International Journal of Computing and Digital Systems
ISSN (2210-142X)
Int. J. Com. Dig. Sys. 6, No.5 (Sep-2017)

http://dx.doi.org/10.12785/ijcds/060507

Fourier Descriptors for Iris Recognition

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Received 14 Jul. 2017, Revised 20 Ag. 2017, Accepted 25 Aug. 2017, Published 1 Sep. 2017

Abstract: Automated identification of individuals is one of the most popular works today. Human verification, especially the iris pattern recognition is widely applied as a robust method for applications that demands high security. Many reasons are considered for choosing the iris in human verification, for example, the stability of iris biometric features throughout human life and unaffected of its patterns by human genes (genetic independency). This paper presents a new contribution in iris recognition biometric system. It uses Fourier descriptors method to extract the iris significant feature for iris signature representation. The biometric system is proposed and implemented using four comparative classifiers. It involves four sequential processes: the image enhancement process; iris feature extraction and patterns creation process; template construction process; and finally, the recognition and classification process. The mathematical morphology operations and canny edge detector are both applied for best outer/inner boundary localization procedure. The system satisfied 100% accuracy result regarding iris-pupil boundary localization for CASIA-v1and CASIA-v4 dataset. Also, when the identity of 30 persons were verified, the maximum matching result was %96.67 for Back propagation and lowest rate was %83.5 for Radial basic function.

Keywords: Iris recognition; Fourier descriptors; Pattern Recognition, Neural networks.

1. Introduction

In last years, security and surveillance has become an important issue because the increasing number of frauds and scams, also many access control systems suffer from some violations and breaches, especially the traditional methods like password or Personal Identification Number (PIN). To avoid these violations, a modern society has directed to more reliable methods that uses biometric technologies to provide more security of human identification and authentication. Biometric systems have been developed based on fingerprints, voice, handwriting, hand geometry, facial features, retina, iris.., etc. The recognition system works by first capturing a sample of feature, such as taking a digital color image for face or iris, the sample is then transformed using some sort of mathematical function into a biometric template. The biometric template will provide a normalized, efficient and highly discriminating to represent the feature which then can be compared with other templates to determine identity [1]. This paper presents a new contribution of iris verification using Fourier Descriptors (FD). The major idea of Fourier descriptors is to describe the contour by a set of numbers which represents the frequency content for full form, so it encodes any two-dimensional object by transforming its boundary into a complex numbers in frequency domain. This transformation is based to extract the iris features and create the templates. Relying on the FD analysis, it will generate a small set of numbers called the Fourier coefficients, which describes the shape and not the noise like that influences on the spatial position for boundary pixels. Four neural network classifiers are used to evaluate the recognition and matching results. The paper could be organized as follows: section 1 is the introduction, section 2 presents the related work demonstration, Section 3 illustrates the proposed iris verification system and the Fourier descriptors procedure respectively Section 4 tabulates the results of the four classifiers; it shows the verification accuracy that is applied on 30 CASIA iris datasets. Finally, section 5 discusses and concludes the best accuracy result and its related neural network classifiers.

2. Review of Related Work

The idea of using iris in human identification was originally suggested in 1936 by ophthalmologist Frank Burch. In 1987, Aran Safir and Leonard Flom, the two American ophthalmologists adopted Burch's idea of identifying people based on individual iris features, but their clinical experience was unable to develop such a process. In 1993, J. Daugman used phase code by applying "Gabor filters" for iris recognition. The system is registered excellent performance on different databases of

