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Face Recognition: A Survey

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Abstract

Face recognition has gained a significant position among most commonly used applications of image processing furthermore availability of viable technologies in this field have contributed a great deal to it. In spite of rapid progress in this field it still has to overcome various challenges like Aging, Partial Occlusion, and Facial Expressions etc affecting the performance of the system, are covered in first part of the survey. This part also highlights the most commonly used databases, available as a standard for face recognition tests. AT & T, AR Database, FERET, ORL and Yale Database have been outlined here. While in the second part of this survey a detailed overview of some important existing methods which are used to dealing the issues of face recognition have been presented. Said methods include Eigenface, Neural Network (NN), Support Vector Machine (SVM), Gabor Wavelet and Hidden Markov Model (HMM). While in last part of the survey several applications of a face recognition system such as video surveillance, Access Control, and Pervasive Computing has been discussed.

Keywords: Face Recognition, Partial Occlusion, Illumination, Pervasive Computing, Video Surveillance

1. Introduction

The field of biometrics has gained utmost attention & made its place as the most reliable option for recognition during the recent past due to the availability of feasible technology after extensive research in this field and loopholes in other systems of identification. Nevertheless, efforts are still in hand to develop a more user-friendly system meeting requirements of security systems, yielding more accurate results, to protect our assets and secure our privacy. Ambiguities exist in traditional methods of recognition as they authenticate people and grant them access to virtual and physical domains examining an individual's behavioral and physiological traits and characteristics in order to realize their purpose. For instance PINs and passwords are somewhat hard and difficult to remember. These passwords can be easily stolen, speculated or forgotten; plastic cards, smart cards, keys, tokens and the other such things can be misplaced, robbed or reproduced; magnetic cards can become tarnished and illegible. However, biological characteristics and traits of an individual cannot be stolen, forged, forgotten or misplaced. Reliable methods of identification based on other biometric features e.g. fingerprint analysis & iris recognition already exist which require the participation of the individuals. Among all these human faces is the most significant & promising featuring thus turning as a great choice for recognition? Similarly, a system based on frontal images is in vain without such cooperation. Thus, a significant benefit of face recognition is that it can be carried out without physical contact. Database for face recognition systems varies from static controllable photographs to uncontrollable videos. This constraint and imposes a large range of technical challenges for such systems in image processing, analysis, and understanding. In Face Recognition, there are different challenges [1-4] such as a large set of images, inappropriate illuminating [5-6]. For solving these issues a general statement of the issue can be resolved, formulated and observed first. Any face recognition system comprises three main parts of that are pre-processing, feature selection and classification [7].

Human beings are capable of recognizing hundreds of faces by learning throughout their whole life span and identify and recognize easily familiar faces even after separation of some years. This skill and ability is fairly apt in human beings that it is hardly affected even after the lapse of the period and various changes in visuals due to viewing aging, expressions, distractions and conditions such as beards or change in hair styles and glasses. The ability of humans to deduce intelligence or facial appearance character can be suspected but face recognition is an essential and important element of the ability of perception system of a human and is a usual assignment for all humans. Building a system similar to human perception system is still an active area of research. However, it yields successful results only under restricted conditions. An ideal and better face recognition method and technique should consider classification issues as well as demonstration and representation. Face recognition has become a vital and an important issue for many applications such as security system, card verification, video surveillance, credit criminal identification, person identification; people tagging, Database Investigation and Pervasive Computing. Within the last several years, numerous algorithms and methodologies have been suggested for recognizing a face. In these methodologies computers have focused on detecting and recognizing features and traits of individuals such as the

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nose, head outline, eyes, mouth and describing a face shape and model by the size, position, and relations between these traits and features. Several researchers have noticed that the recognition rate of faces is high, if 3D faces are used [8].

2. Factors Affecting Face Recognition

Recognizing the human faces from images and videos is indeed a hard nut to crack. There are many approaches to carry out this task but none is able to accomplish it with 100% accuracy because of the numerous challenges facing this system. These factors are divided into 2 categories, Intrinsic and Extrinsic factors. [9] Intrinsic factors include the physical condition of the human face e.g. aging, facial expressions etc affecting the system while extrinsic factors are those factors that become a reason to change the appearance of the face e.g. lightening condition, Pose variation.

