Face Recognition System Approach Based on Neural Networks and Discrete Wavelet Transform

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Abstract— The technology of face recognition is attractive and full of technology research challenges; It is used for recognizing people by using digital images. Although face recognition has an important role in several areas such as security, face recognition technology still encounters many challenges that need to be solved with more scientific methods. One of These challenges lead can be the variations of the face of the same person due to lighting or pose. This project explores and investigates the use of combined hybrid algorithms based on neural networks and discreet wavelet transform for face recognition in order to enhance the recognition rate for a face from identified data set of faces. Two techniques have been used in this research; the First one is applying the discrete wavelet transformation method in order to improve and compress the images of the data set. The second one is implementing a well-known approach called Principal Component Analysis. The training and testing face images are selected from ORL database, which contains 400 images for 40 different persons and have minimum pose variation. The experimental results confirmed that the proposed methodology provides a feasible and effective solution for recognizing faces.

Keywords— Face detection, Face recognition, Discrete Wavelet Transform, Principal Component Analysis (PCA), Neural Network, K Nearest Neighbors

I. INTRODUCTION

Identifying a person from his or her face is an easy task for humans. But, is it the same for a machine? This question identifies the problem of automatic face recognition, which spawned a great deal of research work during last twenty years. The face can be considered as a biometric data. The physiological biometric indices are innate biological/chemical traits, whereas biometric behaviors are associated with learned or acquired behaviors. Biometric data has become unavoidable data for security application such as in person's identification and verification. Identification methods or identity verification based on a biometric data offer certain advantages compared to methods based on a password or PIN.

Three reasons can justify the superiority of biometric data over passwords or PIN codes. First, biometric data is individual data, whereas passwords may be used or stolen by someone other than the authorized user.

Secondly, a biometric data is very convenient because there is nothing to wear or memorize. Thirdly, biometric technologies have become more and more precise, and its cost in a constant decrease.

Automatic facial recognition is relatively a new concept and technique. The first semi-automated system of facial recognition has been developed in 1960s, it requires the administrator to locate the eyes, ears, nose and mouth on the face and enter calculated distances and ratios at a common reference point, which were then compared to the baseline data.

Security remains the main axis of application of face recognition. Recognized faces are required for identification and authentication. A good example of this use is at the airport of Frankfurt (Germany), where the recognition for automate passengers' control [31]. Another example of face recognition is the analysis of videos captured by external camera systems managed in big cities for identification and tracking suspect persons [34].

Google and Facebook have implemented algorithms to identify people in their photo database. In the United States, this technology continues to develop, it is even used by Federal Bureau of Investigation (FBI) Agencies or by private companies. While in Brazil, the police are preparing for the 2014 "*Fédération Internationale de Football Association*" (International Federation of Association Football (FIFA) World Cup in their own way: they use glasses equipped with a camera capable of filming 400 images per second and compare them with a digital database of 13 million photos [46]. While, Aibo (Artificial Intelligence Robot) looks like a puppy, albeit a robo-approximation. It makes vaguely dog-like sounds, walks around, plays with toys, responds to commands, occasionally misbehaves and uses cameras and facial recognition technology to interact differently with each person it encounters [44].

A. Statement of the Problem

The problem of face recognition can be formulated as follows: Given one or more face images, the task is to find out or verify the identity of a person by comparing his face to the set of face images stored in a database. Facial recognition poses many challenges because faces are deformable objects 3D. Researcher limit herself in this research project to a recognition from 2D face image unconstrained environments. Such systems must be able to overcome the following problems; namely: (1) influence of the variations of the pose, (2) Influence of lighting changes, and Influence of facial expressions.

1) *Influence of the variations of the pose:* Orientation changes and changes in the angle of inclination of the face cause many appearance changes in the collected images. Deep rotations cause the occultation of certain parts of the face as for three-quarter views.

2) *Influence of lighting changes*: The intensity and direction of lighting during the shooting have a great influence on the appearance of the face image. Indeed, in most common applications, changes in lighting conditions are inevitable, especially when views are collected at different times, indoors or outdoors. Given the specific shape of a human face, these lighting variations Shadows highlighting or hiding certain features facial.

3) *Influence of facial expressions:* Faces are unregulated elements. Facial expressions conveying emotions, combined with speech-induced deformities, can produce important appearance changes, and the number of possible configurations is too important for them to be described in a realistic way.

B. Research Objectives

The purpose of this research project is to design and implement a facial recognition application capable of recognizing faces. This application must meet the standard requirements of speed and robustness. The proposed application consists of a hybrid algorithm based on neural networks and discreet wavelet transform for face recognition in order to perform the recognition rate. The study includes a comparative study of different techniques used in the field of face recognition.

C. Research Limitations

Faces can be partially masked by objects or by wearing accessories such as glasses, a hat, a scarf, occlusion might be, therefore, intentional or not. In this study, the researcher has excluded the occluded faces.

D. Significances of the Study

Face recognition system is one of those technology marvels, by which a machine is modelled intelligently as human brain in order to identify and recognize a person from her/his face and distinguish it from the rest of stored images of persons' faces. So, the ability to recognize faces is very important in many aspects of life. It does not only help us to recognize those who are close to us, but it rather allows researcher to identify individuals, so that researcher can be more aware of possible dangers.

E. Research Organization

The structure of this report is arranged as follows: Section II that follows this introduction reviews and discusses previous works, research and different techniques used in face recognition and identification. Section III presents the proposed approach. Whereas Section IV discusses and analyses the results and makes a comparison between the characteristics of different techniques. The researcher concludes this report by summarizing the contributions and findings and providing recommendations for further research works.

II. RELATED WORK

Faces constitute a unique stimulus category due to the huge amount of information that they convey. They are both the primary visual vectors of individual identity, and the essential vectors of intentions communication, facial expressions and emotions between individuals. Perceptually, face recognition is one of the most amazing capacity, and the most performing task of the human visual system. Human beings are capable of distinguishing and recognizing a very large number of faces, even when faces constitute a homogeneous stimulus category share a set of similar traits or a common structure, they undergo significant changes with age for example, or with different facial expressions.

The purpose of face recognition is to design computer systems capable of copying the extraordinary recognition powers of the human brain. However, although there is an advancement of research on this issue over the past three decades, robust faces recognition system remains very difficult task, as shown in the recent evaluation study conducted by the National Institute of Standards and Technology (NIST) Studies [30].

The difficulties mainly stem from the high variability of the data to be classified (due to changes in facial expressions, in face pose, in the conditions of illumination and partial occlusion, and in the fact that the faces images constitute very large data. Nevertheless, and despite all these difficulties, the field of facial recognition remains important for many researchers given the multitude of fields of application. This variability in applications has given rise to the availability of several commercial products allowing the following steps:

- Identification, by comparison of a face to those stored in a database.
- Verification, by comparison of the identities declared with the identities associated with memorized faces.
- Supervision, which allows to follow the face of a person in a video sequence [16].
- Surveillance which makes it possible to find in real time a person in a video from a list of faces.

A. Main difficulties of face recognition

For the human brain, the process of face recognition is a high visual task level. Although humans can detect and identify faces in a scene without a lot of trouble, building an automatic system that accomplishes such tasks and represents a serious challenge. This challenge will be greater when the conditions for acquiring images are very variable. There are two types of variations associated with face images: inter and intra subject. Inter-subject variation is limited because of the physical resemblance between individuals. However, the identification through the intra-subject variation is larger. It can be attributed to several factors. The following section lists and discusses the main difficulties encountered by automatic facial recognition system in real conditions; namely: (1) illumination, (2) Pose, (3) Facial expressions, (4) Occlusions.

