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Face Recognition System Using Principal Component Analysis (PCA)

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Abstract— Face is a complex multidimensional structure and needs good computing techniques for recognition. Our approach treats face recognition as a two-dimensional recognition problem. This Project work aims at providing a system to automatically record the student's attendance during lecture hours in a hall or room using facial recognition technology instead of the traditional manual methods. In this scheme face recognition is done by Principal Component Analysis (PCA). Face images are projected onto a face space that encodes best variation among known face images. The face space is defined by eigenface which are eigenvectors of the set of faces, which may not correspond to general facial features such as eyes, nose, and lips. If the user is new to the face recognition system then his/her template will be stored in the database else matched against the templates stored in the database. The variable reducing theory of PCA accounts for the smaller face space than the training set of face

***Index Terms*—Eigen Faces, Face Recognition, PCA, LDA.**

I. INTRODUCTION

With the rapid development in the field of pattern recognition and its uses in different areas e.g.(signature recognition, facial recognition)arises the importance of the utilization of this technology in different areas in large organizations. This is mainly because these applications help the top-management take decisions that improve the performance and effectiveness of the organization. On the other hand, for an organization to be effective, it needs accurate and fast means of recording the performance of the people inside this organization. Biometric recognition has the potential to become an irreplaceable part of many identification systems used for evaluating the performance of those people working within the organization. Although biometric technologies are being applied in many fields yet it has not delivered its promise of guaranteeing automatic human recognition. This research is the one of its kind to attempt to provide an automated attendance system that recognizes students using face recognition technology through image/video stream to record their attendance in lectures or sections and evaluating their performance accordingly [1]. In addition, an automated performance evaluation would provide more accurate and reliable results avoiding human error.

Every time when a lecture starts, the lecturer or teaching assistant delays the lecture to record student's attendance. This is a lengthy process and takes a lot of time and effort, especially if it is a lecture with a huge number of students. It also causes a lot of disturbance and interruption when an exam is held [1].Biometric scanning systems typically do not record the entire imprint of a physical feature but only that portion or "template" that should be time-invariant within some statistical limit. Since the body changes over time, the statistical algorithm must be elastic enough to match a stored image with a later live scan from the same person without normally matching two similar individuals [2]. This process could be easy and effective with a small number of students but on the other hand, dealing with the records of a large number of students often leads to human errors.

II. PRINCIPAL COMPONENT ANALYSIS

PCA also known as Karhunen-Loeve method is one of the popular methods for feature selection and dimension reduction. Recognition of human faces using PCA was first done by Turk and Pentland [8] and reconstruction of human faces was done by Kirby and Sirovich [9]. The recognition method, known as eigenface method defines a feature space which reduces the dimensionality of the original data space. This reduced data space is used for recognition. But poor discriminating power within the class and large computation are the well known common problems in PCA method. This limitation is overcome by Linear Discriminant Analysis (LDA). LDA is the most dominant algorithms for feature selection in appearance based methods [9]. But many LDA based face recognition system first used PCA to reduce dimensions and then LDA is used to maximize the discriminating power of feature selection. The reason is that LDA has the small sample size problem in which dataset selected should have larger samples per class for good discriminating features extraction. Thus implementing LDA directly resulted in poor extraction of discriminating features. In the proposed method [10] Gabor filter is used to filter frontal face images and PCA is used to reduce the dimension of filtered feature vectors and then LDA is used for feature extraction. The performances of appearance based statistical methods such as PCA, LDA and ICA are tested and compared for the recognition of colored faces images in [11]. PCA is better than LDA and ICA under different