2.1 Aging

Aging is one of the intrinsic factors influencing face recognition techniques as it turns to be a mess for algorithms. Permanence is an essential quality for any biological measurement to be treated as biometric. The face is a blend of skin tissues, facial muscles & bones. When muscles contract they result in the deformation of facial features. However, aging causes significant alterations in facial appearances of an individual e.g. facial texture (wrinkles etc) and face shape with the passage of time [10]. The face recognition systems should be capable enough of accommodating this requirement. Many researchers with the prime objective of addressing this issue have been carried out [11-13]. It becomes difficult to collect the data to train the system to deal with the aging factor for recognition purpose because of the slow aging process [14]. The research carried out keeping age factor into account has gained much popularity.

2.2 Facial Expression

Facial expression is an approach of nonverbal communication as it conveys messages using expressions. However, expression variation creates vagueness for the face recognition systems. Many systems for face recognition have been developed that work well for the images under a controlled environment. Different facial expressions show different moods, attitudes of people, and change the geometry of the faces and, if there is minor variation in the image it becomes difficult for the system to recognize the face. Researchers have worked for face recognition with taking facial expression into consideration [15-19]. There are different approaches that can be used to deal with this issue like model base approaches, muscle base approaches, motion-based approaches [20]. It is a perception that although face shape of a person change because of various facial expressions but there may be still some features that are less likely to be affected due to the same. The face is a combination of bones, skin tissues & muscles. Static signals such as color, gender or color etc and slow signals like bulges & wrinkles although do not convey emotion but they have an impact on the rapid signal of facial expression. Facial expression work as a rapid signal that is immediately affected due to contraction of muscles of facial features like eyebrows, cheeks etc. After identification of such features, the non-rigid face recognition problems can be reduced to rigid one. However, no perfect shape with total shape invariant quality can be found.

2.3 Pose Variation

Pose variance is yet another hurdle in achieving a successful face recognition system. People pose differently every time they take a picture. There is no standard similar pose. So this makes it difficult to distinguish and recognize the faces from images with varying poses. Pose variations degrade the performance of the facing requirement. Most systems work under inflexible imaging conditions. Depending on the type of gallery images used the methods dealing with variation in pose can be divided into two kinds i.e. multi-view face recognition and face recognition across pose. Multi-view face recognition can be considered as an annexure of frontal face recognition in which gallery image of every pose is considered. On the other hand, across a pose in face recognition, we consider face with such a pose which has not been seen before by the recognition system. A good face recognition approach should have good pose tolerance and the capability to recognize different poses. Several issues in this regard are still open such as lack of perceptive subspace pose variant images. Several researchers are working to deal with this issue [21-25]. However, no system with 100% accuracy is available yet. There are some different methods and approaches that can be used to tackle the problem of face recognition varying and changes in pose that are divided into three categories including general algorithms, 2D methods for face recognition across pose, Face recognition across pose with the assistance of 3D models [26].

2.4 Partial Occlusion

Occlusion refers to natural or artificial obstacles in an image. The approaches to face recognition with partial occlusion are categorized into different categories including Part Based Methods, Feature based methods and Fractal-Based Methods [27]. Many areas of image processing have been impacted by partial occlusion such as recognition by ear is occluded due to earrings. Occlusion affects the performance of a system when people deceive it either by the use of sunglasses, scarves, veil or by placing mobile phones or hands in front of faces. Sometimes other factors like shadows due to extreme illumination also act as occluding factors. Local approaches are used to deal with the problem of partially occlude faces which divide the faces into different parts [28]. This problem can be addressed by eliminating some of the features creating trouble in accurately recognizing the image. Mostly local methods are based on feature analysis, in which best possible features are detected and then they are combined. Another approach that can be applied for this purpose is near holistic approach in which occlude features, traits and characters are eradicated and rest of the face is used as valuable information. Different techniques are being developed by the researchers to cope up with this problem [29-30].

