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Face Recognition Using Eigen-Wavelet-Face Method

Sura Abdulkareem Abdulrahman[1*] Bayan Mahdi Sabbar[2]

[1,2]Information and Communication Engineering Department,

College of Information Engineering, Al-Nahrain University –Iraq

*Email sura_abdulkarim@yahoo.com, dr_b2012@yahoo.co.uk

Abstract

This work is concerned with investigation for face recognition methods suitable for different environments. Eigenface method based on Principle Component Analysis (PCA) is modified here by operating on wavelet transformed face image to extract recognition features in a hybrid scheme called Eigen-Wavelet-Face aiming to improve the recognition rate and/or complexity. Four standard face image databases are used in the work. The databases have different parameters related to size, type, expressions, lighting, orientation, and the number of images per person. The original Eigenface and suggested Discrete Wavelet Transform (DWT) face recognition methods are also used in the work for the sake of comparison. The results showed that the Eigenface method is a time consuming due to its huge computations. For databases having large number of training images and variations, the proposed hybrid method achieved 100% recognition rate, while for those databases with smaller training sets DWT method obtained the best recognition rate of 95% under favorite condition.

Key words: Face recognition, Eigenface, PCA, DWT, Feature extraction.

1- Introduction

Face recognition usually consists of preprocessing stage, face feature extraction, and classification. The preprocessing may covered different operations such as cropping, background removal, color conversion, filtering, and histogram equalization. Its aim to present the input image in a best way to the feature extraction process. Features of an image face are the core for the recognition process and may involve complex operations. Classification is the final stage where a recognition decision is obtained based on some sort of metric measure.

Face recognition provides feasible technologies for a range of applications in identity authentication, access control, commercial and law enforcement. Since the 1960's there are many efforts towards finding the best recognition methods that work perfectly in different environments. The use of Eigenfaces based on PCA in face recognition method appeared in 1990 [1,2] and later used in face detection and tracking [3]. They measured the recognition performance under varying conditions of light, size and head orientation using their own created database. After that Eigenface approach had a dominant role as a basis for many face recognition methods. Improved recognition rate is obtained by an automated recognition method based on DWT/PCA using Haar, Biorthogonal-9/7 , and Coiflet-3 wavelet with 1,2, and 3 levels [4]. Relatively, better recognition results are obtained when combining PCA with neural network classifier [5]. In 2014, genetic algorithm is linked with PCA to find the optimal underlying distribution of the training images, which is more suitable for classification [6]. They found that accuracy and classification time are more superior compared to PCA if used by itself. Back Propagation Neural Network is used with PCA to ease the task of face recognition where face features are compressed by Discrete Cosine Transform (DCT). As a result an acceptable recognition rate of more than 90% is achieved [7].

In this paper a hybrid Eigen-Wavelet-Face is proposed for the used databases aiming to improve the recognition rate and/or complexity. The remaining parts of the paper are: recognition methods, the used databases and preprocessing, and test results.

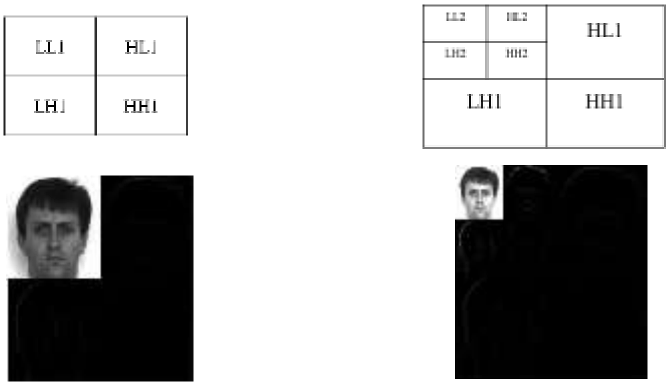
2- Recognition Methods

Three face recognition methods are used in the work, classical Eigenface method, DWT, and the proposed Eigen-Wavelet-Face method. The first two methods are briefed here followed by the details analysis of the proposed method.

