Face Recognition Based on Correlation and Back Propagation Neural Networks

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Abstract

This paper aims to present the design and implementation of a face recognition system. Biometric identification is the automated technique of measuring the biological data. The term biometrics is commonly used today to authenticate a person by analyzing his/her physical characteristics and comparing them to a database such as fingerprint recognition, retinal scanning, face recognition etc. Face recognition is one of the biometric techniques that are used for identifying and verifying the identity of a person. The design methodology of the face recognition system (FRS)in this paper includes two main steps. The first step is the extraction of the image's features and the second one is the recognition according to the classification of patterns. This paper introduces the design and implementation of three approaches of face recognition system. **The first approach** includes face detection, preprocessing of ROI (Region of Interest), features extracting (nose detection, mouth detection and eyes detection), geometrical transformation and cropping (crop the image from start of eyes to mouth). **The second approach** has main steps such as face detection, features extraction. From the feature extraction, we have 11 measurements of each person. The recognition step for both approaches is performed by computing the correlation coefficients between the test image's geometrical measurements and training database. The system will accept a facial image of the person as authenticated if the percentage of correlation is greater than a chosen threshold otherwise it rejects it. **The third approach** has the same steps of the first approach except the recognition step is performed by Back propagation neural network (BPNN).These three approaches are implemented using MATLAB. The recognition rate of the proposed three approaches has achieved an accuracy level more than 90% of other approaches.

Keywords: *Biometric, Face recognition, Face detection, Correlation Coefficient, Back Propagation Neural Network.*

1. Introduction and Problem

Biometrics as a terminology refers to the combination of the Greece words (Bio) and (Metrics) which mean ''life measurements'' [1]. The goal of a biometric is either automatic identification or verification of identities of persons. It means that the input data (images, speech or videos) is given to the system and it compares this input to a database [2].The system is thus used for several security purposes such as identification/verification of one's identity, access control, user authorization, data protection and security management [3]. A biometric may be physiological or behavioral. Physiological biometric detects the physical features of a person and uses resources such as (retina, iris scans, fingerprints and face recognition). Behavioral biometric is based on a user's behavior and includes the analysis of information like the shape and flow of one's handwriting, timing of keystrokes [4]. Figure1 indicates the two types of biometrics [4].

Face recognition is one of the non-intrusive biometric techniques commonly used for verification and authentication [5]. Faces are one of many forms of biometrics identification. These faces are used to identify and verify their identities. Face recognition is the automated method of differentiating between two human faces [6]. The facial features (such as eyes, nose and mouth) of human achieved a very important role in the recognition. Face recognition is the most popular technique in biometric recognition area [7, 8, 9]. Many algorithms and methods have been proposed for face recognition. These methods differ in the number of features processing tools which may affect the system performance. The objective of this paper is to present a face recognition system that applies and compares three solutions to achieve face detecting and recognizing performance. **The first solution** uses the Viola and Jones method for face detection. It is based on achieving a high face detection rate with the smallest amount of time. This detector uses features which are calculated using 'Integral Image' [10]. Because of the main problem of face recognition such as the variation of face images, we carry out a preprocessing stage for the ROI (Region of Interest). **The second solution** is the face localization in which the detection of face region is done from the image, and then the feature extraction is carried out (nose detection, mouth detection, eyes detection). From the extracted features, we can obtain 11 measurements for each person. **The third solution** uses the neural network as the recognition method for the same steps of the first solution. The neural networks are a parallel distributed information-processing structure consisting of set of processing elements (nodes) interconnected via set of links (unidirectional signal channels) called connections [11]. There are two main problems of neural networks pattern recognition. The first problem is designing a suitable network topology (i.e., indicate the architecture of the network, the form of connection, the number of neurons and its weights, etc.). The second problem is finding a fast and effective algorithm for invariance extraction.

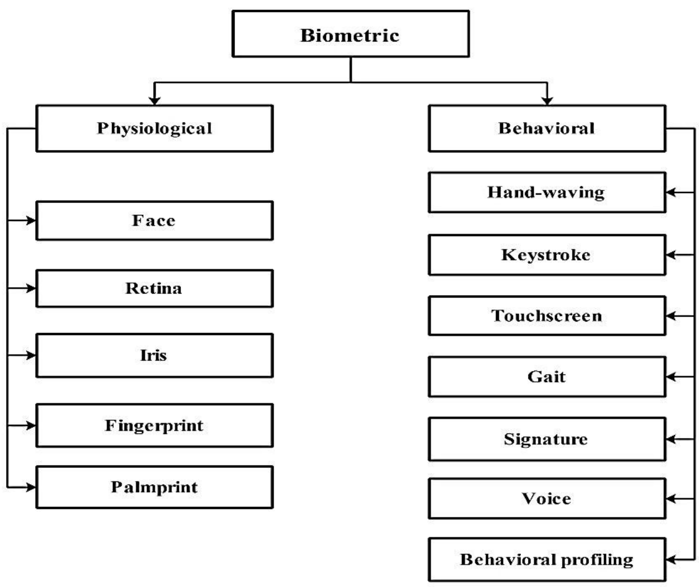


Figure.1 The two types of biometrics [4]

The rest of this paper is organized as follows: Section 2 is a literature review which presents the previous related work in the same problem; Section.3 presents how we create the different databases to use in the recognition steps and proposes a real illustrative example in each step. Section.4 clarifies different methods that we use here in the recognition part. Section .5presents some experimental results of the used approaches in the face recognition system. Section.6discussesthe results and compares them with the other approaches of face recognition systems. We sum up in conclusions in section.7.Finally, we introduce some of the future work points in section.8 and a list of the used references is given at the end of the paper.

2. A literature Review

In this section, we present how the problem of designing face recognition systems has been treated by the researchers. There are many different recognition methods. We try here to summarize some of them. Some researchers began with preprocessing the input image and then they used the back propagation neural network algorithm recursively until the M.S.E (i.e., Mean Squared Error) reached a value of 0.000100 [12]. Other researchers proposed a face recognition system using neural network for mobile devices [13]. The Neural network has been studied in the past few years and become one of the major fields in face recognition. Neural network can be applied for such problems [14 - 16]. The main steps of face recognition were the face detection, feature extraction, feature dimension reduction using PCA. The recognition is performed by two neural networks which are the Back Propagation Neural Network (BPNN) and the Radial Basis Function (RBF).It achieved accuracy levels more than 90%. Another system was proposed based on face detection, feature extraction [17]. From the features, we calculated six distances as the input of neural network. The recognition methods are BPN with accuracy 96.66% and BPN+RBF with accuracy 98.88%. A design and implementation of face recognition system for mobile phone platform was proposed including face detection, eye detection, applying a set of preprocessing for ROI and the recognition methods which are: the Principal Component Analysis (PCA) that achieves an accuracy of 93.8% and the Linear Discriminant Analysis (LDA) that achieves an accuracy of 96% [18]. Geometrical measurements such as (eyes nose and mouth) are extracted from the person's face using Fast Wavelet transform and multi-scale that solves the main problems of face recognition such as rotation and expression [19]. This system achieves recognition accuracy rate of 95% which is greater than the rates of other approaches. A face recognition system is based on back propagation neural network and on applying PCA to reduce the dimension of face recognition and the recognition step is done by BPNN. It has a face recognition accuracy rate more than 90% [20].