2.5 Effect of Illumination

Illumination variation affects the face recognition system a great deal, thus turned to an area of attention of many researchers. It becomes difficult to recognize one or more persons from still or video images. It's quite easy to extract desired information from images taken under a controlled environment where the background is uniform, however; in uncontrolled environment face needs to be recognized from

various backgrounds. It includes variation due to shadows, over exposure and under exposure. Researchers have been working hard to deal with this issue. There are three methods to deal with it namely gradient, gray level and face reflection field estimation technique. Gray level transformation technique carries out in-depth mapping with a non-linear or linear function. Gradient extraction approaches are used to extract edges of an image in gray level. As illumination is a factor that greatly affects the recognition of faces from images or videos, the techniques are developed to ignore the effect caused by this issue [31-35].

3 Available Databases of Faces

When a face recognition algorithm is developed, atest of the system is being made to find out its recognition rate. For testing face recognition system a database of faces is required. Using a standard database for testing purpose is highly recommended. There are numerous standard databases available and an appropriate one should be selected as per requirement. Here some of the most commonly used face databases are discussed.

3.1 FERET Database

This database consists of 1564 sets of 14,126 images of 1199 subjects with 365 duplicate set of images. It was formed in 11 sessions from Aug 1993 to Dec 1994[36]. A duplicate set of images is in the second for a person already in the database usually taken on different dates. FERET database developed on the basis of two rules facilitates both algorithm development and evaluation. First is that a common database of facial images is required for both development and testing for evaluation purposes. Second is that diversity of the problems defined by the images should increase.

3.2 AT&T (formerly ORL) Face database

AT&T face database is a database of ten different facial images of 40 individuals with total 400 images. These images were collected from Apr 1992 to Apr 1994. Some of these images were taken at diversified times varying conditions against a dark homogeneous background. It's quite an easy database which makes it a good choice for initial tests.

3.3 Yale Face Database

Yale face database has two parts Yale face A (aka yalefaces) and Extended Yale face database B. It is a database of 15 different subjects (14 males and 01 female). Varied conditions are used in facial images like variations in an expression like happy, sad or normal etc, lighting conditions like left, right or center light and picture with glasses and without glasses were included. Moreover, no editing has been done on the images. Yale face database is yet another good choice for initial tests but it is a step forward from AT&T database because it presents harder problems. Extended Yale face database is a dataset of 2414 images of 38 subjects. No variation in expression and no occlusion are found in the images but more focus is on extracting feature apt to illumination and they are available in cropped version. It is a merger of two databases.

3.4 AR Database

This database consists of 4,000 color images of 126 different people in which 46 females &70 males. The pictures were taken under restricted conditions but with variation in illumination, facial expression & occlusion with sunglasses, scarves & hair styles. The images of a single person were collected on 2 different days with a difference of 14 days. This database is publically available and can be obtained free for academic purposes.

4. Face Detection

A process of detecting and locating faces from a single or series of images is known as Face Detection. It's not essential that images contain faces only they might come with complex backgrounds. Human beings are capable of detecting facial features and other components of an image instantly, however, it's a tough job for computers. The prime objective of the face detection is the separation of faces from non-faces. Teleconferencing, Tagging, Face Recognition, facial feature recognition, gender recognition, automated camera, video surveillance system and gesture recognition are some of its applications [37]. Face detection [38-39] is a stepping stone for the methods of all these applications especially face recognition [40]. Hence, to be an input for these systems the face needs to be detected first. Although all of the pictures were taken today are colored but most of the existing face detection techniques rely on grayscale& only a small number of techniques deal with color images. And these systems either apply window based or pixel-based techniques to get the results. These are the major categories of techniques of face detection system. The pixel-based approach lags in differentiating the face from another skin area of the human's like's hands while the window based approach lacks the ability to view faces of different angles. Among various techniques and methods of the major categories used for face detection, some most commonly used are Template Matching Method [41-42], Neural Networks [43], and SVM [44-45] etc.

5. Face Recognition Methods

In this section, some of the many techniques which are used to recognize the faces from the images are discussed. The techniques those are discussed include Eigenface, Gabor Wavelet, HMM, NN and SVM.

5.1 Eigen Face

Eigenface[46] technique is among one of the face recognition methodologies. This method is also called as Eigen Vector or Principal Component Analysis (PCA). Distinctions among multiple faces are measured using Eigen Vectors [47]. These Eigen Vectors [48] are computed from Covariance Matrix. Computing the Eigen Vector and Eigen Values from Covariance Matrix of the high dimensional vector space is known as PCA [49-57]. These constructed eigenfaces describe each face. These eigenfaces are computed by measuring the distance between key features of the human faces. These key features include nose tip, mouth and eye corners and chin edges.