Eigenface method uses the PCA technique which transforms the training images into Eigenfaces. First, each face image is converted into 1D image vector. The average of these face images vectors is calculated and then subtracted from each image. The Eigenfaces are resulted by calculating the eigenvectors of the covariance matrix determined by the normalized face images. The centered images are projected into face space by multiplying it with the Eigenfaces. The number of Eigenfaces (Eigen vectors) corresponding to the largest K eigenvalues are usually preserved. K here is the design parameter for this method. The projected images form the feature vectors for the recognition process. The detailed processing of face recognition using Eigenface method can be found elsewhere [3].

DWT is an efficient implementation of wavelet decomposition and can be used in face recognition due to its efficient multi-resolution analysis [8]. In the present work 2D-DWT is performed where each face image is decomposed into four subband images ,three details subbands and one approximation subband when using 1-level decomposition. Only approximation subband LL1 is used to produce the next level (2^{nd} level) of decomposition if required. Figure 1 shows the decomposed subbands for both 1-level and 2-level DWT, respectively. For the 1^{st} level these subbands are called LL, LH, HL, and HH. LL is considered as the smoothing image of the original image which contains the most information of the original image while the other subbands contain the details [9]. Thus, LL1 and LL2 are the only subbands considered in feature extraction for the case of 1-level and 2-level decompositions, respectively. The wavelet coefficients are considered as the image feature. Daubechies wavelet is used in the decomposition. Three different orders (filter length) of Daubechies wavelet are used to see its effect on the recognition rate. These orders are 2, 6 and 14, and known here as Db2, Db6 and Db14 respectively.

The Proposed Eigen-Wavelet-Face or hybrid method is suggested here to overcome the Eigenface method limitations: huge computations and sensitivity of recognition rate to illumination and orientation. The intention here is to improve the recognition for non-standard (or real) face image database as in the case of the present work. The aim of the proposed hybrid method is to overcome Eigenface limitations by considering only LL subband of DWT in PCA processing of Eigenface. The proposed method here starts by applying wavelet transform to the input image using 2D-



(a) 1-Level (b) 2-Level

Figure 1 Decomposed subbands for both 1-level and 2-level DWT

DWT. This is followed by applying Eigenface method. Figure 2 shows the proposed hybrid method. The main steps for hybrid method are:

Step-1 Decompose the M input images F with dimension of $N_x \times N_y$ using 2D DWT to get LL1, LH1, HL1 and HH1. Only LL1 will be used in the next steps if 1-level is used, while 2D DWT is applied again to LL1 subband for 2-level decomposition to get LL2 subband.

Step-2 Choose 1-level (LL1) or 2-level (LL2) output and convert it into image feature vector B_i (for i=1,2 . . .M) representing the wavelet coefficients of the LL subbands. The dimensionality of B_i depends on the decomposition level used. This dimensionality is assumed to be given by the number is N.

Step-3 Calculate the average of the face image coefficients vectors Ψ using:

$$\Psi = \frac{1}{M}\sum_{i=1}^{M} B_i \qquad (1)$$

Step-4 The average is subtracted from each face image coefficients vector using:

$$\Phi_i = B_i - \Psi \qquad (2)$$

The resulting vectors { Φ_i } are used to construct the matrix A of size according to decomposition level. The matrix A is called the centered images. The matrix A is given by:

$$A = [\Phi_1 \Phi_2 \Phi_3 \cdots \Phi_M] \qquad (3)$$

Step-5 Calculate the covariance matrix C, where:

$$C = AA^T \qquad (4)$$

Then the eigenvectors of the matrix $A'^T A'$ having size of $M \times M$ is calculated. Now:

$$A^T A\, v_i = \lambda v_i \qquad (5)$$

$$AA^T A v_i = A \lambda_i v_i \qquad (6)$$

$$A^T A\, (A v_i) = \lambda_i\, (A v_i) \qquad (7)$$

with $u_i = Av_i$ is the eigenvector of A^TA as in the original Eigenface method, using the fact that eigenvalues of both AA^T and A^TA are the same.

Step-6 Now the method keeps only K eigenvectors, corresponding to the K largest eigenvalues. The centered images $\{\Phi_i\}$ are projected into face coefficient space by multiplying it with the chosen K Eigenfaces $\{u_i\}$. Thus each projected image coefficients are given by:

$$w_j = u_j^T \Phi_i \qquad \text{for } j=1,2,\ldots.K. \tag{8}$$

The final weight vector Ω_i covering all projected images is given by:

$$\Omega_i = \begin{bmatrix} w_1^i \\ w_2^i \\ \cdot \\ \cdot \\ w_K^i \end{bmatrix} \qquad \text{for } i=1,2,\ldots M \tag{9}$$

This projected image coefficients form the feature vector for recognition.