illumination variations but LDA is better than ICA. LDA is more sensitive than PCA and ICA on partial occlusions, but PCA is less sensitive to partial occlusions compared to LDA and ICA. PCA is used as a dimension reduction technique in [12] and for modeling expression deformations in [13]. A recursive algorithm for calculating the discriminant features of PCA-LDA procedure is introduced in [14]. This method concentrates on challenging issue of computing discriminating vectors from an incrementally arriving high dimensional data stream without computing the corresponding covariance matrix and without knowing the data in advance. The proposed incremental PCA-LDA algorithm is very efficient in memory usage and it is very efficient in the calculation of first basis vectors. This algorithm gives an acceptable face recognition success rate in comparison with very famous face recognition algorithms such as PCA and LDA. Two appearance–based techniques such as Modified PCA (MPCA) and Locality Preserving Projections (LPP**)** are combined in [15] to give a high face recognition rate. PCA is used as a feature extraction technique in [16]. These feature vectors are compared using Mahalanobis distances for decision making. Tensor based Multilinear PCA approach is proposed in [17] which extracts feature directly from the tensor representation rather than the vector representation. This method shows a better performance in comparison with the well known methods in distance varying environments. PCA can outperform over many other techniques when the size of database is small. In proposed algorithm [18] the database was sub grouped using some features of interest in faces. Only one of the obtained subgroups was provided by PCA for recognition. Despite the good results of PCA, this technique has the disadvantage of being computationally expensive and complex with the increase in database size, since all the pixels in the image are necessary to obtain the representation used to match the input image with all others in the database.

Different dimensionality reduction techniques such as PCA, Kernel PCA, LDA, Locality preserving Projections and Neighborhood Preserving embedding were selected and applied in order to reduce the loss of classification performance due to changes in facial appearance. The performance of recognition while using PCA as well as LDA for dimensionality reduction seems to be equal in terms of accuracy. But it was observed that LDA requires very long time for processing more number of multiple face images even for small databases. In case of Locality Preserving Projections (LPP) and NPE methods, the recognition rate was very less if increasing number of face images were used as compared to that of PCA and KPCA methods. The proposed method [19] provided considerable improvements in the case of illumination variations, PCA and kernel PCA are the best performers. Modified PCA algorithm for face recognition were proposed in [20], this method was based on the idea of reducing the influence of eigenvectors associated with the large eigen values by normalizing the feature vector element by its corresponding standard deviation. The simulation results show that the proposed method results in a better performance than conventional PCA and LDA approaches and the computational cost remains the same as that of PCA and much less than that of LDA. A new face recognition method based on PCA, LDA and neural network were proposed in [21].

This method consists of four steps:
i) Preprocessing
ii) Dimension reduction using PCA
iii) Featureextraction using LDA and
iv) Classification using neural network.

Based on an information theory approach, PCA decomposes face images into a small set of characteristic features images called “Eigenfaces” that can be described as the principal components of the initial training set of images. In the language of information theory, the extractions of the most applicable information in a face images desired then encode it as effectively as possible and compare one face encoding with a database of models encoded similarly.

In PCA, one can transform each original image of the training set into a corresponding eigenface. Therefore, one important feature of PCA is that the reconstruction of any original image from the training set by combining the eigenfaces is possible. Eigenfaces are the characteristic features of the faces. Therefore one could say that the original face image can be reconstructed form eigenfaces if one adds up all the eigenfaces (features) in the right proportion. Each eigenface represents only certain features if the face, which may or may not be present in the original image.

If the feature is present in the original image to a higher degree, the share of the corresponding eigenface in the sum of the eigenfaces should be greater. On the other hand if the particular feature is not present in the original image, the corresponding eigenface should contribute a smaller part to the sum of eigenfaces. Indeed, in order to reconstruct the original image form the eigenfaces, one has to build a kind of weighted sum of all the eigenfaces. That is, the reconstructed original image is equal to a sum of all eigenfaces, with each eigenface having a certain weight. This weight specifies, to what degree the specific features (eigenface) is present in the original image.

If all the eigenfaces extracted from the original images are used, one can reconstruct the original images from the eigenfaces exactly. But using only a part of the eigenfaces is applicable. Hence, the reconstructed image is an approximation of the original image. However, losses due to omitting some of the eigenfaces can be minimized, which is

achieved by selecting only the most important features (eigenfaces).

Therefore, using these weights one can determine two important things:

1. Check whether the image is a face. In the case the weights of the image differ too much from the weights of face images, the image probably not a face.
2. Similar faces (images) possess similar features (eigenfaces) to similar degrees (weights). If weights form all images available is extracted, the images could be grouped to clusters. Thus, all images having similar weights are likely to be similar face [12].

