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Implementation of Principal Component Analysis on Masked and Non-masked Face Recognition

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***Abstract*— This paper represents an implementation of Principal Component Analysis (PCA) on masked and non-masked face recognition. Security is an essential term in our today's life. In various Biometric technology, face recognition is widely used to secure any system because it is better than any other traditional techniques like PIN, password, fingerprint etc. and most reliable to identify or verify a person efficiently. In recent years, face recognition is a very challenging task because of different occlusion or masks like the existence of sunglasses, scarves, hats and different types of make-up or disguise ingredients. The accuracy rate of face recognition is influenced by these types of masks. Many algorithms have been developed recently for non-masked face recognition which are widely used and give better performance. Still in the field of masked face recognition, few contributions has been done. Therefore, in this work a statistical procedure has been selected which is applied in non-masked face recognition and also apply in the masked face recognition technique. PCA is more effective and successful statistical technique and widely used. For this reason in this work, PCA algorithm has been chosen. Finally, a comparative study also done here for a better understanding.**

Keywords—Face recognition, PCA algorithm, Eigen face, Eigen value, Masked face.

I. INTRODUCTION

Face recognition is one of the most promising field of computer vision. Recognize a face and verifying a person automatically from images, known as face recognition system [1]. Face recognition plays an important role in our regular life. In a passport checking, ATM, credit card, voter verification, smart door, criminal or terrorist investigation and many other purposes face recognition is widely used to authenticate a person automatically and accurately. For those reasons, face recognition is the most popular than any other Biometric techniques.

In all automated personal identification system, face recognition has gained much attention as a unique Biometric recognition technique. For protecting the assets of many industries in the world are now trying to implement this authentication technique in their organizations. Throughout the world, many of the governments also interested to secure the public places such as railway stations, airports and bus stations etc. by using face recognition system. However for poor recognition rate, in real time recognizing remain unsuccessful. Recognition rate depends on quality of image. Recognition rate decreases for noisy and low quality image. That's why pre-processing is needed for better recognition rate. Some pre-processing techniques like cropping, resizing, sharpening, de-noising, normalizing, enhancing are used in face recognition process [2]. Recently many algorithms have been developed for reliable face recognition. Different techniques depend on different methods and they have different recognition accuracy. All of these algorithms, Principal Component Analysis (PCA) gives a better accuracy rate in normal or non-masked face recognition [3]-[5].

In present days masked face recognition is more important. Mainly terrorists and criminals covered their face with mask for disguise. Besides this, sunglass, hat, color festoon etc. also act like mask. Using different types of masks or occlusions the key features to identify a person is decreasing. Lower numbers of face features in the masked face cause difficulties than other normal face recognition technique [6]. Consequently the accuracy rate of recognition is decreasing. That's why masked face is being one of the majors concerned factor in the field of face recognition. Figure 1 shows some of masked faces.

Fig. 1. Human faces with different types of masks.

For face recognition, at first we need to detect the face from image. After detecting face, we can recognize the person.

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It is easy for human to detect a face but harder for a system to detect face. For this reason at first we need to train the system for detect face portion from images. Here we use Viola-Jones algorithm to detect face from an image. Viola-Jones algorithm detect face using machine learning approach from any digital image [7]. After detecting face from input image, then we use PCA algorithm for feature extraction from image, which are used for training.

This work also presents a statistical difference of accuracy between masked face recognition and non-masked face recognition using the most successful algorithm Principal Component Analysis. All the result are shown in both graphically and tabulated form.

The paper is organized as follows: Section 2 presents our face detection and face recognition methodology. Section 2 describes about face recognition process. Section 3 signifies dataset. Section 4 shows experimental results and section 5 draws conclusions.