Step-7 Recognizing of an unknown face

To recognize an unknown face the coefficient vector B_{un} is calculated then the centered coefficient are determined by:

$$\Phi_{un} = B_{un} - \Psi \tag{10}$$

The centered coefficients image of the unknown face Φ_{un} is projected into face space to calculate its weight vector w_i:

$$w_i = u_i^T \Phi_{un} \tag{11}$$

to form the unknown weight vector:

$$\Omega_{un} = \begin{bmatrix} w_1 \\ w_2 \\ \cdot \\ \cdot \\ w_K \end{bmatrix} \tag{12}$$

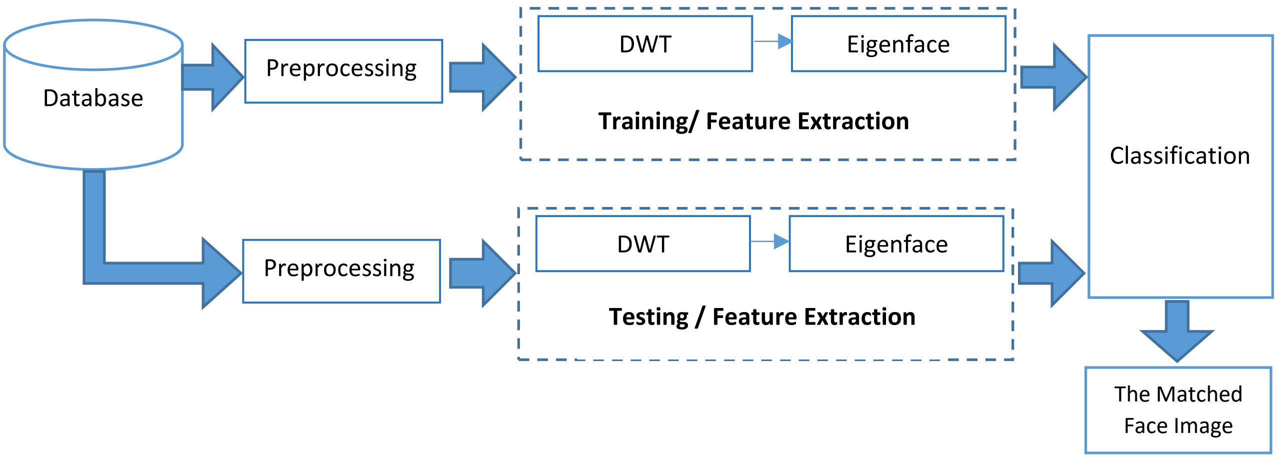


Figure 2 Block diagram of proposed Hybrid method

3- The Used Databases and Preprocessing

The input databases are carefully chosen and categorized into: four standard face images databases (DB-1 to DB-4) that are widely used by different researchers around the world. DB-1 contains Faces94, Faces95, Faces96, and grimace known databases [10]. In DB-1 there are 393 different individuals with ten images for each one person resulting in 393x10= 3930 training images. An additional image for each person is taken as the test image. Figure 3 shows a sample of DB-1. DB-2 is created using DB-1 but with five images per person being used, thus resulting in 393x5=1965 training images and 393 test images. The third database DB-3 contains images with high variations in expressions and orientations (ORL database [11]). Only three images per each person are considered from the original database. These are selected with high variability to make it difficult for recognition. Thus a total of 40x3=120 training images are used with 40 test images. Figure 4 shows a sample of DB-3. DB-4 is a mix of DB-1 and DB-3 databases. Seventy persons from DB-1 and forty persons from DB-3 are chosen to make the training set. Three images per person are selected, thus a total of 110x3=330 training images are used in DB-4. The number of test images is 62 in this database.

In order to enhance the face recognition performance, many preprocessing steps may be performed. The only preprocessing steps required for DB1-DB4 database are resizing and conversion of RGB to gray scale images.