III. Eigen Face Approach

The algorithm for the facial recognition system uses the concept of eigenfaces. Firstly, the original images of the training set are transformed into a set of eigenfaces E. Afterwards; the weights are calculated for each image of the training set and stored in the set W. When observing an unknown image X, the weights are calculated for that particular image and stored in the vector W x. Afterwards, W x is compared with the weights of images, of which one knows for certain that they are faces (the weights of the training set W).

One way to do, it would be to regard each weight vector as a point in space and calculate an average distance D between the weight vectors from W x and the weight vector of the unknown image W x (the Euclidean distance). If this average distance exceeds some threshold value, then the weight vector of the unknown image W x lays too far apart from the weights of the faces. In this case, the unknown X is considered not a face.

IV. Eigen vectors and Eigen values

An eigenvector of a matrix is a vector such that, if multiplied with the matrix, the result is always an integer multiple of that vector. This integer value is the corresponding eigen value of the eigenvector. The corresponding eigen value is the proportion by which an eigenvector's magnitude is changed. This relationship can be described by the equation M * u =k * u, where u is an eigenvector of the matrix M and is the corresponding eigen values. This means, an eigen value of 2 means that the length of the eigenvector has been doubled. The eigen value of 1 explains that the length of the eigenvector stays the same.

Eigenvectors possess following properties:

1. They can be determined only for square matrices.
2. There are n eigenvectors (and corresponding eigenvalues) in an n * n matrix.

All the eigenvectors are perpendicular, i.e. at right angle with each other.

The mathematical steps for feature extraction are as shown below:

For being acquainted with the terms and notations that are going to be used during the eigenfaces algorithm evaluation, refer to Appendix A.

Step 1: Gather and prepare the data.
Let the training set of face images be T1, T2… TM.

Step 2: Subtract the mean.
The average matrix ψ has to be calculated, then subtracted from the original faces (Ti) and the result is stored in the variable ϕ i.

The average of the set is defined by

$$\Psi = \frac{1}{M}\sum_{n=1}^{M}\Gamma_n$$

Each face differs from the average by the vector

$$\phi = \Gamma_i - \Psi$$

Step 3: Calculate the eigenvectors and eigenvalues of the covariance matrix.
This set of very large vectors is then subject to principal component analysis, which seeks a set of M orthonormal vectors, U_m which best describes the distribution of the data. The K_{th}vector,

$$\boldsymbol{\lambda}_K = \frac{1}{M}\sum_{n=1}^{M}(U_K^T \phi_n)^2$$

U_K, is chosen such that is a maximum, subject to

$$U_I^T U_K = \delta_{IK} = \begin{cases} 1, & if\ I = k \\ 0, & otherwise \end{cases}$$

The vectors U_K and the scalars λ_K are the eigenvectors and eigenvalues.

Step 4: Calculate the covariance matrix.
The covariance matrix C is calculated according to

$$C = \frac{1}{M}\sum_{n=1}^{M}\Phi_n\Phi_n^T = AA^T$$

Where the matrix A= [ϕ 1,ϕ 2,ϕ 3 …ϕ M]

Following the matrix analysis, the M * M matrix L= $A^T A$ is constructed, where L mn = $\phi^T_m \phi_n$ and the M eigenvectors, V_I of L is computed.
These vectors determine linear combinations of the M training set face images to form the eigenfaces U_l.

$$U_l = \sum_{k=1}^{M} V_{lk} \phi_k, \quad l=1 \ldots M \qquad \text{(vii)}$$

The success of this algorithm is based on the evaluation of the eigenvalues and the eigenvectors of the real symmetric matrix L that is composed from the training set of images. After this step, the "training" phase of the algorithm is accomplished.

We implement this face recognition process in matlab using GUI functions. In GUI there is a callback function which is used to callback the each function used in the code such as capture video ,crop image ,save ,exit and recognize .In our project we use Microsoft excel sheet for databse storage of student information like phone number ,their Roll number and array is maintained for attendance marking and if student is not recognized during testing than SMS is sent to that particular student by fetching the data from the database which we had stored

V. AUTOMATIC FACIAL RECOGNITION PROCESS FLOW

Generally any biometric system goes through the same processes of the four modules explained earlier, biometric capture, feature extraction and comparison with templates available in the database as explained in figure 3.2.