3. Database Construction

Face recognition consists of two main parts. The first one is the face detection to create database. This database is used to decide if the person is known or not. The second part is the face recognition. Face detection is an estimation of the location, scale of the face and localizing facial landmarks (e.g., eyes, nose, mouth, and facial outline). Face detection can be seen as a task of distinguishing between the face and non-face in the image. Face recognition is a task of distinguishing between faces of different individuals according to the face database that is stored in the system. In this section, we will explain two approaches of face recognition systems. These systems have the same recognition method, but they are different in the features extraction method. Main steps to create database is illustrated in flow chart in Figure. 2

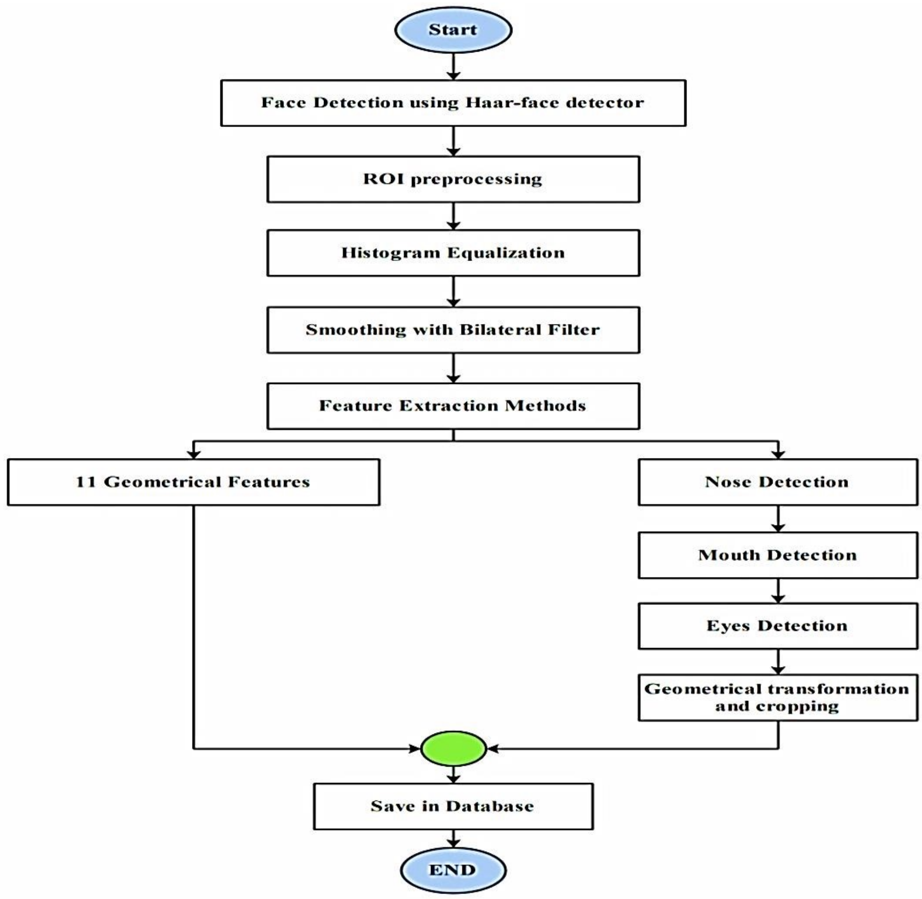


Figure.2 Database creation steps

3.1. Face Detection

It is the first step in the system. For face detection, there are two types of face detectors: the first one is the Haar-based face detector and the second is the Local Binary Pattern (LBP) face detector. In this system, we use the Haar-based face detector as a face detector for two reasons: (1) it is more powerful to distinguish between face and non-face classifiers (2) it is more efficient than other methods [21]. Figure.3 explains the Haar-like face detection algorithm. It takes an input image with dimensions 400x300 pixels from a live camera and applies the Haar-face detection on this image. The detection technique is based on the idea of wavelet template that recognizes the shape of an object according to the subset of wavelet coefficients of the input image [22]. Blocks diagram of face detection process is shown in Figure.3

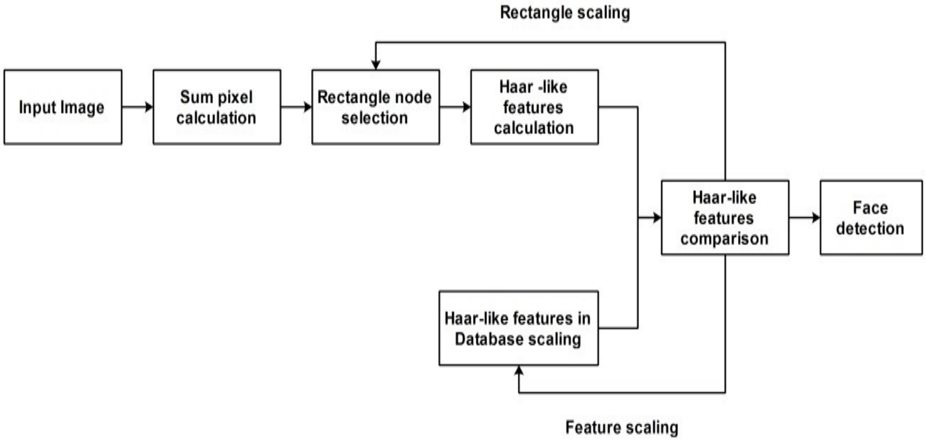


Figure 3 Diagram of the Haar-face detection algorithm

The operations of face detection are explained as follows:

(a) Input Image: This is to take an image of the person we want to detect his/her face. This is shown in Figure.4.

Figure.4 Input image

(b) Sum of the pixels: We calculate the sum of intensity values of an image by the following formula:

$$ii(x, y) = \sum_{\substack{x' \leq x \\ y' \leq y}} i(x', y') \quad (1)$$

Where: i(x, y) is the intensity of the gray scale image at pixel (x, y).

(c) Rectangle node selection: After indicates the four points of rectangle (A, B, C and D). We make summation of intensity pixels of rectangular area ABCD can be calculated from the Equation. The illustration parts of Eq.(2) is indicated in Figure.5

$$\sum_{(x,y)\in ABCD} i(x, y) = ii(D) + ii(A) - ii(B) - ii(C) \quad (2)$$

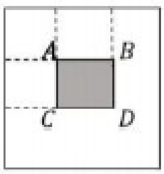


Figure.5 Rectangle area of ABCD

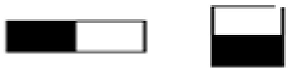
(d) The Haar like features calculation: Examples of the haar-like features are shown in Figure 6 including 2-rectangle filter, 3-rectangle and 4-rectangle. The sefeatures can be applied to the original image from the Eq.(3)

f=[ii(D)+ii(A)-ii(B)-ii(C)]—[ii(F)+ii(C)+ii(D)-ii(E)] (3)

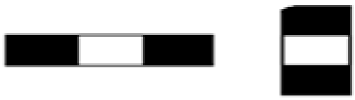
(e) The Haar like Features comparison: To test the features and train the classifier, we use the Ad boost as a classifier and it can be defined as:

$$h(x, f, p, \theta) = \begin{cases} 1 & if\ pf(x) < p\theta \\ 0 & otherwise \end{cases} \quad (4)$$

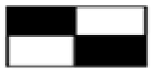
where: f is the selected features from the set of features in Figure.5, p is the polarity, θ is the chosen threshold and x is the training sub window of size 24x24 pixel [23]. Figure. 7illustrates face detection step in real example.