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large numbers of images. In matching phase he used Hamming distance between two codes (bit to bit). Daugman system achieved high accuracy and high speed performance, he satisfied accuracy rate of 99.90% [1]. In 1998, Boles et al proposed an algorithm to extract a set of one dimensional (1-D) signals using iris signatures and he obtained the zero-crossing representations of these signals. Also, he applied wavelet transform to generate the zero-crossing representation and matching diameters of the two irises. Boles system reports 91.87% accuracy rate [2]. Son et al. in 2004 used a Discrete Wavelet Transform (DWT), linear discriminant analysis (LDA), Principal Component Analysis (PCA), and Direct Linear Discriminate Analysis (DLDA) to extract features. These features experimented on combinations for Iris recognition [3]. In 2006, K. Miyazawa et al offered a phase based algorithm for iris recognition [4]. They introduced idea of 2D Fourier Phase Code (2D FPC) or phase congruency for representing iris information to decrease the size of iris data registration. In 2007, R. Al-Zubi and D. Abu-Al-Nadin used circular Hough transform and polynomial fitting technique in segmentation process using CASIA v1.0 database [5]. They used Sobel edge detector to find the pupil's location and area. Also, they applied Log-Gabor filter to extract and encode the feature vectors. This algorithm acquired best performance that obtained 99%. The iris region was encoded by using a 2D Gabor filter by S. Nithyanandam in 2011 [6]. Hamming distance is used to compare two iris codes. Reed-Solomon technique is used directly to encrypt and decrypt the data to improve the security. In 2013 G. Kaur proposed two different methods for iris recognition. The first method is a Support Vector Machine (SVM) and the second one is a phase based procedure. The first method showed Average FRR=19.8%, and FAR = 0%. The second method showed FRR = 0.01%, FAR = 0.09% and overall accuracy rate = 99.9% [7]. Jayalakshmi and Sundaresan in 2014 proposed K-means algorithm and Fuzzy C-means algorithm for iris image segmentation [8]. The two algorithms were executed separately and the performances of them were 98.20% of accuracy rate with low error rate. In 2016, A. Kumar and A. Singh, proposed method for an iris feature extraction and recognition depended on 2D discrete cosine transform. It applied 2D DCT to extract the most discriminating features of an iris [9]. The extracted feature has been tested on two publicly available, the IIITD and CASIA v.4.0 database for matching the iris templates using Hamming distance. The proposed method is acquired accuracy rate of 99.4% and 98.4% on CASIA V4 and IITD database respectively.

3. IRIS RECOGNITION SYSTEM

The iris recognition system uses a sequence of sequential processes starting from acquiring high quality eye image and complete by verifying human identity. The main system components are:

1. Image acquisition device
2. Iris/pupil boundary detection and segmentation
3. Feature Extraction and template creation procedures
4. Training and pattern matching procedures

The component procedures are constructed and programmed using MATLAB (R2016b) code. Four classifiers of neural network are considered for performance measurement purposes. These classifiers are:

- Back Propagation (BP)
- Radial Basis Function (RBF)
- Probabilistic, and
- Euclidian distance

A pre-processing image enhancement step for CASIA iris dataset is implemented to remove or decrease any degradation like noise or poor image histogram. Next, the iris inner and outer boundaries are highlighted by applying morphology operation, canny edge detector, and circular Hough transforms [10].

3.1 Image acquisition

The eye images have been taken from Chinese Academy of Sciences Institute of Automation (CASIA) database for iris verification system. These images are 320 pixels × 280 pixels taken from a distance of 4 -7 cm.

3.2 Iris segmentation

Segmentation operation includes three steps, inner boundary detection (pupil localization), outer boundary detection (iris localization) and iris normalization. The three steps should be achieved with high precision because they significantly affect the decision of the verification process.

A. Pupil localization

The pupil region can be detected and localized by the following steps:

Step1: apply filter median on the eye image to reduce the effects of eyelid and eyelashes.

Step2: convert the grayscale image to binary image by applying suitable threshold (τ), as in (1).

$$I(x,y) = \begin{cases} 1 & f(x,y) = \tau \\ 0 & f(x,y) <> \tau \end{cases} \quad (1)$$

Step3: apply the opening and closing operations on the binary eye image I(x, y) for noise removal.

Step4: Connected component labelling algorithm is used to make the edge of object is connected.

Step5: Find the pupil center P_x and P_y which by calculating the summation of the horizontal and vertical vectors as in (2 and 3), then find the maximum row and column vector respectively in as (4 and 5).

$$hor(x) = \sum_1^x all\ rows \quad (2)$$

$$ver(y) = \sum_1^y all\ cols \quad (3)$$

$$P_x = \max(hor \quad (4)$$

$$P_y = \max(ver) \quad (5)$$

Where x represents (the number of rows) and y represents (the number of columns).

Step6: Find the radius of the pupil (r_p), as in (6).

$$r_p = (\max(hor) - \min(hor))/2 \quad (6)$$

Below figure (1) shows the steps of pupil localization.

