Face Image Recognition Using 2D PCA Algorithm

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ABSTRACT

The global features of face image have been extensively used for face recognition however they are sensitive to variations caused by expressions, illumination, pose, occlusions and makeup.

The paper describes the enhancement in the behavior of the 2D PCA (Principles Component Analysis) based recognition algorithm that recognize face images by adding noise removal filter before and after the recognition stage, PCA algorithm based on information theory concept, seeks a computational model that best describes a face by extracting the most relevant information contained, and compare the eigenface with the eigenfaces in the gallery database, the euclidean distance check the face image acceptance with noise removal filter added as an additional step to modify the performance of classic PCA algorithm to get better recognition.

تمييز صورة الوجه ثنائية الابعاد بأستخدام خوارزمية (PCA) مبادئ تحليل المكونات

الخلاصة

إن آلية تمييز الوجوه تعتبر بحد ذاته تحدي كبير وذلك بسبب أن عملية تمييز الوجوه هي مشكلة والاختلافات بين الوجوه قليلة بالمقارنة لانظمة التمييز الاخرى. عادةً الصفات العامة بالوجه هو مايستخدم لتمييز صورة الوجه حيث انها تكون حساسة جداً من ناحية التغييرات التي تتعرض لها صورة الوجه من خلال تعبير الوجه, الأضاءة, الموقع, المكياج وغيرها.

إن هذا البحث يصف خوارزمية التمييز (مبادئ تحليل المكونات) PCA التي تستخدم لتمييز صور وجه الانسان ثنائية الابعاد, وتعتمد الخوارزمية على مبدأ نظرية المعلومات مع استخدام مزيل ضوضاء الصورة حيث تبحث الخوارزمية عن الصفات المميزة واستخراجها ومقارنتها مع صور قاعدة البيانات المخزونة من خلال استخدام (المسافة الاقليدية), بوجود القيمة المثلى للمقارنة تنتهي عملية التمييز في خوارزمية PCA, أما في هذا البحث فان عملية إضافة مصفي لضوضاء الصورة مرة اخرى بعد التمييز يحسن من أداء الخوارزمية الاصلية لنحصل على تمييز افضل للخوارزمية.

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INTRODUCTION

As one of the most successful applications of image analysis and understanding, face recognition has recently received significant attention, especially during the past few years. In addition, the problem of machine recognition of human faces continues to attract researchers from disciplines such as image processing, pattern recognition, neural networks, computer vision, computer graphics, and psychology [1].

Face Recognition has become one of the most important biometrics authentication technologies in the past few years so its very important in the security issues. Two main reasons for extensive attention on face recognition technology are:

1) Aptness in various application including in content-based video processing system, law enforcement system and in security systems. A strong need for a robust automatic system is obvious due the widespread use of photo-ID for personal identification and security.

2) there are reliable methods of biometrics identifications exist such as fingerprint scans and iris scans.

Face recognition is very challenging because it is an interclass recognition problem and the distinctiveness of face is quite low compared to other biometrics (fingerprints). Moreover, changes caused by expressions, illumination, pose, occlusions and facial makeup (beard) impose further challenges on accurate face recognition [2].

Face recognition algorithms are divided into:

1) 2D face recognition (which use 2D grayscale or color images).

2) 3D face recognition (which use 3D range images or point clouds of faces).

3) Multimodal face recognition algorithms (which use both 2D and 3D facial data).

They also categorize face recognition into (1) holistic, (2) feature-based (referred to as region-based) and (3) hybrid matching faces recognition algorithms. PCA algorithm is a holistic type that match the faces as a whole [3]. The noise is the result of errors in the image, this errors will restrict the recognition process, remove these errors will clear the features of the face image, the proposed PCA algorithm used noise removal filter before and after the recognition to get a specific and accurate features that help the recognition process to get better result.

FACE IMAGE RECOGNITION

As illustrated in Figure (1), the problem of automatic face recognition involves three key steps/subtasks:

1) Detection and rough normalization of faces.

2) Feature extraction and accurate normalization of faces.

3) Identification and/or verification.

