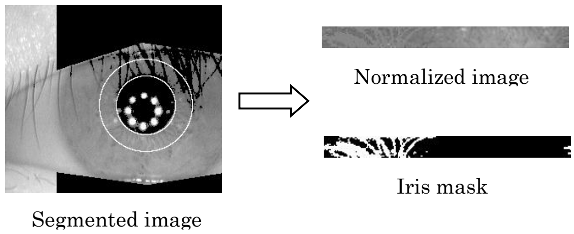


Fig. 6. Normalization of the segmented iris.

3. Iris feature extraction and encoding

Once the segmentation and normalization processes are achieved, the next step is the extraction of the most relevant information present in the iris region. For this reason, the following steps were applied:

(i) The Fast Fourier Transform is applied for each line of the normalized matrix image (FFT to 1D signals).

(ii) Then, the Inverse Fast Fourier Transform IFFT is applied on the multiplication FFT (1D signals) by a 1D Log-Gabor Filter.

The frequency response of a 1D Log-Gabor filter is given by:

$$G(f) = \exp\left(- \frac{(\log(f / f_0))^2}{2 \times (\log(\sigma / f_0))^2} \right) \quad (1)$$

Parameters setting:

(i) A bench of two 1D Log-Gabor filters is used.

(ii) The bandwidth of the 1D Log-Gabor wavelet is given by $\sigma / f_0 = 2$.

(iii) Center frequency of the 1D Log-Gabor wavelet is given by $f_0 = 18$ pixels.

Indeed, the phase of filtred image was quantized using four-quadrants of J. Daugman [5], when going from one quadrant to an adjacent quadrant, one bit is changed as shown in Fig. 7.

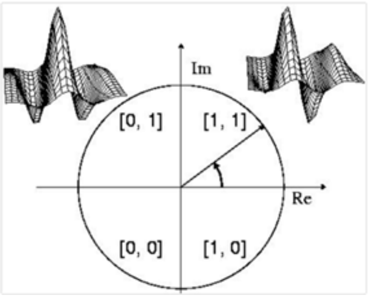


Fig. 7. Quantization Phase [5].

The encoding process produces a bitwise template containing a number of information bits (as shown in Fig. 8 (a)), and a corresponding noise mask which corresponds to corrupt areas within the iris pattern, and mark bits in the template as corrupt (as shown in Fig. 8 (b)). The total number of bits in the template (9600 bits) will be the angular resolution (240) times the radial resolution (10), times 2, times the number of filters used (2).

(a)

(b)

Fig. 8. (a) binary code, (b) mask code.

4. Authentication mode

4.1 Used database

In authentication mode, it is necessary to ascertain whether a person is who they claim to be. It is therefore to compare the distance between two features vectors compared to a predefined threshold during a learning phase [20].

4.2 Matching and decision- Hamming Distance

The matching or comparison of features vectors of two irises is performed by the Hamming distance as follows:

$$HD = \frac{\left\| (codeA \otimes codeB) \cap maskA \cap maskB \right\|}{\left\| maskA \cap maskB \right\|} \quad (2)$$

Where codeA and codeB are two codes calculated from two images of iris by the process previously described, and maskA and maskB represent their associated masks. Literally, the Hamming distance calculates the number of different and valid bits for the two irises between the codeA and the codeB. In fact, more the Hamming distance is smaller more the two codes are similar. A distance of 0 corresponds to a perfect match between the two irises images as two iris images of different persons have a Hamming distance close to 0.50.

4.3 Fusion method based on Dempster Shafer Theory

The fusion method uses Dempster-Shafer (DS) decision theory [22] to combine the Hamming Distances between both irises templates for improving the overall verification results. DS decision theory is considered as a generalization of Bayesian theory in subjective probability and it is based on the theory of belief functions and plausible reasoning. DS decision theory can be used to combine evidences obtained from different sources of system to compute the probability of an event. Generally, DS decision theory is based on two different ideas such as the idea of obtaining degrees of belief for one question from subjective probabilities for a related query and Dempster's rule for fusing such degrees of belief while they depend on independent items of information or evidence [22].

