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How to extract the discriminant information from eyes of an individual?

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Abstract- In this paper, a dual iris authentication using Dempster Shafer theory and a dual iris identification system using support vector machine are presented. The proposed method consists of three main steps: In the first one, the iris images are segmented in order to extract only half iris disc that contains relevant information and is less affected by noise. 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 template. For the authentication and the similarity measurement between both binary irises templates, the hamming distances are used with a previously calculated threshold. The score fusion is applied using Dempster Shafer rule. For the identification, the support vector machine is used as a classifier. The proposed method has been tested on a subset of iris database CASIA-IrisV3-Interval. For authentication, the obtained results give a satisfactory performance with accuracy of 99.95%, FAR of 0%, FRR of 6.10%, EER of 0.92% and processing time for one iris image of 12.37 s. For identification, the experimental results show a good performance with an accuracy of 100% and processing time for one iris image of 23.78 s.

Keywords: Biometric, iris, segmentation, fusion, authentication, identification.

1. INTRODUCTION

The biometric includes different biometric modalities; Contrary to the way that we have and that we can, therefore, lose (a key) or what we know and that we can in this way forget (a password), the biometric modalities speak to what are and they also allow to prove our identity.

Fingerprint, hand geometry, iris, retina, face, palmprint, ear, DNA, voice, signature, keystroke are different biometric modalities.

However, the unimodal biometric systems using one biometric modality for recognition cannot guarantee at present an excellent recognition rate. Furthermore, these systems suffer from limitations such as sensitivity to noise, data quality, non-universality, and spoof attacks. To overcome these problems, Multimodal biometric systems, which combine multiple biometric signatures have been developed on purpose to achieve a better recognition rate.

Fusion of the biometric traits can be done at different stages of the recognition system as follows:

1. *Fusion at feature extraction level*

The data is acquired from each sensor and is utilized to generate a feature vector. Then, the features are fused to form one feature vector.

2. *Fusion at matching score level*

The matching score of each system is combined and compared with the stored template.

3. *Fusion at the decision level*

The final decision is taken from a result of each system. Thus, the individual is accepted or rejected.

In this work, the researchers tried to evaluate the performance of the dual iris authentication system in terms of accuracy and mitigate the errors using a most standard fusion technique: score level fusion. Moreover, a dual iris identification system is elaborated using support vector machine.

The remainder of this paper is organized as follows. The related work is presented in section 3. The proposed method is detailed in section 4. The Experimental results are given in section 5. Finally, conclusions are drawn in section 6.

2. RELATED WORK

The texture of iris is a combination of several elements that make it one of the richest distinctive textures of the human body. It has ligament arches, crypts, ridges, furrows, and ruffles. The location of these components, the crossing between them and the shape that they can have, make that the texture of iris is considered as one of the richest of biometrics.

Daugman's algorithm [1] is one of the best iris algorithms known in biometrics. The algorithm consists of segment iris using Integro-Differential Operator and iris normalization is implemented using Daugman's polar representation. Then, iris encoding is applied using 2D Gabor filters to extract a binary code of 256 bytes. The Matching is processed by computing similarity between two iris codes using Hamming Distance. The more Hamming Distance is small, the more both codes are similar. A distance of 0 corresponds to a perfect match between both iris images, while two iris images of different person will have a Hamming Distance close to 0.50.

In 1997, Wildes [2] proposed an alternative and completely different method compared to Daugman's algorithm [1]. The iris is acquired from a CCD Camera in low luminosity. The iris is segmented using Circular and Elliptic Hough transform and is normalized using a transformation function of pixels. After that, Iris is filtered using Laplacian of Gaussian filters with four different resolution levels. A normalized correlation is calculated for every resolution levels. The median of the values of correlations is computed for the filtered image. The fusion of four values is applied using Fisher's linear discriminant.