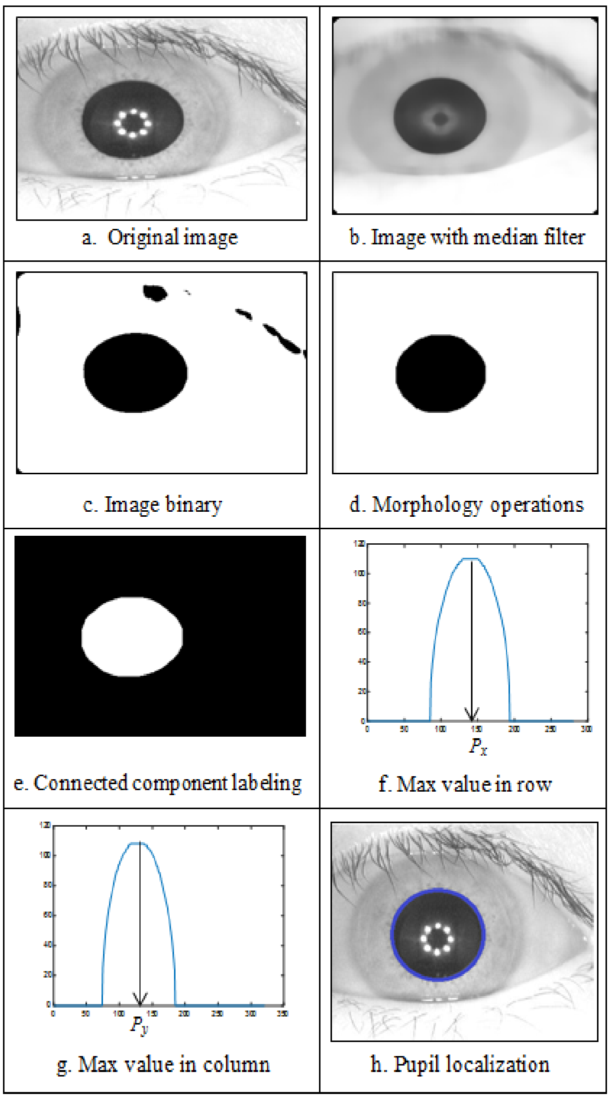

Figure 1. Pupil localization steps.

B. Iris Localization

Canny edge detector and circular Hough transform are both used for iris localization. Canny filters are very important as they applied to locate the boundaries of iris Contour. Next, a circular Hough transform is applied to obtain a complete circle shape and locate the center and Contour. Next, a circular Hough transform is applied to obtain a complete circle shape and locate the center and radius of the iris. Below figure (2) shows the iris localization steps.

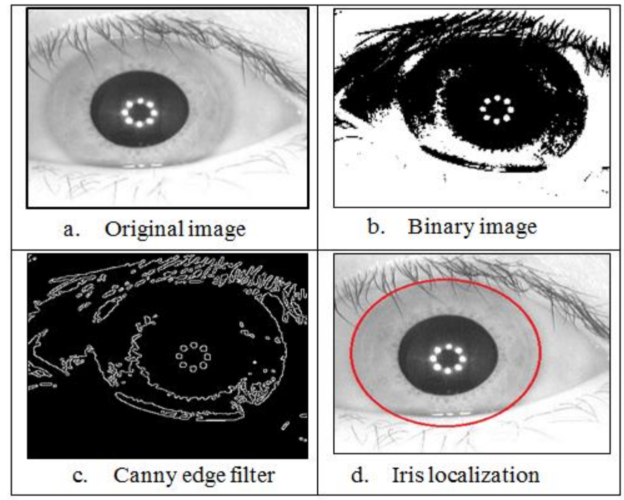

Figure 2. Iris localization steps.

C. Iris Normalization

Normalization is a fundamental and essential step which precedes the verification process when iris images have different sizes and resolutions. Also, normalization reduces the distortion resultant from pupil movement. The process starts by converting the iris region that is evident in a circular shape to a rectangular one, and then it converts the Cartesian coordinates to polar form (r, θ) by applying Daugman's rubber sheet. The process is completed with a standard model regardless the iris/pupil size and resolution. The idea of polar system is to allocate 20 pixels along r and 240 pixels along θ to produce unwrapped strip size of 20 × 240 which will stay invariant for image extension or skewing. Equations (7 and 8) are the mapping functions from Cartesian coordinates (x, y) to polar form (r, θ) are [1]:

