MJCIS Vol . 13 No.1 Dec2017

Mansoura Journal of Computers and Information Sciences

Efficient Iris Recognition Using Multi-feature Fusion

Shaimaa. A.M. Hegazy
Faculty of computers and information systems , I.S dep.
Mansoura University, Egypt
shaimaa_hegazi88@yahoo.com

Mostafa G.M.Mostafa
Faculty of computers and information systems
Ain Shams University , Egypt
mgmostafa@acis.asu.edu.eg

Ahmed Abu Elfetouh
Faculty of computers and information systems , I.S dep.
Mansoura University, Egypt
elfetouh@gmail.com

ABSTRACT
Biometric technologies are very important these days for improving the accuracy of protecting private data from unauthorized access. It helps overcome deficiencies of current security traditional systems. For the last decade, researchers are developing new methodologies that employ biometrics to boost security field. This article proposes effective methods for Iris recognition based on multi-feature fusion.
A feature fusion approach is implemented to improve the iris recognition rate. In particular, Haar Wavelet Transformation (HWT) features and principal Component Analysis (PCA) are used to model the iris texture. Both approaches are fused to improve performance. Fusion results are compared to those from each feature alone and with other reported work. The results obtained with the proposed method are better than the currently reported results.

General Terms
Pattern Recognition, Iris recognition, Multi-feature Fusion.

Keywords
Biometric system, SDUMLA Database, Iris Recognition, Daugman's Rubber sheet, Haar Wavelet Transformation (HWT), Principal Component Analysis (PCA), Euclidean Distance (ED).

1. INTRODUCTION
Biometric systems are truly an evolving means of personal identification. The last decade has witnessed a great improvement in biometric recognition algorithms. Biometrics is divided into three types, namely, physical, behavioral, and intrinsic Biometrics. Physical biometrics is one of the famous biometrics for human identification, because it relies on data derived from parts of the human body, as face, iris, fingerprint, veins, retina, etc. The second is behavioral biometrics that is based on data derived from an action taken by a person, i.e. the manner of a distinguished work by human, e.g. voice, gait, signature, etc. The intrinsic biometrics measure a chemical feature of individual such as DNA, body odor, etc. [15]. Biometrics can be either passive or active. For instance, DNA is a latent biometrics. It does not oblige user's active participation also could be effective without persons notwithstanding knowing that they have been analyzed. But active biometrics likewise the fingerprint, retina examining, and signature recognition, etc., however, do require individual collaboration and will not work if one denies participation in the process.

Biometrics has a lot of advantages for verifying the identity of an individual who claims to be an approved individual to access high safety and security areas. It also could identify criminals and prove them guilty. Also, it does not need to recollect passwords or carry tokens that might be lost, stolen or forgotten.

A biometric system mainly consists of three processes, namely Enrollment, Verification, and Identification [18] as shown in Fig.1.The enrollment process is the process to obtain the biometric samples of users using a biometric sensor and storing their information in the database or recording it on a magnetic card to know the person when he enters the system at any time. The verification process is the process that aims to verify "Are you the one who you claim to be?" The identification process is the process that finds out who the user is?

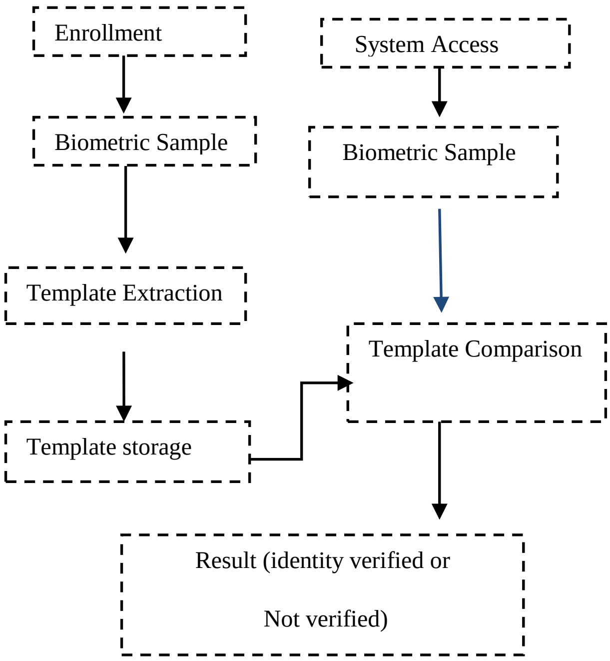


Figure (1): processes of a biometric system [33]

Iris recognition is considered to be the most matured biometric technology and is being used very effectively all over the world. Iris segmentation refers to the process of isolating the iris from the eye images in order to extract features of iris pattern.

In recent years, iris recognition research has gained importance because of its reliability, the left and right eyes of the same individual contain completely different iris, source (iris) rarely gets damaged, more distinctive features, works with high-speed without sacrificing accuracy, unique in nature, the Iris starts at the third month of birth, it wouldn't be changed throughout an individual life [2] [18]. It has been successfully applied by governments, social services, airports, mobile phones, secure access to buildings, and at advanced ATMs.