Sometimes, different subtasks are not totally separated. For example, the facial features (eyes, nose, mouth) used for face recognition are often used in face detection. Face detection and feature extraction can be achieved simultaneously, as in Figure (1). Depending on the nature of the application, for example, the sizes of the training and testing databases, clutter and variability of the background, noise, occlusion, and speed requirements, some of the subtasks can be very challenging. For example, face detection is need to initialize face tracking, and extraction of facial features is needed for recognizing human emotion, which is in turn essential in Human-Computer Interaction (HCI) systems.

Isolating the subtasks makes it easier to assess and advance the state of the art of the component techniques. Earlier face detection techniques could only handle single or a few well-separated frontal faces in images with simple backgrounds, while state-of-the-art algorithms can detect faces and their poses in cluttered backgrounds. Extensive research on the subtasks have been carried out and relevant surveys have appeared on [1].

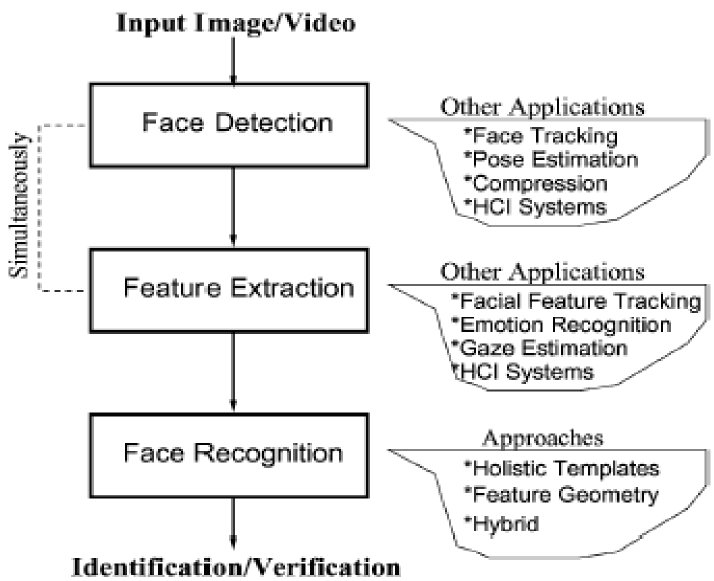


Figure (1) Automatic Face Recognition.

Face recognition has attracted much attention due to its potential values for applications as well as theoretical challenges. Many representation approaches have been introduced. Principal Component Analysis (PCA) computes a reduced set of orthogonal basis vector or eigenfaces of training face images. A new face image can be approximated by weighted sum of these eigenfaces. There are many recognition algorithms which are:

1- PCA provides an optimal linear transformation from the original image space to an orthogonal eigenspace with reduced dimensionality in the sense of the least mean square reconstruction error,
2- Linear Discriminate Analysis (LDA) seeks to find a linear transformation by maximizing the between-class variance and minimizing the within-class variance.
3- Independent component analysis (ICA) uses high-order statistics to generate image bases.
4- Elastic bunch graph matching (EBGM) uses Gabor wavelets to capture the local structure corresponding to spatial frequency (scale), spatial localization, and orientation selectivity.

5- Local Binary Pattern (LBP), originally proposed as a descriptor for textures, provides a simple yet effective way to represent faces. The face image is equally divided into small blocks and LBP features are extracted for each block to represent the texture of a face locally and globally. Weighted Chi square distance of these LBP histograms is used as a dissimilarity measure for comparing the two images. The above works have shown that PCA based methods can produces good results for face recognition in 2D images. Boosting learning with local features have recently been proposed as a promising approach [4].

FACE RECOGNITION TASKS

The two main tasks performed by any automatic human recognition system are verification/authentication and identification. These are discussed in the following sections:

1. Verification

Verification/authentication: is a one-to-one matching task where in a person claims to be a specific entity known to the system the proposed system does not depend on one-to-one verification/authentication.