$$X(r,\theta) = (1-r) * X_P(\theta) + r * X_i(\theta) \quad (7)$$

$$Y(r,\theta) = (1-r) * Y_P(\theta) + r * Y_i(\theta) \quad (8)$$

Where:

$$X_p(\theta) = X_{p0}(\theta) + r_p * \cos(\theta) \quad (9)$$

$$Y_p(\theta) = Y_{p0}(\theta) + r_p * \sin(\theta) \quad (10)$$

$$X_i(\theta) = X_{i0}(\theta) + r_i * \cos(\theta) \quad (11)$$

$$Y_i(\theta) = Y_{i0}(\theta) + r_i * \sin(\theta) \quad (12)$$

Where (X_p, Y_p) represents the center of the pupil, (X_i, Y_i) represents the center of the iris, and r_p and r_i represent the radius of the pupil and iris. Below figure (3) shows the iris normalization and de-noise iris normalized image by applying median filter, respectively.

a. Iris normalization

b. Apply median filter

Figure 3. Iris normalization.

3.3 Feature Extraction using Fourier Descriptors

The extracted iris patterns are not ready yet for comparison. There are many approaches for template generation such as: Gabor wavelet; zero-crossing wavelet; local variance; spatial filters; and 1D local texture pattern. FDs are considered here to generate the feature vectors and templates by computing the shape transformed coefficients form in frequency domain. The low frequency descriptors represent the information about the general features of the object while the high frequency descriptors represent the information about accurate details of the object. The number of created coefficients from the transformation is usually large, so just sufficient coefficients can be selected to describe the object features [10, 11]. The FD procedure is:

Step1: Count boundary points.

$$z(t) = x(t) + i * y(t) \tag{13}$$

Step2: select sampling number, N.

Step3: Calculate centroid distance.

$$r(t) = \sqrt{[x(t) - x_c]^2 + [y(t) - y_c]^2} \tag{14}$$

$$x_c = \frac{1}{N}\sum_{t=0}^{N-1} x(t) \quad , \quad y_c = \frac{1}{N}\sum_{t=0}^{N-1} y(t) \tag{15}$$

The centroid distance represents the location of the shape from the boundary coordinates, that makes the representation is invariant to translation [11].

Step4: Compute Fourier transforms values.

$$FD_n = \frac{1}{N}\sum_{t=0}^{N-1} r(t) * \exp\left(\frac{-2j\pi nt}{N}\right) \tag{16}$$

FD_n, n = 0, 1, … N-1.

Step5: Normalize the FD coefficients by dividing them on the DC value.

$$f = \frac{|FD_1|}{|FD_0|}, \frac{|FD_2|}{|FD_0|}, \dots\dots \frac{|FD_{N/2}|}{|FD_0|} \tag{17}$$

The extracted features resulted from FD procedure on the rectangular iris are very large, the FDs coefficients are 512 complex values. It is suitably reducing this large number to the half or even quarter coefficients size to make the proposed system simple and fast. So, carefully selection of the high frequency features that contains the fine iris detail will improve the process of recognizing and classifying. Figure (4) illustrates the new iris signature after selecting 150 significant coefficients out of 512 feature values.

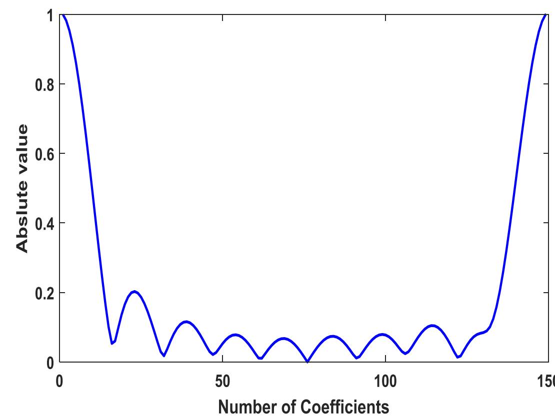

Figure 4. Representation of the FD coefficients (iris signature).

3.4 Training and Pattern Matching

In this stage 90 iris images are considered to verify the identity of 30 persons. Four NNs classifiers are designed and implemented for comparing the classification results. The Back propagation is implemented with 4 layers: input layer, two hidden layers and output layer. The input layer contains 150 neurons; the two hidden layers contain 60 neurons for each layer and the output layer contains 30 neurons, as shown in figure (5).