DS theory combines three function ingredients: the basic probability assignment function (*bpa*), the belief function (*bf*) and the plausibility function (*pf*). Let $\Gamma^{Left\ iris}$ and $\Gamma^{Right\ iris}$ be two Hamming distance sets obtained from the matching between left irises and right irises templates, respectively. Further, $m(\Gamma^{Left\ iris})$ and $m(\Gamma^{Right\ iris})$ the *bpa* functions for the Belief measures $Bel(\Gamma^{Left\ iris})$ and $Bel(\Gamma^{Right\ iris})$ for the individual irises respectively. Then, the belief probability assignments *(bpa)* $m(\Gamma^{Left\ iris})$ and $m(\Gamma^{Right\ iris})$ can be combined together to obtain a Belief committed to Hamming Distance set $C \in \Theta$ according to the following combination rule [23] or orthogonal sum rule:

$$m(C) = \frac{\sum_{\Gamma^{Left} \cap \Gamma^{Right} = C} m(\Gamma^{Left})\, m(\Gamma^{Right})}{1 - \sum_{\Gamma^{Left} \cap \Gamma^{Right} = \emptyset} m(\Gamma^{Left})\, m(\Gamma^{Right})}, C \neq \emptyset \quad (3)$$

The denominator in Equation (3) is a normalizing factor which denotes the amounts of conflicts between the belief probability assignments $m(\Gamma^{Left\ iris})$ and $m(\Gamma^{Right\ iris})$. Since the both irises templates are different and used for matching, there is an enough possibility to conflict the belief probability assignments and this conflicting state is being captured by the two *bpa* functions. The final decision of user acceptance and rejection can be established by applying a threshold to *m(C),* as shown in Fig. 9.

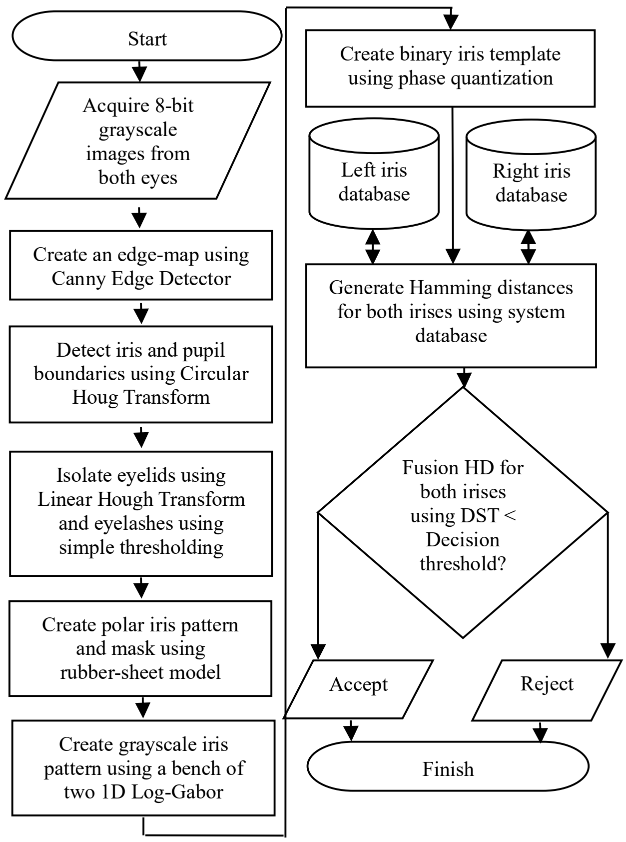


Fig. 9. Flowchart of the proposed dual iris authentication system.

4.4 Experimental results

4.4.1 Performance of the system

The performance values of a system were calculated using the followings, where *interclass* = comparison between imposters, *intraclass* = comparison between genuines, *nb_class* = number of classes, *nb_image* = number of images in class, *TPR* = True Positive Rate, *FPR* = False Positive Rate, *TNR* = True Negative Rate, *FNR* = False Negative Rate.

$$\text{interclass} = \frac{\text{nb\_class} \times (\text{nb\_class} - 1)}{2 \times \text{nb\_image} \times \text{nb\_image}}$$

$$\text{intraclass} = (\text{nb\_class}) \times \frac{\text{nb\_image} \times (\text{nb\_image} - 1)}{2}$$

$$\text{TN} = \text{interclass} - \text{FP}, \qquad \text{TP} = \text{intraclass} - \text{FN},$$

$$\text{TPR} = \frac{\text{TP}}{\text{intraclass}} \times 100, \qquad \text{FPR} = \frac{\text{FP}}{\text{interclass}} \times 100,$$

$$\text{TNR} = \frac{\text{TN}}{\text{interclass}} \times 100, \qquad \text{FNR} = \frac{\text{FN}}{\text{intraclass}} \times 100,$$

$$\text{Accuracy} = \frac{\text{TP} + \text{TN}}{\text{intraclass} + \text{interclass}} \times 100 \qquad (4)$$

4.4.2 Performance for single and dual iris system

Table 1: Comparison between single and dual iris system in terms of performance.