(a) 2-rectangle



(b) 3-rectangle



(c) 4-retangle

Figure.6 the Haar-like features face detection

Figure.7 Face detection

3.2. ROI preprocessing

After the face detection step is done, we need to enhance the detected image. This enhancement includes two types of enhancement:

(a) Histogram-equalization of face detection

It is used to map the image pixel intensity to a histogram equalized value as follows:

$$Sk = \sum_{i=0}^{k} \frac{ni}{n}, k = 0,1,2, \dots \dots, L - 1 \quad (5)$$

where S_k is the histogram equalized intensity value, k_{th} is intensity value, L is the total number of intensity values of the original and target images, n is the number of pixels in the original and target image, and n_i is the number of image pixels that have intensity value iin the original image. After applying the histogram equalization, face intensities look more uniform and the contrast is dramatically improved [24]. The histogram equalization process consists of four steps:

1. Find the running sum of the histogram values.
2. Normalize this value in step 1 by dividing the sum by the total number of pixels.
3. Multiply the values in step 2 by the maximum gray level value and round.

4. Map the original gray level values to the results in step 3 using one-to-one correspondence. Figure.8 shows the first enhancement of face detection using histogram equalization.

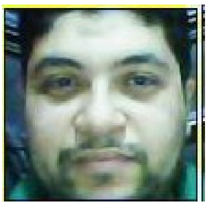


Figure.8 face detection 1st preprocessing method

(b) Smoothing with bilateral filters

After applying the histogram equalization, we apply bilateral filtering on the detected image to make it very smooth, to preserve the sharp edges and to reduce the noise. The bilateral filter is given by:

$$J_s=\frac{1}{Ks}\sum_{p\in\Omega} f\,(p-s)\,g(Ip-Is)Ip \qquad (6)$$

$$K_s=\sum_{p\in\Omega} f(p-s)g(Ip-Is) \qquad (7)$$

where s is the coordinate of the center pixel, p is the current pixel, Ω is the set of all pixel coordinates, J_s is the pixel intensity, I_s and I_p are intensities of p and s, f(p-s) is the geometric distance between p and s and $g(I_p-I_s)$ is photometric similarity between I_p and I_s [25]. The filtering process using bilateral filter consists of three steps:

1. Establish the parameter values.
2. Filter the Intensity Image
3. Compute Gradient MagnitudeFigure.9 presents the second enhancement of face detection after applying bilateral filter.

Figure.9 face detection 2nd preprocessing method

3.3. Facial Features Extraction

After applying ROI on the face image, the step of features extraction of person. These features are used in pattern recognition model of the faces to classify them in the process of recognition part. There are two methods of features extraction are illustrated below:

3.3.1. ROI Features Extraction

We use the computer vision tools to extract the facial discriminative features and information (such as the position of eyes, mouth and nose) from facial images and it extracts the main facial features This extraction is done by the previous steps that shown above [26].

(a) Nose Detection

Computer vision can detect the nose by the position of it where the vertical line represents the center of the nose region (ROI). Detect the nose as a rectangle region was also investigated and then determined this region (ROI) in the human face.Figure.10 illustrates the first facial feature is nose detection

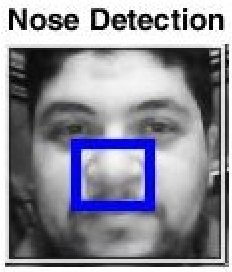


Figure.10 Nose detection

(b) Mouth Detection

Mouth detection using the computer vision is based on the mouth figure approach to detect the location of mouth. Equations that indicate the mouth figure and mouth repairing figure are illustrated in (8, 9). Figure.11 illustrates the second facial feature is the Mouth detection.

$$\text{MouthMap}=C_r^2\,(C_r^2-\eta\frac{Cb}{Cr}) \tag{8}$$

$$\text{EMouthMap}=S*(C_r^2(C_r^2-\eta\frac{Cb}{Cr})^2) \tag{9}$$

$$\eta= 0.95*\frac{\frac{1}{N}\sum \mathrm{Cr2}}{\frac{1}{N}\sum\frac{cr}{cb}} \tag{10}$$

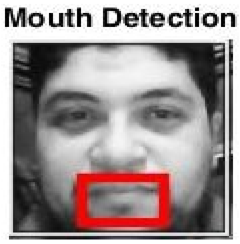


Figure.11 Mouth detection

(c) Eyes Detection

We used the Eye Map algorithm to detect the location of eyes region. This method builds two Eye Maps are Eye MapC and EyeMapL; then, these two maps are combined into a single map. Experiments find high C_b components and low C_r components around the eyes, and EyeMapC is calculated as follows:

$$\text{EyeMapC}=[C_b^2+(255-C_r)^2+\frac{Cb}{Cr}]\,/3 \tag{11}$$

Where C_b^2 , $(255-C_r)$ and $C_b=\frac{\mathrm{Cb}}{\mathrm{Cr}}$ are normalized in the range [0,255]. EyeMapL is calculated as follows:

$$\text{EyeMapL}=\frac{Y(x,y)\oplus g(x,y)}{Y(x,y)\ominus g(x,y)} \tag{12}$$

where g(x,y) represents the ball structuring element, ⊕ and Θ denote the gray scale dilation and erosion operations . EyeMap is obtained by multiplying EyeMapC and EyeMapL as shown in the Equation.(13).

$$EyeMap=EyeMapL x EyeMapC \quad (13)$$

Figure.12 illustrates the third Facial feature is the eyes detection

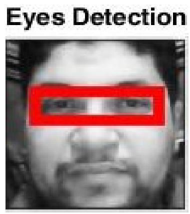


Figure.12 eyes detection

3.3.2. Geometrical feature measurements

These measurements are computed based on the facial parts locations as follows:

Assume the pixel of the center of the left eye is taken as (x_1,y_1), the pixel of the center of the right eye is taken as (x_2,y_2), the pixel of the center of the nose is taken as (x_3,y_3) and the pixel of the center of the mouth is taken as (x_4,y_4). The distance between these points is calculated by distance calculation algorithm in the formula [27]:

$$Distance = Sqrt((x_i-x_j)^2)+((y_i-y_j)^2) \quad (14)$$

By applying the previous formula for i, j are 1,2,3,4, there are six distances are obtained as:

(a) Distance between the centers of eyes ball (d_1).
(b) Distance between the right eye center to the nose center (d_2).
(c) Distance between the left eye center to the nose center (d_3).
(d) Distance between the right eye center to the mouth center (d_4).
(e) Distance between the left eye center to the mouth center (d_5).
(f) Distance between the nose center to the mouth center (d_6).

