M.N. Abdullah
Computer Eng. Dept
University of Technology
Baghdad, Iraq
120002@uotechnology.edu.iq

H.A. Jeiad
Computer Eng. Dept
University of Technology
Baghdad, Iraq

R.A. Hussein
Laser and Optoelectronic Eng. Dept. University of Technology , Baghdad, Iraq

Received on: 19/07/2016
Accepted on: 19/01/2017

Multibiometric Identification System based on SVD and Wavelet Decomposition

Abstract*-Biometric systems refer to the systems used for human recognition based on their characteristics. These systems are widely used in security institutions and access control. In this work three biometric sources were used for identification purposes. Singular value decomposition (SVD) was employed as a tool for feature extraction and artificial neural network (ANN) was used as pattern recognition for the model. High accuracy was obtained from this work with 95% recognition rate.*

Keywords*-Multi-biometric, SVD, Discrete Wavelete, Artificial Neural Network.*

How to cite this article: M.N. Abdullah., H. A. Jeiad., and R.A. Hussein, "Multibiometric Identification System based on SVD and Wavelet Decomposition," *Engineering and Technology Journal*, Vol. 35, Part A, No. 1, pp. 61-67, 2017.

1. Introduction

The researchers that are specialists in the information security issues think of biometric systems as one of the leading methods for security and access control systems. These systems use individual's body measurements like fingerprint or iris, or behavior like gait or key stroke in order to distinguish between people for identity verification purposes. In general, a multibiometric approach provides more accuracy and reliability when applied to the verification systems and the identification systems.

A biometric system is a pattern recognition system which consists of a number of stages starting with acquiring biometric data from an individual, followed by feature extraction, and comparing the extracted feature against the template in the database [1]. Unimodal biometric systems uses single biometric source for identity verification for individuals. These models face a variety of problems and cannot present a 100% accuracy. Multimodal biometric systems have been introduced and are widely used due to the fact that they produce higher accuracy and provide more reliability and they avoid many of the shortcomings encountered with unimodal systems [2].

The identification and verification are the two operations that can be performed by the biometric systems. Mainly, the identification operation is used to determine the record of the identity of an unknown person if it is already founded within a database of people. The biometric system in the identification determines the person with identity of that have similarity template of higher degree otherwise rejects that identity person, while in the verification operation the system is used to determine that the pretended person is really the concerned person. That can be performed by means a comparison for the acquired trait of the intended user with the previously saved template of the pretended person. The result of the verification process will be either match or not [3]. Figure1shows a block diagram of verification and identification system.

Over the past years many researchers introduced various biometric systems that used either unimodal or multimodal biometric. Darabkh1 et al. [4] introduced an iris feature extraction and recognition method that uses mean thresholding and mean by median thresholding which achieved a recognition rate of about 98.3264%. Kim et al.[5] used SVM as classifier by using both of the matching score result for face and the left and right iris after fusing them as an input for the SVM, this model achieved EER of about 0.131 %. Chadha et al. [6] introduced face recognition system that uses Discrete Cosine Transform (DCT) for Local and Global Features extraction and recognition. The system achieved 87.18% in local feature method and 88.25% in global features and a higher rate of 90.4%when both methods were combined. Reference [7] for Mitul Dhameliya and Chaudhari introduced a multimodal biometric recognition system that uses palm print and finger print as biometric sources. Features were extracted using Gabor filtering, the comparison of database template and

https://doi.org/10.30684/etj.2017.127311
2412-0758/University of Technology-Iraq, Baghdad, Iraq

the input data is done with the help of Euclidean-distance matching algorithm. The average verification accuracy obtained was 87% when only 250 features were used.

This work proposes a multibiometric identification model. The proposal is a multimodal biometric system that considers three different traits types which are face, iris and fingerprint. The fusion of these templates or traits is applied as a level fusion for features. An Intelligent based recognition approaches were applied in order to recognize and classify the considered pattern. Two more tools were used for this model SVD and wavelet decomposition for the purpose of enhancing the performance and increasing the accuracy of the model. A brief review of these tools will be stated next followed by the description of the stages followed in designing the model finally the results are reviewed and the concluded points are discussed.

