A Comparative Study of Face Recognition Techniques

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Abstract – **Face recognition is a widely used biometric technique with many advantages of being non-intrusive and natural. Recently, many applications are based on face recognition techniques including video surveillance, law enforcement, identity authentication, or any other application These systems are widely used online and provide a very fast recognition rate. Use face recognition as primary biometrics. Face recognition is very important especially in uncontrolled environment. It is a challenging task to recognize faces due to illumination, occlusion, pose variation, expressions, aging factors and alignment, etc. Paper describes the different methods and techniques that deal with these conditions, also the advantages and limitations of these techniques.**

Keywords – **Face Recognition Techniques, Biometrics, Principal Component Analysis, Linear Discriminant Analysis, Independent Component Analysis.**

I. INTRODUCTION

Human face is an extremely complex dynamic structure with characteristics that can quickly and significantly change with time. The human ability to recognize face is remarkable. Human can recognize thousands of faces, but after some time separation we will be unable to recognize them. That happen only due to the face variability. Human Face is a rich source of information, that lets human to identify whether the person is male or female, approximate age, facial expression, and so on. Human face detection and recognition has been drawn considerable interest for decades. Automatic Face recognition is typically used in security system and can be compared to other biometrics such as fingerprint or iris recognition system. Face recognition is playing very important role in our life and hot research area in the field of computer vision and it is one of the biometrics that is being used for the last 50 years[1].

The purpose of face recognition is mainly to identify a person, as a key to security (Biometric face recognition technology) and a wide variety of applications such as identification for law enforcement, matching of photographs on passports or driver's licenses, access control to secure computer networks and facilities such as government buildings and courthouses, authentication for secure banking and financial transactions, automatic screening at airports for known terrorists, and video surveillance. Face recognition has attracted much attention and its research has rapidly expanded by not only engineers but also neuroscientists, since it has many potential applications in computer vision communication and automatic access control system and it has the great advantage of being able to work in places with large concourse of unaware visitors because human beings are not capable enough to recognize the strangers[2].

There are several key factors that can significantly affect face recognition system performances like pose variations, illumination variations, occlusion, time delay, low resolution and age and change in expressions. Regarding these challenges, the researchers are always trying to evaluate the best face recognition algorithm. Different evaluations have been conducted by researchers This paper presents the challenges which hinder the face recognition and discuss the algorithms which are used to solve face recognition problems with merits and demerits of these algorithms.

In section 2, Illustrate Challenges of Face Recognition.

In section 3, provide Major Steps for Face Recognition.

In section 4, Study of different methods of Face Recognition.

In section 5, A survey of different face recognition Techniques.

In section 6, Comparative Analysis For advantages and disadvantages of Face Recognition Techniques with some of the applications and limitations which facing the face recognition. Then, the choice of appropriate technique to solve every problem and types of databases and software tools used with these techniques.

II. CHALLENGES OF FACE RECOGNITION

Face localization, detection and then identification or verification has been a challenging task due to a number of factors. Face is so non-rigid and has so many variations that no one technique can cope with all these variations. That is why in spite a large number of algorithms and technique a robust system is still far from real implementation. The challenges associated with face recognition can be returned to the following factors:

A. Changes in skin texture

Some plastic surgery makes people look younger or more attractive by removing face scars, acnes or taking skin resurfacing. As a result, the skin texture will change.

B. Changes of global face appearance

Global facial plastic surgery will change the global face appearance, in other words, not only part of the face component and the skin texture will change, but also the whole face geometric structure and appearance will be disturbed [3].

C. Changes in illumination

The variation in illumination changes the appearance of the face drastically. It is found that the difference between two images of the same person taken under varying illumination is greater than the difference between the images of two different persons under same illumination [4].

D. Changes in Pose

Pose variations in an image is also a matter of concern in face recognition. The changes in the posture strike a serious problem for the identification of the input image. This is because the available image in the database may have only the frontal view of the face which may differ in pose with the input image and so may result in faulty identification [5].

E. Changes in Expression

The facial expressions also impose problem in identifying the face [6].

F. Age variations

With the increasing age, the appearance of a person also changes which affect the face recognition system [7].

G. Occlusion

The unavailability of the whole input face is also one of the important challenges. This is when some parts of the face are missing for e.g. when an image is captured from a surveillance camera; the face in the image lacks some parts. This is also possible due to glasses, beard, moustache, scarf, etc. Such a problem can severely affect the classification process [8].