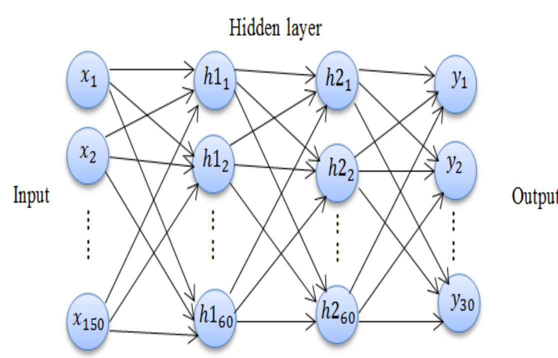

Figure 5. Architecture for BP neural network

In RBF and the Probabilistic neural network, we use three layers; the input layer contains 150 neurons, in the hidden layer 200 neurons and 30 neurons for output layer.

4. Experimental Results

The proposed method verified the identity of 30 persons; each one has three images for training and one image for testing. The verification system processes are illustrated in figure (6). Table I shows the performance of the pupil and iris localization method where it is compared with other existing methods using 756 iris images of CASIA-v1 and 1000 iris images of CASIA-v4-interval dataset. The using of morphological operations and connected component labeling algorithm increased the accuracy of our proposed method to 100%.

4.1 BP Training Results

The performance of BP is measured by mean square error. Figure (7) shows the plot diagram of training process (epoch) vs. MSE. It is noticed that the MSE is reached to zero for 20000 epochs. Table II contains the other neural networks training results; it shows that the lowest training time is satisfied with Probabilistic NN for 3.678 sec., while the highest training time is 318.74 sec. for BPNN.

4.2 BP Testing Results

The most important standards that are used for performance evaluation measurement are: False Accept Rate (FAR), False Reject Rate (FRR) and Accuracy rate (ACC) as described in (18, 19, and 20). Table III displays the test performances of FAR, FRR and ACC rate for iris recognition system using the Back propagation. Figure (8) shows the Receiver Operating Characteristics (ROC) curve for recognition results of CASIA-v1.0 for 30 classes. Table IV shows the the comparison between Back propagation and other models in terms of performance of FAR, FRR and ACC rate.

$$FAR = \frac{No.\ of\ accepted\ imposter}{Total\ no.\ of\ imposter\ assessed} * 100 \quad (18)$$

$$FRR = \frac{No.\ of\ rejection\ genuine}{Total\ no.of\ genuine\ assessed} * 100\% \quad (19)$$

$$\text{Accuracy}(\%) = \frac{N_c}{N_t} * 100 \quad (20)$$

Where,

N_c : denotes to the number of correct iris samples.

N_t : is the total number of iris samples.

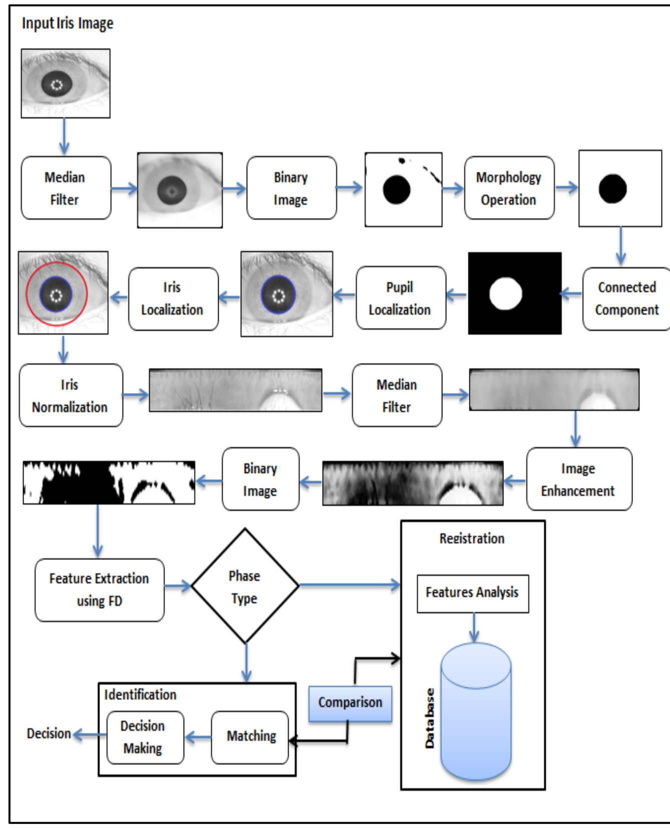

Figure 6. The proposed system procedure.