1) *Illumination:* Variations in illumination cause considerable variations in the appearance of a face. Two types of lighting can influence this: global (or ambient) and local illumination. While global illumination affects the whole face evenly (or almost), local illumination creates shadows and illuminated areas, non-linearly. Figure 1 shows an example of a face with a moving light source. Many approaches have been proposed to manage these lighting problems. An implicit modeling of brightness in creating a face model can be performed. The extraction of invariant characteristics at brightness changes is also an approach widely described in the literature [16]. Finally, note that a number of approaches address the problem of brightness upstream of recognition by a preprocessing step which its main objective is often to correct artifacts due to variations in brightness [35].

Figure 1: Example of lighting variation face recognition

2) *Pose:* The face recognition rate drops considerably when variations in poses are present in the images. This difficulty has been demonstrated by tests of evaluation developed on the FERET and FRVT data bases [10, and 20]. Pose variation is considered a major problem for facial recognition. When the face is in profile in the image plane (orientation <30°), it can be normalized by detecting at least two facial features (passing through the eyes). However, when the rotation is greater than 30°, the geometric normalization is no longer possible; as shown in Figure 2.

Figure 2: Examples of pose variation in face recognition system

3) *Facial expressions:* The appearance of a face greatly varies in the presence of facial expressions; as shown in Figure 3. Facial elements such as the mouth or the eyes can then undergo significant deformations, which can cause failure for facial recognition system. The mouth is usually the most varied facial element, but the appearance of the eyebrows can, for example, be greatly modified [39].

Figure 3: Examples of facial expressions variations

4) *Occlusions:* Partial occlusions frequently appear in applications; as shown in Figure 4. They can be caused by a hiding hand part of the face, by long hair, glasses, sunglasses, a scarf or any other object. It also happens that part of the face hides another, as in the case of an out-of-plane rotation for example.

Figure 4: Examples of facial occlusion

B. 2D face recognition

Several face identification methods have been proposed during the last twenty years. Face recognition or identification has been studied by a number of researchers in various knowledge fields, such as psychology, artificial vision and computer graphics, among others. Before detailing the different techniques related to 2D face recognition, let's first present an overview of the studies conducted by researchers on cognition and facial recognition. Knowing the results of these studies is important because it allows the development of new approaches. The ultimate goal of facial recognition is to compete with the human capabilities of recognition.

A face image is a 2-dimensional signal acquired by a digital sensor (digital camera, scanner). This sensor will code the color or intensity of the different points of the image in two-dimensional pixel array. After image normalization and scaling towards a fixed size (m x n), the face image can be considered as a vector in a multidimensional space. The number of points constituting this space quickly becomes very large, even for small images.

For non-parametric methods, the number of examples needed to represent effectively distributing data which may be insufficient. The case of face is quite particular: the face is formed by smooth surfaces and a regular texture. It has a strong symmetry (in the case of frontal images) and it is formed from the same objects (eyes, nose and mouth), which have the same positions for all faces. These specificities give rise to several findings:

- The different pixels of the face image are highly correlated;
- The images of the different faces are also correlated;
- A large number of points in images space do not represent faces.

C. Global Approaches

These methods identify a face by using the entire face image as input of the recognition system. Each face image of dimension n by m is represented by a simple vector of dimension n x m, by concatenating the values of the gray level of all the pixels of the face image. For example, consider a small 64×64 image, in gray scale coded on 8 bits (values from 0 to 255). The space I containing all the face image vectors is called image space. The advantage of this representation lies in the observation that it preserves simplicity of the necessary texture and shape information for face recognition. In addition, it allows a better capture of the overall appearance of the face than local representations. However, its use of subspace modeling techniques has significantly advanced the facial recognition technology. Techniques among global methods can be divided into: (1) linear techniques, and (2) non-linear techniques [39].

1) *Linear techniques:* Linear techniques are linearly project data from a large space on a lower dimension subspace. Unfortunately, these techniques are unable to preserve the non-convex variations of different faces in order to differentiate people. In a linear subspace, the Euclidean distances and more generally the Mahalanobis distances, which are normally used to compare data vectors, do not allow a good classification between the "face" and "non-face" shape classes and also between the individuals themselves. Linear techniques are limited by crucial factor that may affect precision of detection and recognition of the face [39]; as shown in Figure 5.

A very popular method, based on the PCA technique, is also known as Karhunen-Loeve (KL) transformation or Eigenface method [20]. The Eigenface method is based on the idea that a face image x can be processed (compressed or reconstructed) from an average image m, to which a small number of images of well determined size. Recently, Nayar, Nene and Murase view objects at various angles by using eigenspace projection [19]. Finlayson et al. (2017) applied angles in eigenvectors or called eigenfaces. While, PCA mainly focuses on changing the 2D image into 1D in eigenspace, in which the covariance matrix is taken from the facial characteristics and appearance. This eigenspace is the result of converting PCA by using the facial characteristics and match them with the sample dataset.

The orthonormal vector is taken from the result of Singular Value Decomposition (SVD) which is projected on to a database, which will be greatly reduce the size of the coefficient that represents the image. This characteristic also assists in decreasing the total analysis time by taking the best match between the test and reference image.

According to Imran [23], face expressions recognition obtained by eigenfaces has a great advantage, namely the reduction in size and noise sensitivity. However, it is not optimal during class separation when a large variability of light with in the same class associated with variability interclass.
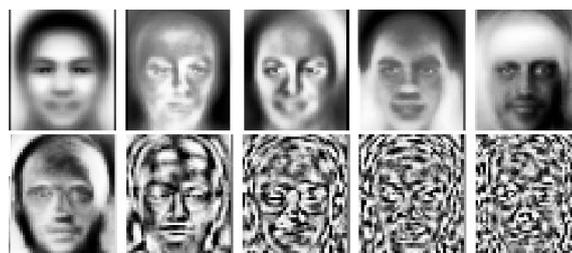

Figure 5: Examples of the first 5 clean faces built with the PCA approach.

Bartlett in [6] have shown that the first and second order statistics allow to extract information only on the spectrum of an amplitude image while rejecting the phase spectrum. Nevertheless, Multidimensional

Scaling (MDS) is another well-known method of reducing linear dimension [9]. Instead of keeping the variance of the data during the projection, it tries to preserve all the distances between each pair of dist. examples (*xi, xj*) by searching a linear transformation that minimizes energy.

Wen-ShengChen proposed another method which aims to represent the face without using the notion of class is the Non Negative Matrix Factorization (NMF) [43].The NMF algorithm, like that of PCA, represents the face as a linear combination vectors of the reduced space base.

The research of Nicholl and Amira in [28] concentrated on automatic calculation of the discriminative coefficients in a DWT/PCA that uses the inter-class and intra class standard deviations. So, eigen-faces are selected according to the eigen-values with conflict caused by the illumination factors among trained images.

Methods based on Linear Discriminant Analysis (LDA) determines the most directions discriminating projection screens in eigenspace. For this, they maximize the variations inter person versus intra-person variations.

The probabilistic method transforms the problem of face identification into a problem of two classes. It assesses the probability of the difference between a test image and a prototype image belonging to the intra-person and inter-person classes. Note that the intra-person distribution cannot be evaluated in the case of an example per person.

