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Face Recognition Using The Basic Components Analysis Algorithm

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Face Recognition Using The Basic Components Analysis Algorithm

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ABSTRACT
Since all the things surrounding us have characteristics, therefore, of course, there are several characteristics and features of the human face that distinguish it and know it from others, making it a distinct organism with certain features that can be classified and identified on its basis. Since the detection and cutting of faces from the image is a critical problem that has gained importance in recent times, they play a major role in facial recognition systems. In this research, we present a new method for identifying faces using the Principal Component Analysis PCA algorithm, through the passage of the image in several stages, starting with the stage of obtaining the image (taking it); then, the face detection phase of the original image, and aligning the image (i.e. adjusting the face angle to the camera angle). After that, we enter the image with the stage of extracting the important basic features of the image; then, we match the required image with the available image store. The proposed algorithm was tested with several images and faces and faces without faces were successfully recognized. The proposed algorithm is characterized by a high efficiency in the detected faces. The accuracy of this algorithm is more than 95% in the detection faces. The proposed algorithm is a prerequisite for any system that uses the face as the main feature.

KEYWORDS. Image processing, Face Detection, Eigenvectors, Eigen faces, Eigenvalues, PCA.

1. INTRODUCTION

Because of the growing concern with regard to security issues around the world, there is an increasing concern in general about the accuracy of computer systems for face recognition (FR). This has led to the development of several security applications and systems in this field, and the algorithms used have varied between simplicity and sophistication [1]. Various researchers have over the past years focused on the development of several commercial products for improving the performance of automatic FR algorithms during FR-related activities. Hence the necessity of developing this field with the aim of obtaining a system with a very high accuracy of FR [2]. Thus, FR systems can be referred to as computer applications that can identify or verify people based on a video frame or a digital photo by comparing the image of the person being displayed with the computer data; when the features are identical, the system identifies the required person. A set of complex algorithms is used to program this FR system, with each of

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the algorithms performing a different function, but works synergistically to complement each other. So, all the algorithms must be working at optimal condition for the task to be achieved or accomplished correctly. Some FR algorithms determine the features of the face by extracting features from the face image, for example one of the algorithms analyzes the relative position of the members of the face and their size, such as the nose, for example, it determines its size and location in the face in addition to its distance from the eyes, and it also determines the distance between the eyes in addition to their shape. Identification algorithms can be mainly divided into two parts:[3][4]

Engineering algorithms: They look at the distinctive features appearing on the face without careful scrutiny of the facial features. For example, they define the shape of the face, its size and the position of its members inaccurately.

Optical algorithms: It is a statistical approach that delineates the image of the face accurately, based on the data given by the engineering algorithms, and then compares the figure drawn with the primary face in order to eliminate the differences and define its features accurately.

There are various techniques for facial recognition, including three-dimensional, and it is considered the most sophisticated and accurate technique among facial recognition techniques. It does its job through a set of accurate sensors. It captures the smallest details of the face, such as the degree of hair density in the beard or its absence, and determining the color and quality of the skin and the extent Its smoothness, it picks up the visual details of the skin and analyzes it through digital and optical scanning, so the spots become clear in the person's skin in addition to scars. This method is called analyzing the skin texture. Experiments confirmed that adding skin tissue analysis technology to facial recognition systems will increase its accuracy rate and give it correct results by 20-25%. And facial identification technology is a technique used in a variety of applications that define the human face from digital images, but what sets it apart from its predecessor is that it is able to recognize the psychological process that a person's face is going through [5].

Facial identification algorithms are more accurate and sophisticated than the previous ones. Similarly, to the recognition technology, the matching of the person’s image with the database images is done slowly as it focus not only on the facial shapes and features, but also on the changes in facial expressions since such variations between the database images and the person’s image will affect the performance of the system. In our research, an algorithm is applied to analyze the basic components of facial recognition through several stages that the image passes through, which will be mentioned sequentially. Fig. 1 below the stages of the face recognition system [6].