H. Low Resolution

The images taken from a surveillance camera generally consists of very small face area and so its resolution is very low [9].

III. MAJOR STEPS FOR FACE RECOGNITION

Facial recognition (or face recognition) is a type of biometric software application that can identify a specific individual in a digital image by analyzing and comparing patterns [10].

Generally face recognition works in two steps:

A. Face detection

For face detection we use a simple camera to take clear photo of a person. Then we detect face from that image. After detect many face from image we make database of it. And it is used for comparison with test image.

B. Face recognition

Test image face is also detect by using face detection technique. Then that face is compared with the constricted database. On basis of that comparison we can say face is known or not [11].
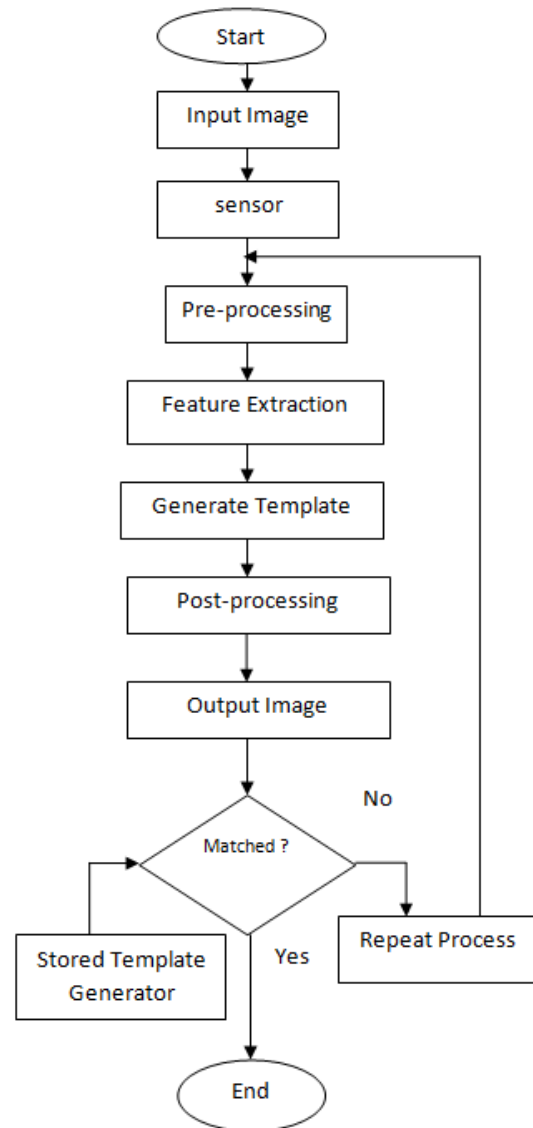
IV. METHODS OF FACE RECOGNITION

Basically face recognition can be done by the two main methods.
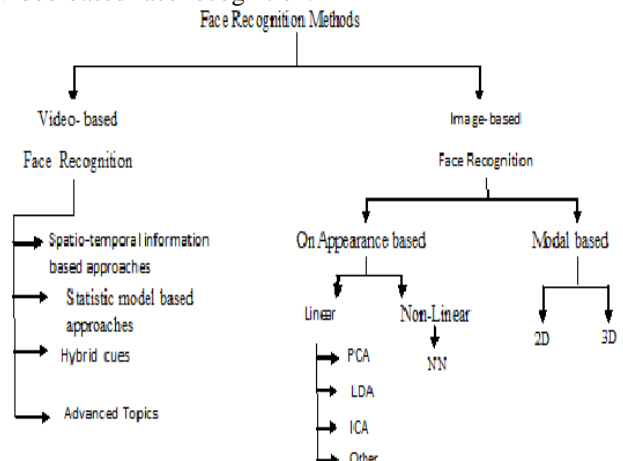Image-based face recognition.
Video-based face recognition.

Fig.1. Image\ Video- base face recognition [12]

Fig.1 Facial recognition methods are divided into two parts Image based face recognition and Video based face recognition. As shown in diagram image based face recognition is sub-divided into two parts that is appearance based and Model based. Appearance based is sub-divided into two parts that is linear and non-linear. PCA, ICA, LDA and etc. are sub-types of linear appearance based, and Neural Network is sub-type of Non-Linear appearance based. Model based is also sub-divided into two types 2D and 3D.

