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SURVEY ON FACE RECOGNITION METHODS

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Abstract— Face recognition is a biometric technology to identify or verify one or more persons from still or video images of a scene using stored database of face images. It has many advantages over other biometrics like finger-print and iris recognition.This paper gives an overview of the current research work in face recognition and gives the direction to develop a robust face recognition method that can be useful for many commercial applications. This paper reviews the approaches in 2D and 3D face recognitions, databases available for face recognition and recognition accuracies in detail. Examples given in this paper are taken from the published work of the researchers in face recognition with references.

Keywords— biometrics, 2D/3D face recognition

I. INTRODUCTION

Face Recognition is a biometric method used to identify or verify a person from a still image or video image using stored database of images. The term biometrics describes the methods for uniquely identifying humans based on the physical or behavioral characteristics. Before face recognition, several other biometrics is used for example finger print, iris recognition, retina, voice, skin texture, ear shape, hand geometry, vein pattern and hand-written signature. Each has its own advantages and may be particularly suited towards specific applications. Unlike other biometric methods face recognition is a non-intrusive system that provides a friendly and convenient identification method. Face recognition is mainly used in law enforcement especially mug-shot searching and forensics. It can be even used in surveillance systems where a large number of CCTV's can be monitored to look for known criminals, drug offenders so that authorities can be notified when one is located. It is also used in security systems which makes access control to buildings, airports, ATM's, border check points and email authentication on multimedia workstations. The technology is used for general identity verification like electoral registration, banking, driving license and in smart card applications where the face print can be stored in the smart card barcode instead of maintaining database facial images, so that the authentication is performed by matching the live image and stored template. Thus face recognition is becoming an emerging field of research and developing robust face recognition is still a challenge task for researchers. Hence this survey paper gives an overview of the research going on in face recognition. In the following sections we are giving brief introduction to face recognition, general steps in face recognition system and the methods employed in 2D and 3D face recognitions. We also list the popular databases that are available to test the performance of the face recognition approaches.

II. INTRODUCTION TO FACE RECOGNITION TECHNOLOGY

Face recognition is an important biometric technology to verify or recognize the identity an individual based on the unique, measurable characteristics of a person. Face recognition technology is classified into two domains namely, identification and verification. For an identification or recognition system, input face is matched against all faces in an available database, which in turn provides the determined identity. A verification or authentication system compares an input face with a similar claimed face from a database. It either validates or rejects the claim based on the matching score.

2.1. GENERAL STEPS IN FACE RECOGNITION

Face recognition system performs the following steps for actual recognition.

- Image acquisition
- Face detection
- Feature extraction
- Classification

These steps are depicted in figure 1 and explained in detail in the following.