2. Identification

Identification is a one-to-many matching task where in an unknown individual's identity is established by comparing his/her biometric against a database of known individuals. The closest matches in the gallery are found, this section is obvious well in figure (2). For example a person may be identified by comparing against a database of mugshots in a police department. A generalization of the identification task is the watch list task. In a watch list task, each probe is compared against signatures of all entities known to the system and entities resulting in the highest n similarity scores that are also above a predefined threshold value are considered matches. Setting a predefined threshold value seems to be is an arbitrary protection against selecting gallery individuals among the top n matches that are not close in appearance to the probe. The performance of an identification system can be evaluated in terms of a cumulative match characteristic (CMC) curve. This formulation assumes a 'closed universe' model where all individuals that query the system are present in the gallery. The CMC curve is a plot of the Recognition Rate (RR) versus the top n database matches considered. It is the ratio of the number of probes for which the correct gallery match is present among the top n matches to the total number of probes that query the system. If the closed universe assumption is false, a probe is not present in the gallery, then the maximum RR achieved is less than 100%. Verification, identification, and watch list tasks present different design challenges. For example, imposters attempting to fool a verification access control system would disguise themselves as someone known to the system.

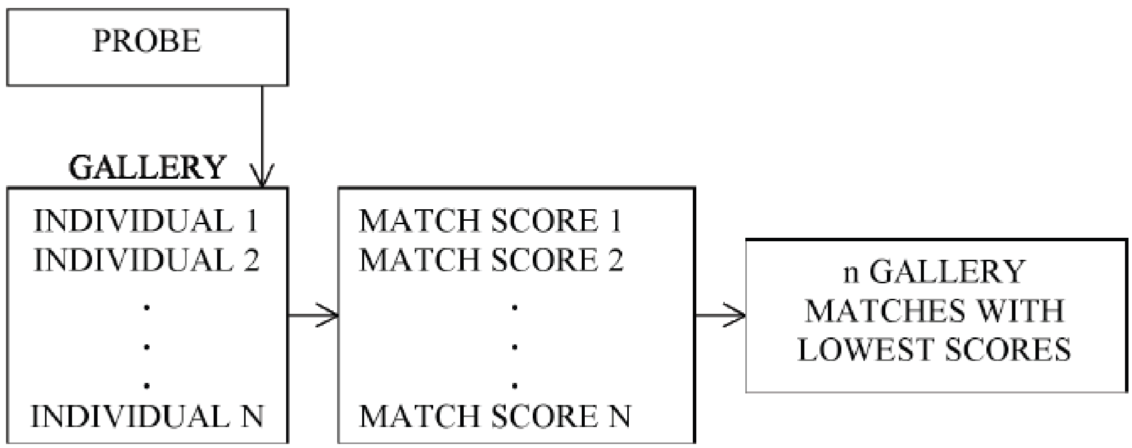


Figure (2) A schematic Diagram of an Automatic Biometric Identification System.

Thus, it is important that a high security access control system have a low FAR (False Acceptance Rate) so as not to falsely allow access to an imposter. By comparison, persons attempting to evade identification merely need to disguise themselves as anyone other than themselves. Hence, the FRR (False Rejection Rate) of, airport screening systems should be low, so that individuals with disguises are correctly identified. Hence, while designing biometric systems it is necessary to keep in mind the final intended application. A system optimized for one application may not perform acceptably for another [5].

PRINCIPAL COMPONENT ANALYSIS

Principal component analysis is a standard technique used in statistical pattern recognition and signal processing for data reduction and Feature extraction. As the pattern often contains redundant information, mapping it to a feature vector can get rid of this redundancy and yet preserve most of the intrinsic information content of the pattern. These extracted features have great role in distinguishing input patterns. A face image in 2-dimension with size $N \times N$ can also be considered as one dimensional vector of dimension $N2$. For example, face image from ORL (Olivetti Research Labs) database with size 112×92 can be considered as a vector of dimension 10,304, or equivalently a point in a 10,304 dimensional space. An ensemble of images maps to a collection of points in this huge space. Images of faces, being similar in overall configuration, will not be randomly distributed in this huge image space and thus can be described by a relatively low dimensional subspace. The main idea of the principle component is to find the vectors that best account for the distribution of face images within the entire image space. These vectors define the subspace of face images, which we call “face space”. Each of these vectors is of length $N2$, describes an $N \times N$ image, and is a linear combination of the original face images. Because these vectors are the eigenvectors of the covariance matrix corresponding to the original face images, and because they are face-like in appearance, we refer to them as “eigenfaces”. Let the training set of face images be $\Gamma_1, \Gamma_2, \ldots, \Gamma_M$, then the average of the set is defined by:

$$\Psi = \frac{1}{M} \sum_{n=1}^{M} \Gamma_n \qquad \text{….. (1)}$$

Each face differs from the average by the vector:

$$\phi_i = \Gamma_i - \psi \qquad \text{….. (2)}$$

This set of very large vectors is then subject to principal component analysis, which seeks a set of M orthonormal vectors, Um , which best describes the distribution of the data. The kth vector, Uk , is chosen such that:

$$\lambda_k = \frac{1}{M} \sum_{n=1}^{M} \left(U_k^T \Phi_n \right)^2 \qquad \text{….. (3)}$$

is a maximum subject to:

$$U_I^T U_k = \delta_{Ik} = \begin{Bmatrix} 1, & if\ I = k \\ 0, & otherwise \end{Bmatrix} \qquad \text{….. (4)}$$

The vectors Uk and scalars λ_k are the eigenvectors and eigenvalues, respectively of the covariance matrix:

$$C = \frac{1}{M} \sum_{n=1}^{M} \Phi_n \Phi_n^T = AA^T \qquad \text{….. (5)}$$

where the matrix A =[Φ_1, Φ_2....Φ_M]. The covariance matrix C, however is $N^2 \times N^2$ real symmetric matrix, and calculating the N2 eigenvectors and eigenvalues is an intractable task for typical image sizes. We need a computationally feasible method to find these eigenvectors. Consider the eigenvectors v_i of A^TA such that:

$$A^T A v_i = \mu_i v_i \qquad \text{…. (6)}$$

Pre-multiplying both sides by *A*, we have:

$$AA^T A v_i = \mu_i A v_i \qquad \text{...... (7)}$$

Where we see that Av_i are the eigenvectors and μ_i are the eigenvalues of $C= AA^T$. Following these analysis, we construct the $M \times M$ matrix $L= A^T A$, where $L_{mn}=\Phi m^T \Phi n$, and find the *M* eigenvectors, v_i , of *L*. These vectors determine linear combinations of the *M* training set face images to form the eigenfaces U_I.

$$U_I = \sum_{k=1}^{M} v_{lk} \Phi_k \,, \quad I = 1, \ldots, M \qquad \text{.... (8)}$$

The associated eigenvalues allow us to rank the eigenvectors according to their usefulness in characterizing the variation among the images. The eigenface images calculated from the eigenvectors of *L* span a basis set that cauld be used to describe face images. Figure (3) illustrate the block diagram of the PCA algorithm is [6]:

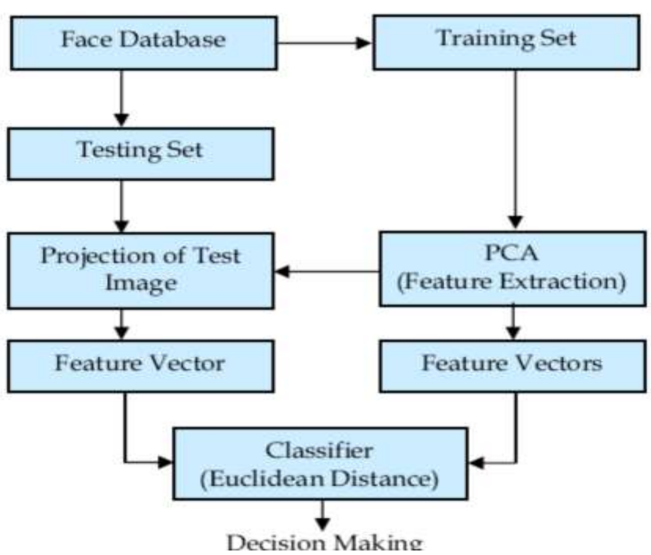


Figure (3) The Block Diagram of PCA Algorithm.