Video-based face recognition divided into four approaches such as Spatio-temporal information based approaches, Statistic model based approaches, Hybrid cues based approaches and Advanced Topics. They will be explained some of these techniques in detail at the following section.

V. FACE RECOGNITION TECHNIQUES

There are numbers of techniques have been proposed in the area of automatic face recognition and summarize the advantages and limitations of different techniques.

A. Principal Component Analysis (PCA)

The Eigenface algorithm uses the Principal Component Analysis (PCA) for dimensionality reduction to find the vectors which best account for the distribution of face images within the entire image space. These vectors define the subspace of face images and the subspace is called face space.

All faces in the training set are projected onto the face space to find a set of weights that describes the contribution of each vector in the face space. To identify a test image, it requires the projection of the test image onto the face space to obtain the corresponding set of weights. By comparing the weights of the test image with the set of weights of the faces in the training set, the face in the test image can be identified [13, 14]. PCA can be illustrated in Fig.2.

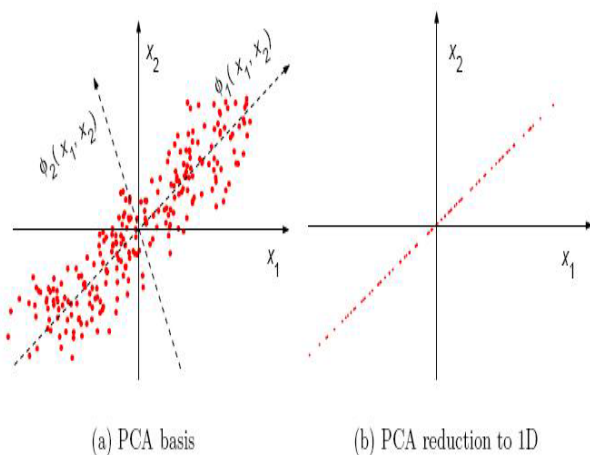(a) PCA basis   (b) PCA reduction to 1D

Fig.2. The Principle of PCA [15]

Fig.2 Principal components (PC) of a two-dimensional set of points. The first principal component provides an optimal linear dimension reduction from 2D to 1D, in the sense of the mean square error.

B. Linear Discriminant Analysis(LDA)

Both PCA and ICA construct the face space without using the face class information [16,17]. The whole face training data is taken as a whole. In LDA the goal is to find an efficient or interesting way to represent the face vector space [18,19]. But exploiting the class information can be helpful to the identification tasks [20]. LDA can be illustrated in fig. 3.
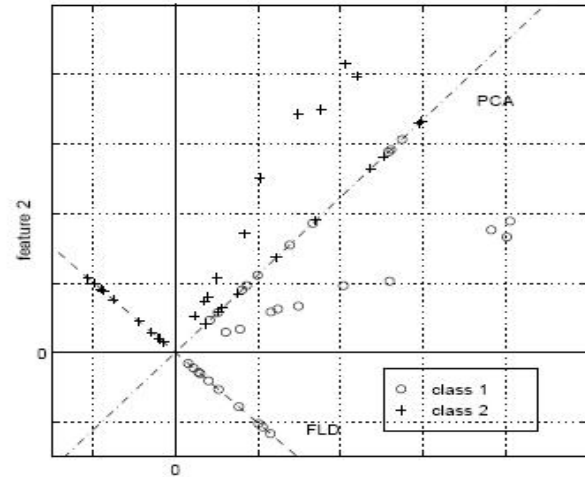

Fig.3. A comparison of principal component analysis (PCA) and Fisher's linear discriminant (FLD) for a two class problem where data for each class lies near a linear subspace . It shows that FLD is better than PCA in the sense of discriminating the two classes.

C. Independent Component Analysis (ICA)

ICA is a recently developed statistical technique that can be viewed as an extension of standard PCA and does not consider LDA . Using ICA, one tries to model the underlying data so that in the linear expansion of the data vectors the coefficients are as independent as possible. ICA bases of the expansion must be mutually independent while the PCA bases are merely uncorrelated. ICA has been widely used for blind source separation and blind convolution. Blind source separation tries to separate a few independent but unknown source signals from their linear mixtures without knowing the mixture coefficients [21]. ICA can be described in Fig. 4.
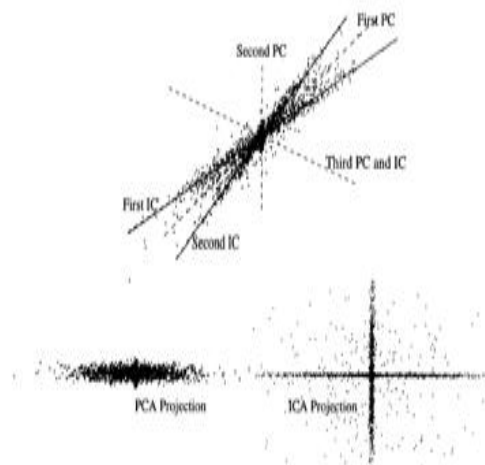