In 1998, W. Boles and B. Boashash [3] proposed a new approach for the recognition of individuals from iris images. The algorithm is insensitive to variation in the lighting conditions and noise levels. A Median filter is used for preprocessing. The advantage of this technique is to extract a features vector from 1D signals rather than 2D images analyzed in [1], [2] using zero-crossings of the dyadic wavelet transform at various resolution levels. Only a few selected intermediate resolutions are used for matching. The matching is applied using different dissimilarity functions thereby making algorithm faster and less sensitive to noise and quantification error.

In 2004, Ma et al. [4] presented an efficient algorithm for iris recognition. The iris region is located by Canny Filter and Hough Transform. Then, the iris is enhanced by histogram equalization and is normalized. A 1D Wavelet Transform is used to represent resulting 1D intensity signals. The position of local sharp variation points is registered as features. The similarity function (exclusive or operation) is used for Matching. This algorithm is efficient and faster than Daugman's algorithm [1].

However, the different iris recognition systems don't guarantee good performance. The researchers have used more than one biometric trait, and thus the multibiometric systems have emerged in purpose to improve overall performance.

Numerous multi-biometric systems have been developed which fusion is made at matching score.

In [5], the authors presented a multimodal system of identification combining the iris and the fingerprint. A stage of modeling based on Artificial Immune Recognition System is tested, a good performance was achieved.

In [6], the authors presented a framework for multimodal biometric fusion based on the uncertainty concept of Dempster-Shafer theory. A combination of quality measures and the accuracy of classifiers (equal error rate) are proposed to encode the uncertainty concept in order to improve the fusion.

In [7], the authors presented a novel fusion method at matching score called Choquet integral tested on face and fingerprint.

The above multi-biometric systems show very good performance. But, using two or more different algorithms increase the complexity of the systems. To solve this problem, the authors propose to deal with just one algorithm using both irises of the same person.

The most important recent works to our knowledge that deal with the biometric recognition of person from both eyes are:

In [8], the authors proposed a novel approach for iris recognition using both eyes. The iris is detected using Hough transform and is normalized using pseudo-polar transformation. A feature extraction is performed using
Discrete Wavelet Transform at two-level. Then, an approximate image is divided into 8x8 blocks at first level and 4×4 blocks at second level then the mean is calculated and combined in each block to generate the feature vector. A classification is carried out using neural networks (MLP) on the feature vectors containing 184 and 96 coefficients. Learning is applied to the feature vectors extracted from the left and right iris while for the test can be applied either on the left or right iris.

In [9], the authors proposed a new approach for recognition using both irises. The iris is segmented using Canny filter and Hough transform. Then, the segmented iris is normalized by J. Daugman’s rubber sheet model. The iris feature extraction is carried out using convolution of the normalized iris with 1D Log-Gabor filters then the The Matching operation consists of comparing the two iris feature vectors of a person with the others; if the Hamming Distances are less than the threshold then the person is identified.

This paper proposes a dual iris authentication and identification systems that follow these main phases:

1. Segmentation based on circular Hough transform to delineate iris and pupil circles.
2. 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.
3. 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 Daugman [10].

This work presents a contribution related to the iris segmentation phase. This contribution consists of extract only the interior half of the iris disc rather than the whole iris disc which contains the most relevant information and it is less affected by noise. In addition, a dual iris authentication system is developed using Dempster Shafer theory and a dual iris identification system is established using as a classifier: support vector machine. The systems are tested on CASIA-IrisV3-Interval.

3. PROPOSED METHOD

The proposed method is composed of four main stages: preprocessing, feature extraction, fusion, and matching.

3.1. Preprocessing Stage

First, the eye images require going through the preprocessing phase including segmentation and normalization.

3.1.1. 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 as shown in Fig. 1.

1. Iris image is smoothed using the Gaussian filter with size 13 x13 pixels, and standard deviation $\sigma = 2$.
2. We calculate Horizontal gradient and vertical Gradient using:

$$G_V = \begin{matrix} -0.5 & 0 & 0.5 \\ -1 & 0 & 1 \\ -0.5 & 0 & 0.5 \end{matrix}, \quad G_H = \begin{matrix} -0.5 & -1 & -0.5 \\ 0 & 0 & 0 \\ 0.5 & 1 & 0.5 \end{matrix}$$

The vertical Gradient is used to detect iris-sclera boundary. The vertical and horizontal gradient is used to detect iris-pupil boundary.