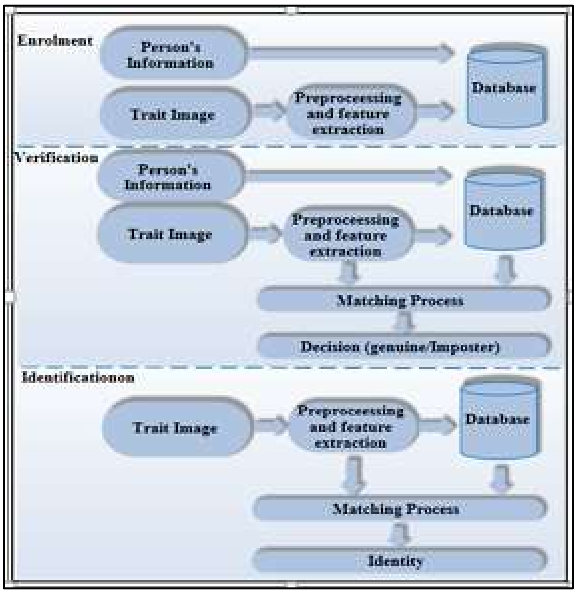

Figure 1: Block Diagram of Verification and Identification System [1]

2. Singular Value Decomposition (SVD)

SVD is a tool that can be applied for decomposing a matrix. There is a certain SVD for every matrix and the hidden characteristics of the matrix can be expressed by means of SVD. Also, SVD can be used as a tool for reducing the dimension [8]. Let A ∈ R_r^MxN , then two orthogonal matrices U and V will be derived that can be defined as follow:

$$A = U\sum V^T \quad (1)$$

Where,$\sum = \begin{bmatrix} S & 0 \\ 0 & 0 \end{bmatrix}$,$S = diag(\sigma_1, \dots, \sigma_r)$ and$\sigma_1 > \cdots \sigma_r > 0$. Then we have

$$A = [U_1 U_2] \begin{bmatrix} S & 0 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} V_1^T \\ V_2^T \end{bmatrix} \quad (2)$$

$$= U_1 S V_1^T \quad (3)$$

The $\sum$ is considered unique for each matrix and v, u are two orthogonal vectors [9]. Figure 2 shows the SVD decomposition operation.

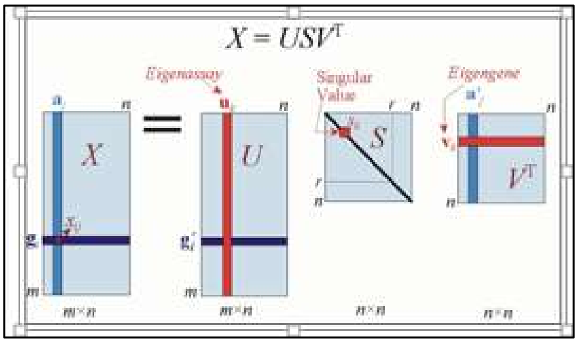

Figure 2: SVD operation.

3. Wavelet decomposition

A signal can be decomposed using the wavelet decomposition method, the amount or percentage of energy that can be obtained from the wavelet bookkeeping vector and the wavelet decomposition vector can be used [10]. Wavelet decomposition provides local information in both space domain and frequency domain [11].

The energy of wavelet gives a percentage of energy corresponding to the approximation component while the vector containing the percentage of energy corresponding to the detail components. The metric of wavelet energy is used to evaluate the quality of the vector effectively and efficiently. An information related to the global image enhancement is provided by the coefficients of approximate wavelet energy while a statistics related to the image details is provided by the coefficients of the detailed wavelet energy [12]. The DWT are given by equations (4) and (5).

$$W_\varphi(j_0, k) = \frac{1}{\sqrt{M}} \sum_x f(x) \varphi_{j_0,k}(x) \quad (4)$$

$$W_\Psi(j, k) = \frac{1}{\sqrt{M}} \sum_x f(x) \Psi_{j,k}(x) \quad (5)$$

Where, $f(x)$ denotes to a function of discrete variable (x) where x = 0,1,2, … $M - 1$., and φjo,k (x) denotes to the approximation coefficient. Symbol Ψj,k(x) is the detail coefficient. In addition wavelet decomposition provides a mean of compression. Figure 3 shows the wavelet decomposition where, (cA) approximation coefficient and (cD) is the detailed coefficient that will be calculated [13].