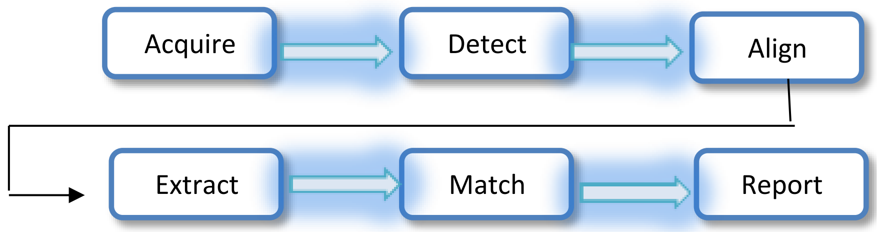

Fig. 1 The stages of the face recognition system

2. PREVIOUS WORKS

- Paul Viola and Michael Jones, in 2001."The Face Detection Algorithm Set to Revolutionize Image Search"[7] Where the researchers in the field of computer came up with an algorithm called (Viola-Jones) from the quick and simple algorithms that were later used in many cameras. Where the researchers ignored the issue of recognition (Recognition) and directed their attention only to the issue of detection (Detection) and also focused on the faces in terms of the forehead only ignoring to be seen from any other side. Using these boundaries, they were able to determine that the nose usually formed a more prominent vertical line than the eye socket that was near it, and they also noticed that the eyes were often in the shade, forming a dark horizontal band. Thus, Viola and Jones built an algorithm that searches first in the image for a prominent vertical range that denotes the nose, then searches for the dark horizontal range that may denote the eyes, and then searches for other general forms related to faces.
- Maha Salih Abdulreda, in 2012, "Face detection and tracking in video stream". Where the researcher presented a hybrid algorithm for identifying and tracking faces that includes merging between feature-based methods and Appearance based approaches, where each frame of the video was to be examined in search of skin areas with the skin color algorithm first Then examine the resulting areas for holes that represent the mouth, eyes and nose, and

accept the areas that contain two or more holes. In the final stage, a decision is made whether or not the organisms to be examined face-to-face, using the Eigen face technique.

- Nidhal K.E Abbadi, Ali Abdul Azeez Qazzaz, in 2015, " Detection and Segmentation of Human Face" [8].Which in turn presented a new method for detecting and cutting the face based on the color of the face, as it used the YCbCr color space as a way to divide the image into several areas. The gray-level presence matrix used to extract the important features of the skin, then the Tamura tissue is used to remove all non-skin points recognized as skin by GLCM. The proposed algorithm is highly efficient in detecting faces and segmented faces from the background.

- **FACIAL RECOGNITION SYSTEMS**

1. Acquired stage.
2. Detecting stage.
3. Image alignment.
4. Extracting stage.
5. Matching stage.
6. Report stage.

These stages vary by increasing or decreasing according to the system we are programming and its goal. Within this proposal, we will explain the implementation of a PCR-based FR system. The role of automatic FR systems is to identity a person based on a provided image and the images stored in a database. The memory of the facial recognition system is formed and extracted from the training set, which is a set of images that are previously presented to the system. The training kit in this project consists of features vectors that were extracted from a known set of faces portraits of several different people (as will be explained in detail later). The ray of features means any of the matrices - so to speak - selected from the original image matrices and represent the important and basic values within the original images, thus reducing the size of the images to the rays that represent the summary of the images.

Thus, the task of the recognition system lies in the process of finding the most similar feature vector in the training group to the feature beam extracted from the image presented for testing - that is, the image whose identity is requested through the identification system (as in Fig. 3). Here and within this system, we want to know and distinguish the identity of a person, by passing the image of that person to the system, and in this case this image is provided to identify it with a test image. In order to extract the feature rays from the images within this project, we will rely on the PCA algorithm in the process of extracting feature rays from the images.