2) *Non-linear techniques:* Wang in [42] applied Analysis in Kernel Principal Component Analysis (KPCA) which is the nonlinear reformulation of the classical linear technique that is main component analysis by using kernel functions. Thus, for several years, the reformulation of classical techniques using the "kernel trick" has led to the emergence of many techniques such as support vector machines (SVM) [15]. The PCA technique with cores computes the main eigenvectors of the matrix of nuclei rather than the covariance matrix.

D. Local approaches

Local approaches use local facial features for face recognition. Researcher can classify local methods into two categories: those based on local characteristics: extractions and localization of characteristic points, and those based on local appearances: partitions of face images into characteristic regions [7].

1) *Methods based on local characteristics:* These methods are effective. However, their performance is particularly dependent on localization accuracy of characteristic points. The task remains very difficult in practice, more precisely in situations where the shape and appearance of the face can change dramatically. The approaches based on extraction characteristic of points can be subdivided into two categories: geometric approaches and graph-based approaches.

- *Geometric approaches*

    They are based on the extraction of the relative position of elements that make up the face (such as the nose, mouth and eyes). Most geometric approaches use points of interest (such as the corners of the mouth and eyes).The cost of storing geometric techniques is very low compared to that of other techniques. However, purely geometric approaches present some disadvantages, including; Geometric features are generally difficult to extract, especially in complex cases: variable illumination, occlusion. Worth to mention that, Geometric characteristics alone are not enough to represent a face.

- *Graph-based approaches*

    Instead of using purely geometric methods, some researchers have chosen to represent the local characteristics of the face under form of graphs. Face recognition is then formulated as a problem of graphs mapping. However, once constructed, the topological graph can't be changed. But facial images easily change appearance due to different variations (illumination, expression, pose, etc.), and in fact a diagram of fixed topological graph is no longer adequate.

    Sarkar in [37] has extended the use of LDA to a well-known method called Elastic Bunch Graph Matching (EBGM), where the graph nodes are located on a certain number of selected points of the face. Sayantan Sarkar used Gabor's wavelets for extract the characteristics of detected points, because Gabor filters are robust to changes in illumination, distortions and variations in scale.

2) *Local methods based on face appearance:* Once the local regions have been defined, it is a question of choosing the best way to represent information from each region. This step is critical for the performance of the recognition. The characteristics commonly used are: Gabor coefficients [8], and Harr's wavelets [22], Fourier transforms, SIFT (Scale Invariant Feature Transform) [29] , features based on the Local Binary Pattern (LBP) method [7], LPQ (Local Phase Quantization) [18] , BSIF (Binarized Statistical Image Features) [24].

- *Scale-Invariant Feature Transform*

    The Scale-Invariant Feature Transform (SIFT) technique is an approach for detection and extraction of local characteristics descriptors which are reason ably invariant to changes in lighting, image noise,

rotation, scaling and small changes in perspective. It was developed in1999 by the researcher David Lowe [27]. According to Lowe, the operation of the SIFT algorithm involves five steps:
- Detection of extremes in the scale space,
- Precise location of key points,
- Orientation assignment,
- Descriptors calculation of key points,
- Correspondence.

- *Local Binary Pattern (LBP) and its New Form*
    The initial LBP approach represents the pixels of an image with decimal numbers, which give a code to the local structure of every pixel. Figure 6, illustrates how the researcher works: each pixel is matched with its eight neighbors in a 3×3 by subtracting the value of the main pixel; strictly negative values resulting are coded with 0 and the others with one. For each specific pixel, a binary number is gotten by concatenating all of these binary values clockwise, which starts from one of its neighbors in the upper left.

E. Face detection

Face detection of an image is an essential and crucial treatment before the recognition phase. Indeed, the face recognition process can never become fully automatic if it has not been preceded by an effective detection step. The processing consists of looking at an image for the position of the faces and extract in the form of a set of sub image in order to facilitate their processing ulterior. A face is considered correctly detected if the size of the extracted sub image does not exceed 20% of the actual size of the facial region, and that it essentially contains eyes, nose and mouth.

A classification of facial localization methods has been proposed by Yang [45].The methods are divided into four categories; namely: (1) Knowledge based method, Feature invariant approach, template machine methods, and appearance based method.

1) *Knowledge-based methods:* These methods are based on the knowledge of the different elements that constitute a face and relationships that exist between them [6]. So, the relative positions of different key elements such as mouth, nose and eyes are measured to serve later for the classification of 'face' and 'non face'. The problem in this type of methods is that it is difficult to clearly define a unique face. If the definition is too detailed, some faces will be missed, but if the description is too general, the rate of false positives will increase.

2) *Feature invariant approaches:* These approaches use the invariant elements with variations in illumination, orientation or expression such as texture or skin color for detection.

3) *Template matching methods:* Characteristic models of a whole face or part of a face (mouth, eye, and nose) are created. The localization is then done on the basis of the correlation of these models with candidates.

4) *Appearance-based methods:* These methods use the same principle as presented in the previous point but they are based on models learned from a test set. These methods present the advantage of running very quickly but take a long time drive. The methods belonging to this category have shown good results compared to the three other types of methods. Researcher can cite among these, the neural network method [36], the method of Schneiderman [38] based on a naive Bayes classifier as well that the famous algorithm of Paul [32] operating in real time, and this the latter will be detailed below.

F. Data base

Several databases containing information that allow the evaluation of face recognition systems are available. However, these data bases are generally adapted to the needs of some specific algorithms recognition, each of them was built with image acquisition conditions of diverse faces (changes in illumination, pose, and facial expressions) as well as the number of sessions for each individual.

The oldest databases (ORL and YALE) were the most used and allow to compare new methods more easily. The most recent ones (Color FERET, FRGC, CVL, AR and IV2) contain more people and are therefore useful for larger scale assessments. Other face bases are available and intended for assessments adapted to certain variability of the face such as the bases of UMIST, BANCA, PF01, Yale and PIE. These last three bases for example (PF01, Yale and PIE) have a large number of different poses but only contain a few dozen people acquired in a single session.

- *ORL database*
    They are designed by AT&T laboratories at the University of Cambridge in England, the ORL database (Olivetti Research Laboratory) is a reference database for automatic face recognition systems. Indeed all the systems of face recognitions found in literature have been tested against ORL, this

popularity is due to the number of constraints imposed by this database because the most share of possible and predictable facial changes were taken into account, such as for example: change of hairstyle, beard, glasses, changes in facial expressions, etc. As well as the acquisition conditions such as: change of illumination and the change of scale due to the distance between the acquisition device and the individual.