TABLE I. ACCURACY RATE FOR IRIS SEGMENTATION.

Database Name	Reference of Method	Accuracy Rate
CASIA V1	Amoli [12]	87.3%
	Wildes [13]	86.49%
	Buddharpawar [14]	95%
	Proposed method (Tested on all iris images 756 images)	100%
CASIA V4 - interval	Das [15]	80%
	Nkole [16] (Tested on 320 iris images)	98%
	Proposed method (Test on 1000 iris images)	100%

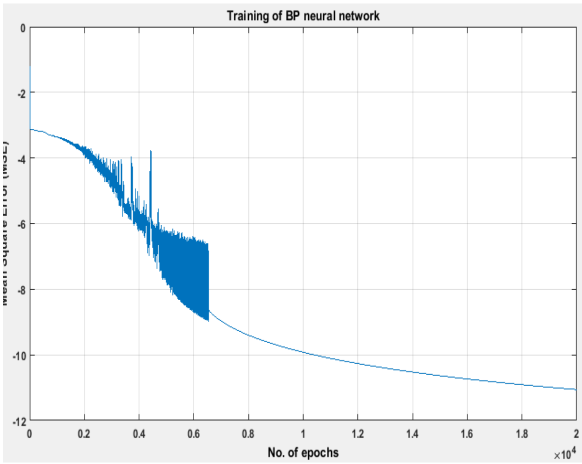

Figure7. The training of BP neural network.

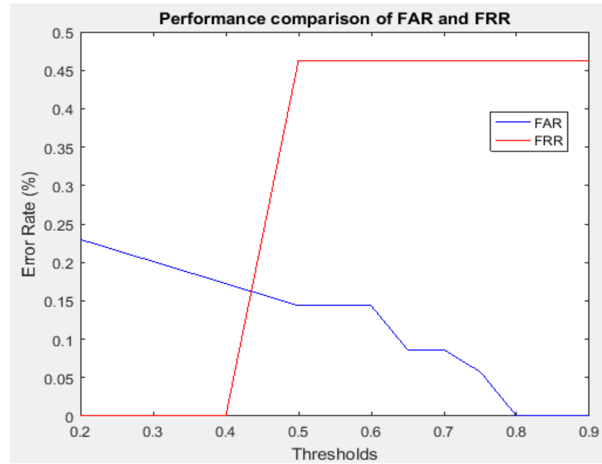

Figure 8. The ROC curve for recognition results of CASIA v1.0.

TABLE II. THE PERFORMANCE OF TRAINING FOR FOUR NEURAL NETWORK MODELS

Mode	**No. of epochs**	**Time of training**
BPNN	20000	318.74
RBF	60	11.541
Probabilistic	2000	3.678
Euclidean distance	150	104.446

TABLE III. THE PERFORMANCE OF IRIS RECOGNITION SYSTEM WITH BPNN

Threshold	**FAR%**	**FRR%**	**Accuracy%**
0.2	0.2298	0	100%
0.3	0.2011	0	100%
0.4	0.1724	0	100%
0.5	0.1436	0.4629	96.67%
0.6	0.1436	0.4629	96.67%
0.65	0.0862	0.4629	96.67%
0.7	0.0862	0.4629	96.67%

TABLE IV. THE COMPARISON BETWEEN BACK-ROPAGATION AND OTHER MODELS

Mode	**FAR%**	**FRR%**	**ERR%**	**Accuracy%**
BPNN	0.0862	0.4629	0.17	96.67
RBF	0.6034	4.3103	1.8	83.33
Probabilistic	0.1149	3.4482	1.2	86.67
Euclidean distance	0.0287	0.4629	0.22	96.67

5. Conclusion

In this paper, a new contribution of iris recognition biometric system is proposed and implemented. The system used Fourier descriptors as a feature extractor method to represent the sufficient coefficients of iris signature. These coefficients have been selected carefully to represent the significant parameters locating in high frequency bands. The iris inner/outer boundaries were located precisely, so the segmentation procedure satisfied 100% accuracy rate. The pattern matching phase was implemented using four different classifiers. The proposed system verified the identity of 30 CASIA dataset where, the performance of BPNN was most effective. It satisfied 96.67% accuracy rate with FAR=0.0862, FRR=0.4629, ERR=0.17 and training time of 318.74 sec. The lowest rate was belonged to RBF model. It obtained 83.3% accuracy rate with 104.446 sec training time. The experimental result shows that the proposed method has good recognition performance when the BP is considered as a classifier comparing with other classifier models.