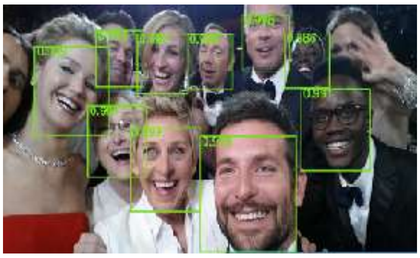

Fig. 2.Face detected using Viola-Jones Algorithm

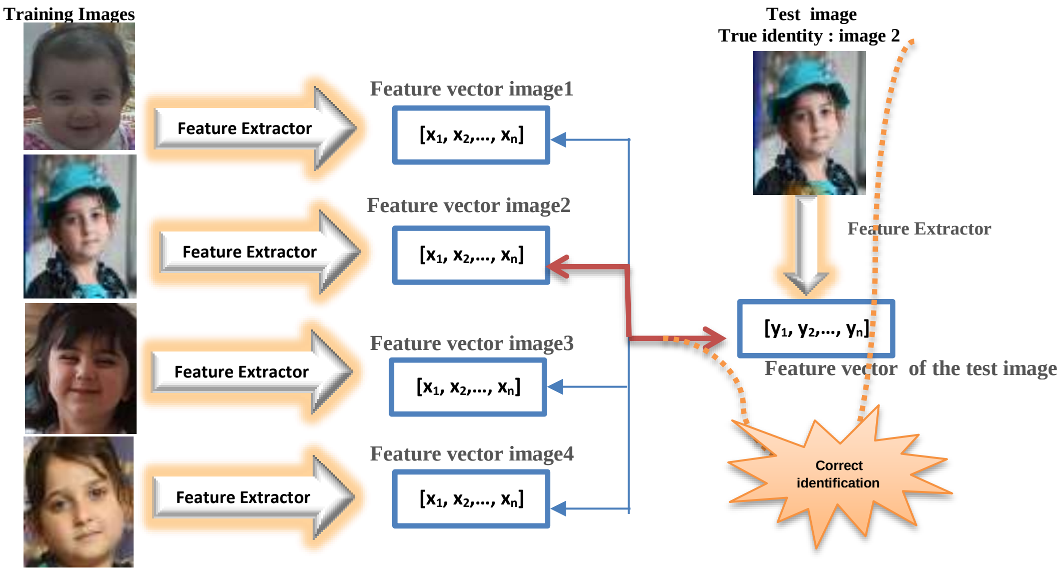

Fig. 3. Identify by finding the most similar and closest feature vector ray within the training set.

3. PRINCIPLE COMPONENT ANALYSIS (PCA)

It is one of the techniques used to summarize data as it converts the large number of implicitly but partially related variables into a smaller set of independent variables usually known as the principal components (PC); the PCs are mainly calculated from the original variables and their amounts and proportions vary according to their individual role and impact [9].

3.1 Recognition Systems and Large Dimensional Problems

A potential problem of the FR systems is the interation of the systems with areas of large dimensions (for example image processing) and to avoid such problem, efforts must be made towards improving them by matching the existing data and transferring it to data with a space of less distance. Then, it will be possible to reduce the original large dimensional space to smaller dimensions of the new area [10][11].

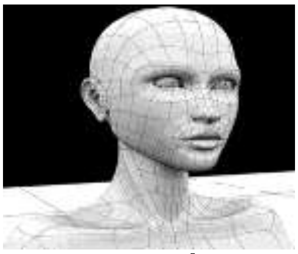

Fig. 4. Recognition Systems and Large Dimensional Problems.

Let us, for example, have the next ray, and that is within a space composed of N dimension. By reducing the dimensions, we move to another beam, that is, to a space composed of K dimension such that K <N. In principle, dimensional reduction results to information loss, but the PCA algorithm aims to reduce the data dimensions without losing much of the important original data information. This implies the preservation of most of the changes and variations in the original data. Therefore, PCA aims at the estimation of the linear transformation which in turn maps data in the higher dimensional space with the information in the related lower dimensional space as shown below [12]:

$$\begin{cases} y_1 = t_{11}x_1 + t_{12}x_2 + \cdots + t_{1N}x_N \\ y_2 = t_{21}x_1 + t_{22}x_2 + \cdots + t_{2N}x_N \\ \cdots \\ y_K = t_{K1}x_1 + t_{K2}x_2 + \cdots + t_{KN}x_N \end{cases}$$

Or in other words: $y=Tx$

Where:

$$\mathbf{T} = \begin{bmatrix} t_{11} & t_{12} & \cdots & t_{1N} \\ t_{21} & t_{22} & \cdots & t_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ t_{K1} & t_{K2} & \cdots & t_{KN} \end{bmatrix}$$

The optimal conversion $\mathbf{T}$ is the conversion in which the value $\| x - y \|$ is minimal.