A gradient is calculated using the following equation:

$$|G| = \sqrt{G_x^2 + G_y^2} \quad (1)$$

3. The local maxima are suppressed to obtain the binary image.

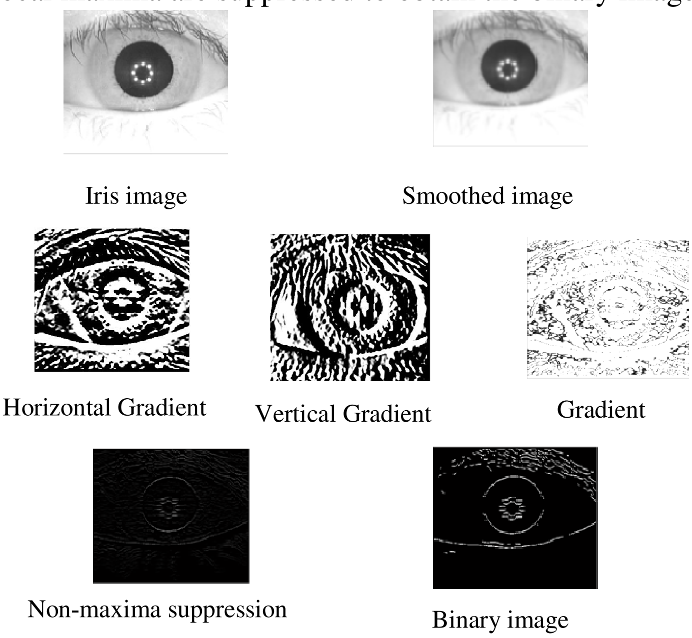

Fig.1. Edge map using Canny Edge detector.

Then, a Circular HoughTransform detects at first the iris/sclera boundary and the iris/pupil boundary.

The eyelashes are detected by global thresholding (T= 100).

In this work, the objective is to extract only relevant information from iris, 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 [11] and it is less affected by the noise, as shown in Fig.2. Indeed, the proposed technique decreases the complexity and the computation load without losing information.

Fig.2. Delimitation of only the internal half of iris disc.

TABLE 1. COMPARAISON : TOTAL IRIS DISC VS HALF IRIS DISC.

	ACCURACY(%)	PROCESSING TIME FOR ONE IRIS IMAGE(%)
TOTAL IRIS DISC	99.87	22.88
HALF IRIS DISC	99.95	12.37

Discussion

From Table. 1, we denote that treatment using only half iris disc is more efficient with an accuracy of 99.95% and processing time for one iris image of 12.37 s than the treatment using a whole iris disc with accuracy 99.87% of and processing time of 22.88 s.

4.1.2. 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:

1. Different acquisition conditions of the eye images. Dilation and contraction of the pupil due to the variation of the illumination level.
2. The circles of iris and pupil are not concentric.

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 [10]. 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.3.

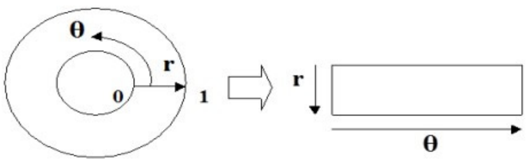

Fig.3 Daugman rubber sheet model [10].

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 and which is less affected by noise, are retained for the next steps of the processing, as shown in Fig.4.

Fig.4. Normalization of the segmented iris.

3.2. Feature Extraction Stage

After that, the feature extraction stage is applied in purpose to extract the most discrimination information present in the iris region. For this reason, the following steps were applied:

1. The Fast Fourier Transform is applied for each line of the normalized matrix image (FFT to 1D signals).
2. 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:

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

Parameters setting:

1. A bench of two 1D Log-Gabor filters is used.
2. The standard deviation of the 1D Log-Gabor wavelet is given by $\sigma = 2$.
3. The center frequency of the 1D Log-Gabor wavelet is given by $f_0 = 0.05$.

