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Fusion of Hybrid Domain features for Iris Recognition

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Abstract*— The Biometric systems are used for personal authentication. Iris based Biometric systems are more efficient compared to the systems based on other Biometric traits. In this paper, Fusion of Hybrid Domain features for Iris Recognition (FHDIR) is proposed. The CASIA Iris database is considered for the performance analysis. The pre-processing step includes resizing, binarization, cropping and splitting the Iris image into left half and right half. The Fast Fourier Transform (FFT) is applied on the left portion of the Iris to generate absolute value of FFT coefficients. The Principal Component Analysis (PCA) is applied on right portion of Iris to generate Eigen vectors. The FFT and PCA coefficients are fused using arithmetic addition to generate final feature vector set. The test Iris features are compared with the database feature set using Euclidean Distance to identify persons. It is observed that the performance parameters such as FRR, FAR and TSR values are better in the case of proposed algorithm compared to the existing algorithms.

***Keywords*— Iris Recognition; PCA; FFT; TSR; Euclidean Distance;**

I. INTRODUCTION

Authentication of an individual is an important aspect in security issues and techniques opted may vary according to circumstances and requirements. The traditional authentication may be carried out by identity cards, pin codes, smart cards, passwords etc., but these are easily misused. A better way of individual identification is based on human biological features, which leads to biometric identification. The biometric authentication includes physiological and behavioral traits. The physiological traits are parts of the human body and are almost constant through out the life time. They include iris, retina, face, finger print, DNA etc. The behavioral traits such as voice, signature, key stroke dynamics and gait, depend on mood and circumstances.

Any physiological and behavioral biometric features shall posses the following desirable characteristics: *Universality*: Each person should have the biometric characteristic. *Distinctiveness*: Any two persons should be sufficiently different in terms of the characteristic. *Permanence*: The characteristic should be sufficiently invariant with respect to the matching criterion over a period of time. *Collectability*: The biometric characteristic can be measured quantitatively. *Acceptability*: It indicates the extent to which people are willing to accept the use of a particular biometric characteristic in their daily lives.

The biometric system can be utilized in two contexts: verification and identification. Verification is a one-to-one match in which the biometric system tries to verify a person's identity by comparing the distance between test sample and the corresponding sample in the database, with a predefined threshold. If the computed distance is smaller than the predefined threshold, the subject is accepted as being genuine, else the subject is rejected. Identification is a one-to-many match in which the system compares the test sample with all the samples in the database and chooses the sample with the minimum computed distance i e., greatest similarity as the identified result. If the test sample and the selected database sample are from the same subject, it is a correct match. The term authentication is often used as a synonym for verification.

A simple biometric system has four important modules:

(1) *Enrolment module* acquires the biometric samples of a number of individuals. The acquired samples are pre-processed by resizing, gray scale conversion, cropping, thinning of images, image enhancement etc.
(2) *Feature extraction module* extracts features such as pixel density, angle, area, energy, transforms coefficients etc, from the pre-processed images and stored as templates.
(3) *Matching module* in which the feature values are compared against those in the template by generating a matching score.
(4) *Decision-making module* in which the user's identity is established or a claimed identity is either accepted or rejected based on the matching score generated in the matching module.

Iris lies between the sclera and the pupil of human eye. Iris is an internal organ and is well protected by the eye-lid when compared to other physiological characteristics. Iris recognition is a method of biometric authentication that uses pattern-recognition techniques based on high-resolution images of the irides of an individual's eyes. Iris scanning is less intrusive of the eye related biometrics, requires camera with Infra-red illumination and without physical contact of a person. Iris recognition efficacy is rarely impeded by glasses or contact lenses. A key advantage of iris recognition is its stability or template longevity, as barring trauma, a single enrolment can last a lifetime.

An Iris pattern contains many distinctive features such as arching ligaments, furrows, ridges, crypts, rings, corona, freckles and a zigzag collarette. The striated trabecular mesh work of elastic pectinate ligament creates the predominant texture under visible light whereas in the near infrared wavelengths stromal features dominate the Iris pattern [1].