The optimal conversion is the conversion in which the value is minimal. As per PCA theory, the lowest optimum dimensional space can be determined based on the best eigenvectors of the data's covariance matrix. "Principal components". Suppose that ***I1, I2, …, I_M*** a set of **M** is a beam, and each beam has the following dimensions, $N \times 1$.
Below we have mentioned and explained the basic steps of the PCA algorithm: [12]

$$\bar{\mathbf{I}} = \frac{1}{M} \sum_{i=1}^{M} \mathbf{I}_i$$

Step 1: We calculate the average beam of the given ray.
Step 2: We perform Normalize for all the rays, by subtracting them from the middle beam that was calculated in step1, $\Phi_i = \mathrm{I}_i - \bar{\mathrm{I}}$.
Step 3: Form a Matrix $\mathbf{A} = [\, \mathbf{\Phi}_1, \mathbf{\Phi}_2, \ldots, \mathbf{\Phi}_M]$ with a Dimensional Matrix $N \times M$.

$$\mathbf{C} = \frac{1}{M} \sum_{n=1}^{M} \mathbf{\Phi}_n \mathbf{\Phi}_n^T = \mathbf{A}\mathbf{A}^T$$

Step 4: We calculate the covariance matrix, It is a matrix of dimensions $N \times N$ (and load the values for data variance)
Step 5: Calculating the eigenvalues $\lambda_1, \lambda_2, \cdots, \lambda_N$ and eigenvalues $\mathbf{u}_1, \mathbf{u}_2, \cdots, \mathbf{u}_N$ of the array $\mathbf{C}$ (assuming that $\lambda_1, \lambda_2, \cdots, \lambda_N$).
Since the matrix $\mathbf{C}$ is symmetric, a group of $\mathbf{u}_1, \mathbf{u}_2, \cdots, \mathbf{u}_N$ ie basis rays forms a basis, and therefore any beam I within the same space can be written as a linear combination of the eigenvectors, using the rays that have been normalized, and therefore we have the following:

$$\mathbf{I} - \bar{\mathbf{I}} = y_1\mathbf{u}_1 + y_2\mathbf{u}_2 + \cdots + y_N\mathbf{u}_N = \sum_{i=1}^{N} y_i \mathbf{u}_i$$

Step 6(diminishing the dimensions): In this step, each ray $\mathbf{I}$ is represented here by preserving only the values corresponding to the largest K Self value:

$$\hat{\mathbf{I}} - \bar{\mathbf{I}} = y_1\mathbf{u}_1 + y_2\mathbf{u}_2 + \cdots + y_K\mathbf{u}_K = \sum_{i=1}^{K} y_i \mathbf{u}_i$$

Since K <N, in this case, the affinity $\mathbf{I}$ is $\mathbf{I}$ so minimal $\| \mathbf{I} - \mathbf{I} \|$. Therefore, the linear transformation $\mathbf{T}$ embedded within the PCA is defined by the basic components of the covariance matrix.

$$\mathbf{T} = \begin{bmatrix} u_{11} & u_{21} & \cdots & u_{K1} \\ u_{12} & u_{22} & \cdots & u_{K2} \\ \vdots & \vdots & \ddots & \vdots \\ u_{1N} & u_{2N} & \cdots & u_{KN} \end{bmatrix}$$

We will interpret and represent the PCA algorithm geometrically so that we can better understand how it works (Fig. 5.)[13].
The magnitude and magnitude of the eigenvalues correspond to the variance of the data along the directions of the e-rays. To decide how many principal components, we have to keep (meaning the value of K), the following criteria can be used:

$$\frac{\sum_{i=1}^{K} \lambda_i}{\sum_{i=1}^{N} \lambda_i} > t$$

Where t is the threshold threshold (for example: the following values take 0.8 or 0.9). The value of t determines the amount of information to be kept in the data. Once the value of t is determined, then the value of K. can be determined. We can say that the error resulting from the dimensional reduction step is given by the following statement:

$$error = \frac{1}{2} \sum_{i=K+1}^{N} \lambda_i$$

It should be noted that the principal components depend on the units used to measure the original variables as well as on the range of values assumed. Therefore, we must always standardize (make it standard) data before using the PCA algorithm.

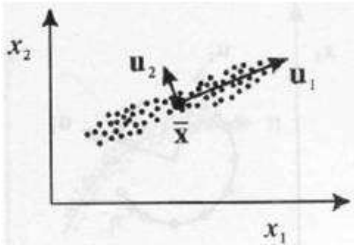

Fig. 5. Geometric interpretation of PCA algorithm

3.2 The PCA Algorithm to Eigenface

This eigenface approach relies on the PCA algorithm for low dimensional space facial representation, and this space can be extracted using the best eigenvectors for covariance matrix of the face images.