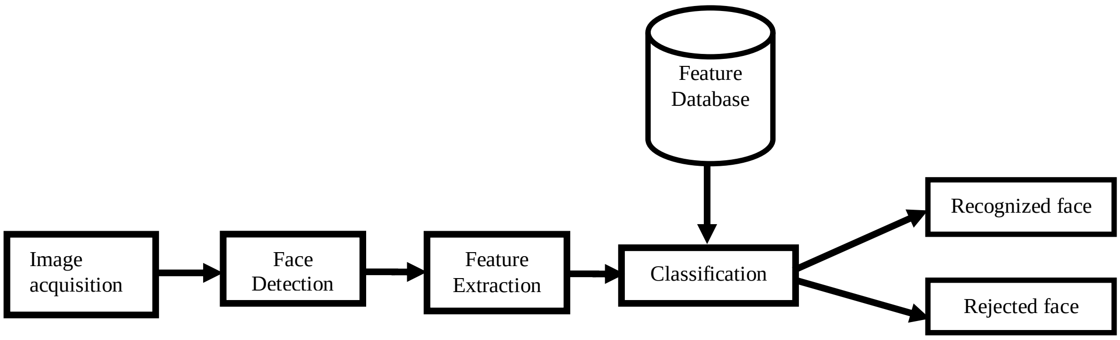

Figure1. Steps in the face recognition system

- **Image acquisition:** In image acquisition step the live image of the face is acquired by camera or it can be taken by scanning an existing photograph.
- **Face detection:** Almost in any face recognition system, a face detection stage is needed. It is the process to detect the location of the faces in the acquired image. More information about the state of the art in face detection can be found in Ming-Hsuan et al [1].
- **Feature extraction:** Feature extraction is the process of representing discriminate or interesting features of a face in a compact feature vector. Various feature extraction approaches used in face recognition are given in next sections.
- **Classification:** classification stage is to compare the features generated in step three with the features of known faces from face-database. Finally the output of the system is either recognized face or rejected face.

III. DATABASES FOR FACE RECOGNITION

When testing face recognition with an algorithm it is recommended to use a standard database so that researchers can directly compare the results. FERET [2], CMU-PIE [3], AR Faces [4] represents popular 2D face image database collection. Each database is designed to address specific challenges covering a wide range of scenarios. For example, FERET represents a good testing framework if one needs large gallery and probe sets, while CMU is more indicated when pose and illumination changes are the main problem. Finally, AR Faces is the only database providing natural occluded face images. In case of 3D, there are very few 3D face models databases available and they contain very little amount of data. Example of 3D face model database represented by clouds of points. 3D meshes are also available today from newer technologies but in most cases they are just proprietary databases. Table 1 gives detail information about available databases to test face recognition.

Table 1: Databases for face recognition

S.No	Database	No. of subjects	Conditions	Image resolution	Number of images	url of the database
1	PIE Database [3]	68	Pose, Illumination Expressions	640 x 486	database have a subset of one picture per individual	http://www.ri.cmu.edu/projects/project_418.html
2	AR database [4]	116 (63 men and 53 women)	Facial expression, Illuminations Occlusions	576 x 768	3288	http://rvl1.ecn.purdue.edu/~aleix/aleix_face_DB.html
3	MIT Database[5]	16	Head orientation Illumination Scale	120×128	433	http://whitechapel.media.mit.edu/pub/images/
4	Yale Face Database [6]	15	With or without glasses Illumination Facial expressions	320×243	165	http://cvc.yale.edu/projects/yalefaces/yalefaces.html
5	FERET(The Facial Recognition Technology) [7]	1199	Facial expressions Illumination Pose Time	256×384	1451	http://www.itl.nist.gov/iad/humanid/feret/feret_master.html
6	FRGC v 2.0 [8]	100	Neutral, surprise, happy, puffy cheeks, anger, frown	640 x 480	4007	http://www.nist.gov/itl/iad/ig/frgc.cfm
7	ORL[9]	40	All frontal and slight tilt of the head	92 x 112	400	http://www.uk.research.att.com/facedatabase.html
8	BU3D-FE [10]	40	Neutral, angry, fear, sadness, disgust, happiness, surprise	512 x 512	2500	http://www.cs.binghamton.edu/~lijun/Research/3DFE/3DFE_Analysis.html
9	Bosphorus [11]	105	Neutral, happy, anger, disgust, fear, sadness, surprise	1600 x1200	4666	http://bosphorus.ee.boun.edu.tr/default.aspx
10	Gavab Database [12]	61 (45 male , 16 female)	Expression, Pose	---	549	http://www.gavab.etsii.urjc.es/recursos_en.html#GavabDB

IV. FEATURE EXTRACTION TECHNIQUES

Feature extraction can be considered as finding a set of unique features from a face image. Following are successful feature extraction techniques in face recognition.