Iris Biometric systems are widely used in many applications such as access control to secure facilities, verification of financial transactions, welfare fraud protection, law enforcement, and immigration status checking when entering a country. Iris is considered as living passport.

Contribution: In this paper, an efficient algorithm for human authentication using an Iris recognition system is proposed. Resizing, binarization, cropping and splitting are performed for pre-processing an Iris image. FFT and PCA are applied on the left and right sides of the pre-processed Iris image respectively. The extracted features are fused by using an arithmetic addition operator. Finally, matching between the test image and database image is done by using Euclidian Distance.

Organization: The paper is organized as follows. Section I gives an introduction to biometrics recognition. In Section II, we discuss about literature survey. In Section III, we present the proposed model for the Iris recognition system. In Section IV, we present the algorithm. The performance analysis is given in Chapter V and conclusion in Chapter VI.

II. LITERATURE SURVEY

The existing techniques are described for individual recognition using the Iris recognition system in this section.

Daugman [2, 3] proposed a phase based Iris recognition system where localization is done using the Integro-differential operator. The phase information is extracted using quadrature 2-D Gabor wavelets and Iris recognition is done by test of statistical independence, involving many degrees of freedom. Xianchao Qui et al., [4] proposed a method in which pre-processing includes Gabor filter bank and k-means clustering for construction of Iris-Texton vocabulary, to represent visual primitives of Iris images. Iris-Texton histogram was used to record the difference between the Iris textures. Martin Roche et al., [5] used the Discrete Dyadic Wavelet Transform to represent the features of an Iris by fine-to-coarse approximations at different resolution levels. In the pre-processing stage, the image of an eye is converted to gray scale and its histogram is stretched. Iris is detected using a grinding process.

Libor Masek [6] proposed an Iris recognition system in which Localization was done by applying Hough transform. The phase data from 1D Log-Gabor filters is extracted and quantized to four levels to encode the unique pattern of an Iris into a bit-wise template. Hamming distance is employed for recognition. Xiaomei Liu et al., [7] proposed an Iris recognition system with high accuracy. Focus was mainly on variation of performance of the system with image quality and the amount of user cooperation required in real time environment. Karen Hollingsworth et al., [8] proposed techniques to increase recognition rates using fragile bit masking, signal-level fusion of iris images, and detecting local distortions in Iris texture. Fragile bit masking eliminates the effects of inconsistencies in Iris code that arise from the quantization of the complex filter response in a canonical Iris biometrics algorithm.

Wildes [9, 10] proposed a system based on texture analysis. Isolation of an Iris is done by simple filtering and histogram operations. Localization is done through edge detection and Hough transform. Emine Krichen et al., [11] proposed a method that relied on use of packets of wavelets for the production of an Iris code. A hybrid method is used for Iris segmentation. Hough transform is used to locate the outer boundary and Integro-differential operator is used to detect the inner boundary of an Iris. Boles and Boashash [12] proposed a method that uses Zero-crossings of wavelet transform to identify the Iris. Features of an Iris were represented by fine-to-coarse approximations at different resolution levels. Localization of the Iris is done through edge detection techniques where centre of the pupil is located and then Iris information is extracted. Feature extraction is based on its Dyadic Wavelet Transform.

Li Ma et al., [13] proposed an Iris recognition system based on local intensity variations. An Iris recognition system includes four modules; image quality assessment and selection, pre-processing, feature extraction, and matching. In image quality assessment stage, Fourier transform is applied on Iris located and Support Vector Machine (SVM) is used to distinguish whether the corresponding Iris image is clear. Localization is done by projecting the pupil in horizontal and vertical directions to find the centre. The binarization is done and exacted parameters are calculated by applying Hough transform and canny edge detector. For normalization, the Iris ring was unwrapped counter clockwise into a rectangular block of fixed size. Image enhancement is done through histogram equalization. Feature extraction is done by constructing a bank of spatial filters. For matching Fisher Linear Discriminant is first used to reduce the dimensionality of the feature vector and then the nearest centre classifier is adopted for classification. Sateesh Kumar et al., [14] proposed Iris recognition using Empirical Mode Decomposition (EMD) and Fast Fourier Transform (FFT). The eye image is pre-processed, using Circular Hough Transform and Daugman's Rubber Sheet model. The EMD and FFT are applied on the pre-processed image for features extraction. Raju Dehankar et al., [15] explained edge detection technique for Iris using Haar wavelet. Anuradha Shrivas and Preeti Tuli [16] proposed Iris recognition algorithm based on Hough transform for localization and removal of occlusions. The outer boundary of Iris is obtained by circular summation of intensity. The localized Iris image transformed from Cartesian to polar coordinate system. Corners in the transformed Iris image are detected using covariance matrix of change in intensity along rows and columns. All the detected are corners are features.