Fig.3. The Principle of ICA [15]

Fig.4 Example 3D data distribution and the corresponding principal component and independent component axes. Each axis is a direction found by PCA or ICA. Note the PC axes are orthogonal while the IC axes are not. If only 2 components are allowed, ICA chooses a different subspace than PCA. Bottom left: Distribution of the first PCA coordinate of the data. Bottom right: distribution of the first ICA coordinate of the data. For this example, ICA tends to extract more intrinsic structure of the original data clusters.

D. 2D

2D System In the past [22], facial recognition programs depended on two dimension (2D) picture to compare it with the image sorted in the data base, but these programs did not succeed only if the person is looking just to the camera. Of course anyone suspect will be warned that he/she will see a camera in place, and here lies the problem where this fails by depending on the 2D system. Beside, the additional changes in the environment surrounding the person, such as light will produce images the computer cannot have in the corresponding memory, also the changes in the same person can cause a system failure in face recognition [23, 24].

E. 3D

3D System Modern system for face recognition based on the pattern of three-dimensional (3D) [25], where the special cameras will captured images of three-dimensional views of the suspected person, and using the special main features of each face that are not changed significantly with time , such as eye hole, the distance between the eyes, nose shape and others. These features are a source of information for a facial recognition system as the changes in the lighting or surrounding environmental conditions do not affect these measurements, for example: can operate these systems in any lighting conditions even if the place was dark and even if the person is not in the face of camera.

F. Neural Network (NN)

Neural networks have been applied successfully in many pattern recognition problems, such as optical character recognition, object recognition, and autonomous robot driving. The advantage of using neural networks for face detection is the feasibility of training a system to capture the complex class conditional density of face patterns [26].

G. Support Vector Machine (SVM)

The Support Vector Machines (SVM) method views the problem in difference space. This technique was formulated to solve two-class face recognition problem. The classes are: dissimilarities between images of the same person and the dissimilarities between images of different persons [27]. SVM is basically a binary classification method and to apply it to multi-class face recognition problem, combination of SVMs is to be used. But as the classes in face recognition is generally very large, large number of SVMs has to be used and hence, the Bayesian SVM method [28] was developed. The Bayesian method converts the multi-class face recognition problem to two-class problem effectively and so SVM can be used directly.

H. Gabor wavelet

Gabor wavelets were introduced to image analysis because of their similarity to the receptive field profiles in cortical simple cells. They characterize the image as localized orientation selective and frequency selective features. Therefore, low level features, such as peaks, valleys and ridges are enhanced by 2-D Gabor filters. Thus, the eyes, nose and mouth, with other face details like wrinkles, dimples and scars are enhanced as key features to represent the face in higher dimensional space. Also, the Gabor wavelet representation of face image is robust to misalignment to some degree because it captures the local texture characterized by spatial frequency, spatial position and orientation. [29].

I. Scale Invariant Feature Transform (SIFT)

Scale Invariant Feature Transform (SIFT) features are extracted from images to help in reliable matching between different views of the same object [30]. The extracted features are invariant to scale and orientation, and are highly distinctive of the image.
They are extracted in four steps:

The first step computes the locations of potential interest points in the image by detecting the maxima and minima of a set of Difference of Gaussian (DoG) filters applied at different scales all over the image.

Then, these locations are refined by discarding points of low contrast.

An orientation is then assigned to each key point based on local image features.

Finally, a local feature descriptor is computed at each key point. This descriptor is based on the local image gradient, transformed according to the orientation of the key point to provide orientation invariance.

J. Local Binary Pattern (LBP)

The Local Binary Pattern (LBP) method is relative new approach was introduced in 1996 by Ojala et al. With LBP it is possible to describe the texture and shape of a digital image. This is done by dividing an image into several small regions from which the features are extracted [31].

K. Locality Preserving Projections (LPP)

Locality Preserving Projections (LPP) are linear projective maps that arise by solving a variational problem that optimally preserves the neighbourhood structure of the data set.

