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An optimized Iris Recognition System using MOGA followed by Combined Classifiers

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Abstract- Iris based authentication system is one of the most reliable pattern recognition systems as it makes the use of iris patterns, which are statistically unique, for the purpose of human identification. In this paper, a new technique for iris recognition is proposed which uses combination of Support vector machine (SVM) and Artificial neural networks (ANN). Iris feature extraction is performed using Zigzag collarette area of iris because it captures the most important areas of iris complex pattern and hence achieves high recognition rate. The deterministic feature sequences extracted from iris images using 1D log-Gabor filters and Haar wavelet is applied to train the SVM and ANN sequentially. A multi objective genetic algorithm (MOGA) is proposed to optimize the features and also increase the overall recognition accuracy. This technique outperforms the existing techniques as it is computationally effective and more accurate with the recognition rate of 99.95% and 99.90% on CASIA and Check image database respectively.

Index Terms— Iris Recognition, Support Vector Machine, Artificial Neural Networks, zigzag collarette area.

1. INTRODUCTION

The increasing emphasis on security and the advancements in technology has resulted in increased importance of biometrics based recognition systems for personal verification and identification. Biometric solutions, such as identification based on face, iris, palm prints, fingerprints have many advantages over other traditional authentication systems which are based on what you possess and what you know.

In this paper we focus on iris biometrics as it is the most reliable, accurate and non in-vasive amongst all biometric traits known in research field because of its statistically unique feature[1][2]. Iris is an externally visible coloured ring of tissue between pupil and the white sclera (see in fig. 1), has an extraordinary structure and provides many interlacing minute characteristics such as freckles, coronas, stripes and zigzag collarette area etc. There are 1 in 10^{78} chances of two irises being identical.

Many methods have been proposed till now in order to improve the performance of iris recognition systems in terms of improved matching accuracy and computational effectiveness. Daugman in 1993 [3] first presented an algorithm for iris recognition. He implemented integro-differential operators to detect the limbic boundary followed by the pupillary boundary. Once localized, the iris image is normalized into Cartesian form by projecting it into a dimensionless pseudo-polar coordinate system. The iris features are encoded and a template is created using 2D complex value Gabor filter. Hamming distance is employed for the purpose of matching. Wild (1997) [4] used an alternative segmentation method by using an edge detection method and Hough transform. He properly modeled the upper and lower eyelids with parabolic arcs. Masek (2003)[5], in his segmentation approach, adopted canny edge detection and circular Hough transform. Further technique [6] has been developed employing the same approach but with slight variations by Ma, Tan, Wang and Zhang (2003). An approach [7] based on zero crossing wavelet transform is proposed by Boles and Boashash (1998). Patil and Patilkulkarni (2009) [8] experimented a higher level (6^{th}) of wavelet approximation. Weiqi and Binxiu [9] reported an iris recognition system using surface matching. An improved surface matching algorithm is developed by Wu and Wang (2009) in which illumination intensity difference is taken into account. Monro, Raksit and Zhang (2007) [10] suggested the use of Discrete cosine transform in the features extraction step for iris coding. Chen and Chu (2009) [11] novel iris feature extraction technique with 1D circular profile of iris and intelligent classifier based on parabolistic neural network and partial swarm optimization produced good recognition results. Techniques based on Support Vector Machine are developed by Roy and Bhattacharya (2006) [12] and Ali, Salami and Wahayudi (2008) [13]. An investigation on Iris Recognition system using Morphology and Sequential Addition based grouping has been employed by us [21] in 2015. Rai, Himanshu and Anamika Yadav suggested an improved version of Iris recognition [22] in 2013. They used the combination of Haar wavelet and 1 D Gabor filters for the extraction of features followed by the use of Support vector Machine for the purpose of classification.