	Left irises	**Right irises**	**Dual iris**
Accuracy (%)	99.91	99.90	99.97
FPR (%)	0	0	0
FNR (%)	12.33	12.75	3.58

For single iris system, using only left irises, maximum accuracy of 99.33% is found at decision threshold of 0.41 with FPR of 0.69% and FNR of 4.25% (as shown in Fig. 10 and Fig. 11). To eliminate FPR, a decision threshold is moved to 0.35 where accuracy is increased to 99.91% and FNR increases to 12.33% (as shown in Table 1).

Similarly, using only right irises, maximum accuracy of 99.01% is found at decision threshold of 0.41 with FPR of 0.96% and FNR of 4.25% (as shown in Fig. 12 and Fig. 13). To eliminate FPR, a decision threshold is moved to 0.35 where accuracy is increased to 99.90% and FNR increases to 12.75% (as shown in Table 1).

For dual iris system, maximum accuracy of 99.85% is found at decision threshold of 0.67 with FPR of 0.13% and FNR of 0.75% (as shown in Fig. 14 and Fig. 15). To eliminate FPR, a decision threshold is moved to 0.72 where accuracy is increased to 99.97% and FNR increases to 3.58% (as shown in Table 1), resulting in a 0.06-0.07% increase in accuracy and 8.75-9.17% decrease in FNR compared to single iris system.

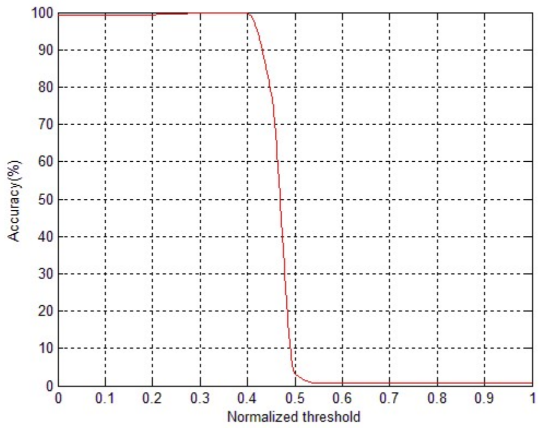


Fig. 10. Accuracy for the left iris matching.

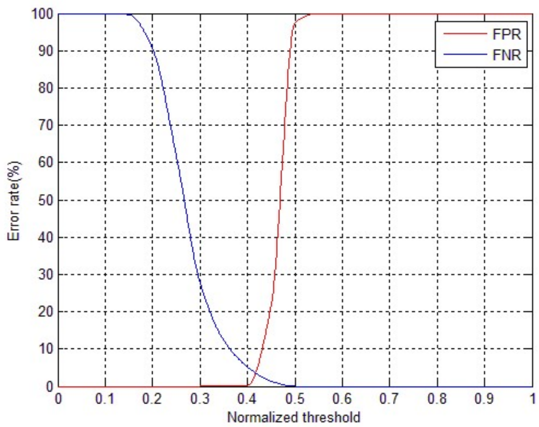


Fig. 11. FNR and FPR for the single iris system (left irises).

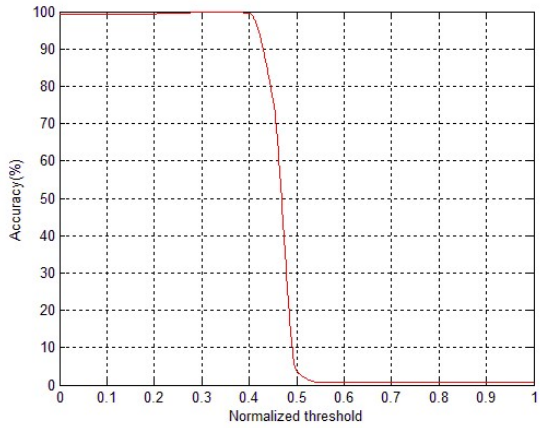


Fig. 12. Accuracy for the right iris matching.

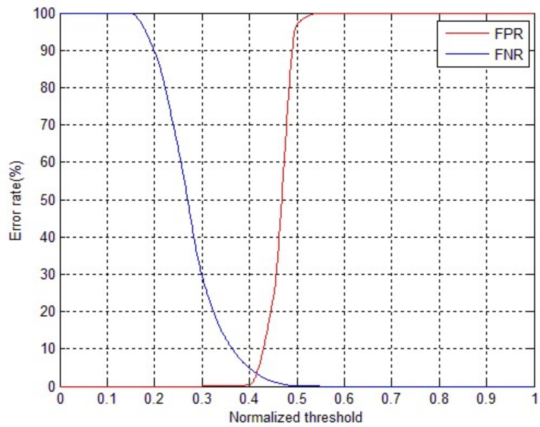


Fig. 13. FNR and FPR for the single iris system (right irises).