This paper is organized as follows: section 2 illustrates related work, section 3 includes the proposed methodology and algorithm, section 4 discusses our results, and, finally, the paper is contained in section 5.

2. RELATED WORKS

Tisse et al. [34] suggested an iris segmentation method relied on a Hough Transform with the integro-differential operator; they did not consider the eyelashes and pupil in their strategy and considered them as noises. Ma et. al. [22] suggested capturing local details of the iris by Gabor filter and segmented the iris by simple filtering, and Hough Transform. Rashad et al. [11] suggested localizing and segmenting iris from original image by canny edge detection and HCT, respectively. They built a hybrid model which relies on Local Binary Pattern (LBP) and histogram properties as statistical techniques to extract features, and aggregate Learning Vector Quantization Classifier (LVQ) as Neural Network strategy for classification on several data, such as CASIA, MMU1, MMU2, and LEI. Wilds [20] proposed the first derivative of the image intensity for the localization the boundaries of the iris. Then, he uses two steps for contour fitting; first, utilization of an inclination based edge detection to acquire a binary edge map. Second, he suggests a technique relied on Hough circular transform to choose the contour of the interesting part in the iris image. Then, a normalization step was carried out by utilizing image enrollment and feature extraction by using Laplacian–of–Gaussian (LoG) filter and matching using normalized correlation. Boles et. al. [19] [28] computed an approximation for iris recognition system of one-dimensional wavelet at different determination; levels of a concentric circle on an iris image to delineate the texture of the iris. They utilized Edge and contour detection for the segmentation techniques. Moreover, normalization using scaling algorithm for two images to have a similar size, they used zero-crossing of wavelet transform to feature extraction, and Iris matching depended on two divergence functions. Patnala [1] proposed another strategy that relies on multiple scale features. Features are extracted by Haar wavelet at different resolutions from the iris image. He realized 100% correct classification for 160 cases and the Percentage Correct Classification (PCC) for the remaining is over 90%. PCC will increase if the numbers of samples are increased and lastly it reaches the saturation point. Wazzan et. al. [6] suggested a study to enhance the time complexity of PCA (Eigenirises), which does not influence the recognition performance. The original and the proposed method were tested on iris database. The results show that the recognition time is minimized by 35%. Manikandan et. al. [12] proposed a technique for extracting the features that rely on two-dimensional discrete Wavelet in order to increase the precision, utilized two sorts of iris databases, which achieved Correct Recognition Rate (CRR) of 99.83% and 98.15% on the various databases. Karthikeyan [18] proposed a Fuzzy Neural Network approach and located iris after pre-processing. The achieved accuracy for trained patterns is 99.25%.

3. METHODOLOGY

The proposed iris recognition system consists of the following main steps: preprocessing which includes (localization, segmentation, and normalization), Feature extraction, and classifications, as shown in Fig. 2. Firstly, we use the Integro-Differential Operator to separate the pupil from the eyes, and then the iris image is segmented by iris localization and normalization. Then, the iris features are extracted using the Haar Wavelet Transform and the Principal Component Analysis. A hybrid system that uses both features is also presented. Finally, we use Euclidean distance for Classification. The basic idea of this work is to enhance the iris recognition performance through feature fusion.

.

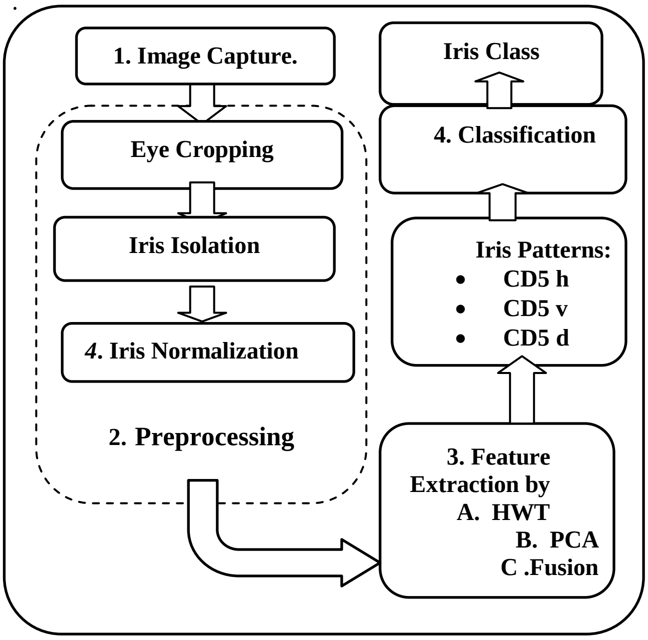


Figure (2): Flowchart proposed for the Iris Recognition System

3.1 Preprocessing

In this step, the iris is isolated from its surroundings. For further details of the used method refer to [13].