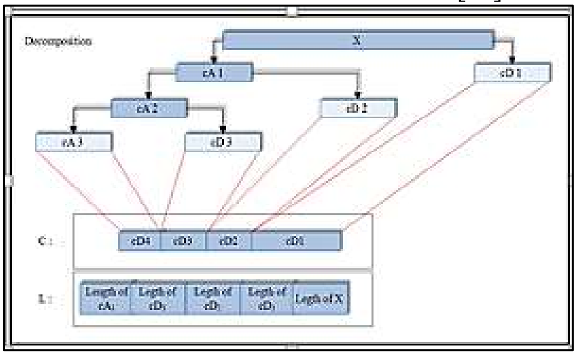

Figure 3: Wavelet decomposition [12].

4. Proposed model

The proposed model uses three types of biometric traits face, iris and fingerprint. Number of stages are taking place for the design of the system. The proposed system will perform in two phases, training and testing. The procedures followed and the tools used are explained in the next sections. Figure 4 shows the basic block diagram of the proposed system.

I. Database

The biometric traits which have been used here are face, fingerprint and iris. These traits are chosen according to two criteria which are their characteristics and advantages over other traits. Three different sources of database are used to provide the necessary images for each trait.For face images the AT&T Laboratories/ Cambridge face database was used. The images used for iris are obtained from iris image database called CASIA with version 1.0 (CASIA-IrisV1) while in the case of fingerprint, the database used were fingerprint image database called CASIA with version 5.0 (or CASIA-FingerprintV5). All the obtained images were prepared and enhanced to be used as input for the model.

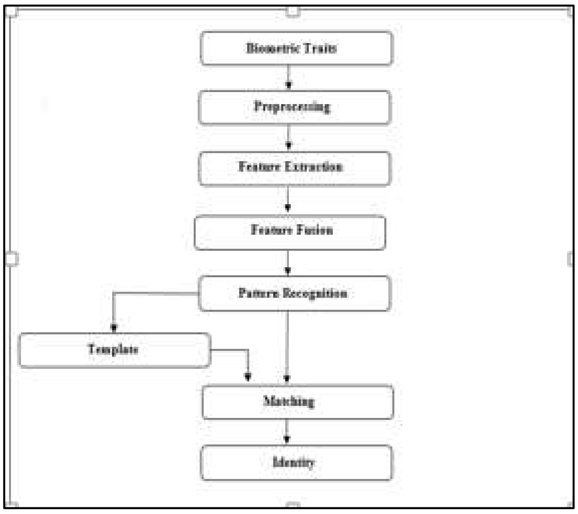

Figure 4: Basic stages block diagram of the proposed model

II. Preprocessing

For a biometric system a preprocessing stage is important and have a great effect on the quality of the model's performance. In preprocessing the acquired images of the biometric traits undergo a number of image processing operations in order to enhance the quality of the image and minimize the effect of noise or corruption that may occur during the capturing process due to some dirt or problems in the acquisition devices. Depending on the type of the trait and the nature of the extracted features, different methods of preprocessing may be performed. In this model. For each biometric trait there were different steps followed. As for face images a binarization operation was performed in order to set the gray value of each pixel to either (0) or (1) depending on the assigned threshold. For this model otsu's global thresholding was used .

For iris images, binarization was also performed. Binarization helps unify the intensity level of the pupil region to black, then a calculation of the radius of the pupil is done and the radius of the iris is defined by adding a fixed number to the radius of pupil. This step helps overcome the differences in the pupil size due to dilation. Using the radius of the iris, the iris region is cropped from the eye image and saved for the next step.