II. METHODOLOGY

Figure 2 demonstrate our proposed method to the problem of robust face recognition under mask and non-mask conditions. For face recognition at first detect the face portion from an image, find out the face features and finally train a system for face recognition. During the training phase, for detecting face portion we used Viola-Jones algorithm in our work and then PCA is used to efficiently represent the gallery images. In this way we obtain a PCA feature space which is called Eigen faces or ghost face. In the test case, a target face image (which can be masked or not) is given to be recognized. At first its PCA representation is computed. As a result, potential facial components are identified. Then, the Eigen faces are selected and used for recognition. The recognition is carried out by comparing the selected features from the target image against selected features from the corresponding template images. The nearest neighbor (NN) classifier distance is taken for the recognition.

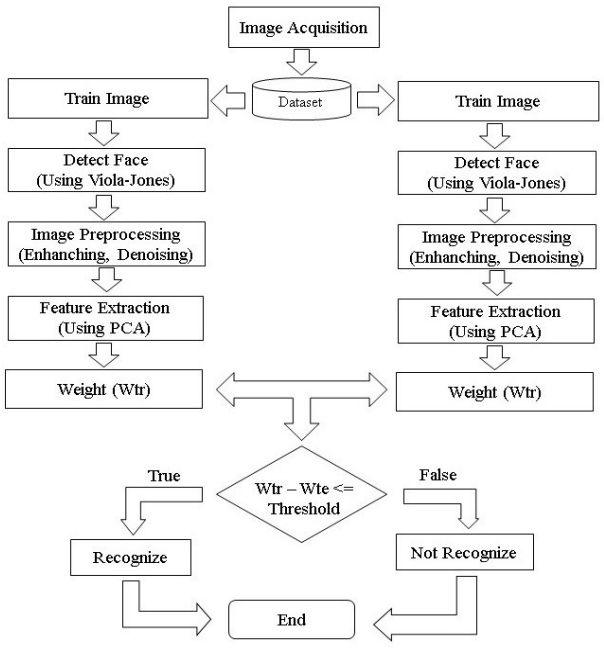

Fig. 2. Flow chart of face recognition process using PCA.

III. FACE RECOGNITION PROCESS

From a digital image or video sources identify or verify a person automatically by comparing facial features is called face recognition. Using various algorithms, features are extracted and then perform comparison between training image and test image for recognize a face.

A. Facial Image Acquisition

Image acquisition is the first stage of face recognition system. After obtaining the images, different methods of processing can be applied on the image. If the image has not been acquired correctly then the desired tasks are difficult to achieve. In this work we use faces from a database named ORL Database and some of our own captured images. We mix up our own masked and non-masked images to the database to enlarge the dataset so that our work is more reliable and efficient.

B. Detecting Face and Preprocessing

After acquiring the images, the first work is to segment out the face for further processing. We choose Viola-Jones face detection algorithm for detecting face region. Then implemented it in the MATLAB library to automatically segment the face region. Some of our face images quality are not much better as we needed. Up to expectation this face detector fails to detect face region in image. Faces which are heavily disguised or most of the important facial features are covered are subjects to fail detect face region. Every face image is normalized and apply image enhancement methods, so to achieve better results. This set of enhanced face images are therefore used to perform further experiments and evaluations.

C. Facial Feature Extraction using PCA

Principal Component Analysis (PCA) is an important statistical procedure and also defined as an orthogonal linear transformation. This algorithm emphasizes variation and brings out strong patterns in a dataset. It is used to minimize a big dataset to a small dataset still contains almost all the information as large dataset. PCA finds the data mean and principal components. It is popular as dimension reduction procedure. The technique is usually used for maximizing variance and seizing strong patterns of features in a dataset [8]. It was introduced by Karl Pearson in 1901. PCA is an effective statistical method.

For correlated data, Principal Component Analysis (PCA) works well. An image is also a highly correlated data. Hence extracting features from images, PCA performs better. Performing different operations on image matrix, it is transformed to a lower dimensional Eigen subspace. There after find out the covariance matrix from the lower dimension matrix. Relative variance between pixels in an image are represented by covariance matrix. Afterward Eigen vectors are calculated from this covariance matrix. Eigen vectors with the highest Eigen values are considered as the principal components.