3.1.1 Iris Isolation

The original eye image is cropped and resized to separate iris from irrelevant parts, then the pupil of the input image is isolated from the image, and the most useful portion of the iris image is found for further processing.

3.1.2 Iris Segmentation

The personal identification system depends on the accurate of segmentation of the iris from all images. This stage consists of two basic operations. First, separating the iris from the irrelevant parts by getting rid of shading of eyelashes and removing eyelids, and removing the noisy regions, as shown in Fig. 3. Second, finding the internal and external limits of iris [17] [3].

Good segmentation depends on the quality of the image. So the Integro-differential operator depends on the first derivatives of the image [14]. Specular highlights from reflections has negatively affected to the efficiency of the algorithm. The Integro-differential operator suggests that the pupil is circular and acts as a circular edge detector for detecting both the lower and upper eyelids.

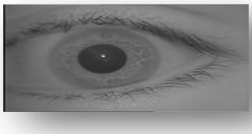
Daugman's Integro-differential operator is defined [14] as:

$$\max(r, x_0, y_0) \left| G_\sigma(r) * \frac{\partial}{\partial r} \oint_{r, x_0, y_0} \frac{I(x,y)}{2\pi r} ds \right| \quad (1)$$

Where I(x, y) is an original image, r is the radius, G_σ (r) is a Gaussian smoothing function as Gaussian of scale (σ) the symbol * denotes convolution thus, G is defined as:

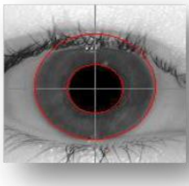
$$G_\sigma(r) = \frac{1}{\sqrt{2\pi r}} e^{\frac{(r-r_0)^2}{2\sigma^2}} \quad (2)$$

, and s is the outline of the circle given by (r, x_0, y_0). I(x, y) along a circular arc ds of radius r and center co-ordinate (x_0, y_0) The Integro-differential Operator searches the gradient maximum over the 3D parameter space, Fig. 3 shows the results of applying these steps for extracting the iris from the eye image.

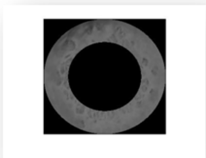


(a) Original Image

(b) Cropped Image



(c) Separate iris



(d) Segmented Iris

Figure 3. Steps of iris segmentation.

3.1.3 Iris Image Normalization

The normalization process of the iris ring from an eye image aim at having the same size radius and fixed dimensions to allow comparisons [3] [11] [13] [35].

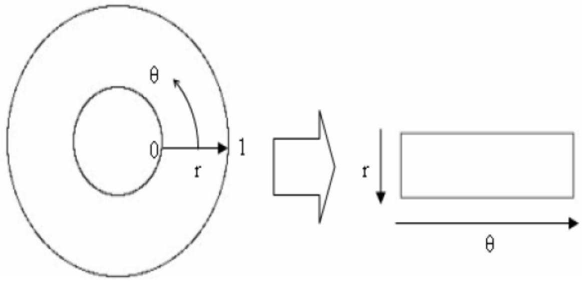
The process of transform from the Cartesian coordinates (x,y) to the polar coordinates (r, θ) form a rectangle are called Daugman's rubber sheet model. Where r is the radius on the interval of [0 1] and θ is in the interval [0,2π]. Where these two variables draw a line around a circle. All the lines are having the same length; as if any line is small padding is done to have equal length has shown in Fig.4 [27]. Daugman's Integro-differential operator is defined as:-

$$\mathbf{I\,(x(r, \theta), y(r, \theta)) = I\,(r, \theta)} \quad \mathbf{(3)}$$

Such that

$$\mathbf{x(r, \theta) = (1-r) * xp\,(\theta) + r * x\,s\,(\theta)}$$
$$\mathbf{y(r, \theta) = (1-r) * yp\,(\theta) + r * y\,s\,(\theta)} \quad \mathbf{(4)}$$

Figure (4): Normalization by Daugman's Rubber Sheet Mode[27]



Where I(x, y) represents conversion of the iris region to the dimensionless non-concentric polar coordinate system (r, θ), (x, y) are Cartesian coordinates, x (r, θ) and y (r, θ) are linear combinations of both the set of pupillary boundary points (x_p(θ), y_p (θ) and the set of limbic boundary points along the outer perimeter of the iris (x_s(θ), y_s (θ)) bordering the sclera [17].

3.2 Feature Extraction.

Feature extraction is a process that extracts the characteristics of the relevant parts of the image, such as information about image, area, angle, and radius, etc, and stored as feature vector that represent the iris [16].

Features set will represent unique small number of iris images, which are later used for identification. These features are used in classification not used for the rebuilding of images [13]. We suggest three algorithms for extracting the feature, which are:

(1) Principal Component Analysis (PCA).

(2) Haar Wavelet Transformation (HWT).

(3) Fusion of the (HWT) with (PCA).

3.2.1 Principal Components Analysis (PCA)

(PCA) is a famous method for representing the information content of an image. It helps in reducing data dimensionality by using the important PCA components, which, in turn, helps in reducing computation time. In the following, we summarize the method for the computation of the PCA of an image.