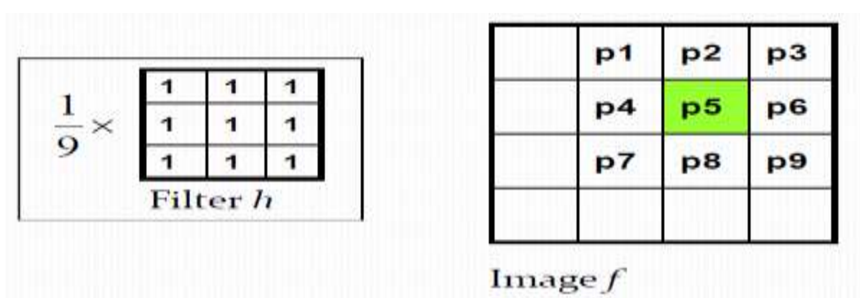
The idea of the Euclidean Distance depend on greatest common divisor of the parameters a and b, when the point *x* is the greatest common divisor of *a* and *b*, then *x* divides *r* = *a* – b, then reduces problem to finding largest *x* that divides r and b, this process will iterated until the end of the points in the eigenvector [6].

NOISE REMOVAL FILTERS

Digital images are prone to a variety of types of noise. Noise is the result of errors in the image acquisition process that result in pixel values that do not reflect the true intensities of the real scene. There are several ways that noise can be introduced into an image, depending on how the image is created. For example: if the image is scanned from a photograph made on film, the film grain is a source of noise. Noise can also be the result of damage to the film, or be introduced by the scanner itself. If the image is acquired directly in a digital format, the mechanism for gathering the data (such as a CCD (Charge-Coupled Device) detector) can introduce noise. Electronic transmission of image data can introduce noise. To simulate the effects of some of the problems listed above, by Removing Noise using Linear Filtering. Certain filters, such as averaging or Gaussian filters, are appropriate for this purpose. Linear filtering is a technique for modifying or enhancing an image. Filtering is a *neighborhood operation,* in which the value of any given pixel in the output image is determined by applying some algorithm to the values of the pixels in the neighborhood of the corresponding input pixel. Linear filtering of an image is accomplished through an operation called *convolution*. Convolution is a neighborhood operation in which each output pixel is the weighted sum of neighboring input pixels. The matrix of weights is called the *convolution kernel*. A convolution kernel is a correlation kernel that has been rotated 180 degrees. The operation called *correlation* is closely related to convolution [7].

LINEAR FILTERING OF IMAGES USING IMFILTER

The imfilter function can perform filtering using either correlation or convolution. It uses correlation by default, because the filter design functions, described in designing linear filters in the frequency domain. It is implemented by a local averaging operation where the value of each pixel is replaced by the average of all the values in the local neighborhood.



Figure(4) Imfilter Function.

2D convolution of an image *f(x,y)* with filter *h(x,y):*

$$g(x,y)= \sum_{x'=-\alpha}^{+\alpha} \sum_{y'=-\alpha}^{+\alpha} h(x',y')f(x-x',y-y')$$

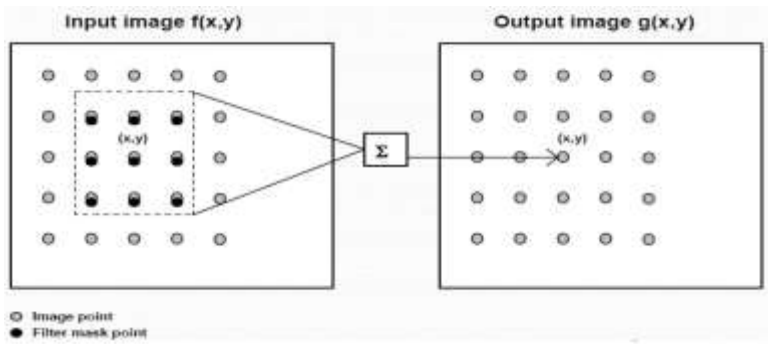


Figure (5) illustrate the Application of linear filter [8].

Original Image Filtered Image

Figure (6) Linear Filter imfilter.