The ORL database consists of 40 individuals, each individual has 10 poses, so the base contains 400 images. The poses were taken at intervals different times of up to three months. Extracting faces from images was done manually. They are presented in the following figures showing the specifics of the ORL reference database.
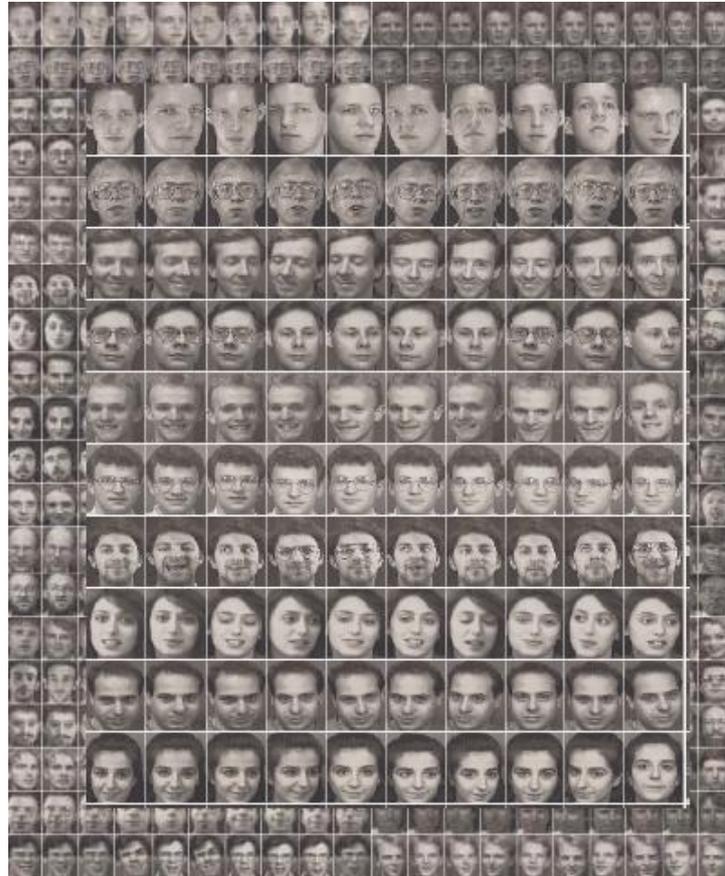
Figure 6: ORL database.

Figure 7 illustrates an example where the acquisition is made under different orientations of the face and under different lights. Nevertheless, an example where the acquisition is done under different lights is shown in Figure 8.

Figure 7: Example of changes in facial orientation in ORL database.

Figure 8: Example of lighting changes in ORL database

Figure 9 shows the scale changes due to the distance between the device of acquisition and the individual. While the ORL database also takes into account facial expressions, such as faces expression as shown in figure 10.

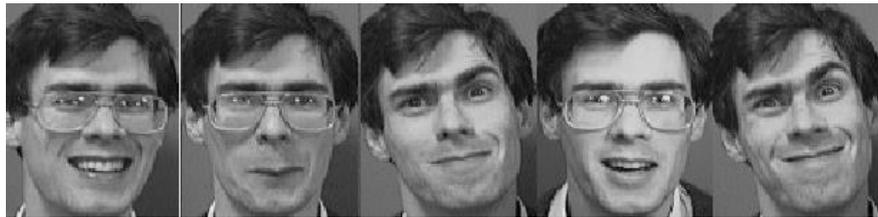*Figure 9: Example of scale changes in ORL database*

Figure 10: Example of facial expressions changes in ORL database.

The ORL Database takes into account the fact that an individual may or may not wear glasses; as shown in Figure 11. While Figure 12 shows the ORL database that includes individuals of different ages, gender and skin colors.

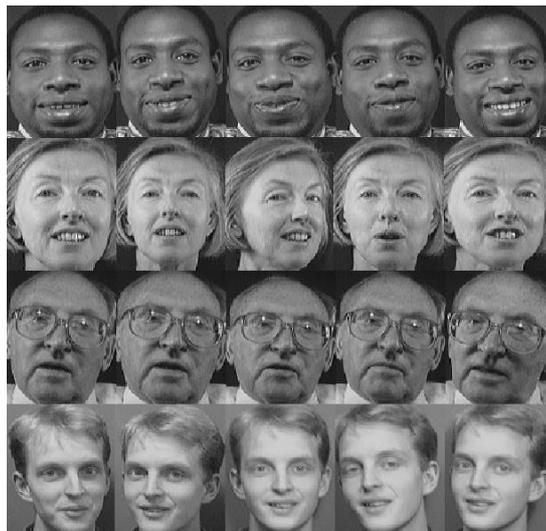*Figure 11: Example of wearing glasses in ORL database*

Figure 12: Example of individuals of different ages, races and sexes.

III.   PROPOSED SOLUTION

Human face is one of the main objects that show our identities, so it plays a major role in many image and video applications especially that applications which is related to Identification and Verification. The human face is a dynamic object and has a high degree of variability in its image appearance such as pose variation (front and profile), overlapping, image orientation, lighting condition and facial expression.

In this project, human face is the Region of Interest (ROI). Face Recognition process needs at least two or more operations involved in such as Face Detection, Features Segmentation and finally Face Recognition. After acquiring an image, Face detection usually is the first-step in many applications requiring location and extraction of the face region from the background.

In the last two decades, different techniques have been proposed for face recognition. Some of face recognition methods were combined as hybrid with other methods or with techniques such as discrete wavelet transforms, because using hybrid system helps to have efficient and accurate system with high performance and less execution time [1].

A. Experimental Setup

Face Recognition approaches can be classified into four methods; as shown in Figure 13.

1) *Holistic Approach:* In this approach, the whole face is considered as a single feature for detection and recognition [12]. It makes a comparison between the similarities of the face and neglecting the individual appearance of mouth, eyes, nose etc.

2) *Feature based Approach*: Feature based approach focuses on the individual characteristics of the eyes, nose, mouth, ears and find out and compare them with the similarities of images [1]. Another method concentrates on using hexagonal features in identifying and detecting the face [40].

3) *Model Based Approach:* It uses 3D facial model by considering active and passive means [4]. It uses infrared rays which directs laser beam onto an object and its reflection will produce a correct 3D model used for identification.

4) *Hybrid Approach:* One of the best method is Hybrid approach. The modern hybrid technique for identifying faces has been searched by Derrick [14]. In this approach, Face identification is determined by recognizing the individual parts like nose and tip as the base for the feature extraction phase and a hybrid 3D model is taken as an aim for the recognition [25] . Their research was based on the Gabor filter approach and the normalization approach of Bai-Ling [5].
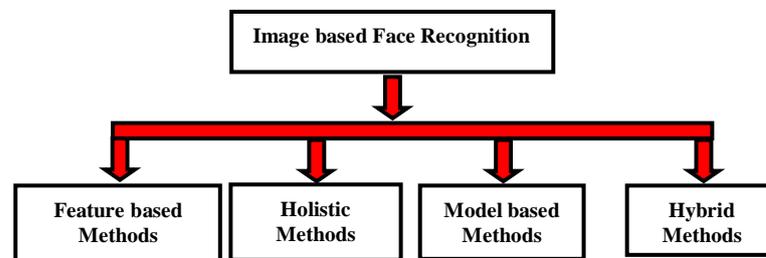

Figure 13: Image based face recognition methods

The research will be presented to study the implementation of a hybrid approach for face recognition. The project is divided into Learning Phase and Recognizing Phase. So we need first to learn the machine about the facial image of the human being which the machine can recognize further. Any facial image is learnt in some pre-defined ways and stored in a knowledge base, then their values are utilized to recognize the face.