Steps of Principal Component Analysis algorithm are mentioned below-

Step 1: Input data

Step 2: Calculate mean value of data

Step 3: Subtract the mean value from each input data

Step 4: Calculate Covariance matrix

Step 5: Calculate Eigen vectors and Eigen values

Step 6: Finding the greatest eigenvalue(s)

Step 7: Calculate Weight

D. Eigenvalue and Eigenvector

Eigenvalue and eigenvector comes from German word "Eigen" that means "Characteristic". In a square matrix eigenvalue is a scalar that represent by λ, which is a Greek letter. Eigenvector is represented by small letter *x* and it is a non-zero vector [9]. Here is an equation which is satisfied by all eigenvector and eigenvalue. Here, *S* is a given square matrix.

$$Sx = \lambda x \tag{1}$$

A huge calculation need in a large matrix and to solve this problem, eigenvalue and eigenvector method is used.

E. Eigen Face

Basically a set of eigenvector is called Eigen face which is used for face recognition of human. Eigen face extract the main feature from image and major Eigen face is selected for face recognition. In face recognition, Eigen face is used for represent the face image efficiently by principal component analysis. Images can be reconstructed as like as original image from a few number of weights and pictures [10]. Eigen face in a face recognition system must be less or equal to the total size of dataset. In figure 3 shows some of Eigen faces.

Fig. 3. Some Eigen faces.

F. Mathematical Analysis

For face recognition we need to train a dataset and then apply Principal Component Analysis on train dataset step by step. At first, we have to convert train dataset into face vector. Each 2D (*p* by *q*) train image is converted into 1D ($p \times q$ by 1) face vector. After converting all images, they are loaded which is called dataset. In this research work, total images K= 12 (face of our dataset). Here K depends on the number of train images and I is a variable which loads all images.

$$\mathrm{I} = \{\Gamma_1, \Gamma_2, \Gamma_3, \cdots\cdots\cdots, \Gamma_K\} \tag{2}$$

After load the dataset next procedure is to calculate average or mean face. Here average face is $\bar{X}$.

$$\bar{X} = \frac{1}{K}\sum_{n=1}^{n=K}\Gamma_K \tag{3}$$

Then, subtract the mean face from each image of the dataset which is called normalization. Here ϕ_n is a variable which stores the result of normalization. Then new matrix D is generated,

$$\phi_n = \Gamma_n - \bar{X}$$
$$\mathrm{D} = \{\phi_1, \phi_2, \phi_3, \cdots\cdots\cdots, \phi_K\} \tag{4}$$

After normalizing, we get a normalized face vector. Then we calculate covariance matrix of normalized vector.

$$C = DD^T\mathrm{s}$$
$$= \{D_{(p\times q)}D^T{}_{(q\times p)}\}_{(p\times p)} \tag{5}$$

Covariance matrix C is a large square matrix. For efficient and accurate calculation eigenvalue and eigenvector is calculated for reducing a huge face space vector. For recognition, we need to calculate weight which is compared with test image weight.

$$\omega_K = \mu^T(\Gamma_n - \bar{X}) \tag{6}$$

Here, ω = weight, μ = eigenvector, Γ = face and $\bar{X}$ = average face.

IV. DATASET AND EXPERIMENTAL ENVIRONMENT

In this work ORL face database [13] is used, which contains a set of faces taken between April 1992 and April 1994 at the Olivetti Research Laboratory in Cambridge, UK. This dataset contains 10 different images of 40 individuals. The files are in PGM format. Each image size is 92x112, 8-bit grey levels. For masked faces we created masked face images dataset using ORL face image and our own captured images. In this experiment, total 500 images used. 300 as a training image and 80-200 images used as test images on different test cases. Figure 4 shows some dataset images of our experiments. All the work done using MATLAB. Here use image processing toolbox of MATLAB 2017a version on windows platform.