As for fingerprint binarization is performed according to otsu's global thresholding followed by performing closing operation for that binarized images through a number of morphological operations which are dilation and erosion. Normally, closing operation is needed for filling the gaps that may appears in the image which as a result helps the enhancement of details of the fingerprint ridges. After that, image skeletonizing is needed to be applied for the resulted image to transform the resulted binary image to another form represent a one bit image. In fact, the closing operation is done to help the extraction of the detailed features of the later fingerprint image. Figure 5 shows the different preprocessing steps performed for each trait type individually.

III. Feature Extraction

At feature extraction stage, for each type of the biometric traits different methods are followed in order to find the distinguished characters of these traits. In the case of face images, the holistic approach is used in order to achieve the features extraction of the face images. This means that the feature is considered to be represented by the overall appearance of the face image. In fact, SVD was used for this purpose where the preprocessed image is decomposed to three vectors (U, S and V). This transform helps finding the characteristics of the feature vector. The matrix S which is a non-zero Eigen values for the image arranged in a diagonal entries will be used as feature vector for the face image .

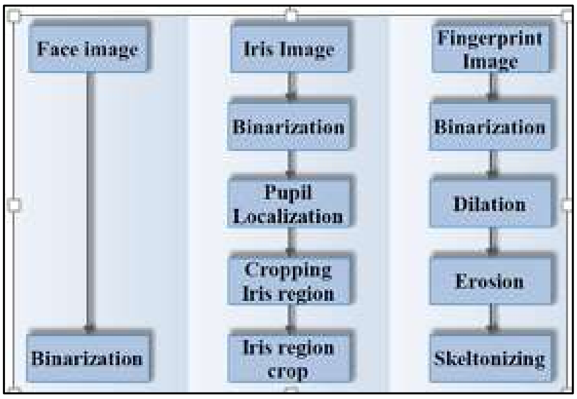

Figure 5: Preprocessing steps

For iris image, the cropped iris image will first be normalized by converting the coordinates of that cropped image from the Cartesian coordinates (x,y) to a fixed block size of polar coordinates (p,θ) by means of the following equations [1]:

$$I\left(X(P,\theta),Y(P,\theta)\right) \rightarrow I(P,\theta) \qquad (6)$$

where

$$X_p(P,\theta) = X_{P0}(\theta) + r_p * \cos(\theta) \qquad (7)$$
$$Y_p(P,\theta) = Y_{P0}(\theta) + r_p * \sin(\theta) \qquad (8)$$
$$X_i(P,\theta) = X_{i0}(\theta) + r_i * \cos(\theta) \qquad (9)$$
$$Y_i(P,\theta) = Y_{i0}(\theta) + r_i * \sin(\theta) \qquad (10)$$

Where r_i denote to the radius of iris r, rp denote to the radius of pupil of the same iris r, notation (xp(θ), yp(θ)) represents the coordinates of the pupil boundary, (xi(θ), yi(θ)) are the coordinates of both iris boundaries in the direction of θ that takes the value of [0,2π], while ρ takes [0,1]. The resulted block will be decomposed using SVD. The Eigen vector (S) resulted from the decomposition would be saved as the iris feature vector.

For fingerprint feature extraction, the number of bifurcation and ridges end for each image is calculated and saved as the feature vector of the image. This is done by scanning the fingerprint image with a (3X3) window and comparing it to a number of kernels that presents possible bifurcation and ridges end. The resulted vector will be a one dimension array of (28) value which differs in size and format from the features obtained from face or iris. In addition the SVD decomposition of such array will result a single Eigen value which will also be different from the saved feature vectors of face and iris. For purpose an out product was performed for the extracted feature array to obtain a 2D vector which after applying SVD decomposition will result the final fingerprint feature vector. Figure 6 shows the feature extraction steps performed for each trait type individually.

