Real-Time Implementation Of Face Recognition System

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***Abstract*— Face Recognition is the ability to detect and recognize a person by their facial characteristics. Face is a multidimensional and hence requires a lot of mathematical computations. Face recognition system is very essential and important for providing security, mug shot matching, law enforcement applications, user verification, user access control, etc and is mostly used for recognition for various applications. These all applications require an efficient Face recognition system. There are many methods that are already proposed and have low recognition capability, high false alarm rate. Hence the major task of the research is to develop face recognition system with improved accuracy and improved recognition time of an face recognition system. This paper proposes a hybrid face recognition algorithm by combining two face recognition techniques by integrating (PCA) principle Component Analysis, (LDA) Linear Discriminant Analysis. Jacobi method is used to compute Eigenvector that are necessary for PCA and LDA algorithms. Face Recognition system will be implemented on Embedded system based Raspberry pi 3 board.**

Keywords— Principle Componet Analysys, Linear Descriminant Analysys, EigenVectors, EigenValues, Raspberry Pi, Python.

I. INTRODUCTION

Everyone has had the experience of not recognizing someone they know due to changes in pose, facial expressions, illumination and expressions. So it's not surprising that computer vision system may face the same problems. Despite of years of work on computer vision scientists from all over the world are not able to match that of human performance. Still Face Recognition Systems are not poor. The best systems can overrun human performance under fixed ideal condition. But the performance decreases drastically as conditions change.

Face recognition system first requires a set of database images. The first task is to create dataset of images on which your algorithm can be tested. Thanks to a readymade dataset of images called " AT& T" dataset images which have been captured with different poses, variations, expressions. In this project these dataset images will be used to test the proposed algorithm which consists of 400 images of 40 persons each having 10 different images which have pose and expressions variations.

The task of Face Recognition Algorithm is to compare two images and determine if they belong to the same person. Face Recognition system are developed to detect and recognize a person that differ in characteristics. The Face Recognition Systems have evolved greatly during the last some decades. Because of this development there is increase in algorithmic complexity which takes long computation time and power. Many algorithms such as Principle Component Analysis, Linear Discriminant Analysis, Independent Component Analysis, Fuzzy Logic, Support Vector machine, Genetic algorithm have been used for face recognition systems.

In this paper a combination of PCA [8] and LDA [7] algorithm have been proposed to implement Face Recognition System on Raspberry pi 3 [11],[12],[13]. The Face is multidimensional and therefore has "Curse Of Dimensionality" that is face requires a lot of memory and time for processing. To overcome this issue optimal features has to be obtained to improve accuracy and remove noise from images. PCA is extensively used to reduce dimensionality. Next after reducing the dimensionality the images are projected onto eigen space using LDA. To do this we need Eigen value calculation. Jacobi Method to calculate Eigen values and Eigenvectors have been used that give approximated Eigenvectors and Eigenvectors.

PCA and LDA algorithms project all the training AT&T dataset images onto eigen space. The unknown image, that is test image is also projected onto eigen space. For the recognition purpose the Euclidean Distance is calculated between the test image and all the training images. The trained image that has minimum Euclidean distance to test image ie Unknown image is the correct match. Face recognition systems have wide applications. An efficient face recognition can be of great help in identification of persons, Forensics science, authentication systems, mug shot matching, user access and security systems.

II. RELATED WORK

This section deals with different work that has already been done in Face Recognition area. Past few decades the face recognition system has gained very popularity due to its various applications. A lot of research work has been done in

this area to build efficient face recognition system. Face recognition system should have high recognition rate and high recognition speed. The aim is to select recognition algorithm that will increase the accuracy and speed up the Face recognition process.

Turk and Pentland [1] developed face recognition system using Eigenfaces approach that was initially developed by Sirovich and Kirby. This was a breakthrough for Face recognition system. This formed the bases of Face Recognition Algorithm. They developed a near real time computer system that can locate and track a subjects head and then recognize the person by comparing characteristic of face to those that are known.

Bartlett, Movellan, Sejnowski [2] also proposed a face recognition algorithm based on Independent Component Analysis. The PCA [5] algorithm is based on the fact that important information of image is contained in pair wise relationship between pixels where as ICA is based on the fact that some important information may be contained in the high-order statistics. Maryam Mollaee, Mohammad Hossein Moattar [14] have proposed face recognition system using modified ICA for better accuracy.