Fig. 6. The PCA Algorithm to Eigenface.

Suppose we had a M trained group $\mathbf{I}_1, \mathbf{I}_2, \ldots, \mathbf{I}_M$ and the image of each face has the following dimensions $N \times N$. Below we have described the basic steps needed to apply the PCA algorithm to a set of face images.

Step 1: The representation of each image $\mathbf{I}_i$ of the following dimension $N \times N$ is transformed into a single beam $\mathbf{\Gamma}_i$ with the following dimensions $N^2 \times 1$. This process can be accomplished by simply passing one row of lines one after the other, converting from a matrix to a single beam [14] (as in Fig. 7).

Note: Before this step, the images should be aligned and standardized to each other.

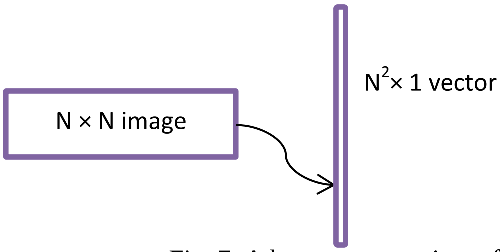

Fig. 7. A beam representing a face image.

Step 2: The mean is calculated by the following relationship:

$$\mathbf{\Psi} = \frac{1}{M}\sum_{i=1}^{M}\mathbf{\Gamma}_i$$

Step 3: Normalize is made for each image ray $\mathbf{\Gamma}_i$ by subtracting it from the middle side as follows:

$$\mathbf{\Phi}_i = \mathbf{\Gamma}_i - \mathbf{\Psi}$$

Step 4: The matrix is formed $\boldsymbol{A} = [\, \boldsymbol{\Phi}_1, \boldsymbol{\Phi}_2, \ldots, \boldsymbol{\Phi}_M \,]$ from a distance $\boldsymbol{N}^2 \times \boldsymbol{M}$

Step 5: Calculate the contrast matrix with dimensions containing face contrast. Based on the PCA technique, the subjective rays $\mathbf{u_i}$ of a matrix $\boldsymbol{AA}^T$ should be calculated. But the matrix is very large (i.e. with dimensions equal to $\boldsymbol{N}^2 \times \boldsymbol{N}^2$), and therefore, it is not feasible to compute the subjective rays of it, instead, the subjective rays $\mathbf{v}_i$ of the matrix $\boldsymbol{A}^T\boldsymbol{A}$ will be considered as are much smaller than the matrix, (meaning that its dimensions $\boldsymbol{M} \times \boldsymbol{M}$). And then we compute the subjective rays of the matrix $\boldsymbol{AA}^T$ from the subjective rays of the matrix [15].

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Step 6: Here we calculate the auto-rays **vi** of the matrix $\boldsymbol{AA^T}$.

We can simply show the relationship between $\mathbf{v}_i$ and $\mathbf{u_i}$. Since $\mathbf{v}_i$ they are the subjective rays of the matrix $\boldsymbol{A^TA}$, they achieve the following relationship: $\mathbf{A}^T\mathbf{A}\mathbf{v}_i = \mu_i\mathbf{v}_i$

where μi represents the related subjective values. If both sides are to be multiplied by the matrix of the next equation $\boldsymbol{A}$, then, we will get$\mathbf{A}\mathbf{A}^T\mathbf{A}\mathbf{v}_i = \mathbf{A}\mu_i\mathbf{v}_i$ or$\mathbf{C}\mathbf{A}\mathbf{v}_i = \mathbf{A}\mu_i\mathbf{v}_i$ or$\mathbf{C}\mathbf{u}_i = \mu_i\mathbf{u}_i$

Consequently, both of them $\boldsymbol{AA^T}$, $\boldsymbol{A^TA}$ have the same intrinsic values while their intrinsic rays are related through the following relationship: $\mathbf{u}_i = \mathbf{A}\mathbf{v}_i$

It is worth noting that the matrix $\boldsymbol{AA^T}$ can have up to N^2 subjective beams, while the matrix $\boldsymbol{A^TA}$ can have up to M subjective beams. Evidently, the auto-rays of the matrix $\boldsymbol{A^TA}$ corresponded to the best M-subjective beam of the matrix $\boldsymbol{AA^T}$ (i.e. the subjective radiations correspond to the larger subjective values) [16].