B.   Flowchart diagram

The first task in this project is to learn the machine about the feature vectors of the input pattern. The following steps are suggested to learn the machine; namely: (1) Taking an image, (2) Pre-processing, (3) Discreet wavelet transform, (4) Feature extraction, (5) Training, and (6) Save the pattern to knowledge base. While for the recognition phase, the researcher proposed six basic steps to test the pattern if it is recognized or not. They are: (1) Acquiring an image, (2) Pre-processing, (3) Discreet wavelet transform, (4) Feature extraction, (5) Classification, and (6) Recognition; as shown in Figure 14 that illustrates the flow chart diagram of the proposed approach.
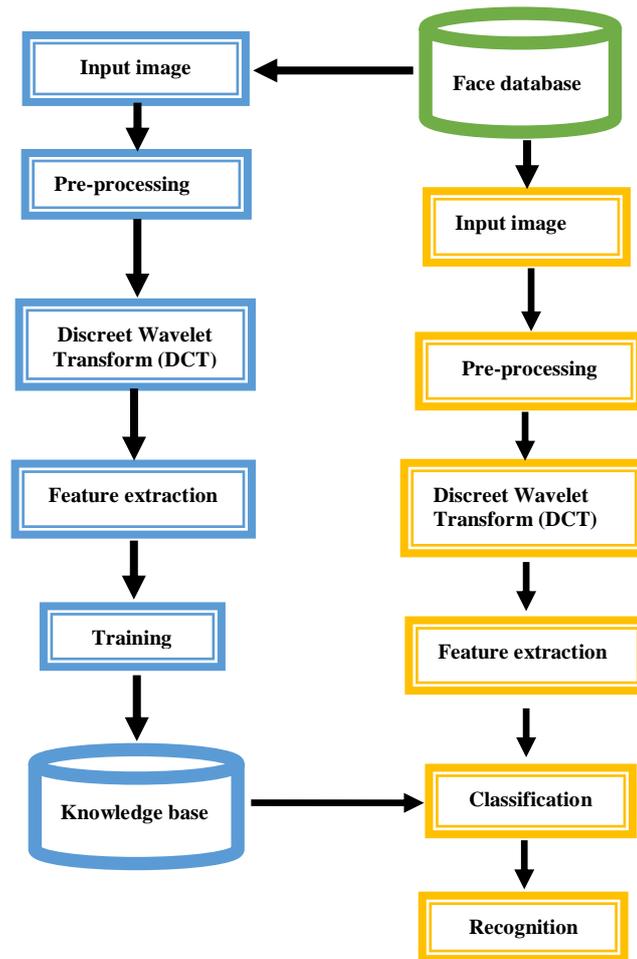
10

Figure 14: Flow chart diagram for Face Recognition

C. Image Pre-Processing Stage

Image acquisition can be achieved by digitally scanning an existing photograph or by using an electro-optical camera to acquire a live picture of a subject. Video can also be used as a source of facial images. The most existing facial recognition systems consist of a single camera. The recognition rate is relatively low when face images are of various pose and expression and illumination. With the increase of the pose angle, the recognition rate decreases. The recognition rate decreases greatly when the pose angle is larger than 30 degrees [40]. In addition, different illumination is a problem for some algorithms such as PCA. To overcome this problem, one needs sometimes some preprocessing such as smoothing, rotation etc.

Before any process, input data should be prepared, so we need a stage called Pre-processing which is one of the most important phases, not only in face recognition systems, but also in many other systems, such as Machine Learning based system [13]. Processing any raw data without any kind of preprocessing may lead to wrong results. So, before extracting its relevant features, we need to ensure that the data has good quality. There are many operations can be performed before feature extraction, such as the following operations:

1) *Red Green Blue (RGB) to grayscale conversion:* Any RGB Image consists of three color channels where creates 3 dimensional matrix. So, to minimize RGB dimensions, one should first convert RGB image into a grayscale image, for instance, Black and White conversion of an image with only 2 dimensions, and the values ranges between 0–255.

2) *Geometric Transformations:* Image may be acquired in various environments which makes the image in improper conditions to be analyzed even if the faces are detected in an input image. Some problems that can arise from these detected ROIs are rotation, scale, and noise [46]. Therefore, it has to guarantee that the face to be classified is as geometrically similar as possible to the faces used when training the classifier. That way, the classifier is fitting to produce more trustworthy results [13].

3) *Denoising Image:* In addition, the background is the main noise problem in the detected ROIs. It is essential to remove the background from the original ROIs because it reduces the noise which can decrease the accuracy of the classifier. Some works were able to manage this kind of noise, but there are a few which tried to crop the ROI even more in order to filter the background .Wavelet transform is able to denoise the images by threshold the generated wavelet coefficients to reduce the contribution of the noise signal.

4) *Image Processing:* Proper geometric transformed ROI might not enough to process image data. Therefore, there are many image processing techniques used to prepare relevant features which are going to be fed to the classifier. Most face recognition systems use the following techniques: (1) Smoothing is often a very important technique used in image processing. By smoothing an image, we can capture relevant patterns while filtering the noise. There are various ways to smooth an image such as bilateral filter and Gaussian filter, and (2) Histograms plot the intensity distribution of an image. Because of potential different lighting conditions that extracted faces may present, the recognition accuracy will likely suffer.

D. Discrete Wavelet Transform

Wavelet has become an important method in image processing and computer vision. Compression, detection, recognition, image retrieval applications have been studied. Wavelet is used not only in face recognition but also in several aspects such as image processing, computer vision, engineering, picturing, and etc. [25]. Wavelet transform has nice features of space-frequency localization and multiresolution. The theoretical framework, the flexibility of choosing bases and the computational simplicity have turned Wavelet to be popular. Wavelets decompose complex signals into sums of basic functions called mother wavelet such as Haar, Meyer, Morletetc. Wavelets can analyze data of different resolutions better than simple sine and cosine because they are local in frequency and time [5].

Wavelet is useful for detecting abrupt change in signals where its accuracy depends on the change of signals and it characteristic. Wavelet transform deals with high-frequency and low frequency of signals in order to generate the coefficients of wavelet. In addition, wavelet can be used in image processing such as denoising and enhancement [41].

Wavelet transformation of the extracted face image is an art of its representation. This method of transformation became popular during the last 10 years. The purpose of this transformation is to allow the generation of such facial characteristics that are invariant to lighting conditions and overlapping. The wavelet transformation manages the image in subdivisions that are localized in accordance with their orientation and frequency, and the coefficient of every subdivision is localized in sapce [11].

In the current project, the researcher uses Haar Discrete Wavelet Transform which is one of discrete family wavelet transformation methods used in feature extraction and works at frequency domain [31], its general principle is shown in figure 15. It is efficient technique to keep image details such as edges and its orientations. It is also effective and takes less time to execute in comparison with other transforms because it uses addition and subtraction operations rather than multiplication. In fact, Haar Discrete Wavelet Transform is used in several area such edge detection, compression as well as, image coding [3].
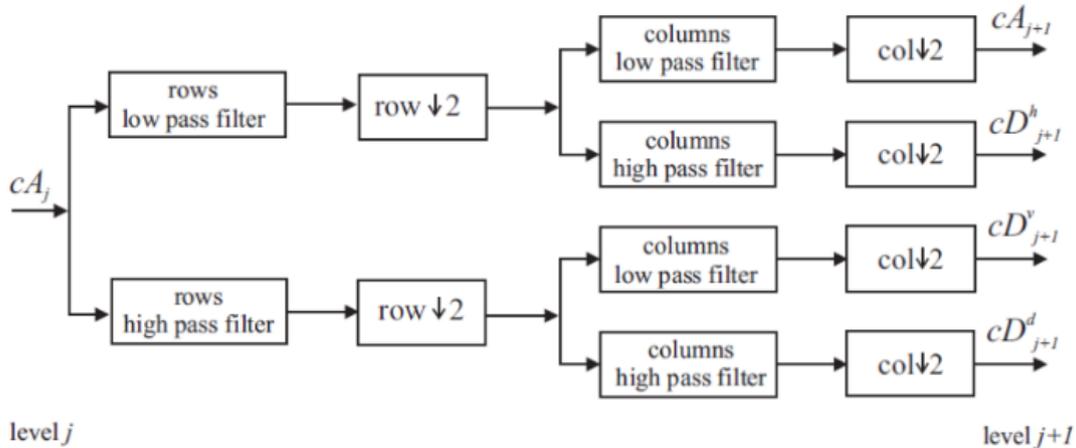

Figure 15: Haar Discrete Wavelet Transform

The majority of Images are normally stored as two dimensions, by which they have to be transferred into 2D array with size N*M; N represents the rows number and M for the columns number. So converting the images to

2D is the initial step to apply in Haar Discrete Wavelet Transform on the image .The process is done by multiplying columns matrix by the original image matrix, then the output is multiplied by the transformed rows matrix.