THE PROPOSED 2D FACE IMAGE RECOGNITION SYSTEM

The face image is the actual data for any person even with the changes that appear to the face image depending on the face expression, pose, and illumination, so the recognition process is very important for recognizing person in the most government building that need to recognize each strange person entire to the building. The following steps explain the proposed PCA recognition algorithm:

Step 1: Input 2D query face image with any size.

Step 2: Pre-Process the face image through Resize the image to be equal with the size of the sample images in the gallery.

Step 3: Filtered the image with linear noise removal filter (imfilter) as illustrate in figure (4).

Step 4: The filtered face image will transformed to black and white areas by using face masking method.

Step 5: The initial facial image and the facial image in question are compared using Euclidean method (as in section 4) according to the points of the two eigenfaces images picking out certain features and calculates the distance between them.
Step 6: Set the initial threshold value to (95%) the (5%) will be the false tolerance of the comparison, then calculate the comparison stage value with the value of the threshold if the comparison value above the threshold value then retrieve the information of the known image, if not then apply noise removal filter to the eigenface and repeat the recognition stage. The block diagram of the proposed system is shown in figure (7):

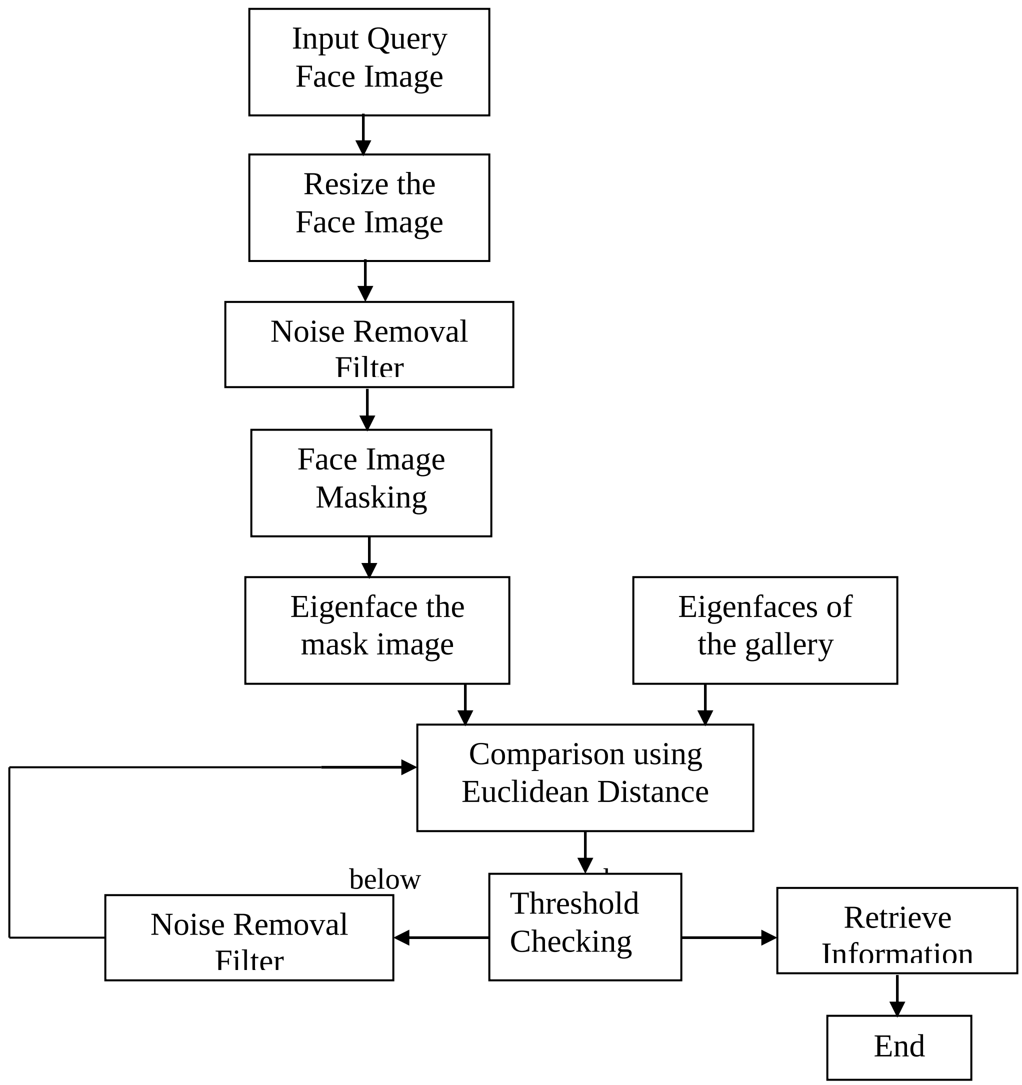


Figure (7) The Block Diagram of the Proposed PCA Algorithm.

THE RESULTS

The proposed algorithm depends on any type of 2D image (grayscale, color image) with a different size. This section represents the results of the proposed PCA-algorithm which the query image passing through stages noise removal and masking process before transforming to eigenvector, figure (8) illustrate these two preprocesses (noise removal and masking process):

2D face Image

Linear Filter

Masking Stage

Figure (8) Noise Removal & Masking Stages.

In the recognition stage the gallery is shown in figure (9), which is a sample of face images:

Figure (9) Sample face Images.

To extract the features of each image, it will converted to eigenface images as in Figure (10) and compare the captured image with each eigenface image in the gallery through using the Euclidean Distance and check if the captured image is a known person which mean exist in the database, then retrieve its information if not input the eigenface in noise removal process and repeat the comparison process.