LPP represents a linear approximation of the nonlinear Laplacian eigenmaps introduced in [32]. When high-dimensional data lies on a low dimension manifold embedded in the data space, then LPP approximate the eigenfunctions of the Laplace Beltrami operator of the manifold. LPP aims at preserving the local structure of the data. This is unlike PCA and LDA, which aims at preserving the global structure of the data.

LPP is unsupervised and performs a linear transformation. It models the manifold structure by constructing an adjacency graph, which is a graph expressing local nearness of the data. This is highly desirable for face recognition compared to nonlinear local structure preserving, since it is significantly less computationally expensive and more importantly it is defined in all points and not just in the training points as Isomaps and Laplacian Eigenmaps.

VI. COMPARATIVE ANALYSIS FOR MERITS AND DEMERITS OF FACE RECOGNITION TECHNIQUES

The comparative study of the different algorithms which are used for face recognition have been shown in table1. we discuss Merits and Demerits for the different types of methods which have been employed in automatic face recognition like Principal Component Analysis (PCA), Linear Discriminant Analysis(LDA), Independent Component Analysis (ICA), 2D, 3D, Neural Network (NN), Support Vector Machine (SVM), Gabor wavelet, Scale Invariant Feature Transform (SIFT), Local Binary Pattern (LBP) , Locality Preserving Projections (LPP).

Table 1: Comparative Analysis of Face Recognition Algorithms

Approaches/ Algorithm Used	Advantages	Challenges
Principal Component Analysis (PCA) [Eigenvectors of the covariance matrix used] [33]	Recognition is simple and efficient compared to other matching approaches. Data compression is achieved by the low dimensional subspace representation. Raw intensity data are used directly for learning and recognition without any significant low-level or mid-level processing. No knowledge of geometry and reflectance of faces is required.	The method is very sensitive to scale, therefore, a low-level preprocessing is still necessary for scale normalization. Since the Eigenface representation is, in a leastsquared sense, faithful to the original images, its recognition rate decreases for recognition under varying pose and illumination. Though the Eigenface approach is shown to be robust when dealing with expression and glasses, these experiments were made only with frontal views. The problem can be far more difficult when there exists extreme change in pose as well as in expression and disguise. Due to its "appearance-based" nature, learning is very time-consuming, which makes it difficult to update the face database.
Linear Discriminate Analysis (LDA) [Fisherfaces] [34]	The Fisherface projection approach is aimed to solve the illumination problem by maximizing the ratio of between-class scatter to within-class scatter; however, finding an optimum way of projection that is able to simultaneously separate multiple face classes is almost impossible. LDA based algorithms outperform PCA based ones, since the former optimizes the low dimensional representation of the objects with focus on the most discriminant feature extraction while the latter achieves simply object reconstruction.	An intrinsic limitation of classical LDA is the so called singularity problem, that is, it fails when all scatter matrices are singular. However, a critical issue using LDA, particularly in face recognition area, is the Small Sample Size (SSS) Problem. This problem is encountered in practice since there are often a large number of pixels available, but the total number of training samples is less than the dimension of the feature space. This implies that all scatter matrices are singular and thus the traditional LDA algorithm fails to use.
Independent Component Analysis (ICA) [local basis images+ factorial face code] [32]	Exploits higher order statistics Allow better characterization of data in an n-dimensional space.	
2D	Availability of large 2D image collections. Capture devices are currently cheaper.	Cannot handle pose variations. Sensitive to lighting variations, shadows etc.
3D	Can deal with pose variations – if the cameras can capture the full face Less sensitive to lighting variations Better accuracy during recognition	Cameras are still expensive Takes time to reconstruct models Unavailability of large collections of 3D data
Neural Network (NN) [34]	Reduces misclassifications among the Neighborhood classes. High accuracy (detection rate ~90%) Not difficult to implement	Breach of privacy, Expensive to implement, Comparatively less accurate