Juwei, Plataniotis, Venetsanopoulos [3] proposed a face recognition system using LDA algorithm. This algorithm is also used to reduce dimensionality. LDA was first formulated by Ronald A. Fisher. Both LDA and PCA are Linear transformation technique but PCA is an unsupervised algorithm since it ignores class labelsand its aim is to find directions that maximize variance whereas LDA is supervised and computes direction that represents axis that maximizes the separation between many classes.

Dhanaseely, Himavati, Srinivasan [4] proposed a face recognition system using PCA to reduce Dimensionality and used neural network for classification. The neural network based face recognition system are biologically inspired and behave like neurons of human beings which carry signals from one place to another. Just like neuron a perceptron calculates weighted sum on numerical inputs and determines if a person is recognized or not. Using neural network requires lot of computational work.

Hence from literature survey, it is clear that many algorithms have been proposed for face recognition system. Therefore this paper proposes Face Recognition System by integrating two well known algorithms for face recognition system PCA and LDA. Both these algorithms require computation of Eigen Values and Eigen Vectors. Jacobi method is used to calculate the Eigen Values and Eigen Vectors. The novelty of this approach is to increase recognition rate and reduces recognition time. Any real time application that requires face recognition system can use this approach to build Face Recognition System using any embedded platform

III. Principle Component Analysis And Linear Descriminant Analysis

PCA also known as Karhunen_Lower Trasformation is used to reduce the dimensionality. Its main aim is to reduce the data onto lower dimensional space also called as eigen space by computing the eigen values and eigenvectors of dataset. The output of PCA is the input to LDA algorithm.

The LDA computes the scatter matrix within class and scatter matrix between class thus separating the images within class increasing the recognition rate. After calculating the weight matrix Euclidian distance is calculated.

The PCA and LDA algorithms are based on an efficient computation of Eigen values and Eigenvectors. Many methods are used to compute Eigen value and Eigenvectors such as QR method, Gauss-Seidel method, Power method, Jacobi method etc. The Jacobi method is an iterative method to find eigen value and eigenvector of symmetric matrix.

A. Block Diagram

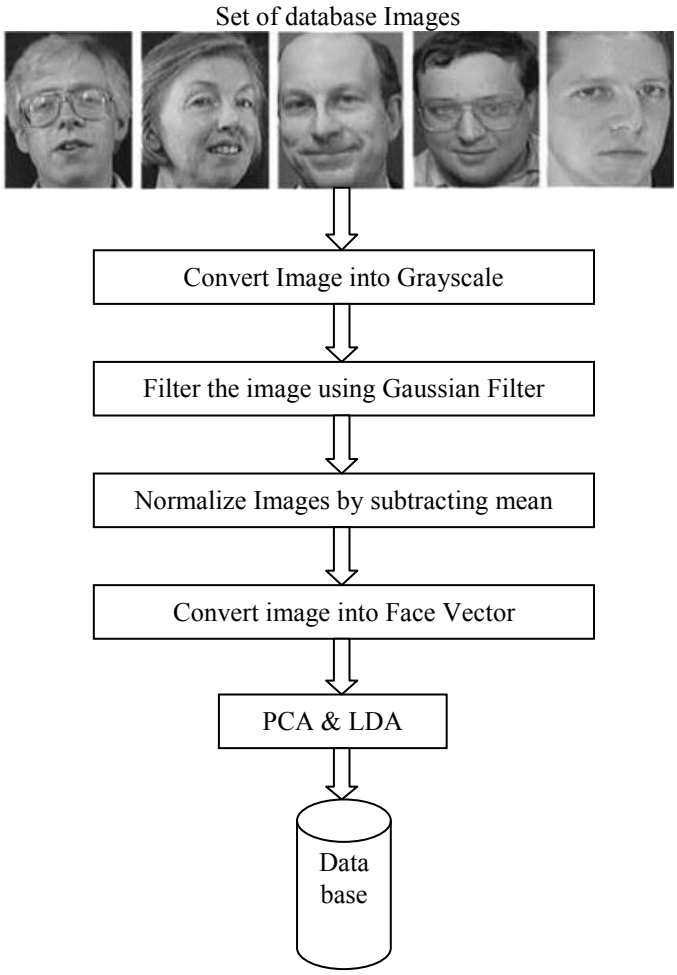

Fig. 1. Design Flow of Tranning Module

The Tranning module consists of Gray scale conversion module where in all colour images are converted into Gray scale images, a Gaussian filter module to filter the image using gaussian mask, Normalisation Module by subtracting the mean of all images from each image to normalize faces, and vector conversion module that convertes 2D image are converted into 1D row vector. Next the PCA followed by