Computation of the PCA [16] [6] [9]

The images of irises are considered as set of matrices. Then for each matrix (iris image) we generate an Eigeniris using the PCA components as follows:

1. Let an iris image is represented as a normalized M×N matrix β(x, y), which is then converted into a vector of dimension M*N×1.

2. The Training set is represented as a matrix B gave as:

$$B = [\beta_1 + \beta_2 + \cdots \ldots . \beta_m] \quad (1)$$

3. The mean iris (α) is the arithmetic average image vector, which is defined as:

$$\alpha = \frac{1}{m}\sum_{i=1}^{m} \beta_i \quad (2)$$

4. Average image vector α is defined as subtracting from the original images β_i and the result is stored in the variable γ_i , which is called the deviation vector for each image, which is defined as:

$$\gamma_i = \beta_i - \alpha \qquad i=1, 2\ldots m \quad (3)$$

5. Consider a distinction matrix A= $[\gamma_1, \gamma_{2,\ldots} \gamma_m]$, which keeps just the difference characteristic for iris images and removes the common features. At that point, Eigenirises are figured by computing the Covariance matrix E of the training image vectors given by:

$$E = A.A^T \quad (4)$$

6. We consider matrix L of size Mt x Mt, which reduces the dimension and gives the same effect. The Eigenirises of E (Matrix X) can be gained by using the eigenvectors of L (Matrix Y) acts as:

$$X_i = AY_i \quad (5)$$

$$X_i^T = [X_1, X_2, \ldots X_M] \quad (6)$$

Training Samples Projection into the Eigenirises

In this step, we will project of the training sample into the Eigenimage space. And we will calculate weight is given to each Eigenvector δ_i to represent the image in the eigenirises space, as given by [16][9]:

$$\delta_i = X_i^T\ (\beta - \alpha)\ , i=1, 2\ldots m' \quad (7)$$

Which X_i is the i^{th}Eigenimages and i=1, 2, 3 ….K, the weight can be obtained from a vector as mentioned before using this equation:

$$\varepsilon_i^T = [\delta_1, \delta_2, \ldots, \delta_{m'}] \quad (8)$$

Average class projection

$$\varepsilon_\alpha = \frac{1}{Z_i}\sum_{i=1}^{Z_i}\varepsilon_i \quad (9)$$

Testing Samples classification

In the test image stage converts to its Eigenirises components. Then, compares the vector of our original image with the mean image and multiply their difference with each Eigenvector. Every value would present a weight and would be saved in the vector X_{test}^T[9].

$$\delta_{test} = X_i^T\ (\beta_{test} - \alpha)\ , i=1, 2\ldots m' \quad (10)$$

$$\varepsilon_{test}^T = [\delta_1, \delta_2, \ldots, \delta_{m'}] \quad (11)$$

Compute the Euclidean distance (average distance) ρ_i(8) between all the training feature vectors and test feature vector.

Recognition is realized by the minimum Euclidean distance ρ_i, between training points and testing points [9] calculate by the following equation:

$$\sqrt{\rho_i = \|\varepsilon - \varepsilon_{\alpha l}\|^2} \quad \textbf{(12)}$$

3.2.2 Haar Wavelet Transformation (HWT)

Definition of Haar Wavelet

Mathematically, Haar wavelet is a succession of re-scaled "square-shaped" as shown in the "Fig. 5" as the first known wavelet basis and extensively used as a teaching example [3]. It is characterized by being of the best performance to calculate the time compared with of the other wavelet techniques such as Gabor wavelets [27].

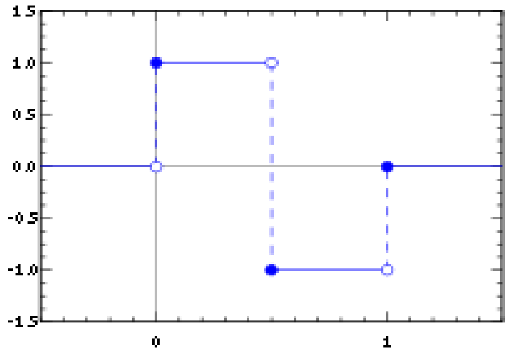


Figure 5: The Haar Wavelet [3]

Decomposition

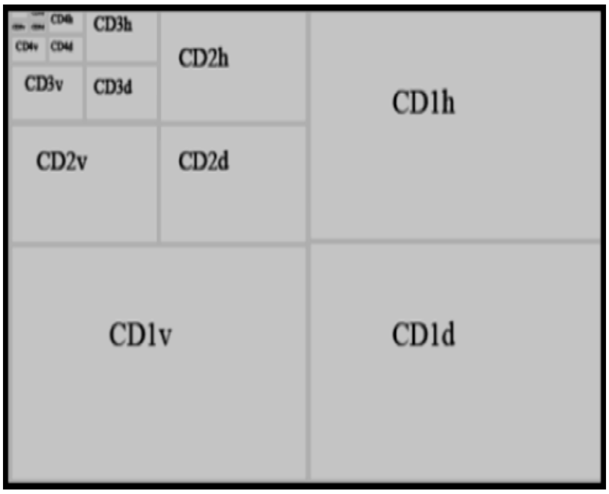
Haar Wavelet is used to extract features at different levels. These levels are decomposed into CD1h to CD5h (horizontal coefficient), CD1v to CD5v (vertical coefficient) and CD1d to CD5d (diagonal coefficient) as show a" fig.6". Therefore those that reveal redundant information can be removed. [3][18].