Indeed, the phase of a filtered image was quantized using four-quadrants of Daugman [10], when going from one quadrant to an adjacent quadrant, one bit is changed as shown in Fig. 5.

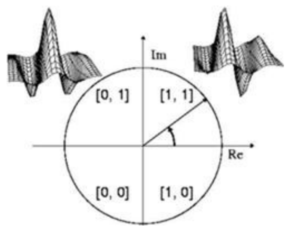

Fig.5. Quantization Phase [10].

The encoding process produces a bitwise template containing a number of information bits (as shown in Fig. 6), 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).

Fig.6. iris code.

3.3.. Matching Stage

The matching consists in comparing two iris code using Hamming distance. The Hamming Distance (HD) is defined by:

$$HD = \frac{1}{N}\sum_{j=1}^{N} X_j \oplus Y_j \quad (3)$$

WhereX_j and Y_j are the two bitwise iris code, N is the number of bits in each iris code. Literally, the Hamming distance calculates the number of different and valid bits for the two iris code between X_j and Y_j .

3.4. Score Level Fusion

Matching score level fusion combines the scores calculated by Hamming distance relating to the left and right iris to affirm the veracity of the claimed identity.

The Dempster Shafer theory of evidence [12] is a powerful tool for representing uncertain knowledge.

The fusion scores using Dempster-Shafer (DS) theory is carried out to combine the scores (Hamming distance) obtained from both irises in purpose to improve the overall performance.

- **Algorithm**

For each individual **indv**
For each different iris $\{i, j\}$: such as i,j belong to iris set of individual **indv**
Calculate the score $S_g(i,j) = 1 - HD_g(i,j)$
Calculate the score $S_d(i,j) = 1 - HD_d(i,j)$
Calculate the fusion of score $S_f(i,j)$

$$S_f(i,j) = \frac{S_g(i,j) \times S_d(i,j)}{\left(1 - \left(\left(1 - S_g(i,j)\right) \times S_d(i,j) + \left(\left(1 - S_d(i,j)\right) \times S_g(i,j)\right)\right)\right)}$$

```
k=1
For s=0:0.05:1
  If Sf(i,j) < s then
  FN(k)=FN(k)+1                    %False Negatif
  k=k+1
  End if
 End
End
End
```

For each different individual$\{$ **indvi**, **indvj**$\}$
For each different iris (i,j) such as i belong to iris set of individuals **indvi** and j belong to iris set of individuals **indvj**
Calculate the score $S_g(i,j) = 1 - HD_g(i,j)$
Calculate the score $S_d(i,j) = 1 - HD_d(i,j)$
Calculate the fusion of score $S_f(i,j)$

$$S_f(i,j) = \frac{S_g(i,j) \times S_d(i,j)}{\left(1 - \left(\left(1 - S_g(i,j)\right) \times S_d(i,j) + \left(\left(1 - S_d(i,j)\right) \times S_g(i,j)\right)\right)\right)}$$

```
k=1
For s=0:0.05:1
  If Sf(i,j) ≥ s then
  FP(k)=FP(k)+1                    %False Positif
  k=k+1
  End if
 End
End
End
```

maxindv = number of individuals

nbtr=number of iris images per individual

$$nbinter = maxindv \times \frac{(maxindv - 1)}{2} \times nbtr \times nbtr$$

$nbintra = maxindv \times (nbtr \times (nbtr - 1)/2)$
$TN = nbinter - FP$ % True Negatif
$TP = nbintra - FN$ % True Positif
$TPR = TP/nbintra \times 100$ %True Positif Rate
$TNR = TN/nbinter \times 100$ %True Positif Rate

$FAR = (FP/nbinter) \times 100$ % False Accept Rate
$FRR = (FN/nbintra) \times 100$ % False Reject Rate
$Accuracy = (TP + TN)/(nbintra + nbinte) \times 100$

3.5. Classification of iris code using Support Vector Machine

The support vector machine (SVM) represents well-accepted approach for classification of iris code with high dimension (9600 bits).