The facial recognition process is similar to the general biometric recognition process.

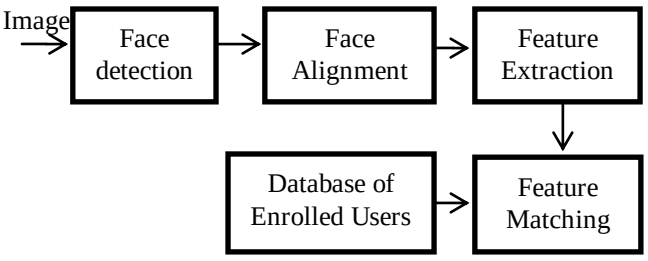

Figure 5.1: Block diagram of face recognition processing flow [1].

The facial recognition process can be divided into two main stages: processing before detection where face detection and alignment take place (localization and normalization) and afterwards recognition occur through feature extraction and matching steps.

1. Face Detection: This process separates the facial area from the rest of the background image. In the case of video streams, faces can be tracked using a face tracking component.

2. Face Alignment: This process focus on finding the best localization and normalization of the face; where the detection step roughly estimates the position of the face. This step outlines the facial components such as face outline, eyes, nose, ears and mouth. Afterwards normalization with respect to geometrical transforms such as size and pose, in addition to photometrical properties such as illumination and grey scale take place.

3. Feature Extraction: After the previous two steps, feature extraction is performed resulting ineffective information that is useful for distinguishing between faces of different persons and stable with respect to the geometrical and photo metrical variations.

4. Face Matching: The extracted features are compared to those stored in the database and decisions are made according to the sufficient confidence in the match score [1].

VI. CREATING DATABASE IN MATLAB

A sony 8.1 MP static camera is used for image acquisition which captures images at spatial resolution (640 x 480) pixels having a frame rate of 25 frames per second. The images are further processed and cropped (240 x 180) resolution so that rest of the background is avoidable and focused on desired faces. The distance between the camera and the person is roughly 7 to 8 meters.

Figure 6.1: Training Database contains images of different people with different expressions. Images are taken by same

camera with different environment but cropped according to desired resolutions (240 x 180).

Figure 6.2: Test Database contain same number of images with same resolution as in training database but placed in a different position. The sequence of all the images in the test database is varied as compare to training database.

Classifying an image with the eigenfaces, a new face image (Γ) is transformed into its eigenface components (projected onto "face space").

$$W_k = U_k^T (\Gamma - \phi) \qquad \text{(ix)}$$

For k=1…M

The weights form a feature vector,

$$\Omega^T = [W_1 W_2 \ldots\ldots W_M] \qquad \text{(x)}$$

Classification is performed by comparing the feature vectors of the face library members with the feature vector of the input face image. This comparison is based on the Euclidean distance between the two members to be smaller than a user defined threshold Θ_k. If the comparison falls within the user defined threshold, then face image is classified as "Known", otherwise it is classified as "unknown" and can be added to face library with its feature vector for later use, thus making the system learning to recognize new face images [13].

Figure 6.3: Represents some examples of eigenfaces [12].

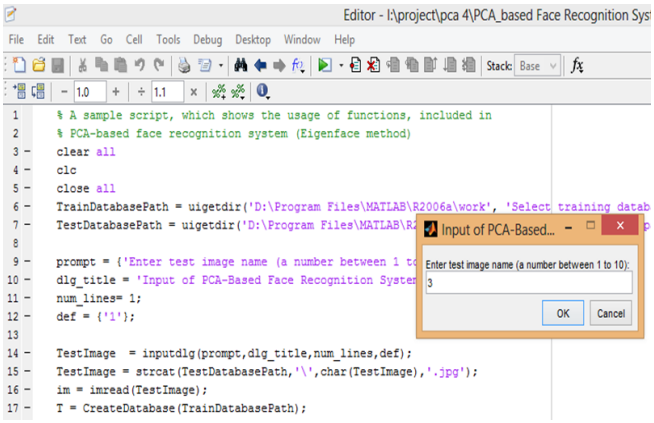

Figure 4.4: Request User Input in Matlab for finding out the equivalent image in training database that has the same face which is requesting by the user from the test database.