There are more five measurements which can be computed for the different parts of: Nose width, Mouth height, Mouth width, Face height and Face width. Thus, there are 11 measurements that can be computed for each person. These values are stored in a (.xlsx excel sheet) to create a database for the authorized persons. In the recognition step, we use these measurements to know if the person is authorized or not. We will propose real example to indicate how we obtain 11 geometrical measurements as shown below. After the face detection of the person. The second step is the features extraction as shown in Figure. 13 where number (1) is the left eye detection with pixel (x_1,x_2), (2) is the right eye detection with pixel (x_2,y_2), number (3) is the nose detection with pixel (x_3,y_3) and number(4) is the mouth detection with pixel (x_4,y_4)

After obtaining previous pixels, we apply in the distance calculation algorithm to obtain the 11 measurements. These measurements are shown in Table.1.

To indicate the five dimensions, indicate the nose width of person in Figure.14. It indicate Mouth width/height in Figure.15 and it indicates face width/height from the cropped face in Figure.16. The five dimensions that calculated from the previous cropped images are displayed in Table.2

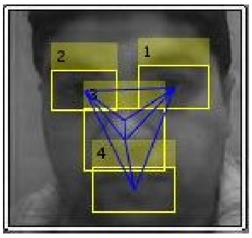


Figure.13 Features Extraction

Figure.14 Nose detection

Figure.15 Mouth detection

Figure.16 cropped face

Table.1 Distances measurement features of each person

D1	D2	D3	D4	D5	D6
61.502	46.3087	37.5366	105.0012	81.1126	84.5473

Table.2 Dimensions features of each person

Nose width	Mouth width	Mouth height	Face width	Face height
36	52	27	97	80

3.4. Geometrical transformation and cropping

After the facial features extraction, we crop the image from the alignment of eyes to the end of mouth. The final image has 180x200 pixels and it is stored in the image database which is used in the recognition step. Before using the crop function, there are some steps to be applied:

(a) Input the face image.
(b) Detect the facial features such as (nose, mouth and eyes).
(c) Determine the cropping parameters such as the start position of cropping, width of cropped image and height of cropped image. To make this step, we used the Matlab function (imcrop) to make manual cropping. Syntax of cropping in the formula:

$$I_2\text{=imcrop } (I_1, [x_1\ y_1\ x_2\ y_2 \qquad (15)$$

Where I_2 is the cropped image (output), I_1 is the original image (input), (x_1,y_1) is the first point at this coordinate (x_1,y_1) , x_2 is the width of the cropped image and y_2 is the height of the cropped image. This step is shown in Figure. 17

Figure.17 cropped image

The cropping image is done as the following scenario. After obtaining the cropping rectangle of the image, we will start from the beginning of image pixel by pixel. In the first pixel in the image, indicates the position of this pixel (x,y). If this position of this pixel not equal to the first point coordinate (x_1,y_1) of the cropping rectangle, assign this pixel in black color and move to the second pixel in the image. If this position of the second pixel equal to the first point coordinate (x_1,y_1) of the cropping rectangle, the cropping rectangle dimensions would assign to white color. All the remaining pixels out of the cropping rectangle are black color.

3.5. Save in Database

This database is done using Matlab. It is used as a reference to compare between persons to know if the person is an authorized user in the system or not. Database is an intermediate stage between enrollment and verification stages. This database consists of images of a number of persons where each person has 10 images. These images are in different light backgrounds, positions and shadows and we will see the effect on them later in section.7.This database can be updated to include as many persons as needed. Each image needs to go through the steps of processing until we reach the final image of each person. There are two samples of database. The first database contains the cropped images from the start of eyes to the end of mouth. The images are stored in the database with dimension 180x200 pixels. Figure.18 illustrates a sample of image database. After the creation of image database, it is converted to a (.MAT) file with dimension of 1xn where n is the number of images in the database.

The second database is Excel sheet database that consists of n rows and 12 columns. The n rows are the number of authorized person that access the person and the 11 measurements is the geometrical features. Table.3 illustrates sample of the second database.

4. Pattern Recognition

Steps of the face pattern recognition are the same like in section 3 except for the fifth step. Instead of saving the face features, a face recognition is carried out. A complete flow chart that illustrates the face recognition system is shown in Figure. 19. There are different approaches for face pattern recognition and each approach uses a different method as shown figure 19.

4.1. The first approach

It consists of face detection, Convert the face detection in gray level, Extract 11 geometrical measurements. The last step is the recognition step is performed by comparing the 11 measurements of the person who wants to access the system with the (.xlsx) database which contains the measurements of the authorized people. The relation between the training and testing parts for 1st face recognition system is shown in Figure 20. If the correlation coefficient is equal to or greater than a certain threshold, the system will accept the person as an authorized one and otherwise the system will refuse the person.

4.2. The Second approach

This approach consists of the following steps Face detection, ROI preprocessing with different methods, Features extraction, geometrical transformation and cropping and the final step is the recognition. This step is performed by comparing the cropped image by all training database images. This relation is shown in Figure 21. This is used to compute the correlation coefficient between them. A mathematical equation of correlation coefficient is as in Eq (10).

$$\text{Correlation coefficient} = \frac{\sum_m \sum_n (A_{mn} - \bar{A})(B_{mn} - \bar{B})}{\sqrt{\left(\sum_m \sum_n (A_{mn} - \bar{A})^2\right)\left(\sum_m \sum_n (B_{mn} - \bar{B})^2\right)}} \qquad (16)$$

Where A'= means (A). If the correlation coefficient is equal to or greater than a certain threshold, the system will accept the person as an authorized one and otherwise the system will refuse the person.

4.3. The Third approach

This approach consists of main steps face detection, ROI preprocessing, Feature Extraction, Geometrical transformation and cropping. All these stages are explained in details in the previous section 3.1. The remaining stages of this approach are cropped image reduction size and the recognition part is done using back propagation neural network. It is identifying the identity of the person if he authorized or not.

4.3.1. Image reduction size

The cropped face image is obtained from the start of eyes to the end of mouth. The dimension of the cropped image is 180x200 pixels. This represents 36000 inputs. These inputs will be applied at the input of the neural network. The main problem of the neural network is the size of the input image. The big size needs a long time for computations. To solve this problem, one of the solutions is applying spatial resolution reduction to the input image before applying it to the neural network. This technique aims to extract the key features from the face and apply to the network instead of using all the image pixels. This reduction implemented by imresize function in Matlab that returns the resized image that is scale times the size of the original image. The original image can be gray-scale, RGB, or binary images. The mathematical equation of this function is shown in Eq.(17).Resize the image again, this time specifying the interpolation method. When you enlarge an image (get the normal image from the reduced image) using Extrapolation method, the output image contains more pixels than the original image. Imresize function uses interpolation to determine the values of these pixels, computing a weighted average of some set of pixels in the vicinity of the pixel location. Imresize bases the weightings on the distance each pixel is from the point.

U= X/scale + 0.5*(1 - 1/scale) (17)

Where: U is the Resized image, X is the original image and scale is the resize factor. Figure.22 illustrates the process of reduction of image size (a) before reduction (b) after reduction.