III. PROPOSED MODEL

In this section, the definitions and proposed FHDIR model are described.

A. Definitions

1) ***False Rejection Rate (FRR)*** is the measure of genuine Iris images rejected. It is defined as the ratio of number of genuine persons rejected to the total number of persons in the database.
2) ***False Acceptance Rate (FAR)*** is the measure of imposters accepted. It is defined as the ratio of number of persons accepted from out of database to the total number of persons out of database.
3) ***Equal Error Rate (EER)*** indicates that the proportion of the false acceptances is equal to the proportions of false rejections. The lower the EER value, the higher the accuracy of the biometric system.
4) ***True Success Rate or Correct Recognition Rate (TSR or CRR)*** is the rate at which the system recognizes all the persons in the database as particular individuals correctly. It is the measure of correctness of the system. It is the ratio of number of persons correctly matched to the total number of persons in the database.

B. Proposed FHDIR model

Figure 1 shows the block diagram of the proposed model. The Iris image is read from the database. Pre-processing is performed to get the desired part of the Iris and exclude the unwanted information. The required feature is extracted using FFT and PCA. The matching between the database image and test image are done using the Euclidean Distance.

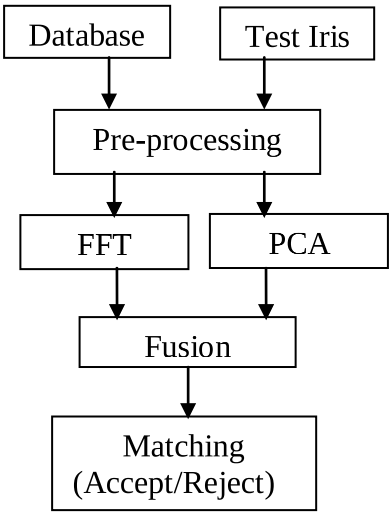

Figure 1. The proposed FHDIR model

1) Iris database: The CASIA Iris database version 1.0 is used as input to the system. The database consists of Iris images from 108 persons. Each person has 7 Iris images. There are total of 756 Iris images. The database is created using 50 peoples' Iris images and 58 peoples' are out of database. The 6 Iris images per person out of 7 images per person are retained in the database and remaining one is used as test image. This classification is done for the computation of FRR, TSR and EER. The FAR computation is done using the out of database images only.

2) Pre-processing: The CASIA database eye image is as shown in Figure 2. The image is resized to 100*300. The eye image is binarized to locate pupil. It is observed that the intensity values of the pixels in pupil are between 0 and 70. The intensity values of pixels less than or equal to 70 are assigned '0' and the intensity values more than 70 are assigned '1' in binarization. The binarized image is shown in Figure 3, in which the pupil is located. The part of the image above and below the pupil is cropped off to obtain the eye image of size 70*300 as shown in Figure 4. 35 pixels to the left and the right of the pupil are detected and cropped. The final pre-processed Iris image parts are shown in Figure 5 and 6. The left and right portions of image are of size 70*35 (rows*columns). The FFT is applied on the left part of the pre-processed image and PCA is applied on the right part of the Iris image to generate features.