The output of the system will consist of the face ID with the closest match, as well as a value representing how close this match is (a distance value). All this information will be displayed on the GUI of the PC. It will always call a stored procedure in the database with image ID as its parameter to record the student's attendance in the database.

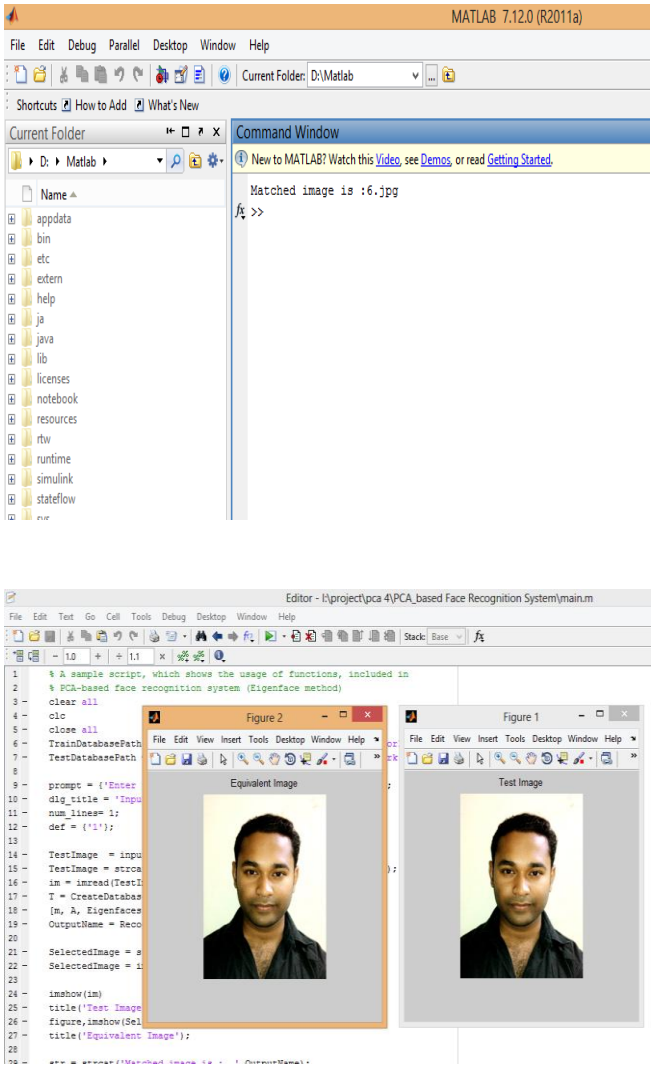

Figure 4.5: Result: Showing Equivalent image from training database by comparing with test image contained in test database.

VII. OPTIMIZATION

The performance of the proposed Face Recognition System is tested on different images in different poses recorded in different conditions. Some of the images include one person while some includes two persons. The database is crucial to the execution of the system and the details of every student taken as consistent. The database is updated as per the changes. The image capturing and processing phase is the source of the input to the system. The improvement on the image is modified according to the incorporation of the 3D model of each student. This model is created from the three views of the student's face by applying PCA and allows the capturing angle range between - 180 to 180 degrees.

VIII. LIMITATIONS AND CHALLENGES OF FACE RECOGNITION TECHNOLOGIES

Face recognition technology, just as any other biometric technology, has not yet delivered it promise. In spite of all its potentials, it is still quite limited in its applied scope. Many researchers have identified different problems or the biometric system; they can be categorized in four main challenges:

1. Accuracy: Two biometric samples collected from the same person are not exactly the same due to the imperfect imaging conditions. In addition, the face recognition technology is not robust enough to handle uncontrolled and unconstrained environments. Inconsequence, the results accuracy is not acceptable. As explained in figure 8.1, inaccuracy can occur in two different forms, either False Non-Match (false reject / Type 1 error) in which the system falsely declares the failure of match between the instance and the correct stored template; or False Match (False Accept / Type 2 error) in which the system incorrectly declares a successful match between the instance and one of the templates in the database.