4.3.2. The Back Propagation Neural Network (BPNN)

After image preprocessing reduction size to the given face image, there is recognition step to recognize the face image by comparing the face image by stored database images. The BPNN is designed with one input layer, one hidden layer and one output layer. The input layer consists of 81 neurons the inputs to this network are feature vectors. We can obtain this vector from the image reduction size 9x9 to obtain feature vector 81x1. Back propagation needs pairs of input and target vectors. The output vector ‘o ‘is compared with target vector ’t ‘. If there is any difference between ‘o’ and ‘t‘ vectors, the weights are updated to minimize this difference. The weights and thresholds are assigned randomly at the beginning of the network. These weights are updated in every iteration until the mean square error between the output vector and the target vector is minimized [29].Main advantage of this algorithm, it can identify the given image if it face image or not and then it recognizes the given input image. Main procedure of the back propagation neural network is indication input of the network and the desired output, modifying set of parameters that called (weights of the network) until the target output is approximately equal to desired output with acceptable error ratio.

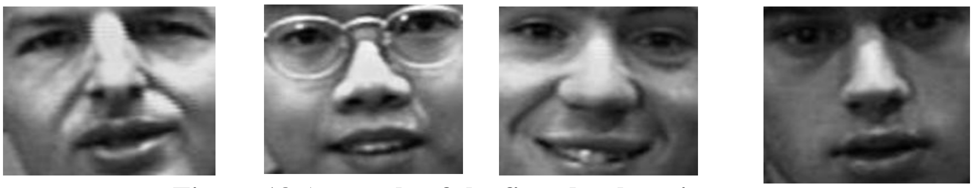


Figure.18 A sample of the first database images

Table.3 A sample of second database

Id	D1	D2	D3	D4	D5	D6	Nose width	Mouth Width	Mouth Height	Face Width	Face Height
1	52.0601	47.2467	44.7772	100.5199	66.017	69.8570	36	52	27	97	80
2	58.6366	54.3530	55	117.7083	77.9631	76.7235	42	53	28	108	89

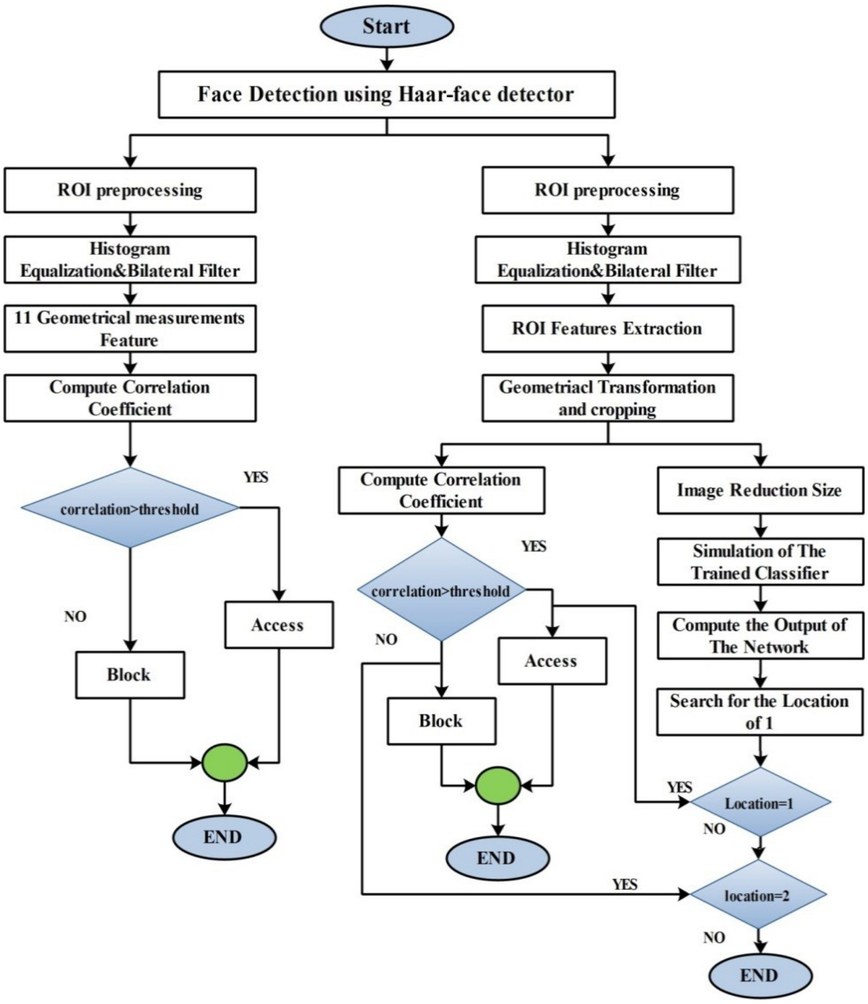


Figure.19 pattern recognition of different approaches

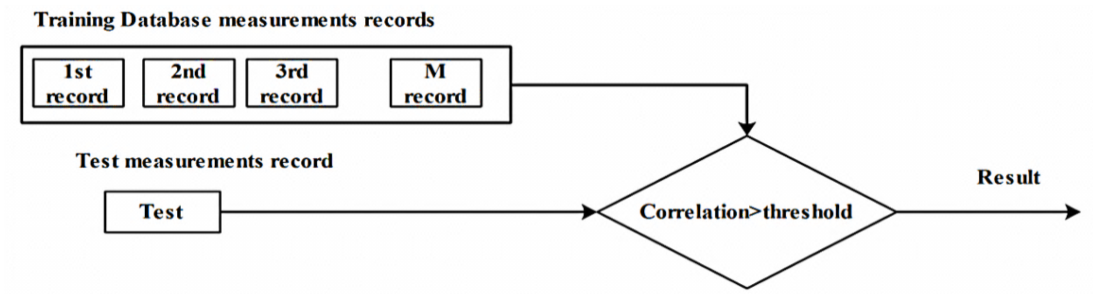


Figure.20 Training and testing parts for 1st face recognition system

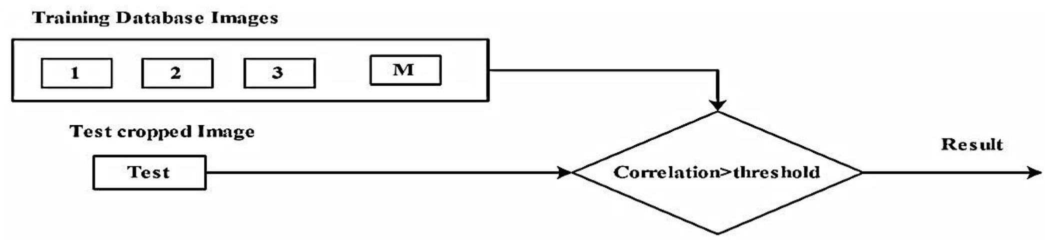
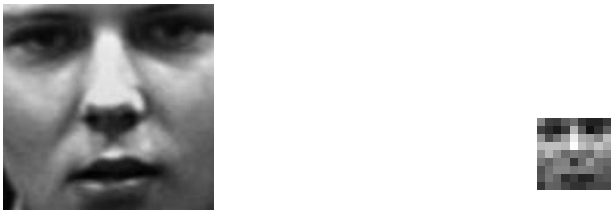