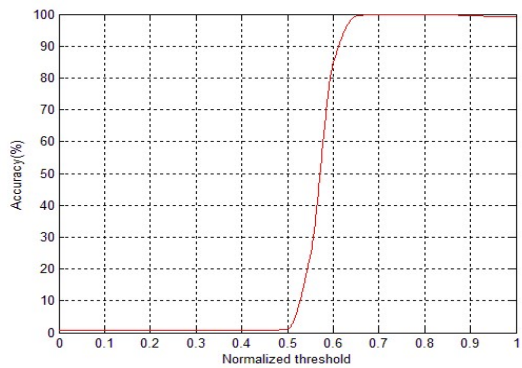


Fig. 14. Accuracy for the dual iris matching.

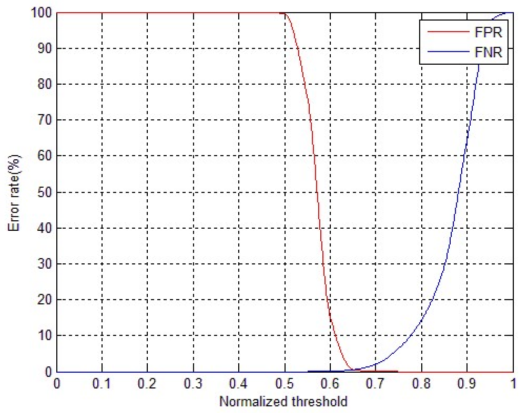


Fig. 15. FNR and FPR for the dual iris system.

Also, the receiver operating characteristic (ROC) space (as shown in Fig. 16), prove the reliability of dual iris system compared to the single iris system (Left irises and Right irises).

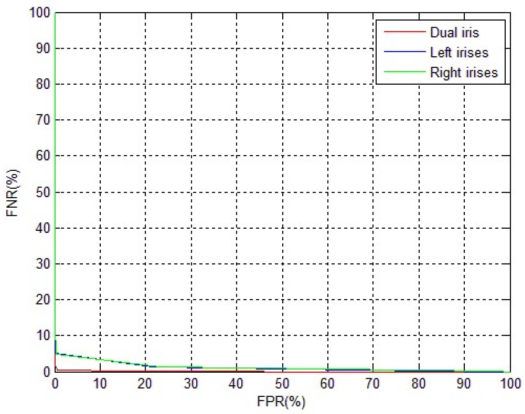


Fig. 16. The ROC Space for single and dual iris authentication system.

4.4.3 Comparison of results with another model

Table 2: The performance of the both approachs.

Iris authentication approach	Accuracy (%)	FPR (%)	FNR (%)
Iftakhar and Ashraful approach [24]	99.92	0	9.96
Proposed dual iris approach	99.97	0	3.58

As it is clear from Table 2, the test results on a subset of iris database CASIA-IrisV3-Interval shows that the performance of the proposed system is better compared to Iftakhar and Ashraful system [24]. The decision strategy in the proposed system is more heuristic and efficient using fusion method based on Dempster's Shafer rule. It represents the uncertainty in the form of the probability of evidence, which allows the system a degree of confidence, while Iftakhar and Ashraful system [24] uses fusion method based on AND rule which is more drastic and leads to improve the FPR.

5. Conclusion

The purpose of this work was to find out a dual iris authentication approach that guarantees a good performance and to make sure that there is no false acceptance rate which promises successful security applications. The proposed system segment, to normalize, characterize and encode the iris. For the segmentation part, the detection of the iris/pupil circles was performed by Hough circular transform. The upper and lower parts of the eye were delimited by two segments by using the linear Hough transform and only the interior half of the iris disc containing the most relevant information which reduces time complexity was extracted. Iris normalization part was performed by the Daugman rubber sheet model with resolution of 10x240. This stage was analyzed by the bench of two 1D Log-Gabor filters to extract the texture characteristics and the encoding was realized with a phase of quantization developed by J. Daugman to generate the binary iris template. Unlike the conventional method which examines a single eye, the proposed method takes images from a person's both eyes, which are matched with the Database used Hamming Distance as the matching metric. Besides, if for both eyes the matching Hamming distances combined using Dempster Shafer rule are less than the threshold, then the person is authenticated as a match. The proposed system shows a good performance with accuracy of 99.97%, FPR of 0% and FNR of 3.58% where the Iftakhar and Ashraful system achieves a lower performance with accuracy of 99.92%, FPR of 0% and FNR of 9.96%.

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