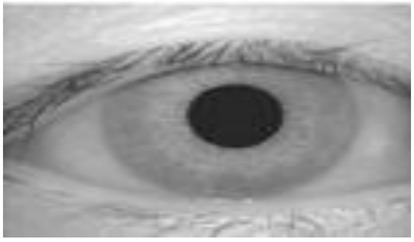

Figure 2. The eye image

Figure 3. The binarised image in which the pupil is located

Figure 4. Horizontally segmented portion of the eye

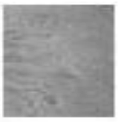

Figure 5. Left half of Iris image

Figure 6. Right half of Iris image

3) Principal Component Analysis: PCA involves the calculation of the Eigen value decomposition of a data covariance matrix or singular value decomposition of a data matrix, usually after mean centring of the data for each attribute. The results of a PCA are usually discussed in terms of component scores and loadings. PCA is the simplest of the true eigenvector based multivariate analyses. Often, its operation can be thought of as revealing the internal structure of the data in a way which best explains the variance in the data.

PCA using the covariance method: The main aim of PCA is to convert a given data set X of dimension M to an alternative data set Y of smaller dimension L by finding the matrix Y, where Y is the Karhunen–Loève Transform (KLT) of matrix X and given by the Equation 1.

$$Y = KLT\{X\} \qquad \text{------------------------ (1)}$$

The data set: Consider a data set of observations of M variables, which need to be reduced so that each observation can be described with only L variables, $L < M$. The data is arranged as a set of N data vectors $X_1, X_{2....}\ X_N$ with each X_n representing a single grouped observation of the M variables. $X_1, X_{2....}\ X_N$ are taken as column vectors, each of which has M rows. The column vectors are placed into a single matrix X of dimension $M \times N$.

The empirical mean: The empirical mean along each dimension $m=1, 2, 3...M$ is found. The calculated mean values are placed into an empirical mean vector u of dimensions $M \times 1$ and this is given by the Equation 2.

$$u[m] = \frac{1}{N}\sum_{n=1}^{N} X[m,n] \qquad \text{--------- (2)}$$

The deviations from the mean: Mean subtraction is an integral part of the solution for finding a principal component as it minimizes the mean square error of the approximation of the data. When mean subtraction is not performed, the first principal component will correspond to the mean of the data. Hence it is absolutely necessary to perform mean subtraction (or "mean centering"), so that it ensures that the first principal component describes the direction of maximum variance, which can be used for the deciphering. Therefore the centering of data is performed by subtracting the empirical mean vector *u* from each column of the data matrix *X*. The mean-subtracted data is stored in the $M \times N$ matrix *B*, as given by the Equation 3.

$$B = X - uh \qquad \text{----------- (3)}$$

Where *h* denotes a 1 x *N* row vector of all 1's, which is given in the form of Equation 4.

$$h[n] = 1 \text{ , for } n = 1 \ldots N \qquad \text{----------- (4)}$$

The covariance matrix: The $M \times M$ empirical covariance matrix *C* is found by using the formula in Equation 5.

$$C = \mathrm{E}[B \otimes B] = \mathrm{E}[B \cdot B^*] = \frac{1}{N} \sum B \cdot B^* \qquad \text{---------- (5)}$$

where

E denotes the expected value operator,

$\otimes$ denotes the outer product operator, and

$*$ denotes the conjugate transpose operator.

The Eigen vectors and Eigen values of the covariance matrix: The matrix *V* of eigenvectors which diagonalizes the covariance matrix *C* is calculated using the Equation 6.

$$V^{-1} C V = D \qquad \text{------------- (6)}$$

D is the diagonal matrix which has the Eigen values of *C*. The Matrix *D* will take the form of an $M \times M$ diagonal matrix, where

$$D[p,q] = \lambda_m \text{ for } p = q = m \text{-------------(7)}$$

The Equation 8 is the m^{th} Eigen value of the covariance matrix *C*, and

$$D[p,q] = 0 \text{ for } p \neq q \qquad \text{------------- (8)}$$

Matrix *V*, is also of dimensions $M \times M$, containing *M* column vectors, each of length *M*, which represent the *M* eigenvectors of the covariance matrix *C*. The Eigen values and eigenvectors so obtained are ordered and paired. Thus the m^{th} Eigen value corresponds to the m^{th} eigenvector.