Figure.21 Training and testing parts for 2ndface recognition system [28]



(a) Original image (180x200) pixels **(b) compressed image (9x9) pixels**

Figure.22 Reduction of image size [28]

4.3.2.1. Simulation of the Trained Classifier

Training step is training the network by set of training face images (known and unknown image faces) and obtaining the feature vector that corresponding to each face image to achieve minimum total mean squared error. The mathematical equations that used in the training algorithm for the propagation network as follows [28]:

x: input vector, t: output target vector, δ_i: error correction weight to the hidden units, δ_j: error correction weight from the output to the hidden unit, α: learning rate, X_i: input unit i, V_{oj}: Bias on the hidden unit j, Z_j: hidden unit j, W_{ok}: Bias on the output unit k and Y_k: output unit k. Neural network training steps as shown in the flow chart in Figure. 23 as follows:

1) Initialize the weights of the neural network or may be selected random.
2) Indicates the pairs of the network (inputs vector and target output).
3) Calculates the actual output of the network. Each input unit receives the input signal xi and sent to all units in the above hidden layer.

$$z\_in_j = v_{oj} + \sum_{i=1}^{n} xivij \quad (18)$$

4) Each hidden layer sums its weighted input signal and applies the activation function to compute the output signal and send it to all units in the output units.

$$z_j = f(z\_in_j) \quad (19)$$

5) Each output unit sums its weighted input signals and apply the activation function to compute the output signal and send it to all units in the output signal as shown in the equations.

$$y\_in_k = w_{ok} + \sum_{j=1}^{p} zjwjk \quad (20)$$

$$yk = f(y\_in_k) \quad (21)$$

6) Compute the error between the desired output and actual output from the relation

$$\delta_k = (t_k - y_k) f'(y\_in_k) \quad (22)$$

7) Calculate the weight correction term to use in updatingw_{jk} later.

$$\Delta w_{jk} = \alpha \delta_k z_j \quad (23)$$

8) Calculate the basic correction term to use in updating w_{ok} later.

$$\Delta w_{ok} = \alpha\delta \quad (24)$$

9) Send δ_k to units in the layer below.Each hidden unit (z_j,j=1,2,…….p) sums its delta inputs (from units in the layer above).

$$\delta\text{-}in_j=\sum_{k=1}^{m}\delta wjk \quad (25)$$

10) Multiply by the derivative of its activation function to calculate its error information term.

$$\delta_j=\delta\_in_i f'(z\_in_i) \quad (26)$$

11) Calculate the weight correction term (used to update v_{ij} later).

$$\Delta v_{ij}=\alpha\delta_j x_i \quad (27)$$

12) Calculate the bias correction term (used to update v_{oj} later).

$$\Delta v_{oi}=\alpha\delta_I \quad (28)$$

13) Adjust the weights of the network in a way that minimizes the error.Updates weights and biases:

a) Each output unit (Y_k,k=1,2,……M) updates its bias and weights (J=0,1,……P):

$$w_{jk}(new)=W_{jk}(old)+\Delta W_{jk} \quad (29)$$

b) Each hidden unit (z_j,j=1,2,…..p) updates its bias and weights (i=0,1,…..n):

$$v_{ij}(new)=v_{ij}(old)+\Delta v_{ij} \quad (30)$$

14) Repeat steps 2 through 13 for each vector in the training set until the total error for the entire set is acceptable error.The training algorithm involves both the forward and back propagation steps to make pattern classification as shown in Figure.23

Notice that the most important information that we obtained from the training step are:

a) The number of epochs the system takes to achieve the goal error.

b) The time that the system spends to achieve the goal error.

c) The difference between the calculated output and desired output.

The two steps are: training step (numbers of correct and false times in the training step) and testing step (numbers of correct and false times in the testing step). In this stage, we extract the feature vector from the test image. This feature vector is simulated with the trained network. After the simulation, we get the output classification then identify if the person is known or not. The network architecture is shown in the Figure.24 [30]

4.3.2.2. Testing the neural network

After finishing the network training, we obtain the total error for the entire set. This error is acceptable if its value is between desired limits. In the testing step, we test the network with the weights that we obtained from the training step to compute the output of the network in each input vector.

This search is done by using the function: Vec2ind (output). It takes only one argument (Matrix of vectors, each containing a single 1) and returns the indices of the 1's. There are two states, if the position of 1’s =1, this means that the person is authorized for access. If the position of 1’s =2, this means that the person is unauthorized and no access is permitted. We will propose an illustrative example to indicate the results of the training neural network. These results are shown in Figure.25 (a) and figure.25 (b) which illustrate the performance curve produced by the network. The training completed a total of 27 iterations and the performance error is 0.00000961.

$$\text{The output classification}=\begin{bmatrix}1\\0\end{bmatrix}$$

After obtaining the output classification, we search for the class of classification by using this command: Output=vec2ind (classification) to indicate the position of 1's in the classification matrix. If output=1 then the person is authorized. The results of the training are shown in Figure.26 (a) and Figure.26 (b) which illustrate the performance curve produced by the network. The training completed a total of 27 iterations and the performance error is 0.0000085535.