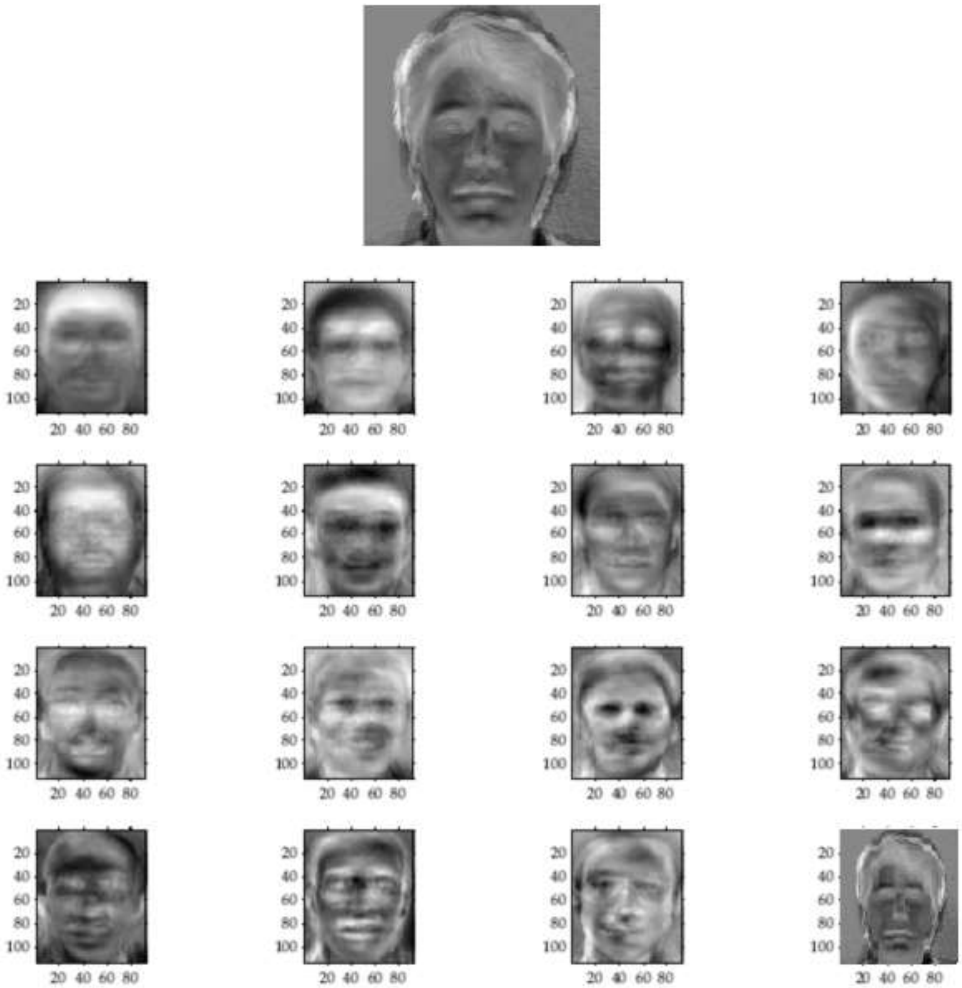


Figure (10) Eigenfaces of The Captured Image and The Gallery.

The summary of the algorithm performance results are shown in table (1) the result of this table depend on the all face samples in the gallery:

Table (1) Algorithm Performance.

	Face Enrollment Results	**Face Verification Results**
1-	98.9% automatic enrollment	False Accept Rate (FAR)<=0.0001%
2-	1.1% Required manual support	False Reject Rate (FRR)<=1%
3-	0% Failure to Enroll	Matching Speed <=2 seconds
4-	Average 5-10 seconds enrollment time	

Table (2) illustrate the comparison between the modified PCA and other recognition algorithms, this comparison depend on the basic parameters that been calculated through the application of the algorithms these parameters are: Accuracy, Uniqueness, Projections, Clarity, Speed of matching, Complexity, and Computation.

Parameters	PCA	Modified PCA	ICA	LDA	LBP
Accuracy	77%	86%	77%	83%	90%
Uniqueness	yes	yes	no	yes	yes
Clarity	75%	95%	90%	90%	80%
Projection	Linear	Linear	Linear	Non-Linear	Linear
Speed of Matching	good	very good	good	slow	good
Complexity	easy	easy	easy	Not easy	Not easy
Computation	10^8	10^9	10^8	10^9	10^8

CONCLUSIONS

1- The proposed PCA algorithm gone through many tests on different captured face images resolution and its able to recognize grayscale and color images.

2- Noise Removal in the PCA algorithm enhance the performance of the original PCA algorithm in the recognition process, it gives more accurate results in recognition especially when removing noise from eigenface after the recognition process failed.