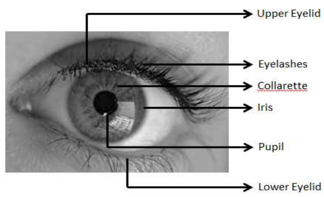

Fig. 1. A labeled eye image

The proposed method is an improvement over the Iris Recognition system suggested by Himanshu Rai and Anamika Yadav [22] in 2013 by fusion of two techniques for classification and addition of MOGA [15] for features selection task. Zigzag collarette area of the iris is selected for the extraction of features because it includes the most important areas of the iris complex pattern. Eyelid detection and eyelash removal is done using parabola detection technique and median filter respectively. Features extraction is performed using Haar wavelet decomposition level 3 and 1 D log Gabor filter. A combination of these two extractors has been used to improve the quality of feature extraction process. In the proposed technique, Multi objective genetic algorithm (MOGA) [15] is additionally applied on the features extracted from Haar wavelet and 1D log-Gabor filter both in order to optimize the features and increase the overall efficiency. After this, for the purpose of classification, Support vector machine is used as the main classifier and artificial neural network is used as the secondary classifier. A combination of these two classification techniques is experimented and results have achieved an improved recognition rate of 99.95 % and 99.90%. This technique has outperformed the already existing techniques in terms of the quality of the matching process and the computational effectiveness. The tests are performed on CASIA [15] as well as Check iris image database [16] using MATLAB 2013b. The proposed authentication system is divided into two phases. The first phase is referred as the enrolment phase and the iris patterns are recorded in this phase. Current iris features are captured and compared with the stored features in the second phase of authentication, which is called the identification phase.

In the remainder of this paper, Section 2 describes the proposed algorithm which is further divided into five subsections which describes the Segmentation, normalization, features extraction and matching algorithms used respectively. Section 3 represents the experimental results and section 4 finally concludes the paper.

2. PROPOSED METHOD

The proposed method involves the implementation of the sequential steps wise algorithms described step by step below as shown in Fig 2.

A. Segmentation

The main task in segmentation stage is to approximate the actual iris region between the iris and sclera (outer boundary) and iris and pupil (inner boundary). This task is achieved by following three main steps. The first step is to detect and draw iris and pupil boundaries using Circular Hough transform algorithm. The second step is to capture the Zigzag collarette area of the iris and the last step is to locate the eyelids present in the resultant iris eye image. In case of the Check image database, The RGB image is first converted into a gray level image and then segmentation is performed on it.

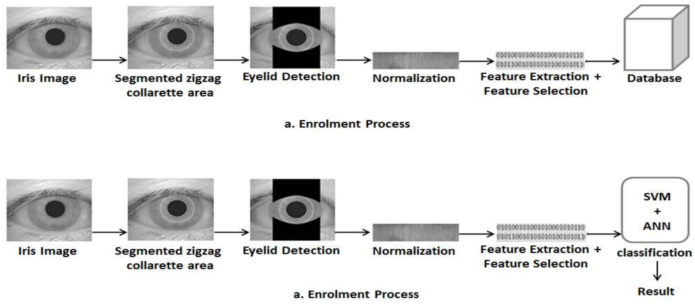

Fig. 2. Block Diagram of the Proposed Iris recognition system

1) Hough Transform

The Hough transform is a technique that is used to determine the parameters of geometrical objects like circles and lines in an image. As iris and pupil boundaries are circular, their center and radius coordinates can be deduced using Circular Hough transform. A circle with radius r and centre (x_c , y_c) can be described by general parametric equations 1 and 2.

1. $x = x_c + r * \cos\theta$ (1)
2. $y = y_c + r * \sin\theta$ (2)

Here θ is the angle swept. If θ sweeps full 360° range, the points (x, y) trace the parameters of the circle. If an image contains many points, some of which fall on the parameter of the circle, then the job of the search program is to find the coordinate triplets (x_c , y_c , r) to describe each circle. The first step taken in order to find circles in an image using Circular Hough transform is to find all the edges in the image. Any edge detection technique can be used to implement this step as it has nothing to do with the Hough transform.

For all the edge points $(x_e, y_e), e = 1, 2, ..., n$. A Hough transform can be written as

$$H(x_c, y_c, r) = \sum h(x_e, y_e, x_c, y_c, r) \quad (3)$$

$$h(x_e, y_e, x_c, y_c, r) = \begin{cases} 1, & if \; g(x_e, y_e, x_c, y_c, r) = 0 \\ 0, & otherwise \end{cases} \quad (4)$$

Where

$$g(x_e, y_e, x_c, y_c, r) = (x_e^2 - x_c^2) + (y_e^2 - y_c^2) - r^2 \quad (5)$$

Fndfhweidjqwoikndansfbwqbhfuqhruq2duqebfuwefbof3odnwdnefnqihdwdnd.

The three coordinates (x_c , y_c , r) for which H(x_c , y_c , r) is highest in equation 3 will become the coordinate of centre and radius of the circle.