The PCA is directly applied to the right half of the pre-processed image. The right half of the pre-processed Iris image of size 70*35 yields PCA coefficients matrix of the size 35*35. This coefficient matrix is converted to a 1D matrix, which is of the size 1x1225, of which the first 252 are selected as they contain sufficient information needed for recognition. The rest are discarded but the amount of information lost is insignificant.

***4) Fast Fourier Transform**:* The Fast Fourier Transform (FFT) is one of the faster methods for calculating the DFT. While it produces the same result as the other approaches, it is incredibly more efficient, often reducing the computation time by hundred times. The DFT is calculated using the formula given in Equation 9.

$$X(k,l) = \sum_{m=0}^{N-1} \sum_{n=0}^{N-1} x(m,n) e^{-\frac{j2\pi km}{N}} e^{-\frac{j2\pi \ln}{N}} \text{ , } \quad 0 \le k,\ l \le N-1 \text{ -------------------- (9)}$$

Where N is the total no of samples, X(k) are the DFT coefficients.

Fast Fourier Transform is used for feature extraction of the left half of the pre-processed image. The left half of the Iris image matrix of size 70*35 is converted into a one dimensional matrix of the size 1*2450 and results in 2450 Fourier coefficients. The first 252 coefficients are selected on the basis of observation as they yield the best results.

5) Fusion: The FFT and the PCA coefficients obtained, form the basis of feature vector and fused to get final feature vector. The final feature vector is formed by arithmetic addition of the FFT and the PCA coefficients element by element. The final feature vector is given in Equation 10.

Final Feature Vector = {$\text{Feature}_{\text{FFT}}$ + $\text{Feature}_{\text{PCA}}$} ------ (10)

***6) Template Matching**:* Euclidean distance is used as a classifier for matching. The Euclidean distance is also called as Pythagorean distance. The minimum Euclidean distance gives the similarity between the unknown Iris images that is being tested and the ones in the database. The Euclidean distance is selected as it gives us the best result.

In Cartesian co-ordinates, if $p = (p_1, p_2 ... p_n)$ and $q = (q_1, q_2 ... q_n)$ are two points in Euclidean Space, then the distance from p to q is given by Equation 11.

$$d(p,q) = \sqrt{(q_1 - p_1)^2 + (q_2 - p_2)^2 + \ldots + (q_n - p_n)^2} \qquad \text{--------(11)}$$

Here $p = (p_1, p_2... p_n)$ are the matrix elements of the person whose being compared (tested) and $q = (q_1, q_2... q_n)$ are the matrix elements of the person who is in the database and with whom the comparison is being done.

IV. ALGORITHM

Problem Definition: Efficient Iris Recognition system using fusion of FFT and PCA features to authenticate a person. The Objectives are to:
i. increase the TSR
ii. reduce FAR and FRR

Table *I* shows the algorithm for the proposed FHDIR system, which verifies the authenticity of a given test Iris. The Iris is pre-processed to obtain left and right portions of Iris. The FFT and PCA are applied to left and right portions of Iris to extract transform and spatial domain features. Euclidian Distance is used for comparison.

***Table I:* FHDIR Algorithm**

Input : Iris image database, Test Iris images
Output : Match/ Mismatch

1. CASIA Iris database is considered.
2. Iris images are pre-processed to obtain left and right portion nearer to the pupil of Iris.
3. FFT is applied on left portion of Iris to generate transform domain features.
4. PCA is applied on right portion of Iris to generate spatial domain features.
5. Fusion of FFT and PCA features using arithmetic addition to generate final feature set.
6. Repeat step 2 to 5 for Test Iris images.
7. Compare Test image features with database features using Euclidean Distance.

V. PERFORMANCE ANALYSIS

The proposed FHDIR model is tested on the CASIA Iris image database–version 1.0, which are the most widely used database containing 756 grey-scale Eye images with 108 unique Eyes or classes and 7 different images of each unique Eye. The algorithm is simulated on MATLAB version 7.8. For the performance analysis, the 6 Iris images of first 50 persons are considered to create database. The remaining one Iris image from these 50 persons is considered for finding FRR and TSR. The 7 images of 58 persons are out of database and used for finding the FAR. Seven samples of a human eye in CASIA Iris database are as shown in Figure 7.