High and low pass filters of Haar produce four coefficients with quarter size of the original image size. These coefficients present the most important information in the image. The upper left corner holds the average image which contains the most features which helps us to identify feature in other quarters. The upper right corner implies horizontal parts of image while the lower left corner represents the vertical ones and lower right corner investigates diagonal details.

Figure 16 shows the first level of Haar wavelet transform. However, Figure 17 presents level 2 of transformed image. We can repeat the process of transform on the approximation portion only which is produced of the first level, and we can continue repeating it until getting good result. The opposite form of Haar wavelet transform can be achieved by reverting the previous process and taking the blurred part as input until having the initial image. Figures 17 and 18 illustrate two levels of discrete Haar/inverse wavelet transform process.
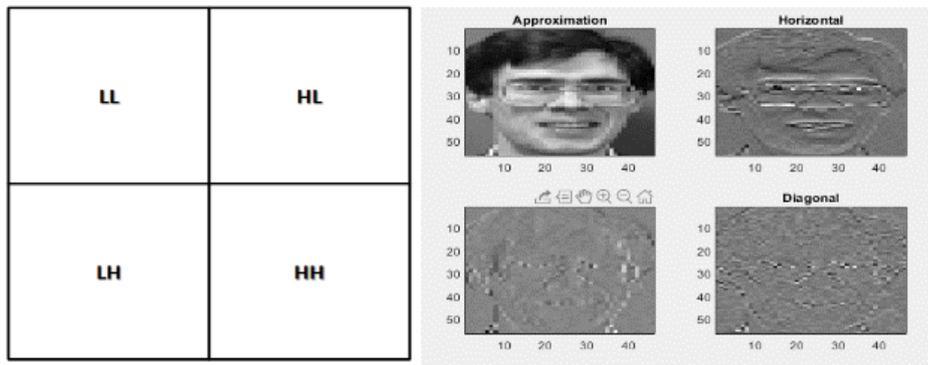

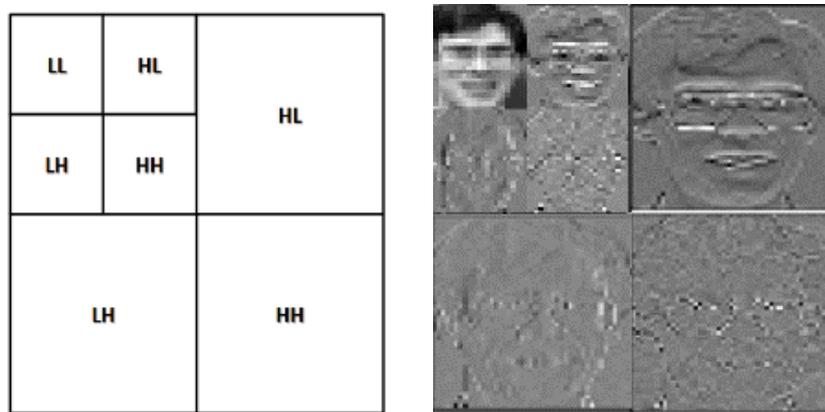*Figure 16: First level of Wavelet Transform*

Figure 17: Second level of Wavelet Transform

E. Face Detection

Face detection is the very beginning of a face recognition system. This technique is responsible for selecting the region of interest (ROI) of an input image which the face that will be fed to the next phases of the face recognition system. In this project, the researcher used Haar feature-based cascade classifiers. Haar cascade classifiers is one of the famous classifiers in object detection which is proposed by [32].

For face detection, the researcher proposes to group approaches that include knowledge of spatial information about the face. Points of interest are automatically detected on faces with variation in expressions and poses. Spatial information is introduced to improve the accuracy of locating these points. The goal is to extract the bounding rectangles eyes, nose and mouth. It includes knowledge on the face, especially on the spatial distribution of these features on the face. For example, the eyes are on the upper part of the face, the nose and the mouth are aligned on the axis of symmetry of the face, etc. Figure 18 and 19 show respectively the basic knowledge used in this research method and example result of face localization.
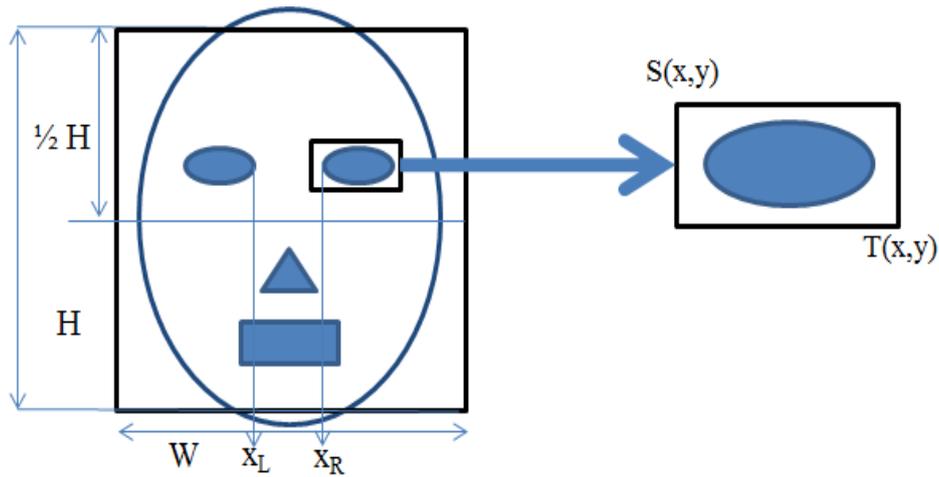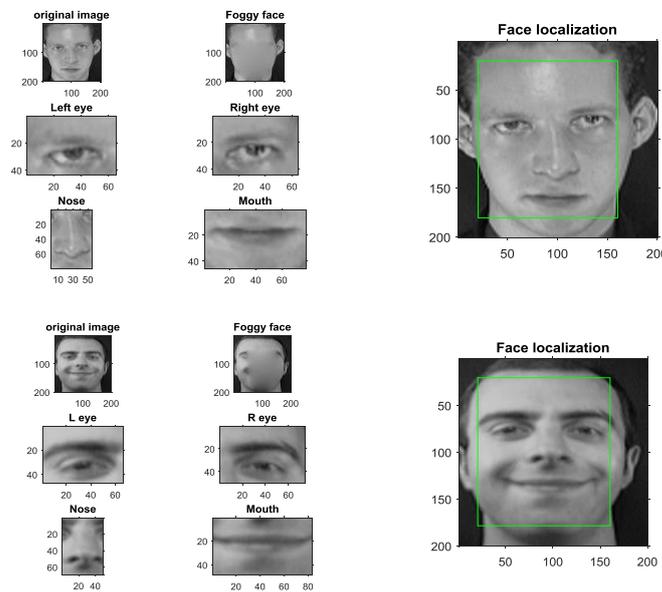
Figure 18: Basic knowledge used in our method.