Step 7: Calculate the subjective rays $\mathbf{u_i}$ of the matrix $\boldsymbol{AA^T}$ using the relationship: $\mathbf{u}_i = \mathbf{A}\mathbf{v}_i$

Note: Normalize for $\mathbf{u_i}$ must be done $\|\mathbf{u_i}\| = 1$

Step 8 (diminishing the dimensions): Each aspect $\mathbf{\Gamma}$ is represented by retaining only the values that correspond to the largest K-value: [17]

$$\hat{\mathbf{\Gamma}} - \mathbf{\Psi} = y_1\mathbf{u}_1 + y_2\mathbf{u}_2 + \cdots + y_K\mathbf{u}_K = \sum_{i=1}^{K} y_1\mathbf{u}_i$$

The simulation of the eigenface approach is shown in Fig. 8 where a group of eigenfaces (that is, subjective faces that correspond to major subjective values) are shown in the first row while as the term “subjective face” comes from the fact that the subjective rays appear as ghostly forms. As for the second row, it shows us a new face, expressed in the form of a linear structure of self-faces.

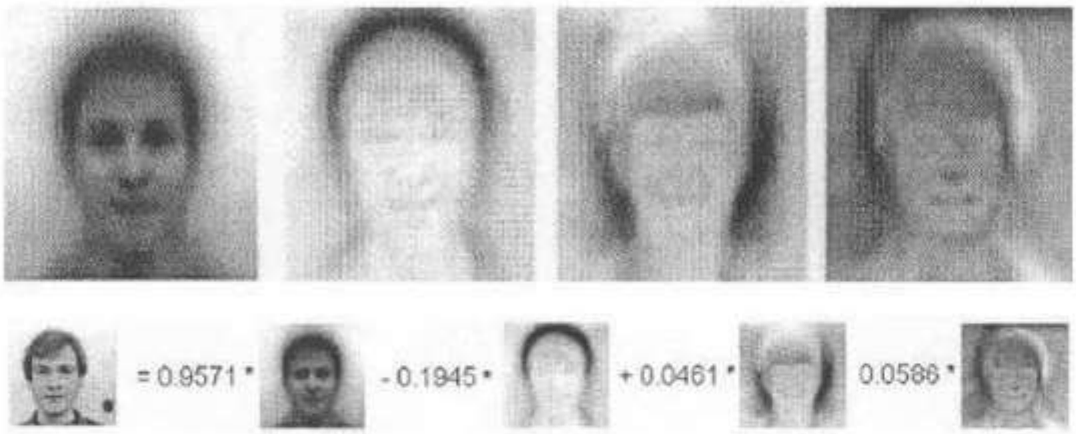

Fig. 8. A simulation and representation of an eigenface approach, each side being depicted as a linear structure of self-faces.

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With PCA, each aspect image $\mathbf{\Gamma}$ can be represented within a space of smaller dimensions than the original image, using longitudinal expansion parameters: [18]

$$\mathbf{\Omega} = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_K \end{bmatrix}$$

3.3 Face Recognition Task Using PCA

To accomplish the task of face recognition, we must first represent all the faces of the training group within space with fewer dimensions using the PCA algorithm. [18]

$$\mathbf{\Omega}_i = \begin{bmatrix} y_{i1} \\ y_{i2} \\ \vdots \\ y_{iK} \end{bmatrix}, i = 1, \cdots, M$$

Assuming that the face $\mathbf{I}$ to be recognized is a dimensional face $N \times N$ (this face is aligned and standardized similarly as the training set images), the following FR steps will be applied:

Step 1: To represent the image $\mathbf{I}$ as a single-dimensional beam $N^2 \times 1$, let it be named $\mathbf{\Gamma}$.