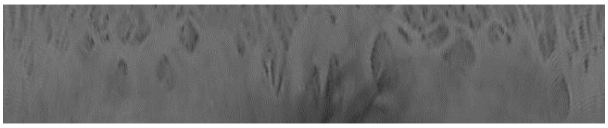
The pattern in CD1h to CD4h can be chosen to decrease redundancy. CD4h can be taken as a delegate of all the information of the four levels. The fifth level does not contain the similar textures and ought to be chosen all in all.

Basically, the fourth and fifth vertical and diagonal coefficients can be taken to express the characteristic designs in the iris mapped picture of sizing (150×650) pixels. Thus, each image can be represented as a blend of three matrices applied to the Haar Wavelet as CD5h, CD5v, and CD5d. Each of the three matrices represents as one single vector is called feature vector.

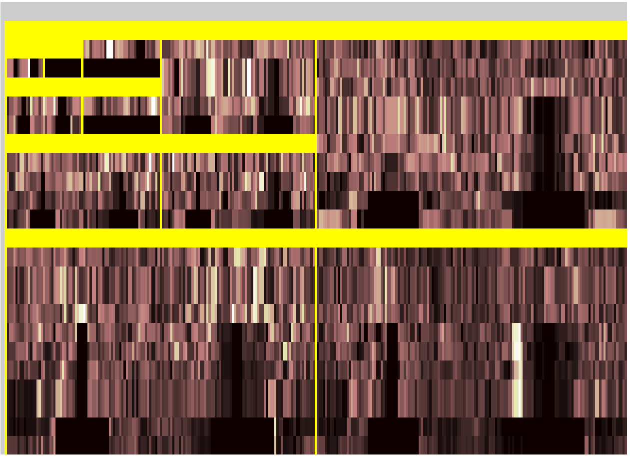
We are denoising, compressing and decomposing images by using the Haar Wavelet transform technique which is applied to the normalized image in a maximum of five levels [27] but we have chosen level five to represent the normalize of the image as shown in the "Fig. 6". We gather the level five in three matrices which are:

- CD5h
- CD5v
- CD5d





A) Iris before decomposition



B) Iris after decomposition

Figure 6: Haar wavelet decomposition at level 5 [18] [27]

3.3.3 Feature Fusion

The (HWT) and (PCA) coefficients are fused to calculate hybrid feature vector which is calculated from addition of the HWT and the PCA coefficients element. Level five becomes as feature vector:

Final Feature Vector = {Feature HWT + Feature PCA}

3.3 Feature Matching

We used the Euclidean distance for matching. It is represented as a classifier and called as Pythagorean distance. It gives the best results for distinguishing the individuals and comparing the results with the database which is stored about individuals to make sure of their identity [16].

In Cartesian directions, if $p = (p_1, p_2,\dots,p_n)$ are the main vector represents the individual who was just looking for the identity or whose being tested and $q = (q_1, q_2,\dots,q_n)$ are the matrix elements of the individual who will be a vector existing in the database, so we can calculate the distance from p to q by the equation[7]:

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

4. RESULTS AND DISCUSSIONS

4.1 Dataset

The SDUMLA iris database of the Shandong University of Machine Learning and Applications [10] is used to test the proposed method. The database incorporates genuine multimodal information from 106 people. Including 61 males and 45 females with age somewhere around 17 and 31

The iris database consists of 2×5×106=1,060 images such that everybody has 10 iris images, each eye has five images with resolution 768 × 576 pixels, in 256 gray-level "BMP" [2]. The values of the iris radius range from 50 to 110 pixels.

We executed a technique for recognizing individuals from the SDUMLA Iris image Database [10]. This contains a total number of 1060 iris images from 106 individuals.

The proposed technique is executed using MATLAB version 8.1 (2013) on Intel core i5 CPU 2.27 GHz processor PC with 4.00 GB of RAM memory. Our experimental results are based on a comparison between the input iris image textures and the iris images stored in the database.

4.2 Results using the Haar Features

RANK	PERCENT
Rank 1	8.73%
Rank 2	8.96%
Rank 3	33.02%
Rank 4	60.14%
Rank 5	69.34%
Rank 6	82.31%
Rank 7	88.68%
Rank 8	91.75%
Rank 9	95.28%

Rank 10	96.23%
Rank 11	97.41%
Rank 12	98.11%
Rank 13	98.58%
Rank 14	98.82%
Rank 15	99.29%

Table (1): Recognition performance using Haar Wavelet Transformation (HWT) method on iris images by Euclidean Distance.