LDA algorithms are applied onto images after which database of images is obtained. This completes the Traning phase of face recognition system.

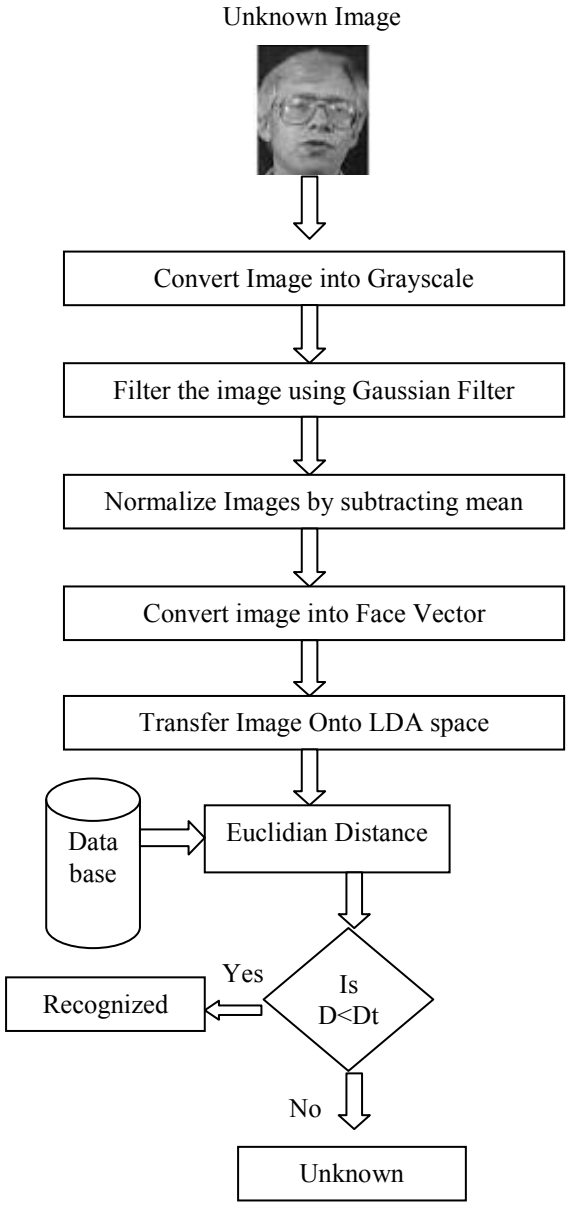

Fig. 2. Design Flow of Recognition Module

During the recognition phase of Face Recognition system the unknow face is first converted into gray scale. Next the test image is smoothened using gaussian filter. Test image is normalized by subtracting the mean of images from test image. Now the image is converted from 2D to 1D row and then is transfered to LDA subface space by multiplying weight of PCA and LDA. Euclidian distance is calculated between the LDA sub space of test image and all the LDAsubspace images in the database. The minimum distance image is classified as recognized image.

IV. Proposed Algorithm

Any Face Recognition system have Face detection system and Face recognition system.

1) Face Detection System:

In this section we will describe a about Face detection which has several modules that are working together as one to make the system to run properly. The phase consists of capturing image and Detecting face in image. Image can be captured in real time from USB webcam connected to Raspberry pi. The function of face detection module is to clarify whether a face is available during real time application. The face detection is done by scanning an image and finding some pattern that represents face. When the system detects the face, it will produce a sub-image such that face appears in the centre and has uniform size.

Open CV already have algorithms to locate faces in images and videos. Haar Classifier which is a modification of AdaBoost [15] algorithm scans the input image from webcam and creates a box for each face present in image. Haar classifier used for face detection tries to find characteristics of face components such as eyes, nose, mouth, etc in an image. It analyses these features and generates a template for each face. The template consists of reduced set of data which represents face bounded in a box.