REFERENCES

[1] J. Daugman, "How iris recognition works?", IEEE Transactions on Circuits and Systems for Video Technology, Vol. 14, No. 1, pp. 21–30, January 2004.

[2] W. Boles, B. Boashash, "A Human Identification Technique Using Images of the Iris and Wavelet Transform", IEEE Trans. Signal Process. Vol. 46, No. 4, pp. 1185–1188, 1998,.

[3] B. Son, H. Won, G. Kee, Y. Lee, "Discriminant Iris Feature and Support Vector Machines for Iris Recognition", in Proceedings of International Conference on Image Processing, vol. 2, pp. 865–868, 2004.

[4] K. Miyazawa, K. Ito, T. Aoki, K. Kobayashi and H. Nakajima, "An Implementation-Oriented Iris Recognition Algorithm Using Phase-Based Image, IEEE International Symposium on Intelligent Signal Processing and Communication Systems (ISPACS2006), pp. 231-234, 2006.

[5] R.T. Al-Zubi and D.I. Abu-Al-Nadi, "Automated Personal Identification System Based on Human Iris Analysis", Pattern Analysis and Applications, Vol. 10, pp. 147-164, 2007.

[6] S. Nithyanandam, K. Gayathri and P. Priyadarshini, "A New IRIS Normalization Process For Recognition System With Cryptographic Techniques", IJCSI International Journal of Computer Science, Vol. 8, Issue 4, No. 1, pp. 342-348, July 2011.

[7] G. Kaur, D. Kaur and D. Singh, "Study of Two Different Methods for Iris Recognition Support Vector Machine and Phase Based Method", International Journal of Computational Engineering Research, Vol. 03, Issue 4, pp. 88-94, April 2013.

[8] S. Jayalakshmi and M. Sundaresan, "A Study of Iris Segmentation Methods using Fuzzy C Means and K-Means Clustering Algorithm", International Journal of Computer Applications (0975 – 8887) Vol.85, No 11, January 2014.

[9] A. Kumar, A. Potnis and A. Singh, "Iris recognition and feature extraction in iris recognition system by employing 2D DCT", IRJET International Research in Computer Science and Software Engineering, and Technology, Vol.03, Issue 12, p. 503-510, December 2016.

[10] M. Nixon and A. Aguado, "Feature Extraction & Image Processing for Computer Vision", third edition, AP Press Elsevier, 2012.

[11] A. Amanatiadis, V. Kaburlasos, A. Gasteratos and S. Papadakis, "Evaluation of shape descriptors for shape-based image retrieval", The Institution of Engineering and Technology, Vol. 5, Issue 5, pp. 493-499, 2011.

[12] G. Amoli, N. Thapliyal, N. Sethi, "Iris Preprocessing", International Journal of Advanced Research in Computer Science and Software Engineering, Vol. 2, Issue 6, 2012.

[13] R.Wildes, J. Asmuth, G. Green, S. Hsu, R. Kolczynski, J. Matey, and S. McBride, "A Machine-Vision System for Iris Recognition", Machine Vision and Applications, Vol.9, pp.1-8, 1996.

[14] A. S. Buddharpawar and S. Subbaraman, "Iris Recognition based on PCA for Person Identification", International Journal of Computer Applications, Conference on Emerging Applications of Electronics System, Signal Processing and Computing Technologies, pp. 9-1, 2015.

[15] A. Das, "Recognition of Human Iris Patterns", M.Sc thesis, National Institute of Technology, computer science and engineering, Rourkela, India, 2012.

[16] I. Nkole and G.B. Sulong, "An Enhanced Iris Segmentation Algorithm Using Circle Hough Transform", UTM Library, Thesis (Sarjana Sains (Sains Komputer)) – Universiti Teknologi Malaysia, 2012.

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