$$\text{The output classification}=\begin{bmatrix}0.0000\\1.0000\end{bmatrix}$$

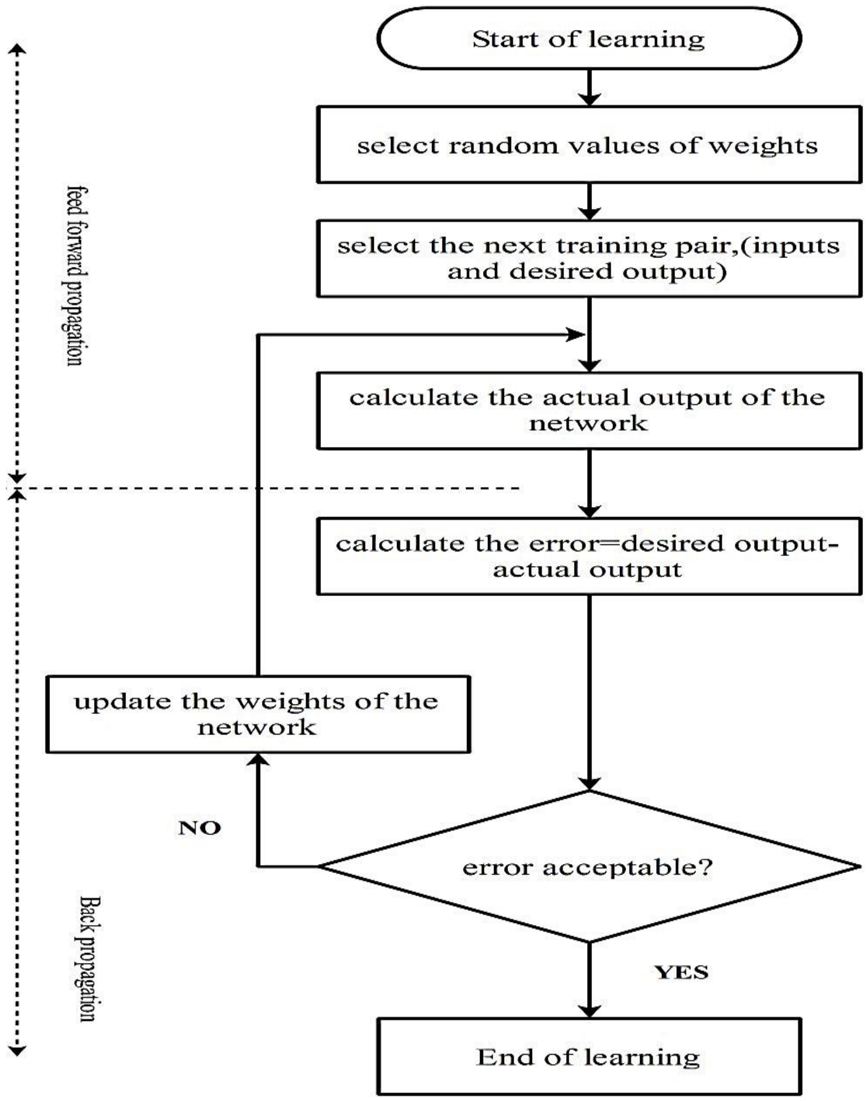


Figure.23 Back propagation neural network training steps [28]

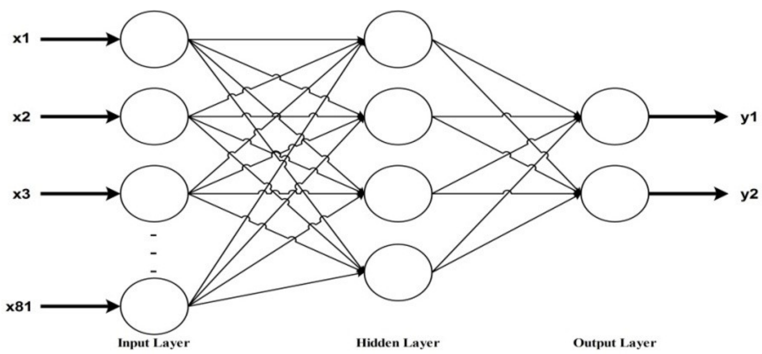


Figure.24 Neural network architecture

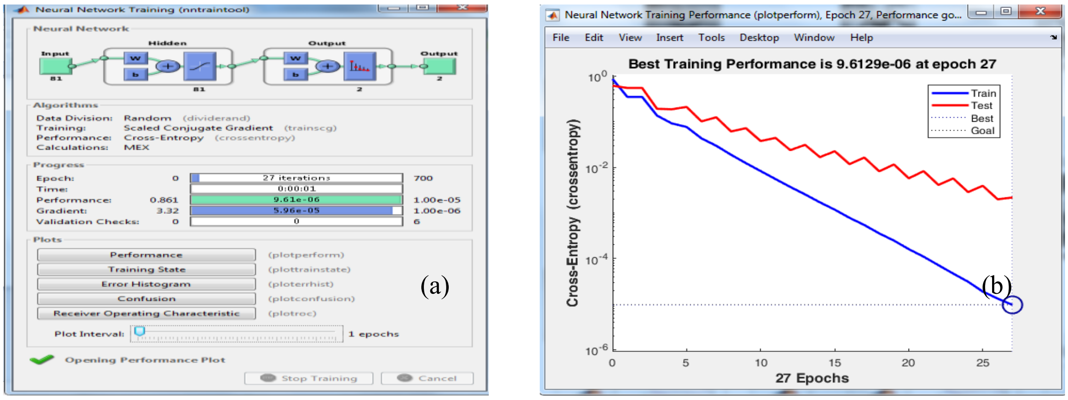
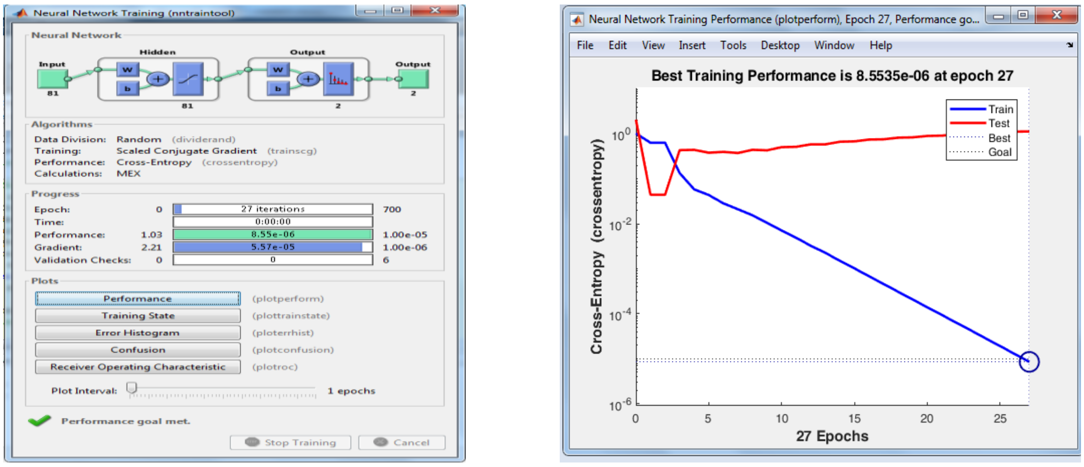


Figure.25 The training result



(a) (b)

Figure.26 The training result

5. Experiment Results

5.1. The correlation method results

In this section, we report and analyze some results of face recognition system. These systems are able to differentiate between the known and unknown faces. This property of the system is called generalization. To evaluate the performance of face recognition system, there are number of parameters that are calculated such as: recognition rate of the system which is calculated from the equation

Recognition rate=

$$\frac{\textbf{number of correctly recognized person}}{\textit{total numbers of perons}} * 100 \tag{31}$$

Average execution time is the amount of time taken to run the system in seconds and false acceptance is the number of times that the system accepts or recognizes unknown faces that are not stored in the image database. The comparison between two approaches according to set of parameters is shown inTable.4and the final comparison is shown in Table.5

Table.4 Comparisons of two approaches face recognition systems

Approach	Total test images	Average Execution time (in seconds)	False Acceptance	Recognition rate
1st	50	0.836999555	3	94%
2nd	30	0.696027586	2	93.33%

Table.5 Final comparison between two face recognition systems

Comparison	1st approach	2nd approach
Preprocessing step included	YES	YES
Recognition rate	High	Low
Complexity	Simple	Not simple
Execution time	High	Low

5.2. Back propagation neural network method

At the start, we assign the two values of inputs and targets. The inputs consist of N images of all face database images of known and unknown persons. These images are images reduction size in dimension 9x9 pixels. Each image is converted into feature vector with dimension 81x1. The dimensions of the input matrix are 81xN. The form of the input matrix is: P=[I1(:) I2(:) ..………………. IN(:)]

The target matrix consists of two classes. The first class is 1 if the person is known and the second class is 1 if the person is unknown. The form of target matrix is:

T= $\begin{bmatrix} 1 \\ 0 \end{bmatrix}$ if the person is known, T= $\begin{bmatrix} 0 \\ 1 \end{bmatrix}$ if the person is unknown. The dimension of the target matrix is 2x81 indicates the class of each person. The network is simulated using the previous inputs and targets and the specification of the network as shown in Table.6 and the training parameters are shown in Table.7. The final simulation of face recognition system with neural network is shown in Table.8.