2) Face Recognition System:

This section deals with PCA and LDA for face recognition. First we need a set of Database of images using which the algorithm will be tested. AT&T dataset images will be used. The first step is to read all the dataset images that will be used for training purpose.

Fig. 3. Figure Shows AT & T database images

In this section we discus all the mathematical steps that will be executed on the Raspberry Pi 3 embedded system board to implement face recognition system on it. This section is divided into two parts i.e. Training phase and Recognition phase.

A. *Training Phase*

In training phase a set of AT&T images are used to create database of images that will be used for recognition. Following steps show how training of images is done

- Consider dataset of images each of size n*m. The images in dataset are converted into grayscale as recognition rate of grayscale images is better than that of RGB images.

$$Z = \begin{bmatrix} a_{11} & \dots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \dots & a_{mn} \end{bmatrix}$$

- Gaussian filtering is done by using 3*3 Gaussian mask to reduce noise on the images to increases the recognition rate.

1/16	1/8	1/16
1/8	1/4	1/8
1/16	1/8	1/16

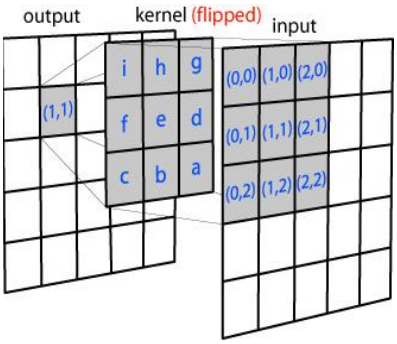

Fig. 4. Figure showimg Gaussian mask

- After Filtering all the images next all images are converted from 2D image to 1D row vector

$$R = \begin{bmatrix} a_{11} & \dots\dots & a_{n*m} \\ b_{11} & \dots\dots & b_{n*m} \\ c_{11} & \dots\dots & c_{n*m} \end{bmatrix}$$

- After converting all images to 1D and appending them to one matrix we get a matrix of row size equal to total number of database images and the column size of number of pixels in each image. Next the mean of formed matrix R is calculated and subtracted from each row matrix to normalize the dataset images. Thus we get Normalized images

- Formula to Calculate Mean of images

$$\psi = \frac{1}{M}\sum_{i=1}^{M}\Gamma_i \quad (1)$$

where M is the total number of images in training set

$$A = \begin{bmatrix} a_{11} - \Psi & \dots & a_{1n} - \Psi \\ \vdots & \ddots & \vdots \\ z_{m1} - \Psi & \cdots & z_{mn} - \Psi \end{bmatrix}$$

where matrix A represents mean subtracted images

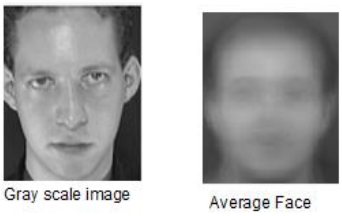

Fig. 5. Figure showimg Gray scale image and mean subtracted average face

- Next the covariance matrix is calculated of Matrix A as the eigen value calculation requires a symmetric matrix by using the formula

$$C = A * A^T \quad (2)$$

But this results in lot of computation as there will be many images in training set. To reduce computation the dimensionality of matrix is reduced by using small variation in formula given by

$$L = A^T * A \quad (3)$$

This results into a z*z matrix where z represents the number of images in training set. Next the eigen values and eigenvectors of symmetric matrix L is calculated using Jacobi Method.

- Next each image is represented in eigen space by multiplying the eigenvectors and normalized matrix A given by formula

$$PCA = U * A \quad (4)$$

where U is the eigenvector of L matrix, A is normalized image. PCA represents all images in Eigen space.

- The next task is to calculate the weight matrix of PCA that will be input to LDA algorithm given by

$$\text{weight\_pca}=A.*PCA^{T} \quad (5)$$

where A represents normalized images and PCA is eigen space representation of database images. The next task is to calculate the weight matrix of PCA that will be input to LDA algorithm given by

This ends the PCA algorithm where in all images are projected onto PCA subspace. The output of PCA algorithm goes as an input to LDA algorithm.