We found that increase of the rank leads to increase in the recognition rate. So when we begin with the first rank, 8.73% iris recognition rate is achieved and by increasing ranks until arriving a rate of 99.29% in the case of rank 15 as shown in table (1)

4.2 Results using the PCA Features

	Eigen Features = 40	**Eigen Features =80**	**Eigen Features = 120**
RANK 1	90.09%	90.57%	91.27%
RANK 2	90,57%	91.04%	91,51%
RANK 3	94,1%	94.33%	94,34%
RANK 4	94,34%	94.33%	94,34%
RANK 5	95,28%	95.05%	94,81%

Table (2): Recognition performance using Principal Component Analysis method on iris images with five ranks by Euclidean Distance

It is clear from the table (2) that we begin by choosing different numbers of features (٤٠, 80, ١٢٠) to reach the best performance for iris recognition rate, so we begin at value =40 in the first rank was 90.09% until arriving the fifth rank 95.28%. And we repeat testing at 80 features to get the 90.57% recognition rate in the first rank until arriving the fifth rank the result was 95.05%. Finally, we repeat testing at value=120 the result was 91.27% until arriving 94, 81% at level five. Briefly, the value 120 realizes the high rate of iris recognition from the first try 91.27% but the value 40 realizes the best performance for iris recognition 95.28% at the fifth level.

4.2 Results using the Fused Features

	Eigen Features = 40	**Eigen Features = 80**	**Eigen Features = 120**
RANK 1	76.65%	79.95%	79.95%
RANK 2	77.59%	84.43%	84.43%
RANK 3	95.75%	93.16%	90.33%
RANK 4	95.99%	93.16%	98.5%
RANK 5	98.58%	98.58%	98.5%

Table (3): Results of Fusion of both HWT and PCA Features by Euclidean Distance.

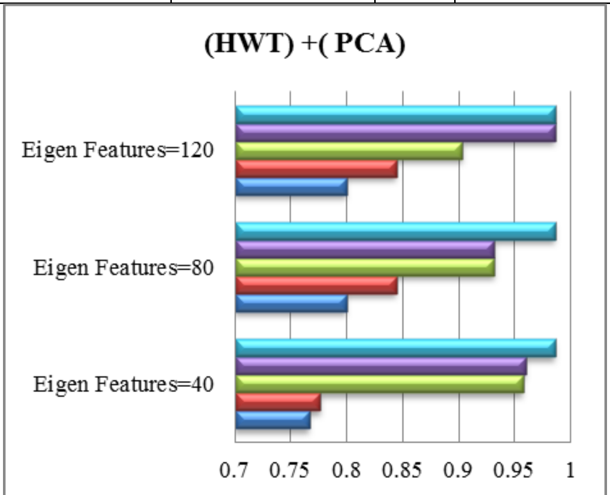
The third approach presented in this paper is a hybrid of two algorithms PCA Algorithm with HWT to improve the strengths and diminish the weaknesses of the individual biometrics and increase system accuracy. It is clear in table 3 that we begin choosing different numbers of Eigen features (٤٠, 80,١٢٠) in different ranges to arrive the best performance for iris recognition rate, so we begin with 40 features in the first rank which resulted in 76.65% recognition rate until arriving the fifth rank which resulted in a rate of 98.58%. And we repeat testing at 80 features. We get the 79.95% recognition rate in the first rank until arriving the fifth rank the result was 98.58%. Finally, we repeat trying at value=120 was the result 79.95% until arriving 98.5% at five level. Briefly, the three values (40, 80,120) realize the best performance for iris recognition 98.5% on the fifth level as shown in the “Fig. 7”.

We have found that the algorithm is robust when we hybrid two algorithms (HWT) with (PCA). A hybrid system which relies on the advantages of both techniques enhances the system performance.

Comparison between the proposed technique and techniques of Ujwalla Gawande et al. [33].

	Feature Extraction	**Year**	**Recognition Rate (%)**
Boles and Boashash [32	one-dimensional wavelet transform	1998	92.62

Martin- Roche et al.[31]	dyadic wavelet transform zero-crossing	2001	93.6
Avila	Zero-crossings discrete dyadic wavelets	2001	97.87
Wildes [25]	Laplacian –of- a Gaussian filter	2006	86.49
Masek [24]	1D Gabor	2008	83.92
Ujwalla Gawande et al.[33]	Haar Wavelet	2012	95.16
Maryam Eskandari et al.[23]	PCA	2012	87.50
Maryam Eskandari et al.[23]	LBP	2012	93.50
Our proposed	Haar wavelet	2016	99.29
Our proposed	PCA	2016	95.28
Our proposed	HWT+ PCA	2016	98.58