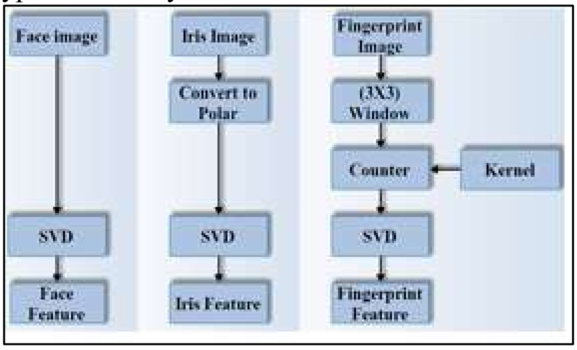

Figure 6: Feature Extraction steps

For fingerprint feature extraction, the number of bifurcation and ridges end for each image is calculated and saved as the feature vector of the image. This is done by scanning the fingerprint image with a (3X3) window and comparing it to a number of kernels that presents possible bifurcation and ridges end. The resulted vector will be a one dimension array of (28) value which differs in size and format from the features obtained from face or iris. In addition the SVD decomposition of such array will result a single Eigen value which will also be different from the saved feature vectors of face and iris. For purpose an out product was performed for the extracted feature array to obtain a 2D vector which after applying SVD decomposition will result the final fingerprint feature vector. Figure 6 shows the feature extraction steps performed for each trait type individually.

IV. Feature Fusion

Fusion at feature level is performed for this model. In recent years work started to focus on fusion on feature level because at this level richer information are obtained which lead to more accurate results. Feature level fusion introduces a number of challenges such as the possibility that the incompatibility between the features vectors to be joined. The relationship between the joint feature vectors may not be linear. In addition, concatenating two feature vectors results a feature vector with a dimensionality that is larger when compared to the fused feature vectors.

In order to overcome these challenges multilevel wavelet decomposition was used for each extracted vector. Four level decomposition was performed and the detailed coefficient of each level was saved to result finally a vector for face, iris and fingerprint. This was performed by separately transferring face, iris and fingerprint to a four values feature vector for each. Each resulted vector represent the energy percentage vector that corresponding to each level of the wavelet transform. The three features are fused by using simple concatenation method. Figure 7 shows the final construction of the fused vector that will be used in the next stage for pattern recognition. The final result is a (12 X1) vector that represents the fused 3 features.

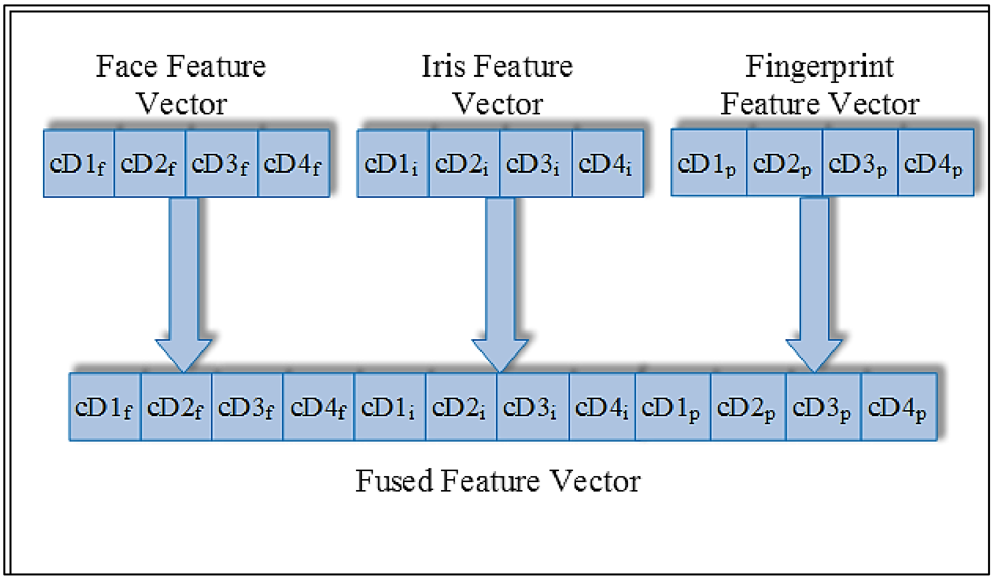

Figure 7: Fused Feature Vector

V. Matching

Neural network was employed for pattern recognition. Using its ability to learn pattern, Elman neural network was chosen. Table 1 shows the network configurations.