1) Approximating the Zigzag Collarete area

The collarette part is the most important part of the iris complex pattern since it is usually less sensitive to pupil dilation and is not affected by the eyelid and eyelashes.
The previously obtained pupil's center value is used again to approximate the zigzag collarette area because it is generally concentric to pupil and the radius of this part of iris is always restricted to a certain range. The detected collarette area on check image database is shown in fig 3.

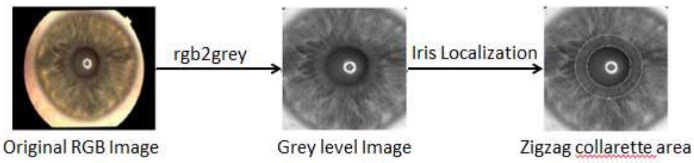

Fig. 3. *Collarette area localization on check image database*

2) Eyelid Detection

Two search regions are selected for the purpose of upper and lower eyelid detection. These search regions are confined within the pupil and the zigzag collarette area of the iris of the eye image.

$$W = R_e - R_p \tag{6}$$

Here, W represents the width of the search region,   represents the radius of the iris (Zigzag area) and   represents the radius of the pupil. W is 24 for CASIA database as shown in fig 4. The step of eyelid detection can be ignored for the CHECK image database because there are no eyelids present in the images of check image database.

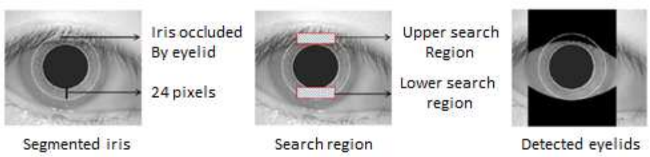

Fig. 4. Eyelid detection after Segmentation of eye image

A horizontal edge map is used to find an edge image of an eye image as eyelid part is present in the upper and the lower eyelid region. A parabolic Hough transform is applied for eyelid detection at each edge point within the search regions.

B. Normalization and Eyelash Removal

The iris region is normalized to create the dimensionally consistent representation of the iris region in order to allow comparisons. The homogeneous Rubber Sheet model suggested by Daugman is used for normalization as it is dimensionally consistent.
In this work, a method for removing eyelashes and restoring the underlying iris pattern has been developed and applied after normalization. In this step, the zigzag collarette area pixels which are occluded by eyelashes are recreated using information from their non-occluded neighbours. For every pixel (x, y) present in the normalized image, It is firstly examined whether the pixel is occluded by eyelash or not.

$$If\ \ I(x,y) < T, \quad pixel\ is\ occluded\ by\ eyelash \tag{7}$$

Where I is the intensity and T is the threshold of the pixel. For every such filter, a median filter is applied on that pixel. In neighborhoods only those pixels which are greater than T are selected as they are not occluded by eyelashes. Finally, all the pixels are sorted in an ascending order and the centre pixel value is replaced with the median value of   window neighborhoods. Fig. 5 demonstrates the normalized image after applying eyelash removal method.

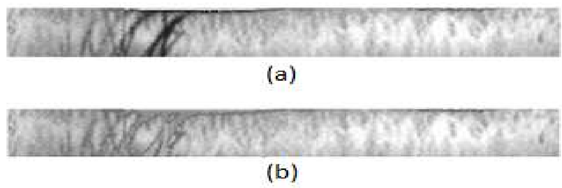

Fig. 5. Normalized eye image

C. Features Extraction and Matching

It is the most important stage of Iris recognition system. The main goal of this stage is to extract the distinguishing characteristics of the iris textures and then generate the corresponding iris code. In this paper, firstly, two methods for feature extraction have been proposed. First one is the Haar wavelet decomposition and the second one is the 1D Log Gabor wavelets. Features are then selected using Multiple-Objective genetic algorithm to select the optimum set of features [15]. Finally, Classification is done using support vector machine as the main classifier and Artificial Neural Network (ANN) as the secondary classifier. Based on extensive testing of different networks, a combination of SVM and ANN is finally found to have better recognition accuracy than using any other single method.