	Eigen Features=40	Eigen Features=80	Eigen Features=120
RANK5	٠.٩٨٥٨	0.9858	0.9858
RANK4	0.9599	0.9316	0.9858
RANK3	0.9575	0.9316	0.9033
RANK2	0.7759	0.8443	0.8443
RANK1	0.7665	0.7995	0.7995

Figure (7): Fused Features

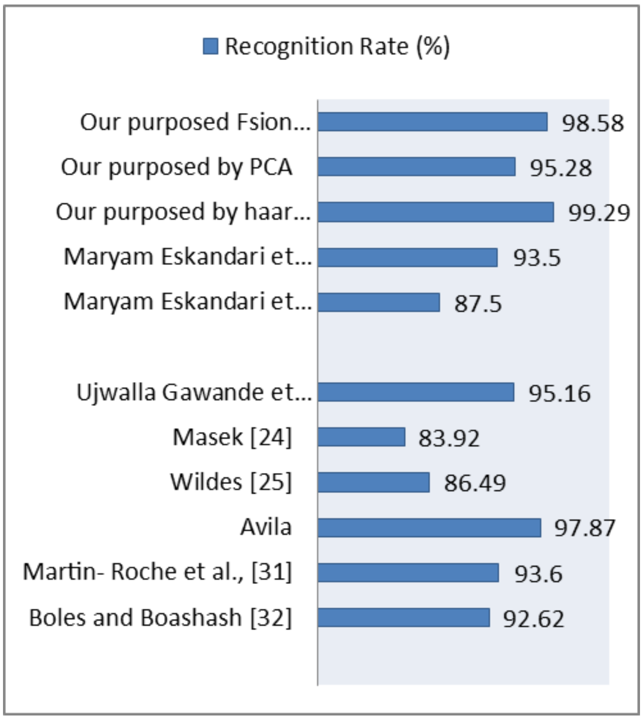


Figure (8): Comparison between the proposed methods

5. CONCLUSION

In this work we suggested a robust algorithm for iris recognition. The Integro-differential operator has been implemented. Then the (Haar Wavelet Transform) and Principle Component Analysis are used to extract the features and reduce the feature dimension. Setting up a hybrid system makes use of the advantages of both methods to improve the strengths and diminish the weaknesses of the individual biometric, reduces time complexity and increase the accuracy of systems. Finally, matching is implemented using the Euclidean distance.

We concluded that the technique was robust when we used the integration of the two proposed algorithms. The HWT algorithm gives an accuracy of 99.29% so it enhances the performance in terms of accuracy, PCA algorithm gives an accuracy of 95.28 % and enhances the performance of the algorithm by reducing the used eigenvectors. Finally to harness the advantages of both methods, the two techniques are fused to give 98.58% accuracy as shown in above tables.

References

[1] Purty, P. S. C., Reddy, E. S., & Babu, I. R. (2009). Iris recognition system using fractal dimensions of haar patterns. International Journal of Signal Processing, Image Processing and Pattern Recognition, 2(3), 75-84

[2] E. Wolff (1976),' Anatomy of the Eye and Orbit. ', The diction. H. K. Lewis & Co.LTD,

[3] Khaladkar, M. M., & Ganorkar, S. R. (2012). A Novel Approach for Iris Recognition. vol. I, (4)

[4] Yin, Y., Liu, L., & Sun, X. (2011, December). SDUMLA-HMT: a multimodal biometric database. In Chinese Conference on Biometric Recognition (pp. 260-268). Springer Berlin Heidelberg.

[5] Sun, J., Lu, Z. M., & Zhou, L. (2014). Iris recognition using Curvelet transform based on principal component

analysis and linear Discriminant analysis. Journal of Information Hiding and Multimedia Signal Processing, 5(3), 567-573

[5] Jie, S. U. N., Lijian, Z. H. O. U., Zhe-Ming, L. U. & Tingyuan, N. I. E. (2015). "Iris Recognition Based on Local Gabor Orientation Feature Extraction". IEICETRANS ACTIONS on Information and Systems, 98(8), 1604-1608.

[6] Abdullah, M., Wazzan, M., & Bo-Saeed, S. (2012). "Optimizing face recognition using PCA". arXiv preprint arXiv: 1206.1515.

[7] Ahmad, F. Najam, A., & Ahmed, Z. (2013). "Image-based face detection and recognition:" state of the art". arXiv preprint arXiv: 1302.6379.

[8] Ghodsi, A. (2006). "Dimensionality reduction a short tutorial," Department of Statistics and Actuarial Science, Univ. of Waterloo, Ontario, Canada, 37, 38

[9] Shemi, P. M., & Ali, M. A. (2012). "A principal component analysis method for recognition of human faces: Eigenfaces approach". International Journal of Electronics Communication and Computer Technology (IJECCT), 2(3), 139-144

[10]SDUMLA iris image database, Online:http://mla.sdu.edu.cn/sdumla-hmtl.[Accessed at: 17/3/2017 2010].