4.1. PRINCIPAL COMPONENT ANALYSIS

Principal component analysis (PCA), commonly referred to as the use of eigenfaces is the technique pioneered by Kirby and Sirivich in 1988 [13] and used by Matthew Turk and Alex Pentland [14] in face recognition. With PCA, basis vectors are computed from a set of training images I (I_1, I2, I_3…I_M). As the first step the average image (Ψ) in I is computed and subtracted from the training images called eigenvectors or eigenfaces. These eigenfaces are the principal components of the training set of images generated after reducing the dimensionality of the training set. Sample eigenfaces shown in figure2 are given by Media laboratory vision and modeling group [5]. Once eigenfaces are selected then each training set image is represented in terms of these eigenfaces. The eigenface representation of unknown face is compared with that of each training set face image then the distance between them is calculated. If the distance is above a specified threshold then it recognizes the unknown face of that person. Since then, PCA has been widely investigated and has become one of the most successful approaches in face recognition.

Figure 2: Sample face image and its standard eigenfaces [5]

Pentland et al [15] extended their early work on eigenface to eigenfeatures corresponding to face components such as eyes, nose and mouth. They used a modular eigenspace which was composed of the above eigenfeatures. This method would be less sensitive to appearance changes than standard eigenface method. The system achieved recognition rate of 95% on the FERET database of 7,562 images of 3,000 individuals. However PCA is the linear and simple method and uses the second-order statistical information in data. As a result, it fails to perform well in non-linear cases. In order to address these problems variants of PCA have been proposed by B. Schelkopf et al and M.H. Yang et al [16, 17]. For example, Kernel PCA (KPCA) proposed by G. H. Huang and H.Shao [18] is able to capture the non-linear correlations among data points. Y. Wang and Y. Zhang [19] proposed a method feature extraction for facial recognition based on KPCA, and the nearest neighbor classifier making use of Euclidean distance is adopted. The experimental result shows that the KPCA method is giving high recognition rate than conventional PCA.

4.2. LINEAR DISCRIMINANT ANALYSIS

Linear discriminant analysis (LDA) or Fisher's linear discriminant analysis used for classifying samples of unknown classes based on training samples with known classes. P.N. Belhumeur et al [20] and W.Zhao et al [21] proposed LDA method in which high dimensional data are linearly projected onto C – 1 number of LDA directions where 'C' is the number of classes such that the ratio of the *between-class* scatter to the *within class* scatter is maximized. Figure 3 represents example classes using LDA. There is large variance *between classes* but small variance *with in classes*.

Figure 3: Example of two classes using LDA [21]

4.3. ELASTIC BUNCH GRAPH MATCHING

Elastic Bunch Graph Matching **(**EBGM) relies on the concept that real face images have many non-linear characteristics such as variations in illumination, pose and expression which are not addressed by many linear methods discussed earlier. Wiskott et al [22] developed elastic graph matching approach based on Gabor filter coefficients extracted from specific facial fiducial points. Gabor wavelet transform creates dynamic link architecture that projects the face onto an elastic grid. The 'gabor jet 'is a node on the elastic grid denoted by circles on the image as shown in figure 4, which describes the image behavior around a given pixel. Jets from all gallery images are combined to form a data structure called a 'bunch'. A flexible 'face graph' is also constructed by connecting fiducial points by straight lines. The face graph and the bunch together form a data structure called an 'elastic bunch graph' (EGB). It is reported that EGBM works well for varying facial expressions and illumination conditions. However, it performs poorly for faces with large pose variations.

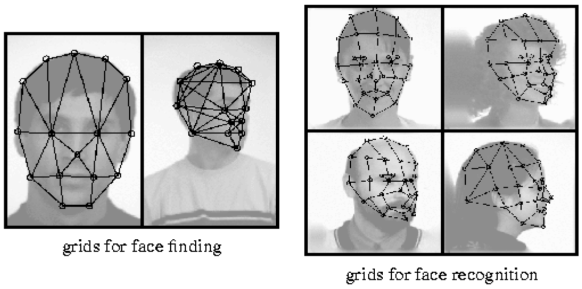

Figure 4: Elastic bunch graph matching [22]

V. CLASSIFICATION

Classification in face recognition is to compare the features generated in the feature extraction step with the face database of known faces. Finally the output of the system is either recognized face or rejected face. This section briefly discusses the classifiers that have been successfully used in face recognition.