3- The recognition process is important in more government building, its use to recognize any strange person and to authorize the person if he known or not.

4- The proposed PCA algorithm is an easy to implement the recognition stages and getting a good result in recognition the 2D face image.

5- The capturing process could be from different camera devices but the important thing is to fronting the face image and input to the recognition process.

REFERENCES

[1]. Zhao, W. R. Chellappa, P. J. Philips, and A. Rosenfeld, “Face Recognition: A Literature Survey”, Technical report, University of Maryland 2003.

[2].Ajmal Mian, Mohammed Bennamoun, and Robyn Owens, “Face Recognition Using 2D and 3D Multimodal Local Features”, The University of Westren Australia, pp. 860-870, 2006.

[3].Ajmal Mian, Mohammed Bennamoun, and Robyn Owens, “2D and 3D Multimodal Hybrid Face Recognition”, The University of Westren Australia, pp. 344-355, 2006.

[4].Stan Z. Li, ChunShui Zhao, Meng Ao, Zhen Lei, “Learning to Fuse 3D+2D based Face Recognition at Both Feature and Decision Levels”, Chinese Academy of Sciences, 2008.

[5].Shalini Gupta, Mia. K. Markey, Alan C. Bovik, “Advances and Challenges in 3D and 2D+3D Human Face Recognition”, University of Texas at Austin, USA, 2010.

[6].Hyeonjoon Moon, P. Jonathon Philips, “Computational and Performance Aspect of PCA-based Face Recognition Algorithms”, State University of New York at Buffalo, Perception, pp. 303-321, 2011.

[7].The MathWorks Inc., “Removing Noise From Images”, https://www.mathworks.com/accesslogin/login.do?uri=http://www.mathworks.com/help/releases/R2012a/pdf_doc/allpdf.html, 2012

[8].Rizzo Rosetta, “Image Noise Removal”, IEEE. Transactions on Image Processing, 2008.