- Let P be number of image samples {x1,x2,x3,....xp} and let each image belong to one of the class c{c1,c2,c3,....cc}. Ni be number of samples in each class.
- The mean of images in PCA subspace is calculated given by formula

$$\mu = \frac{1}{M}\sum_{i=1}^{M} weight\_pca \quad (6)$$

where m is the total number of images in dataset

- To calculate the Scatter matrix we also need the individual mean of images that belong to a particular class. This is calculated by using the formula

$$\mu_i = \frac{1}{N}\sum_{i=1}^{N} weight\_pca_i \quad (7)$$

where μ_i represents mean of all images in one class ci

- Next the Scatter matrix between class is calculated given by the formula

$$S_b = \frac{1}{N}\sum_{i=1}^{c} N_i(\mu_i - \mu)(\mu_i - \mu)^T \quad (8)$$

This scatter matrix Sb separates the images of one class to that of others.

- Next the within class scatter matrix is calculated using the formula

$$S_w = \frac{1}{N}\sum_{i=1}^{c}\sum_{x_k \varepsilon c_i} N_i(w\_pca_i - \mu_i)(w\_pca_i - \mu_i)^T \quad (9)$$

This matrix groups all the images belonging to one person together.

- Next the eigen values and eigenvectors of scatter matrix within class and between class is calculated by using Jacobi method.
- After computing the eigenvector of scatter matrix the eigenvector is multiplied to the weight matrix of PCA algorithm to represent images onto LDA subspace given by the formula

$$\Omega=\text{eig\_lda}^{T}*\text{weight\_pca} \quad (10)$$

where Ω is the calculated weight of LDA algorithm.

- This completes the training phase of Face recognition system

B. *Recognition Phase*

In recognition phase the Image to be tested goes through all the steps of pre-processing starting from color to Gray conversion, Filtering, normalization and column vector conversion.

- The gray scale filtered image is converted into a column matrix

$$r = \begin{bmatrix} a_{11} \\ \vdots \\ a_{mn} \end{bmatrix}$$

- Average face calculated in PCA algorithm is subtracted from the column matrix to normalize unknown image.

$$r = \begin{bmatrix} a_{11} - \Psi \\ \vdots \\ a_{nm} - \Psi \end{bmatrix}$$

- Next the unknown image is projected onto LDA subspace by multiplying weights of PCA and LDA given by the formula

$$\Omega=\text{eig\_lda}^{T*}*\text{eig\_pca}^{T}*r \quad (11)$$

- In the final stage of recognition the Euclidian distance is calculated between LDA face projection of unknown image and that of dataset images given by formula

$$\varepsilon^2=\| \Omega-\Omega i\|^2 \text{ where i=1, 2.....n} \quad (12)$$

- The minimum Euclidian distance represents the authorized face from the dataset.

This does not complete our Face Recognition system. Suppose you try to recognize an image that is not in database, still there will be a match which has the minimum Euclidian distance.

Consider for simplicity we have only 4 images in the training set and an image that is not in our database comes up for recognition task. The Euclidian distance for each of the 4 images in database is calculated from incoming Test image. And even if an image is not in the database it will still say the image is recognized as a person from database whose Euclidian distance is minimum. This is anomaly. It is for this purpose we decide on our threshold value. The threshold value Q is decided heuristically.

Consider a Cartoon image as a face image. The Euclidian distance is calculated between cartoon image and 4 training set images. Let's say D_4 is the lowest score out of all but the image is clearly not belonging to the database.

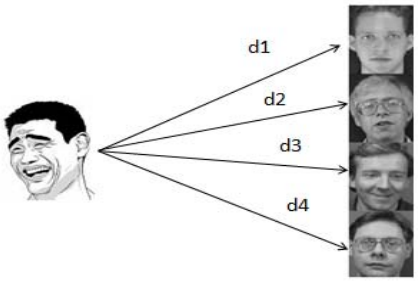

Fig. 6. Figure showing Recognition of image not in database.

V. Implementation Details

Before Implementing the design on Embedded platform the design was initially modeled in MATLAB which is the easiest and simplest environment for Scientists. Matlab is used in both academics and industries as software development tool. It is an interactive numerical computation and data visualization tool which along with wide programming capabilities which makes it useful for almost all areas of science and engineering. Matlab is one of the leading software packages for numerical computation and it mainly deals with Matrices right from scalar to multidimensional matrices.