5.1. EUCLIDIAN DISTANCE

Euclidian distance has been used in object recognition, where the distance between the keypoints on the test image and training image is calculated. Based on the differences a decision is taken whether the image belongs to a specific class or not. But this requires computing the distance of the input image to all training images of all subjects. So it is computationally expensive.

5.2. NEURAL NETWORKS

Neural networks (NN) are popular classifiers which have been widely used in face detection. Jamil et al [23] proposed a method for face recognition that uses eigenfaces with neural networks in which eigenfaces are applied to extract the relevant information in a face image, which are important for identification. Neural networks are used to recognize the face through learning correct classification of the coefficients calculated by the eigenface algorithm. The network is first trained on the pictures from the face database, and then it is used to identify the face pictures given to it. The method achieved recognition accuracy of 95.6% on a database of 80 images of 8 individuals.

5.3. SUPPORT VECTOR MACHINES

To improve the classification performance of the PCA and LDA subspace features, more sophisticated classifiers, support vector machines (SVM) are used [24]. SVM is a learning approach that is considered to be effective for general purpose pattern recognition because of its high generalization performance without the need to add other knowledge. Given a set of points belonging to two classes, a Support Vector Machines finds the hyper plane that *separates the largest possible fraction of points of the same class on the same side, while maximizing the distance from either class to the hyper plane*. According to [24], this hyper plane is called optimal separating hyper plane (OSH) which minimizes the risk of *miss-classifying* not only the examples in the training set but also the unseen example of the test set. In this technique PCA is first used to extract features of face images and then discrimination functions between each pair of images are learned by SVMs.

5.4. NEAREST NEIGHBOR CLASSIFIER

Nearest neighbor classifier **(NNC)** is one of the supervised statistical pattern recognition algorithms that achieved consistently high performance. It is performed in a way that it involves a training set of both positive and negative cases. A new face image is classified by calculating the distance to the nearest training image. The sign of that point then determines the classification of the image. In the standard eigenface approach the nearest neighbor classifier is used to recognize a new face image.

5.5. HIDDEN MARKOV MODELS

Hidden markov models (HMM) have been used in speech recognition for more than a decade [25] and were also promoted for gesture recognition in recent years, only little work has been done on applying HMM to face recognition.Samaria [26] applied HMM to face recognition where faces were intuitively divided into regions such as the eyes, nose, mouth, etc., which can be associated with the states of a hidden Markov model. Since HMMs require a one-dimensional observation sequence and images are two-dimensional, the images should be converted into either 1D temporal sequences or 1D spatial sequences. In this method, a spatial observation sequence was extracted from a face image by using a band sampling technique. Each face image was represented by a 1D vector series of pixel observation. Each observation vector is a block of L lines and there is an M lines overlap between successive observations. An unknown test image is first sampled to an observation sequence. Then, it is matched against every HMM in the model face database where each HMM represents a different subject. The match with the highest likelihood is considered the best match and the relevant model reveals the identity of the test face.

VI. 3D FACE RECOGNITION

From last two decades research has been conducted on 2D face recognition and acceptable performance given using 2D images. However, the 2D face recognition suffers from the problem like complex pose variation, controlled illumination, expression variation, aging and occlusions. To address these issues recent research shifted their focus from 2D to 3D face representations. 3D face models bring shape information that is not affected by pose, lighting or makeup. More over 3D recognition methods work on range images. So the integration of both texture and shape information may lead to increased recognition rate. All 2D face recognition methods given in above sections can be employed for 3D face recognition. Therefore, 3D face recognition is a continuously developing research area with many challenging issues such as variation in pose, illumination, expression and age. In the following section we are giving summery of the recent work on 3D face recognition.