Approaches/ Algorithm Used	Advantages	Challenges
Support Vector Machine (SVM) [35]	There are many folds advantages of using the supervised learning approach of Support Vector Machine (SVM). They are very effective when we have very high dimensional spaces. Also, when number of dimensions becomes greater than the existing number of samples, in such cases too SVM is found to be very effective. SVM uses a subset of training point also known as support vectors to classify different objects hence it is memory efficient. Support Vector Machines are versatile, for different decision function we can define different kernel as long as they provide correct result. Depending upon our requirement and application we can choose types of kernel which is most productive for our application.	The disadvantage of SVM is that if the number of features is much greater than the number of samples, the method is likely to give poor performances. SVM gives efficient result for small training samples as compared to large ones. SVMs do not directly provide probability estimates, so these must be calculated using indirect techniques. Also, we can have Non-traditional data like strings and trees as input to SVM instead of featured vectors.
Gabor wavelet[36]	Better performance Fast Acceptable accuracy Small training set	High dimensionality Affected by complex background Slightly rotation invariance
Scale Invariant Feature Transform (SIFT)	Numerous keys can be generated for even small objects. Partial occlusion/image clutter ok because dozens of SIFT keys may be associated with an object, but only need to find 3 Object models can undergo limited affine projection. Planar shapes can be recognized at 60 degree rotation away from camera. Individual features can be matched to a large database of objects	Fully affine tranformations require additional steps Many parameters "engineered" for specific application. May need to be evaluated on case-to-case basis.
Local Binary Pattern (LBP) [37]	Simple, histogram in local regions tolerates pixel misalignment	Image dividing is problematic when pose variation is large
Locality preserving Projection (LPP) [38]	Lower error rate compared to eigenfaces and fisherfaces approach	Problem occur in estimating intrinsic dimens dimensionality of nonlinear manifold images images

There are many advantages and disadvantages for these algorithms. After summarization for these techniques we can choose the better one which enable dealing with conditions that effect on face recognition like change in illumination, pose variation, change in expressions, Partial Occlusion and Noise and etc.

Table 2: The table illustrates some of the applications and challenges which facing the face recognition with the choice of appropriate technique to solve every problem.

Techniques\ Algorithm Used \ Applications	Medical Application (Plastic Surgery)	Dummy Faces	Varying Illuminations	Pose Variations	Varying Facial Expressions	Partial Occlusion and Noise
Principal Component Analysis (PCA)	√	√	√	√	√	√
Linear Discriminate Analysis (LDA)	√	√	√		√	√
Independent Component Analysis (ICA)			√		√	
2D				√		
3D				√		
Support Vector Machine (SVM)		√			√	√
Gabor wavelet					√	
Scale Invariant Feature Transform (SIFT)		√				
Local Binary Pattern (LBP)		√			√	
Locality preserving Projection (LPP)			√		√	

Table 3: The table illustrates types of databases and software tools used with these techniques to solve the challenges which facing the face recognition

Techniques	Types of Databases Used						Software
Principal Component Analysis (PCA)	Plastic Surgery Database	Dummy Face Database	Yale Face B Database	multi-PIE database	Japanese Female Facial Expression (JAFFE) database	ORL database/ AR face database	MATLAB
Linear Discriminate Analysis (LDA)	Plastic Surgery Database	Dummy Face Database		Yale-B Databases/ CMU-PIE Databases	Japanese Female Facial Expression (JAFFE) database	FERET database	MATLAB
Independent Component Analysis (ICA)	YALEB Databases/ ATT Database				Weizmann database / IMM database / Jaffe facial expression database		
2D+3D	FERET, CMU-PIE, Multi-PIE and LFW Databases						
Support Vector Machine (SVM)	Dummy Face Database		Japanese Female Facial Expression (JAFFE) database		ORL database		MATLAB
Gabor wavelet	Japanese Female Facial Expression (JAFFE) database						
Scale Invariant Feature Transform (SIFT)	Dummy Face Database						MATLAB
Local Binary Pattern (LBP)	Dummy Face Database			Japanese Female Facial Expression (JAFFE) database			MATLAB
Locality preserving Projection (LPP)	YALEB Databases/ ATT Database			Japanese Female Facial Expression (JAFFE) database			MATLAB

VII. CONCLUSION

This paper we discussed the different methods and algorithms for face recognition that used in the various application areas such as information security, video surveillance, law enforcement, identity authentication, Also challenges which impeding facial recognition such as change in (illumination, pose variation, expressions, aging factors, alignment, plastic surgery partial occlusion and noise, etc.). Finally, we provided Merits and Demerits of face recognition techniques which deal with these conditions, And types of databases used with these techniques. Even though many previous face recognition methods which have been proposed in previous, have shown significant promises but robust face recognition is still difficult. So, the future can be to combine the merits of few face recognition techniques and make a more effective model of face recognition.

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