The fused feature vectors were used as an input for the neural network. The output of the training represent the template that will be saved as reference for testing phase. At testing phase the presented testing samples will go through all the previous stages and the resulted pattern of the neural network is compared to the saved template. The closest match is calculated using iterative closest point (ICP) method.

5. Experimental Results

For this system three samples for each trait type were used for training and another two samples for the traits were used for testing. The system was trained and tested for ten subjects. Recognition rate for the system was 95%. False acceptance rate (FAR) of 0% and false rejection rate (FRR) of 0.02%.using ten false samples. FAR and FRR were calculated according to [15]:

$$FAR\ \% = \frac{false\ acceptance\ number}{total\ number\ of\ imposter\ tet}\ x\ 100\% \qquad (11)$$

$$FRR\ \% = \frac{false\ rejection\ number}{total\ number\ of geniuen\ tet}\ x\ 100\% \qquad (12)$$

When compared to other proposed model, this model showed a highly acceptable performance. Table 3 shows a comparison of the obtained results of other models in term of recognition rate, FAR and FRR. In ref. [16] Laheeb M. Alzoubiady, Ibrahim A. Saleh used database collected from 50 different persons (eight images for each person) for hand images. (four images for each person) for dental images. While DNA captured with special device for also 50 person. ANN was used for this model. Mukhwinder Singh and Tripatjot Singh Panag in [17] used fuzzy vault for the fused features extracted from iris and fingerprint .

The use of (SVD) and wavelet decomposition led to a fast and accurate recognition for the proposed model. Where (SVD) provided the unique characteristics of the feature vector. Wavelet decomposition produced a compressed feature vector which in turn helped reducing the number of inputs for the neural network. This made model training and testing be performed in relatively short time (seconds) with high recognition rate.

6. Conclusion

Multibiomatric authentication systems gave good performance to be reliable and accurate for identification and verification purposes. The use of multibiometric achieves high accuracy with minimum required computational operation. Using the tool of singular values decomposition was very suitable for feature extraction and helped eliminate the problem of differences between the used biometric traits. Multilevel wavelet decomposition helped achieving a feature reduction which helped with the neural network in terms of speed and performance. The small feature size led to a small template size which in turn helped ensuring that no large memory space is required. For this model different tools were used each helped increasing the system performance and accuracy.

Table: Neural network configuration

Input data size	12 *30
ANN type	Elman neural network
Training function	Gradient descent with momentum and adaptive learning rate backpropagation
Number of layers	1 input layer (12 node) 2 hidden layers (100 , 30 node) 1 output layer (12 node)
Transfer functions	Tansig , purelin
Maximum epoch	500
MSE	10^{-1}
Best validation performance	0.11468 at epoch 266
Gradient	0.049489 at epoch 266

Table 2: System performance

Recognition rate	FAR	FRR
95 %	0 %	0.02 %

Table 3: A review of results obtained by work of others

References	Recognition rate	FAR	FRR
[16]	**93 %**	**2 %**	**5 %**
[17]	**Not calculated**	**2.3%**	**7.6%**
Proposed model	**95 %**	**0 %**	**0.02 %**

7. References

[1] A. Jain, A. Ross, and S. Prabhakar, "An Introduction to Biometric Recognition," IEEE Transactions On Circuits And Systems For Video Technology, vol. 14, no. 1, pp. 4-20, 2004.

[2] M.N. Almas, et al, "Multimodal Biometric Systems: Study to Improve Accuracy and Performance," International Journal of Current Engineering and Technology, Vol.4, No.1, 2014.

[3] J. Yang, M. El-Abed, C. Charrier and C. Rosenberger, "New Trends and Development in biometrics," In Tech 2012.

[4] K.A. Darabkh, R. T. Al-Zubi, and M. T. Jaludi, "New Recognition Methods for Human Iris Patterns," MIPRO 2014, 26-30 May 2014, Opatija, Croatia.

[5] Y.G. Kim, "Multimodal Biometric System Based on the Recognition of Face and Both Irises," International Journal of Advanced Robotic Systems, Vol. 9, No. 65, 2012.