Step 2: Normalize the beam $\mathbf{\Gamma}$ by deducting it from the average face $\mathbf{\Phi} = \mathbf{\Gamma} - \mathbf{\Psi}$

Step 3: Dropping onto the PCA space (meaning on eignenspace)

$$\mathbf{\Phi} = y_1\mathbf{u}_1 + y_2\mathbf{u}_2 + \cdots + y_K\mathbf{u}_K = \sum_{i=1}^{K} y_i\mathbf{u}_i$$

Step 4: finding the closest face $\mathbf{\Phi}_i$ within the training set for the face, which is required to identify it $\mathbf{\Phi}$, so that the difference and the error between them is smaller, i.e. Since $\mathbf{e_r}$ is the minimum error.

$$e_r = \min_l \|\mathbf{\Omega} - \mathbf{\Omega}_l\|$$

Step 5: If $e_r < T_r$, then, the image is recognized as a face since T_r is a threshold. e_r error refers to the "the distance within the face space" as calculated by using the Euclidean distance. However, the use of other methods, such as the “Mahalanobis distance” to calculate the distance has been shown to offer better results as shown below [19][20][21]:

$$\|\mathbf{\Omega} - \mathbf{\Omega}_l\| = \sum_{i=1}^{K} \frac{1}{\lambda_i}(y_i - y_{li})^2$$

4. EXPERIMENTAL RESULTS

Below we perform the algorithm with different entries of images and apply them to the system. We concluded the following:

1. Number of photos in the training set.
2. Number of images of people without repetition within the gallery set.
3. Dimensions pictures.
4. The number of images that have been tested.

Fig. 9. GUI interface for Face Recognition

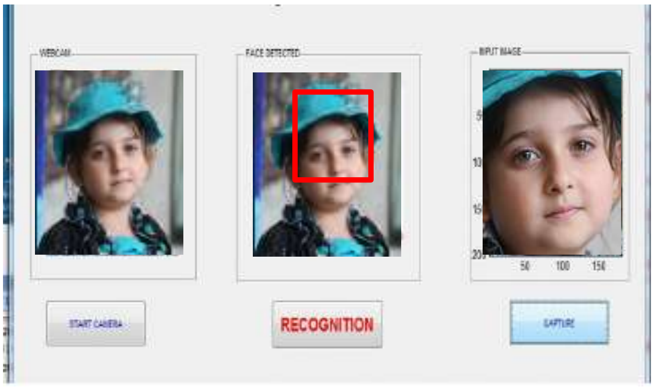

Fig. 10. Detection of Face Region.

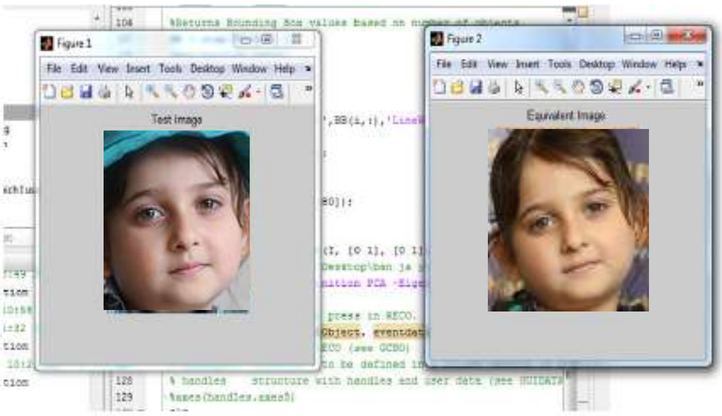

Fig. 11 Result shown at the output.

5. CONCLUSIONS

This paper presents the development of a PCR-based face recognition system for facial recognition and detection. The developed database was used as an interface for matching the input image to the mean. The image is in eigenspace because the higher the number of faces, the higher the recognition rate. Since the general shape of faces comes from the characteristics of those faces and the characteristics that they give, so this study has been proposed to identify faces and track them based on the characteristics of the human face in addition to the general appearance of it. This study, which relied on a new method for identifying faces using the PCA algorithm, through the passage of the image in several stages, starting with the stage of obtaining the image (taking it) and then, the phase of facial image extraction from the total image, along with alignment And image standardization (i.e. adjusting the angle of the face with the angle of the camera). After that, we enter the image with the stage of extracting the important basic features of the image, then we match the required image with the available image store, and finally the stage of issuing a report with the nearest image of the image or the absence of a similar one. The proposed algorithm was tested with several images and faces with faces without faces were successfully recognized. The proposed algorithm is characterized by a high efficiency in the detection of faces. This algorithm has more than 95% accuracy in face detection. The proposed algorithm is a prerequisite for any system that uses the face as the main feature, as the system provided sufficient data and optimal design to implement and test the human face recognition system. Future work can be considered work to remove the image quality issue as always in relation to environment friendly photo taking issues.

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