- One against all and one against one

The approach one against one is used to classify an important number of individuals (classes) efficiently and quickly.

A dual iris identification system is elaborated using left and right iris for learning and left iris or right iris fort test. The cross-validation is used to mitigate errors during the identification process.

4. Experimental Results

4.1. Simulation Environment

The proposed method has been tested on a subset of iris database CASIA-IrisV3-Interval [13] in order to evaluate its performance in authentication and identification mode.

The subset contains 1180 eye images of 118 individuals (class), and each individual has five iris samples for the left eye and five iris samples for the right eye.

4.2. Performance Metrics

False Reject Rate (FRR): also known as Type I error, is the measure of the probability that the biometric security system will incorrectly reject an access attempt by an authorized user.

- False Accept Rate (FAR): also known as Type II error, is the measure of the probability that the biometric security system will incorrectly accept an access attempt by an unauthorized user.
- EER (Equal Error Rate): The EER is the operating point for which the False Reject Rate (FRR) is equal to the False Accept Rate (FAR).

4.3. Dual iris authentication system

TABLE 2. SYSTEM ACCURACY AND FRR FOR VARIOUS APPROACHES.

Iris authentication approaches	Accuracy (%)	FAR (%)	FRR (%)	EER (%)
Daugman approach [10]	99.90	0.01	0.09	-
LDA-based approach [14]	99.14	0.00	0.69	-
Iftakhar and Ashraful approach [9]	99.92	0.00	9.96	-
Proposed dual iris authentication	99.95	0.00	6.10	0.92

Discussion

We denote from Table 2, that (I mean as shown in) the proposed dual iris authentication gives satisfactory results in term of overall performance (Accuracy, FAR, FRR, EER) compared to other approaches. The proposed method uses only half iris disc that contains the most relevant information and it is less affected by noise, contrary to other detection methods and represents the uncertainty in the form of the probability of the evidence, which allows the system a degree of confidence while Iftakhar and Ashraful [9] uses the fusion method based on the AND rule which is more drastic and leads to improve the FPR. In addition, LDA-based approach proposed by Chu and Chen [14], uses a probabilistic neural network (PNN) and requires a training algorithm which increases the computational load.

4.4. Dual iris identification system

TABLE 3. PERFORMANCE OF PROPOSAL APPROACH

	Accuracy (%)	Processing time for one iris image (s)
Proposal dual iris identification	100%	23.78

Discussion

From Table 3, the proposal dual iris identification using left and right iris for learning and left iris or right iris fort testing gives a good performance with accuracy of 100% and processing time for one iris image of 23.78 s. Therefore, the proposed method can be used for identification of individual suffering from illness in their eyes (left iris or right iris).

5. CONCLUSION

The purpose of this work was to find out a dual iris authentication and identification system that guarantees a good performance and that makes sure that there is no false acceptance rate, which promises useful security applications. The proposed method consists in segmenting, normalizing, characterizing and encoding the iris. For the segmentation part, the detection of the iris/pupil circles was performed by Hough circular transform. Only the interior half of the iris disc containing the most relevant information and less affected by noise which reduces time complexity was extracted. Iris normalization part was performed by the Daugman rubber sheet model with a resolution of 10×240. 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. For the authentication and the similarity measurement between both binary irises templates, the hamming distances are used with a previously calculated threshold. The score fusion is applied using Dempster Shafer rule. The experimental results show that the proposed system gives a good performance compared to others approaches with an accuracy of 99.95%, FAR of 0%, FRR of 6.10%, EER of 0.92% and processing time for one iris image of 12.37 s. For identification, the experimental results show a good performance with an accuracy of 100% and processing time for one iris image of 23.78 s.

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