Achermann et al [27], extended eigenface and hidden Markov model (HMM) approaches used for 2D face recognition to work with range images. They present results for a dataset of 24 persons, with 10 images per person, and report 100% recognition using an adaptation of the 2D face recognition algorithms.

Hesher et al [28] explored principal component analysis (PCA) style approaches using different number of eigenvectors and image sizes. The image data set used has six different facial expressions for each of 37 subjects. The performance figures reported result from using multiple images per subject in the gallery. This effectively gives the probe image more chances to make a correct match, and is known to raise the recognition rate relative to having a single sample per subject in the gallery. Medioni et al [29] investigated 3D face recognition using an iterative closest point (ICP) approach to match face surfaces. Till now the researchers in 3D face recognition uses 3D shapes acquired through a structured-light sensor, but, Medioniet al [29] work uses 3D shapes acquired by a passive stereo sensor. Experiments with seven images each from a set of 100 subjects are reported, with the seven images sampling different poses. An Equal error rate of better than 2%is reported.

Moren et al [30] proposed an approach to 3D face recognition by first performing a segmentation based on Gaussian curvature and then creating a feature vector based on the segmented regions. They have reported results on a dataset of 420 face meshes representing 60 different persons, with some sampling of different expressions and poses for each person. Rank one recognition rate of 78% is achieved on the subset of frontal views.

Achermann and Bunke [31] reported a method for 3D face recognition that uses an extension of Hausdorff distance matching. They reported experiments using 240 range images, 10 images of each of 24 persons, and achieve 100% recognition for some instances of the algorithm.

VII. COMPARISON OF FACE RECOGNITION ALGORITHMS

The methods discussed in the previous sections have both advantages and dis-advantages. It means it is very difficult to state which method performs best. The reason is that different algorithm works on different databases. One method tested on frontal images and got high recognition rate another method tested on noisy images with different facial expressions and got low recognition rate. But, beside recognition rate and error rate computational cost also important. So one general evaluation criteria is required to pick a set of significant parameters rather than considering the recognition rate. The example parameters taken into consideration for testing are: 1) database characteristics such as pose, expression, occlusions and age. 2) Probe dimension and gallery images 3) input size etc. Based on these considerations it is possible to investigate which techniques provide a better approximation of pinpointed parameters. The comparison of the above discussed 2D and 3D method are summarized in the table 2.

Table 2: Summary of face recognition methods

S.no	Author / Reference	Method	Database used	Number of subjects	Recognition rate	Remarks
1	Turk [14]	PCA/eigenfa ce approach	FERET	3000	95%	PCA is simple method for extracting features from the face. Need illumination normalization for better performance
2	Pentland [15]	PCA	AR database	3288	70%	Not robust against changes in illumination
3	Belhumeur [20]	LDA/Fisher face approach	AR database	3288	88%	LDA outperforms PCA.
4	Belhumeur [20]	Fisher face	Yale	165	99.6	Better recognition rate because in isherfacecombines PCA and LDA Database is expression invariant.
5	Wiskott[22]	EGBM	FERET	----	80%	Suitable for variation in expression and lighting conditions. But gives poor performance in large pose variations
6	Jamil [23]	Neural networks	ORL	80	95.6%	Neural networks approach contains high computations
7	Heisele [24]	SVM	AT&T	5	100%	Robust performance in a poorly constrained environment. Works well with illumination changes.

VIII. CONCLUSION

Face recognition attracted the interests of many researchers in recent years. From last two decades various investigations has been done in 2D and 3D face recognition methods, tested on large databases and achieved considerable recognition rate. The current state-of-the-art in face recognition is not efficient for more demanding applications even though they offer greater accuracy due to the changes in lighting conditions, pose and expressions. Therefore developing a robust face recognition system which works under all conditions is still a challenge for researchers.

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