[11] Shams, M. Y., Rashad, M. Z., Nomir, O., & El-Awady, R. M. (2011). Iris recognition based on LBP and combined LVQ classifier. arXiv preprint arXiv: 1111.1562

[12] P. Manikandan and M. Sundararajan, "Discrete Wavelet Features Extraction for iris recognition based biometric security", International Journal of Electronic Engineering Research, ISSN 0975- 6450 Volume 2 Number 2, pp.237-241, 2010.

[13] Parashar, A., & Gulati, Y. (2012). Study and Development of Iris Segmentation and Normalization Techniques. International Journal of Advanced Research in Computer Engineering & Technology (IJARCET), 1(5), pp-237.

[14] Daugman, J. (2004). How iris recognition works. IEEE Transactions on circuits and systems for video technology, 14(1), 21-30.

[15] Jampour, M., Estilayee, M., Naserasadi, A., & Ashourzadeh, M. (2011). Extract and classification of iris images by fractal dimension and efficient color of iris. Signature, 3(4), 5.

[16] Prashanth, C. R., Raja, K. B., Venugopal, K. R., & Patnaik, L. M.(2012)," Fusion of Hybrid Domain features for Iris Recognition" International Journal of Engineering Research and Development, ISSN: 2278-067X, pISSN: 2278-800X, www.ijerd.com Volume 2, Issue 2.

[17] Bodade, R. M., & Talbar, S. N. (2014), " Iris Analysis for Biometric Recognition Systems|". Springer, Springer Briefs in Applied Sciences and Technology, ISBN: 978-81-322-1852-4 (Print) 978-81-322-1853-1.

[18] Karthikeyan, T. (2010),"Efficient bio metric iris recognition system using fuzzy neural network". International Journal of Advanced Networking and Applications, 1(06), 371-376.

[19] Boles, W. W., & Boashash, B. (1998),"A human identification technique using images of the iris and wavelet transform". IEEE transactions on signal processing, 46(4), 1185-1188.

[20] Wildes, R. P. (1997). Iris recognition: an emerging biometric technology. Proceedings of the IEEE, 85(9), 1348-1363.

[21] Zhu, Y., Tan, T., & Wang, Y. (2000). "Biometric personal identification based on iris patterns". In Pattern Recognition, 2000. Proceedings. 15th International Conference on (Vol. 2, pp. 801-804). IEEE.

[22] Ma, L., Tan, T., Wang, Y., & Zhang, D. (2003). Personal identification based on iris texture analysis. IEEE transactions on pattern analysis and machine intelligence, 25(12), 1519-1533.

[23] Gawande, U., Spare, A., Jain, A., Bhriegu, S., & Sharma, S. (2013). Fingerprint-Iris Fusion Based Multimodal Biometric System Using Single Hamming Distance Matcher. International Journal of Engineering Inventions e-ISSN, 2278-7461.

[24] Van Huan, N., & Kim, H. (2008, May). A novel circle detection method for iris segmentation. In Image and Signal Processing, 2008. CISP'08. Congress on (Vol. 3, pp. 620-624). IEEE.

[25] Narote, S. P., Narote, A. S., Waghmare, L. M., & Gaikwad, A. N. (2006, November). An automated segmentation method for iris recognition. In TENCON 2006. 2006 IEEE Region 10 Conference (pp. 1-4). IEEE.

[26] J. Daugman, (2002)." How iris recognition works, International Conference on Image Processing", Vol. 1.

[27] Murty, P. S. C., Reddy, E. S., & Babu, I. R. (2009). Iris recognition system using fractal dimensions of haar patterns. International Journal of Signal Processing, Image Processing and Pattern Recognition, 2(3), 75-84.

[28] Boles, W. W., & Boashash, B. (1998). A human identification technique using images of the iris and wavelet transform. IEEE transactions on signal processing, 46(4), 1185-1188.

[29] Qiu, X., Sun, Z., & Tan, T. (2007, September). Learning appearance primitives of iris images for ethnic classification. In Image Processing, 2007. ICIP 2007. IEEE International Conference on (Vol. 2, pp. II-405). IEEE.

[30] Ma, L., Tan, T., Wang, Y., & Zhang, D. (2003). Personal identification based on iris texture analysis. IEEE transactions on pattern analysis and machine intelligence, 25(12), 1519-1533.

[31] De Martin-Roche, D., Sanchez-Avila, C., & Sanchez-Reillo, R. (2001, October). Iris recognition for biometric identification using dyadic wavelet transform zero-crossing. In Security Technology, 2001 IEEE 35th International Carnahan Conference on (pp. 272-277). IEEE.

[32] https://en.wikipedia.org/wiki/Haar_wavelet

[33]https://www.tutorialspoint.com/biometrics/biometrics_overview.html

[34] Tisse, C. L., Martin, L., Torres, L., & Robert, M. (2002, May),"Person identification technique using human iris recognition", In Proc. Vision Interface (pp. 294-299).

[35] Chawla, S., & Oberoi, A. (2011),"A robust algorithm for iris segmentation and normalization using Hough transform', Global Journal of Business Management and Information Technology, 1(2), 69-76.