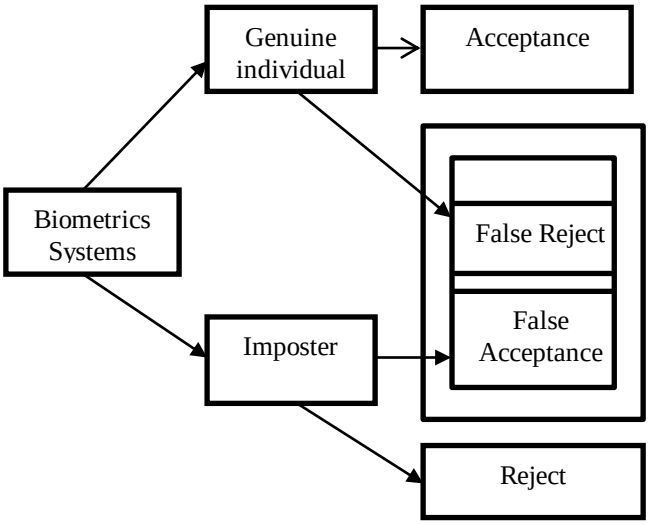

Figure 8.1: Biometrics system errors [9].

These errors are mainly caused by the complexity and difficulties of the recognition process because of the uncontrollable variables such as lighting, pose, expression, aging, weight gain or loss, hairstyle and accessories. This challenge is reduced as more training data is available to enhance the performance of the biometric system.

2. Scale: The number of entities enrolled in the database of the biometric system greatly affects the speed, accuracy and performance in case of identification systems; where each

new instance is compared to all those in the database to find a match. Unlike verification where one to one comparison takes place. As mentioned in this article, according to some studies conducted, a facial authentication takes about 90 msec, while a large scale ID throughput needs about 0.66/ min. That is why, in biometric identification systems, it is absolutely necessary to find more efficient ways for biometric comparison. This can be reached by performing course pattern classification. For example: the captured face is firstly classified into male or female and then an age range can be determined. In this way, the search in the system's database can be narrowed down in an efficient way. The large intra-class variation still represents a great challenge in the field of pattern recognition, where many studies are being conducted to find the best way for indexing patterns similar to the ways used in conventional databases.

3. Security: Facial recognition and other biometric systems are used for many security applications claiming that biometrics is a secure way of authenticating access. But in fact, security of biometrics (especially face), is very questionable. This is caused by two main reasons:

a) Biometrics is not a secret: This means that anyone including the attacker knows exactly the biometric features of the targeted user.
b) Biometrics is not recoverable: This means that one cannot change his face, in case it is became compromised.

4. Privacy: The issue of using recognition based systems has raised many concerns of possible privacy violations; which is a major concern in many locations such as the American Civil Liberties Union (ACLU) which opposes the use of face recognition software at airports due to ineffectiveness and privacy concern.

The database of a biometric system hold irrefutable proof of one's identity; and there are no regulations or guarantees on how these information might be used or what it could be used for. These privacy issues mostly result in the reluctance of users to use these biometric systems.

On the other hand, it is said that this is not true and biometrics is a privacy protection tool rather than intrusion to civil rights. This would be achieved through managing data protection and encryption along the biometric system [9].

IX. Conclusion

The aim is to automate and make a system that is useful to the organization such as an institute or in university. The proposed research work has implemented a face recognition system by using PCA which is eigenvector based multivariate analyses. Often, its operation can be thought of as revealing the internal structure of the data in a way which best explains the variance in the data. By implementing PCA the proposed Face Recognition System supplies the user with a lower-dimensional picture, a "shadow" of this object when viewed from its most informative viewpoint. The algorithm has been tested with multiple audiences in the scene and also captured faces at different angles in the scene.