1) Features Extraction

HAAR Wavelet decomposition

Wavelets are used to decompose and analyze the data of the iris region into components that appear in different resolutions. Wavelets have the advantage over the traditional

Fourier transform that the frequency data is localized, allowing features that occur at the same position and resolution to be matched up. A number of wavelet filters are then applied to the 2D normalized iris region, one for each resolution with each wavelet a scaled version of some basis function. The output obtained after applying wavelets is then encoded in order to provide a compact and discriminating representation of the iris pattern. In this paper, Haar wavelet has been adopted to transform a normalized image of size at three different levels successfully for features extraction. Wavelet transform has been applied and the image is divided into four sub regions HL, LH, HH and LL named as Vertical, horizontal, diagonal and approximation sub images respectively in the first level. The sub-image LL is further decomposed, resulting in two level wavelet decomposition. The result of third level decomposition as shown in fig. 6 gives large reduction in computation without much loss in prominent features. In this work, the region LL3 obtained by performing wavelet transforms three times is considered as the major characteristic region. The values of LL3 region are used as the components of the characteristic input vector to SVM. At this time, the region LL3 contains the information having =512 characters.

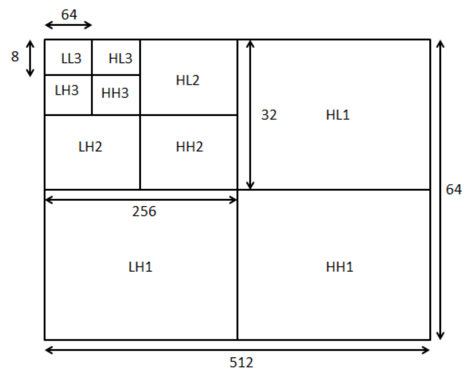

Fig. 6. Three level HAAR wavelet decomposition

1D Log Gabor Wavelet

Feature encoding is implemented by convolving the normalized iris region with 1D log-Gabor wavelets [12]. Firstly, the 2D normalized pattern is broken into a number of 1D signals and then these 1D signals are convolved with 1D Gabor wavelets. Each row of 2D normalized pattern is taken as the 1D signal and corresponds to the circular ring on the iris region. The angular direction is considered instead of considering the radial one, which corresponds to the columns of the normalized pattern, since maximum independence occurs in the angular direction. The intensity values at known noise areas in the normalized pattern are set to the average intensity value of the neighboring pixels. This is done so as to avoid the influence of noise in the output of filtering.

The phase quantization approach as suggested in [17] is then applied to the four levels on the outcome of filtering with each level with each filter producing two bits of data for each phasor. The output of the phase quantization is chosen to be a grey code. This is because in a grey code only one bit change occurs while going from one quadrant to another quadrant. This will minimize the number of bits disagreeing in incase two intra-class patterns are slightly misaligned and thus will provide more accurate recognition. The encoding process provides a bitwise template and a corresponding noise mask which is further used for the classification purpose.

Multi Objective Genetic Algorithm (MOGA)

In this paper, MOGA is proposed to select the optimum set of features [15]. Optimum set of features are selected from both the features extracted from Haar wavelet decomposition and 1D log Gabor filter individually. The main reason of doing feature selection is to use less number of features to achieve the better performance. Each feature subset contains certain number of parameters.

The fitness formula is given by:

$$Fitness = (104 \times Accuracy + (102 \times NZ / NF)) / 10^4 \qquad (8)$$

Where Accuracy denotes the accuracy rate that an individual achieves, NF denotes the number of features used for optimization and NZ represents the number of zeros in the chromosomes. Accuracy is the main concern here and it ranges from 0.7 to l. The NZ and NF ranges from 0 to length of the chromosome code. Overall, higher is the accuracy, higher is the fitness. Moreover, greater number of zeros is obtained by using fewer features, and hence the fitness increases.

2) Matching

The final stage of iris recognition system is matching. In this stage, comparison is done between the images already stored in the database and the current iris image. Finally, acceptance or rejection is made based on the matching score. In this paper, iris region is passed through a combined SVM and ANN based classification approach. The features extracted through HAAR wavelet are used for training and testing of SVM. If correct classification is not done using SVM then ANN is used for further classification. If there are n classes, then n SVM models are developed, one model for each class. Once training phase is finished, the identification of human iris is done by testing the iris image against all n models. The performance of the SVM is analyzed using False Acceptance Rate (FAR) and False Rejection Rate (FRR).