Table.6 Specification of the network

Input Layer	1
Hidden Layer	1
Output Layer	1
No of neurons in input layer	81
No of neurons in hidden layer	81
No of neurons in output layer	2

Table.7 Performance parameter

learning rate	0.01
Goal error	1e-8
number of epochs	700
training ratio from the database	0.9
testing ratio from the database	0.1

Table.8 The final result of the network

Classification output	[1;0] or [0;1]
Vec2ind(Classification output)	1 or 2
Judgment process	"Known" or "unknown"
Number of errors in the execution	Maximum 2 errors or less
Recognition rate	At minimum 98% to 100%

6. Discussion

There are a number of properties of face recognition systems that distinguish between them. Some authors presented a system where the face image varies a lot because of the type of lighting, the direction of lighting, the shadows and the background [18]. In our system, the background of the person doesn't affect the face image because the final image stored in the database is cropped from alignment of the eyes to the mouth. Using the ROI removes the background from the face image. The effect of lighting and shadow on the face image is about 0.1%. Assuming that we have two images (Im_1, Im_2) with different brightness, the brightness of the two images are B_1 and B_2, and the difference in the brightness between the two images is $B= B_1-B_2$. To make the two images having the same brightness, if $B_1>B_2$, the new brightness=B_2+B. If $B_1<B_2$, the new brightness=B_2-B. The effect of this on the correlation is by about 0.1. Figure 27 illustrates the relation between a pair of images that have the same/different brightness and correlation between two images in the two cases of same/different brightness. Note that there isn't any change in the correlation if the two images have the same/different brightness. The two graphs of correlation are identical.

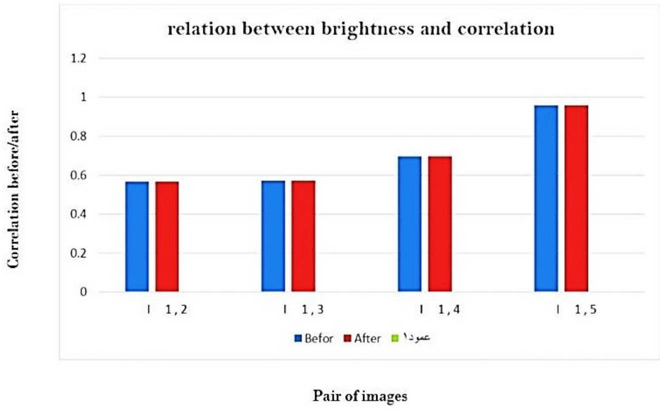


Figure.27 relation between images and correlation

The correlation coefficient is also affected very much by the orientation angle between the images. When the two images have the same orientation angle, the correlation coefficient is found to be about 99%and it is decreased dramatically, if there is some orientation angle between the two images. Table.9 demonstrates the values of the rotation angle between the two images and the percentage of correlation between them. Figure.28 illustrates the relation between the rotation angle of the two images and the correlation coefficient between them.

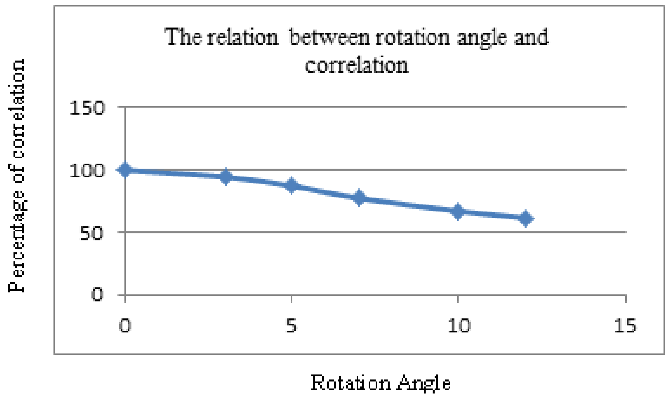


Figure.28 The relation between rotation angle and the correlation

It is interesting to compare between the results of our system and the systems proposed by other research. Table.10illustrates the comparison between the recognition rate of our three approaches and other approaches.

Table.9 values of rotation angle and percentage of correlation

Rotation angle between two images	Percentage of correlation (%)
0	99.97
3	94.35
5	87.24
7	77.5
10	67.09
12	61.63

Table.10 Recognition methods and recognition rate with its approaches

Approaches Reference	Recognition Method	Recognition rate (%)
[18]	PCA	93.8%
	LDA	96%
[17]	BPNN	96.66%
	BPNN+BRF	98.88%
[19]	RDT-DWT	95%
[20]	PCA	92.4%
	PCA+BPNN	96.5
1st approach	Correlation coefficient	94%
2nd approach	Correlation coefficient	93.33%
3rd approach	BPNN	99%

From the table we can highlight the following points:

1) The principal components analysis (PCA) method applied in [20] gives the minimum recognition rate (92.4%) followed by our method of correlation coefficient between the geometrical features of the faces which gives a recognition rate (93.33%)
2) The PCA method applied in [18] gives a recognition rate (93.8%) followed by our method of the correlation coefficient between the face images giving a recognition rate (94%).
3) When the PCA method and the back propagation neural network (BPNN) method are mixed, the recognition rate is increased to (96.5%) as in [20] while the BPNN method is used alone in [17] giving a rate (96.66%) which means more speed and less complexity.
4) When the linear discriminant analysis (LDA) method is applied, the rate is found (96%) as in [18].
5) Mixing the regression decision tree (RDT) and discrete wavelet transform (DWT) methods gives a recognition rate (95%) as in [19]
6) Mixing the BPNN and the Bayesian relevance feedback (BRF) methods increased the recognition rate to (98.88%) as in [17].
7) Our approach of applying the BPNN gives the highest recognition rate (99%) compared with all the previous methods.

7. Conclusion and Future Work

In this paper, we proposed the design of three approaches of face recognition systems. These systems achieve satisfactory performance. From the experimental results, 1st approach of face recognition achieves a higher recognition rate than the 2nd approach and the 2nd approach achieves a less false acceptance times and less execution time than the 1st approach. The 3rd approach achieves the best recognition rate by about 99% than the other two approaches. Practically, the 2nd approach takes more steps (i.e. face detection to extract face width and height, detect nose to extract nose width, detect mouth to extract mouth width and height and detect the 6 distance between features. If there is any error in any previous step, the recognition rate of the system will decrease. These systems can be applied as on-line systems and this means that they can be used in the process of authorizing the network users. The approaches apply face image preprocessing and this means a better recognition added to a fast performance in searching the database images. It is important to have more than one image per person to increase the recognition rate, increase the performance of the system and overcome the problem of orientation angle for each person. The three approaches were compared with the proposed techniques in the previous research and they gives good results where our third approach is giving the highest recognition rate of 99%. In the future work, we intend to implement the given face recognition approaches on Android mobile phone platform.

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