V. EXPERIMENTAL RESULT

Proposed methodology is applied on our dataset images and found the resultant images. First step of face recognition is created a training dataset which contains pre-processed input images. After creating training set, average face is calculated for normalized training set. For normalize the dataset, subtracting an average face from each original face. Figure 5 shows the normalized faces of original face image. Then calculate the Eigen face which are shown in figure 6. Finally test some images for recognition. Here create some masked face images and also test them if it can be recognized

the person properly. Both masked and non-masked face testing images shown in figure 7.

Fig. 4. Some example images from training dataset.

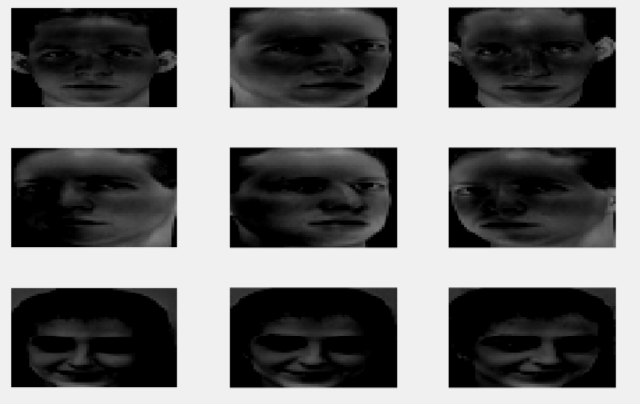

Fig. 5. Some normalized faces

Fig. 6. Some Eigen faces

(a) (b)

Fig. 7. Testing (a) Masked face and (b) Non-Masked face

A statistical comparison between masked face recognition and non-masked face recognition using PCA algorithm shown in table-I. This table shows the recognition accuracy of both masked and non-masked face images. A graphical representation also shown in figure 8 for a better data visualization.

TABLE I. MASKED AND NON-MASKED FACE RECOGNITION ACCURACY

Test no.	Total train image	Total test image	Image types	Accuracy (%)
Test 01	300	80	Non-masked	96.25
	300	80	Masked	73.75
Test 02	300	120	Non-masked	95.83
	300	120	Masked	72.50
Test 03	300	160	Non-masked	95.05
	300	160	Masked	67.13
Test 04	300	200	Non-masked	95.62
	300	200	Masked	68.75

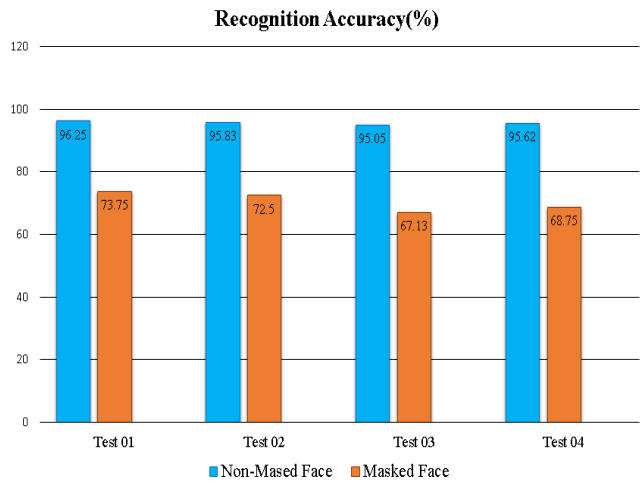

Fig. 8. Graphical representation of both masked and non-masked face recognition accuracy

From the above table, accuracy of masked face image recognition is on average 72% where non-masked face is on average 95%. So PCA gives poor recognition rate for masked face images rather than non-masked faces.

VI. CONCLUSION

This paper analyzed non-masked face recognition and masked face recognition accuracy using Principal Component Analysis (PCA) to recognize a person. It is proved that, a face without mask gives better recognition rate in PCA based face recognition system. But when a person is wearing mask, facial recognition gives poor recognition rate. It is found that extracting feature from a masked face is less than non-masked face. Because of missing features for wearing mask which decrease the recognition rate. Finally, we conclude that traditional statistical algorithm Principal Component Analysis (PCA) is better for normal face recognition but not for masked face recognition. So in the future, our concern to improve the accuracy of masked face recognition using other sophisticated machine learning methods.

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