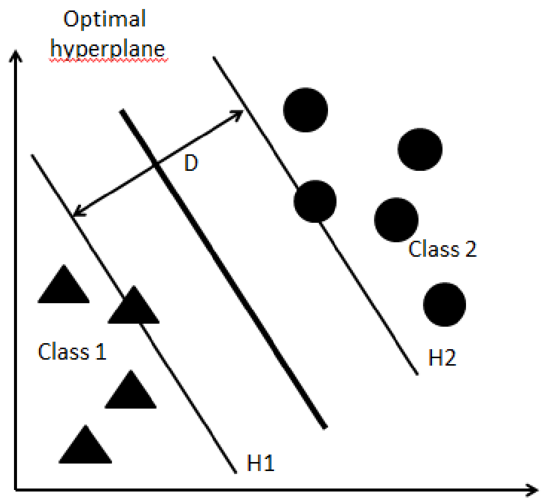

Fig. 7. Representation of matching process

Since, Non-false acceptance rate is very high and the only care that has to be taken is while considering non-false rejection rate. If the given iris template does not belong to any class then either it is falsely rejected or an imposter.

For the iris which is falsely rejected again 2048 bit feature is extracted using 1D log Gabor filter and Artificial Neural Network (ANN) is applied for classification. Here Linear vector quantization (LVQ) neural network approach is used as the second classifier. The work is carried out using LVQ neural network approach because according to a study this approach is less time consuming than other artificial neural network approaches [18]. This process of re-extracting the features using 1D log Gabor filter does not cost very much because more than 91% and 97% templates of CASIA and CHECK image database respectively get correctly classified using SVM. Hence, only less than 9% and 3% iris templates are considered for re-feature extraction for CASIA and CID. For those irises which are not classified by SVM, LVQ neural network approach is implemented for all training images as described in [19]. Fig. 7 shows the working of matching process.

3. EXPERIMENTATION RESULT

All the experiments are done on MATLAB 2013b of MathsWorks. To test the validity of the proposed methodology CASIA database and CHECK image database are used. FAR and FRR values are calculated for both the databases as described in the sections below.

A) Results on CASIA image database

For implementing the work, 400 images of CASIA are used for training and 300 images are used for the testing purpose. The comparison of recognition accuracy between the proposed method using MOGA and dual classifiers and some previous approaches are shown in Table 1.

TABLE I. RECOGNITION ACCURACY ON CASIA DATABASE

Methodology	FAR (%)	FRR (%)	Accuracy (%)
Masek	0.005	0.239	99.75
Ali et al.	0	19.80	80.20
Chen and Chu	0.01	0.64	99.35
Patil and Patilkulkarni	-	-	98.91
Proposed	0.095	0	99.95

B) Results on CHECK image database

For Check image database, 20 images are used for training and 40 images are used for the purpose of testing. The comparison in terms of recognition accuracy between the proposed method and the previously reported work of Sibai et al. [20] is shown in Table 2.

The efficiency of the proposed approach improves with the use of MOGA in comparison with the traditional approach where the entire iris region between the pupil and sclera boundary is considered for recognition.

Table II. Recognition accuracy for CHECK image database

Methodology	FAR (%)	FRR(%)	Accuracy (%)
Sibai et al.	-	-	93.33
Proposed Method	0.129	0.0	99.90

Therefore, the use of MOGA for feature selection optimizes the performance of the system. Also, the use of two approaches during the feature extraction process and combined classifiers for matching have improved the accuracy and computational effectiveness to a great extent as compared to the previous reported techniques

4. CONCLUSION

This paper presents a novel and efficient approach for iris features extraction and classification is presented. Zigzag collarette area of the iris is selected for the extraction of features because it includes the most important areas of the iris complex pattern and hence high recognition rate has been achieved. Eyelid detection is done using parabola detection technique and eyelash removal is done using median filter. Haar wavelet decomposition level 3 and 1 D log Gabor filter have been used for feature extraction. These extracted features are then further passed through Multi objective genetic algorithm (MOGA) to optimize the features and to increase the overall efficiency. Classification is applied on finally extracted features. Support vector machine is used as the main classifier and artificial neural network is used as the secondary classifier. A combination of these two classification techniques has been experimented and results have achieved an improved recognition rate of 99.95 % and 99.90%. This technique has outperformed the already existing techniques in terms of the quality of the matching process and the computational effectiveness. It is clear that the efficiency has been increased when we used separate feature extraction techniques for SVM and ANN based classifier. The results are improved for both CASIA as well as Check iris image database in terms of FAR and FRR. Thus, the proposed approach is efficient.

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