Ones tested and debugged, the entire code was rewritten in python language. Several python libraries were used along with python to perform certain task. Open CV library was used to detect a face in captured image. This helps us for subsequent recognition task using PCA and LDA algorithm and less pre processing is required. The USB web cam sends a video stream of image frames that are received by the Raspberry Pi through USB interface. Once received, the python GUI implements the Face detection using open CV and face recognition using PCA and LDA algorithms. The SD card holds the necessary software to implement these algorithms and it also holds database of Images. Once the test image is tested recognized face along with test face is displayed on the screen.

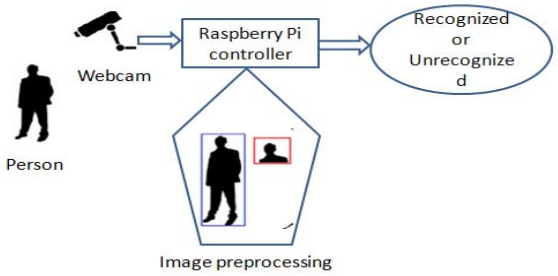

Fig. 7. Figure showing hardware implementation of Face Recognition System.

VI. Results And Conclusion

The performance of proposed algorithm is evaluated on AT&T dataset of images. AT&T dataset of images consists of 400 face images of 40 individuals with 10 images per person each having dimensions of 112*92 pixels. Each pixel consists of an 8-bit gray scale value ranging from 0 to 255. The images are taken at various different times varying in light, facial expressions, pose, etc. The images are in PNG format

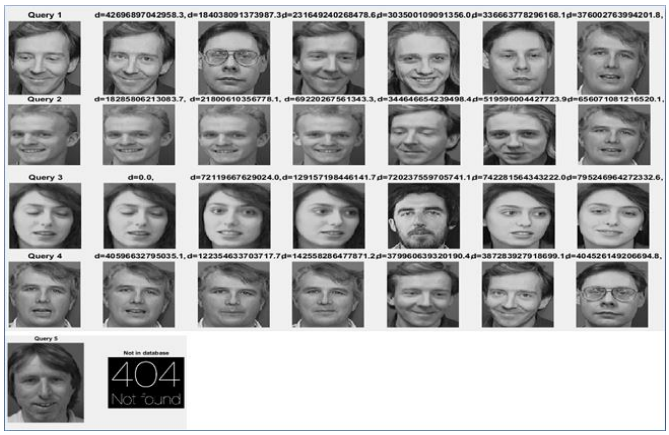

Fig. 8. Figure showing Recognition Results of face recognition system

As can be seen from Figure 8 Query 1 image of a person is used for testing purpose whose similar variant image is present in our database as a result there is a match from our database and person is recognized whose Euclidian distance is minimum.

Query 3 image of a person is present in our database and same image is used for testing purpose as a result there is a match from database and Euclidian distance calculated is zero.

Query 5 image of a person is not present in our database. Hence the result shows that image not found as the threshold value Q is very large. The threshold value that is found in this project is 3500.

Using AT&T dataset of images the accuracy of PCA and LDA algorithm is measured for our Face recognition system. The algorithm was applied to AT&T dataset of 100 training images of 20 persons taking 5 images of each person for training purpose. The accuracy of FACE RECOGNITION

using PCA alone was found to be 91%, the accuracy of LDA alone was found to be 94% and that of proposed method was found to be 97% when implemented on raspberry pi 3 board.

TABLE I. TABLE SHOWING ACCURACY OF ALGORITHMS

Images	Algorithm	Accuracy(%)
100	PCA	91
100	LDA	94
100	PCA+LDA	97

In this paper, I have proposed an efficient Face recognition system based on PCA and LDA. Using these two combination of methods have given me accuracy of 97% by using raspberry pi 3 module. The Raspberry pi 3 module is a cost effective module and is a low weight compact module to be used for recognition system. This project on Face Recognition has given me an opportunity to study many face recognition algorithms that were used and being currently used. This project has also provided me with the knowledge that combining two or more methods increase the accuracy of Face recognition system.

In future this Face recognition system could be incorporated on a Robot to make it more Human like.

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