REFERENCES

[1] A. Jha, "Class-room attendance system using facial recognition system", The International Journal of Mathematics, Science, Technology and Management, Vol. 2,pp. 5-8, 2013.
[2] A. Alterman, "A piece of yourself: Ethical issues in biometric identification", Ethics and Information Technology, Vol 5, pp. 139–150, 2003.
[3] M. H. Yang, N. Ahuja and D. Kriegmao, "Face recognition using kernel eigenfaces", IEEE International Conference on Image Processing, Vol. 1, pp. 10-13, 2000.
[4] G. Roethenbaugh, "Biometrics explained", in Proceedings of the International Committee for Information Technology Standards, Vol. 2, pp. 1-23, 2005.
[5] P. Sinha, B. Balas, Y. Ostrovsky and R.Russell, "Face recognition by humans", inProceedings of the IEEE, Vol. 94,pp. 157-165, 2006.
[6] J. Zhu and Y. L. Yu, "Face recognition with eigenfaces", IEEE International Conference on Industrial Technology, Vol. 2, pp.434-438, 1994.
[7] K. Jain, A. Ross, S. Prabhakar, "An introduction to Biometric Recognition", in Proceedings of the IEEE, Vol. 14, pp. 1-29, 2004.
[8] M. Turk and A. Pentland, "Eigenfaces for recognition," J. Cognitive Neuroscience,vol. 3, 71-86., 1991.
[9] D. L. Swets and J. J. Weng, "Using discriminant eigenfeatures for image retrieval", IEEE Trans. PAMI., vol. 18, No. 8, 831-836, 1996.
[10] C.Magesh Kumar, R.Thiyagarajan , S.P.Natarajan, S.Arulselvi,G.Sainarayanan,‖ Gabor features and LDA based Face Recognition with ANN classifier‖,Procedings Of ICETECT 2011
[11]Önsen TOYGAR
Adnan ACAN ,‖Face recognition
using PCA,LDA and ICA approaches on colored images‖, Journal Of Electrical and Electronics Engineering, vol-13,2003
[12]Y. Cheng, C.L. Wang, Z.Y. Li, Y.K. Hou and C.X. Zhao,‖ Multiscale principal contour direction for varying lighting face recognition‖,Proceedings of IEEE 2010
[13]F. Al-Osaimi·M. Bennamoun · A. Mian,‖ An Expression Deformation Approach to Non-rigid 3D Face Recognition‖, Springer Science+Business Media, LLC 2008
[14]Issam Dagher,‖Incremental PCA-LDA algorithm‖, International Journal of Biometrics and Bioinformatics

(IJBB), Volume (4): Issue (2)
[15]J. Shermina,V. Vasudevan,‖An Efficient Face recognition System Based on Fusion of MPCA and LPP‖, American Journal of Scientific Research ISSN 1450-223X Issue 11(2010), pp.6-19
[16]Ishwar S. Jadhav, V. T. Gaikwad, Gajanan U. Patil,‖Human Identification Using Face and Voice Recognition‖, International Journal of Computer Science and Information Technologies, Vol. 2 (3), 2011
[17] Yun-Hee Han,Keun-Chang Kwak,‖ Face Recognition and Representation by Tensor-based MPCA Approach‖, 2010 The 3rd International Conference on Machine Vision (ICMV 2010)
[18] Neerja,Ekta Walia,‖Face Recognition Using Improved Fast PCA Algorithm‖,Proceedings of IEEE 2008
[19] S.Sakthivel,Dr.R.Lakshmipathi,‖Enhancing Face Recognition using Improved Dimensionality Reduction and feature extraction Algorithms_An Evaluation with ORL database‖, International Journal of Engineering Science and Technology Vol. 2(6), 2010
[20]Lin Luo, M.N.S. Swamy, Eugene I. Plotkin, ―A Modified
PCA algorithm for face recognition‖, Proceedings of IEEE 2003
[21] A. Hossein Sahoolizadeh, B. Zargham Heidari, and C. Hamid Dehghani,‖ A New Face Recognition Method using PCA, LDA and Neural Network‖, International Journal of Electrical and Electronics Engineering 2:8 2008

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