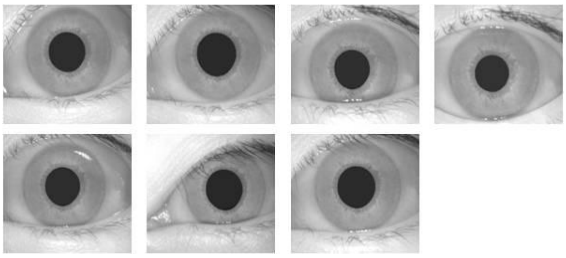

Figure 7. Sample Iris images of a person in CASIA database.

Table *II* shows the performance parameters of the FHDIR system, when FFT, PCA and fusion of FFT-PCA are considered separately. It is observed that the values of TSR and FAR increase, whereas FRR decreases with increasing threshold, when PCA is used for feature extraction. The TSR in the case of PCA is around 6% with high values of FAR and FRR. In the case of FFT, the value of TSR is around 96% with FRR value of 0.04 and FAR value of 0.71 at the threshold value of 90. In the case of proposed FHDIR algorithm, the TSR is 100% for threshold value of 80, which is an improved TSR value compared to individual PCA and FFT techniques.

***Table II:* Performance Analysis by applying PCA, FFT and FHDIR**

Threshold	PCA			FFT			Proposed FHDIR method		
	TSR (%)	FRR	FAR	TSR (%)	FRR	FAR	TSR (%)	FRR	FAR
10	0	1.0000	0.0000	0	1.0000	0.0000	0	1.0000	0.0000
20	0	1.0000	0.1207	0	1.0000	0.0000	0	1.0000	0.0000
30	6	0.9400	1.0000	2	0.9800	0.0000	4	0.9600	0.0517
40	6	0.9400	1.0000	14	0.8600	0.0345	34	0.6600	0.1207

50	6	0.9400	1.0000	26	0.7400	0.0517	64	0.3600	0.3276
60	6	0.9400	1.0000	56	0.4400	0.1552	84	0.1600	0.5172
70	6	0.9400	1.0000	70	0.3000	0.3276	96	0.0400	0.7069
80	6	0.9400	1.0000	88	0.1200	0.4655	100	0.0000	0.8448
90	6	0.9400	1.0000	96	0.0400	0.7069	100	0.0000	0.9310
100	6	0.9400	1.0000	96	0.0400	0.7931	100	0.0000	1.0000
110	6	0.9400	1.0000	96	0.0400	0.9138	100	0.0000	1.0000

The efficiency of the FHDIR model is compared with that of existing methods namely, Xianchao Qui et al., [4], Boles and Boashash [12], Martin-Roche et al., [5], Li Ma et al., [13]. From the Table *III*, it can be seen that the FHDIR model has a better efficiency than the existing ones.

Table III: **Comparing efficiency of FHDIR model with existing techniques.**

Method	Efficiency (%)
Xianchao Qui et al.,[4]	91.02
Boles and Boashash [12]	92.62
Martin- Roche et al., [5]	93.6
Li Ma et al.,[13]	98.06
Proposed FHDIR model	100.00

VI. CONCLUSION

The Biometrics is used to identify an individual proficiently than the existing traditional methods of identification. The proposed FHDIR system is tested on CASIA Iris database. In this method Binarization technique is applied at the pre-processing stage, to obtain left and right portions of Iris. On the left portion of the Iris, FFT is applied and on the right portion of Iris, PCA is applied to obtain their respective coefficients at the Feature Extraction stage. The FFT and PCA coefficients are combined using arithmetic addition to obtain the final feature vector. Euclidean Distance is used to compare the test features with the database feature set. Finally it is noted that the performance parameters are enhanced in the case of proposed FHDIR system than the existing systems. For the future work, pre-processing can be done by using Histogram and/or Edge Detection. Also Dual Tree Complex Wavelet Transform (DTCWT) can be used to generate the features.

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