Figure 19: face localization example

F. Feature extraction based on Principal Component Analysis

Once the pre-processing phase is done, one can extract the relevant highlighted features. In a Face recognition system, the relevant features are facial features. The quality of these features plays a huge role in system accuracy; therefore, several techniques to extract features were developed in Computer Vision. The most popular feature extraction techniques include:

1) *Local Binary Patterns:* LBP is known as one of the best methods for texture processing. This algorithm aims to compare a center pixel with its 3×3 square neighborhood.

2) *Optical Flow*: Optical Flow is a method that can only be used in a sequence of frames (video) since it aims to assess the magnitude and direction of motion.

3) *Action Units (AUs):* Action units are individual muscle movements that constitute facial expressions. AUs were inspired by physiological, psychological, and sociological theories that claim that different facial expressions trigger different facial muscles.

4) *Principal Component Analysis (PCA):* Principal Component Analysis is a method used to reduce the dimension of a large number of features keeping most of their information. At the potential expense of a small amount of accuracy, one can simplify data by reducing the huge amount of variables. In face

recognition system, this algorithm can be used to reduce redundant facial features, leading to an increase of the computational efficiency [13].

Eigenfaces are the most common linear techniques used in facial recognition systems. Components analysis depends on this Eigenface method and principal component analysis (PCA). The principal components resulted of the PCA technique will compose Eigenfaces or face templates.

PCA computes the covariance matrix Eigenvectors and aims to transform the original information into a smaller dimensional characteristic space defined by Eigenvectors with large Eigenvalues. The Eigenvectors calculated are known as the Eigenface in face representation and recognition. Every face image is transformed into a vector to construct the covariance matrix. Each vector element is the intensity of the pixel. This pixel matrix transformation destroys the image's geometric structure.

G. Neural network architecture

Artificial Neural Network plays an important role in many aspects such as face detection and recognition. In fact Artificial Neural Network (ANN) is a mimic for human brain. So, it usually contains many neurons that is the reason of using it in face detection and recognition.

1) *Perceptron:* A perceptron is a neural network unit (an artificial neuron) which is responsible for doing certain computations to detect features in the input data. In Perceptron model, many real-valued are taken as inputs and the model will produce a single binary as output. Each input in the model has weight which presents the importance of the input in decision process. In this type of model, there is 0 or 1 output as shown in figure 20.
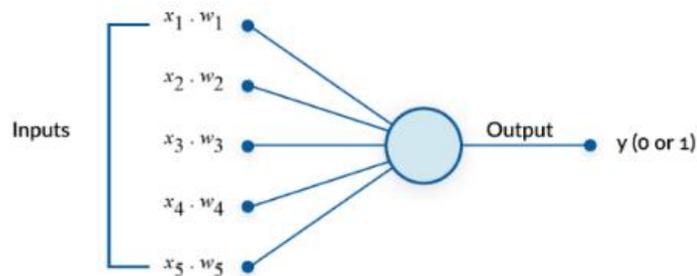

Figure 20: Perceptron Input and Output

2) *Sigmoid neurons:* Sigmoid Neuron can be used for both binary classification and regression problems. The output of this model will not be only '0' and '1' but also a value between '0' and '1'. The output value will tell us whether it belongs to 'class 0' or 'class 1' for binary classification. For instance, the output value of 0.70 can be classified to 'class 1', however a value of 0.2 will be classified to 'class 0'. The architecture of neural networks: MLP
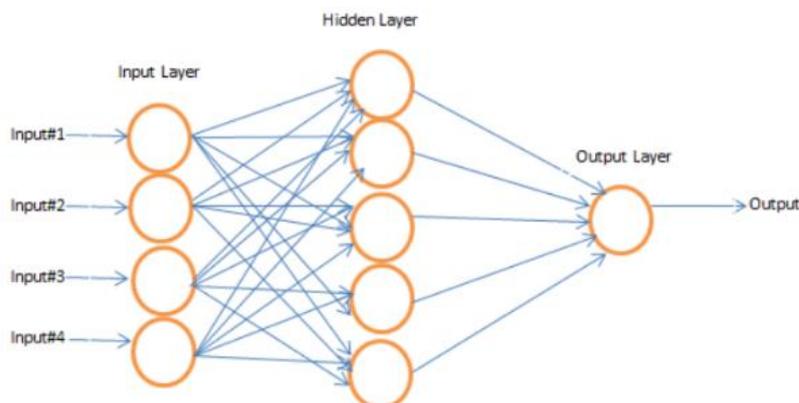

Figure 21 Architecture: MLP

These artificial neurons represented in at least three layers, input, hidden and finally output layer. The connection among layers determine the flow of data between nodes. It presents many shapes and architectures depending on the process characteristics. They can be unidirectional, when the information flows from one direction and bidirectional, when the information flows in either direction. In Face Recognition systems, there are several algorithms may be used beside the ANN such as back propagation algorithm [21]. Back Propagation is the feed forward supervised learning method. Neural networks consist of three layers including input layer, hidden layer and output layer, as shown in Figure 21. An input image runs through several hidden layers of the Neural Network that will decompose it into features. Those features are then generally used for classification through a Sigmoid Symmetric Transfer Function that retrieves the highest probability from the classes' probability distribution as the predicted class.

3) *Neural network training algorithms:* In fact, sigmoid algorithm is a common function which produces several sigmoid functions by changing the values of weight (w) and bias (b). Any change in weight values and bias values will also create change of the slope and the displacement of the curve as well. In order to use the learning algorithm, one must find weight and bias values. Researcher have to obtain the predicted output close to the true output when we pass the input in the sigmoid function equation. In the first time, the value of weight and bias will be random because the training has not started yet. Therefore, when weight and bias pass through the input-output points, we know that whenever we pass the value from the training data, the output of sigmoid function gives a very close result to the true output. The objective of our learning algorithm is that the values of weight and bias are learned correctly so that the loss on my training data is minimized.

H. K Nearest Neighbors

K nearest neighbors is a simple algorithm that stores all available cases and classifies new cases based on a similarity measure. KNN has been used in several aspects such as statistical estimation and pattern recognition. Euclidean distance (ED) is basically the distance between two points in Euclidean space. Some of the reviewed works have used this metric for classification: calculating the distance from facial features of a certain facial expression to the mean vector of facial features for each emotion. The emotion that presents the closest distance is then assigned to the input face. The ED between two points (x, y) is defined through the following equation:

$$d(x, y) = \sqrt{(x_1 - y_1)^2 + (x_2 - y_2)^2}$$

The Euclidean distance between landmarks is used as a morphometric measure. Once facial feature points are obtained from a facial image or a two-dimensional face, they select some significant distances between them and compute the corresponding Euclidean distances. Then, these distances are used to compare faces for face recognition systems.