Test Image

Training Images

Figure 3 Sample of DB-1

Training Images **Test Image**

Figure 4 Sample of DB-3

4- Test Results

The results of the tests are given by the recognition rate. It is the percentage of dividing the number of correctly identified images to the total number of test face images. This is given by:

$$Recognition\ Rate = \frac{number\ of\ correctly\ identified\ images}{The\ total\ number\ of\ test\ images} \qquad (13)$$

Euclidean Distance is used to classify and obtain the matching face. It is widely used because it is faster than other classifiers and simple. Euclidean Distance is the root of square differences between the coordinates of a pair of subjects. The Euclidean Distance (ED) for N training images can be computed as shown below:

$$ED_i(X,Y)=\sqrt{\sum_{i=1}^{N}(X_i-Y)^2} \quad (14)$$

where $\{X_i\}$ are the training images and Y is a test image.

Tests are performed to evaluate the performance of the three suggested methods, a comparison of the results are performed for all used databases. Table 1 shows that all methods provided best recognition rate with DB-1. This is due to the large size of training database where in DB-1 10 face images per person are available covering all expressions and orientations with best condition of illumination and photo shooting. The results reached 100% for the case of 2-level for Eigen-Wavelet-Face method with all orders and one case for 1-level with order 6. Wavelet and Eigenface come close to achieve 100% as well. Relatively, a good recognition rates also obtained when operating with DB-2. This database is formed from DB-1 with only 5 face images per person. Here, the most of the best results are obtained with DWT method rather than with Eigenface or Eigen-Wavelet-Face method. When DB-3 and DB-4 are considered, the least recognition rates are given by Eigenface method. On the other hand DWT method shows a good behavior for almost all levels and orders of wavelet function. The hybrid method shows moderate recognition rates for most orders and levels tested here with some exceptions (as in the cases of 1-level with Db2 and 2-level with Db14). Both DB-3 and DB-4 have 3 images per person, which is considered to be big limitation when having small database with large variations. The number of Eigenfaces (K) affects the recognition rate, so a test is performed with different K. The results of Eigenface method with DB-2 is shown in Figure 5. For K between 5 and 20 there is gradual increase in recognition rate, while after K=20, it remains at its maximum value of 92.37%.

Table 1 Recognition rates for all methods.

Database	**No. of Training Samples**	**Eigenface Method**	**Decom. level**	**DWT Method**			**Eigen-Wavelet-Face Method**		
				Db2	**Db6**	**Db14**	**Db2**	**Db6**	**Db14**
DB-1	393x10=3930	99.75%	1	98.98%	99.24%	99.49%	99.76%	100%	99.76%
			2	99.24%	98.98%	99.23%	100%	100%	100%
DB-2	393x5=1965	92.37%	1	93.12%	93.63%	93.63%	92.11%	92.11%	92.62%
			2	93.12%	93.38%	94.14%	92.36%	92.62%	93.12%
DB-3	40x3=120	80.00%	1	92.50%	92.50%	90.00%	80.00%	85.00%	87.50%
			2	92.50%	95.00%	90.00%	82.50%	90.00%	80.00%
DB-4	110x3=330	83.87%	1	95.16%	95.16%	91.93%	83.87%	91.93%	87.09%
			2	95.16%	95.16%	91.93%	88.70%	95.16%	83.87%

5- Conclusions

The proposed Eigen-Wavelet-Face hybrid method achieved 100% recognition rate for databases having large number of training images and variations as in DB-1 used in the work. For databases having smaller training sets DWT method obtained the best recognition rate (about 95% under favorite condition). Eigenface method provides good recognition rate but needs extensive computations based on PCA. DWT method needs fewer computations compared to Eigenface.

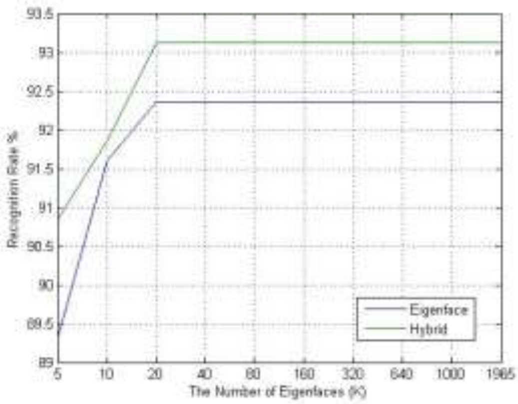


Figure 5 Recognition rate for various K of DB-2

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