[6] A.R. Chadha, P. P. Vaidya, and M. M. Roja, "Face Recognition Using Discrete Cosine Transform for Global and Local Features," Proceedings of the International Conference on Recent Advancements in Electrical, Electronics and Control Engineering, 2011.

[7] M.D. Dhameliya and J. P Chaudhari, "A Multimodal Biometric Recognition System based on Fusion of Palmprint and Fingerprint," International Journal of Engineering Trends and Technology (IJETT) - Volume4, Issue5, May 2013.

[8] B.G. Patil and S. Subbaraman, "SVD-EBP Algorithm for Iris Pattern Recognition," arXiv preprint arXiv: 1202-2023, 2012.

[9] A.J. Laub, Matrix analysis for scientists and engineers: Siam, 2005.

[10] G. Madhavilatha, A. Mallaiah and T. Venkata, "Advanced Speaker Verification System Using Wavelets," International Journal of Engineering Research and Applications (IJERA), vol. 1, no. 3, 2011.

[11] M.A. El-Sayed and M.A. Khafagy, "An Identification System Using Eye Detection Based on Wavelets and Neural Networks," arXiv preprint arXiv: 1401.5108, 2014.

[12] M.C. Hanumantharaju "Natural Color Image Enhancement Based on Modified Multiscale Retinex Algorithm and Performance Evaluation UsingWavelet Energy," Springer, 2013.

[13] V. Shinde and V. Mane, "Pattern Recognition using Multilevel Wavelet Transform" International Journal of Computer Applications, vol. 49, no. 2, 2012.

[14] J. Haryati and R.D. Athiar, "A Review of Multibiometric System with Fusion Strategies and Weighting Factor," International Journal of Computer Science Engineering (IJCSE), Vol. 2 No.04 July 2013.

[15] O. M. Aly, et al.," An Adaptive Multimodal Biometrics System using PSO," (IJACSA) International Journal of Advanced Computer Science and Applications, Vol. 4, No.7, 2013.

[16] L. Alzoubiady, "Multibiometric Personal Identification based on Hybrid Artificial Intelligence Technique using Serial Mode Architecture," International Journal of Computer Applications, vol. 87, no. 18, 2014.

[17] M. Singh, T.S. Panag, "Heterogeneous Multimodal Biometric System with Fuzzy Vault Template Security," (IJARCSSE) International Journal of Advanced Research in Computer Science and Software Engineering, vol. 4, no. 7, 2014.

Author Biography

Mohammed Najm Abdullah: Received the B.Sc. degree in 1983 in Electrical Engineering from Collage of Engineering, University of Baghdad, Baghdad, Iraq. He is received the M. Sc. degree in Electronic and Communication Engineering from the same Collage of Engineering/University of Baghdad in 1989. He is received the Ph.D. in 2002 in Electronic Engineering from Al-Rasheed Collage of Engineering and sciences, University of Technology, Baghdad, Iraq. Now, He is an Assistant Professor in the Department of Computer Engineering in the University of Technology, Baghdad, Iraq. His area of interests is Air-borne computer, DSP Software and Hardware, and PC- Interfacing, e-learning, Information Systems Management, Wireless sensor Networks.

Hassan Awheed Jeiad: Received the B.Sc. degree in 1989 in Electronics and Communications Engineering from University of Technology, Baghdad, Iraq. He is received the M. Sc. degree in Communication Engineering from University of Technology, Baghdad, Iraq in 1999. He is received the Ph.D. in 2006 in Computer Engineering from University of Technology, Baghdad, Iraq. He is currently a lecturer in the Department of Computer Engineering in the University of Technology, Baghdad, Iraq. His research interests include computer architecture, microprocessors, computer networks, multimedia, adaptive systems, and information systems.

Reem Ali Hussein: Received the B.Sc. degree in 2007 in Computer Engineering from University of Technology/ Baghdad. Received the M. Sc. degree in Computer

Engineering from University of Technology/Baghdad in 2015. She is currently an assistant lecturer in Laser and Optoelectronic Engineering department in University of Technology, Baghdad, Iraq. Her research interests include Adaptive Systems, Information Technology, and Database Systems.