1) *Classification and Regression:* A classification model is responsible for predicting a certain label given an input image or features. A regression model determines the connection between a dependent variable and independent variables. Both methods used the most popular classification. In this project, the researcher used the most familiar classification and regression algorithm which is the artificial neural network.

Classification becomes the last step in face recognition process. In this part of recognition, we compare two faces by projecting the images into faces pace and measuring the Euclidean distance between them. In the system the mean of the training images (m) is calculated, and the matrix of image vectors after each vector getting is subtracted from the mean vector (m). After calculating the mean (m) and the matrix (A), we need to find eigenvectors of Covariance matrix (C) of training database.

Eigen faces is an early example of employing eigenvectors in face recognition; Kohonen used simple neural network to perform face recognition for aligned and normalized face images [45]. The neural network computes and describes a face by approaching the eigenvectors of the image's autocorrelation matrix. Later, they will be Eigenfaces.

IV.   IMPLEMENTATION

The proposed system processed whole face by comparing it to Eigenfaces. It also processed face regions or characteristics (eyes, mouth, noses, etc.) which were extracted in preprocessing stages. Figure 22 shows face regions and figure 23 shows face recognition result, respectively.
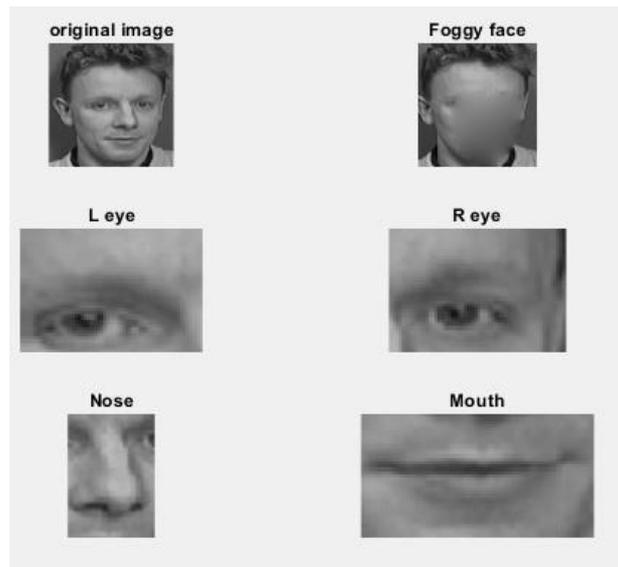
Figure 22: Face Regions

The primary goal of the proposed system is to increase face recognition rate as well as enhance performance of face recognition operation. The proposed system of hybrid neural networks and discrete wavelet transform methods uses enhanced and compressed data. The system has been trained using different parameters such as Eigen vectors number and number of training samples. Many cases have been used in order to attain the best experimental results of the system. Therefore, different training images samples with various values of eigenvectors were applied to obtain the best results and better performance evaluations.
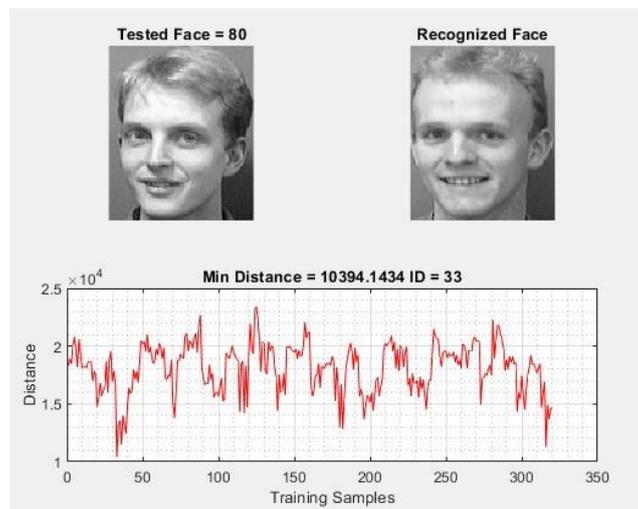

Figure 23: Training Sample from ORL Database

Wavelet transformation plays an important role in the enhancement of all dataset images, the ORL database in the researcher's proposed system. In the planned system, Haar wavelet and its inverse approach took only about one minute to enhance all images of the database. The obtained data set was saved in the system folder and submitted to the user control. All results of testing various eigenvectors values, different numbers of training set and eigenfaces have been implemented for the purpose of attaining excellent results.

Table 1 shows how the Number of Eigenvector affects the recognition rate and execution time. So, from the table, we can say that the best Number of Eigenvector is 20 which gives us the best result in both recognition rate and less execution time. However, using big number of eigenvectors value leads to decrease the recognition rate as presented in table (1).

Table 1: Recognition rate results using several number of Eigenvectors

K Number of Eigenvector	Recognition Rate	Execution time
5	95	21.074
10	92.5	20.436
15	95	20.345
20	96.25	19.962
30	93.75	20.75465
40	92.5	31.14852
60	92.5	21.647
80	91.25	22.952

Table (1) also demonstrates the relationship between the number of images in the training set with the Recognition Rate and Execution Time. We can notice that the ratio of recognition increases when the number of images in the training set grows up. Therefore, the number of training sample is a powerful tool in controlling the ratio of recognition. Table (2) gives the recognition rate and execution time in term of training set size.

Table 2: Recognition rate results using different Number of Training samples

Training Set	Recognition Rate	Execution Time In Second
160	89.14	61.05737
200	86	52.053
240	90	41.11353
280	92.5	31.14852
320	95	21.985
360	95	11.206

V. CONCLUSION AND FUTURE WORK

Face recognition technologies are key components of the application of facial image processing and have increased their importance as a field of research. They use human biometric information and are easily applicable instead of fingerprints, iris, signatures, etc., as these types of biometrics are not suitable for non-collaborative individuals. For people and security cameras in modern life, face recognition systems are usually used and preferred. Although face identification has been studied by different researchers, it is still an important area and deserves more and more studies, especially with the huge and rapid advancement of the computer technology and its applications related to robotics, games etc.

The suggested system in this project is composed of a hybrid algorithm depending on neural networks and discreet wavelet transform to achieve an excellent ratio of face recognition. It is an efficient technique to keep image details such as edges and its orientations. Discreet wavelet transform is also effective and takes less time to be executed in comparison with other transforms because it uses addition and subtraction operations rather than multiplication. In fact, Discrete Wavelet Transform is used in several areas such edge detection, compression and image coding.

This proposed system has been divided into Learning Phase and Recognizing Phase. The first phase is to train the machine about the facial image of the human being which the machine can recognize then in the recognition phase. The researcher used artificial neural network which plays an important role in many aspects such as face detection and recognition. In fact, artificial neural network (ANN) is a mimic for human brain so it usually contains many neurons that was the reason for using it in this proposed system.

In the recognition phase, classification is becoming the last step in face recognition process. The proposed system uses PCA with different methods for classification applying distance difference integrated with minimum mean of difference for clustering images. PCA computes the covariance matrix Eigenvectors and aims to convert the original information into a smaller dimensional characteristic space. This algorithm can be used to reduce redundant facial features, leading to an increase of the computational efficiency. It is robust feature extraction for face recognition but it must optimize with clustering for person recognition. The test results show

that PCA with mean of clustering gave best results with Euclidian distance method with recognition rate of 96%.

This proposed system has the ability to recognize faces in a very high recognition rate. In this proposed system, the researcher used ORL database to train and test my proposed system. ORL is a limited database which contains 400 images only. In the future, I hope to train and test the proposed system by using several datasets with different types of images.

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