The Eigenface method was introduced by Sirovich and Kirby in 1987[58]. Later this methodology was successfully used by Turk and Pentland [59] for face recognition which is motivated by information theory. PCA reduces the dimensionality of the face space and only the part important

for face recognition is left behind. The faces to be tested are projected onto this reduced face space [60] ("feature space").

The figure 1, 2, 3 shows the face database, mean image, and eigenfaces.

Fig 1. Face Database [61]

Fig 2. Mean Image [61]

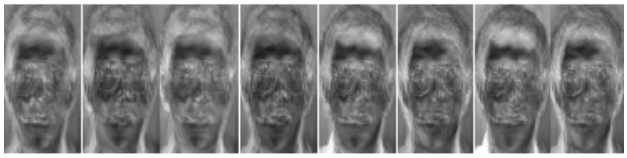

Fig 3. Eigen Faces [61]

Preprocessing is required on the image especially to reduce the effect of illumination [62]. Eigenface based face recognition systems typically work well on the images containing the frontal face but some researchers identifying a face with different poses have also been made [63-64]. A hybrid approach can also be used for Face recognition by using containing eigenfaces and ANN [65], this can give good results. Selecting an optimized threshold value for recognizing the faces as a selection of threshold value is of critical importance for improving the performance of the face recognition system using eigenfaces [66]. The comparison of face recognition methodologies on the basis of Eigen Face is given in Table 1.

Table 1. Comparison of face recognition techniques on the basis of Eigen Face

Methods	Year	Database	Techniques	Accuracy		
Slavković et al [49]	2012	ORL Face Database	PCA Eigen Faces	No. of Principal Components	Euclidean Distance	Manhattan Distance
				5	77.5%	80%
				20	97.5%	97.5%
				190	97.5%	97.5%
Rahman, ArmanadurniAbd, et al [50]	2014	-	PCA Eigen Faces	70%		
Saha, Rajib et al. [51]	2013	FRAV Face Database	Eigen Face	96%		
Thakur, S., et al. [53]	2008	AT&T Face Database, UMIST Face Database	PCA, RBF NN	94.10%		
Abdullah et al. [54]	2012	Face94	PCA	100% i.e. 0% FAR		
Aishwarya, P. et al. [60]	2010	RICE Face Database	Multiple Eigenface Subspaces	94.8%		
Rizon, Mohamed, et al.[61]	2006	ORL Face Database	Eigenface, BackpropagationNN	-		
Agarwal, Mayank, et al. [65]	2010	Olivetti Face Database, ORL Face Database	PCA, Feed Forward Back Propagation NN	97.018%		
Gupta, Sheifali, et al. [66]	2010	ORL Face Database	Eigen Face	97%		

5.2 Gabor Wavelet

Gabor wavelet is also known as Gabor Filter[67]. Gabor filters were introduced as a tool for signal processing in noise by Dennis Gabor in 1946. Gabor Filters were presented for 1-D Signals by Dennis Gabor, Later Daugman rediscovered and generalized them to 2-D Gabor Filters [68]. Gabor wavelet [69] method is such a method that uses local features for face recognition. Multi-Orientational information of a face image can be extracted by using the Gabor Wavelets. The features extracted by Gabor filters [70]

are called Gabor Features [71] and these features are in local regions at multiple scales [72-73].
Redundancy is present in Gabor features because these features are usually high dimensional data [74] and sometimes overlapping occurs between the supports of Gabor filters that result in redundancy of information of features [75]. Feature reduction can be done using Gabor Wavelet transformation method [76]. Face recognition can also be done by using Gabor features in the global form [77-78].

Gaussian envelope function restricts the Gabor filters[79-80]. An image can also be represented by the Gabor wavelet transform allowing the description of both the spatial relations and spatial frequency structure. Gabor Wavelet has a property to allow it to capture the properties of spatial localization, spatial frequency selectivity, and orientation [81-82]. It extracts edge and shape information. Since the feature based methods represent the faces in a compact way [83] in a similar way Gabor Wavelet method also represents the faces in a compact way. Fig 5 shows the 2D Gabor Representations of Human Face.

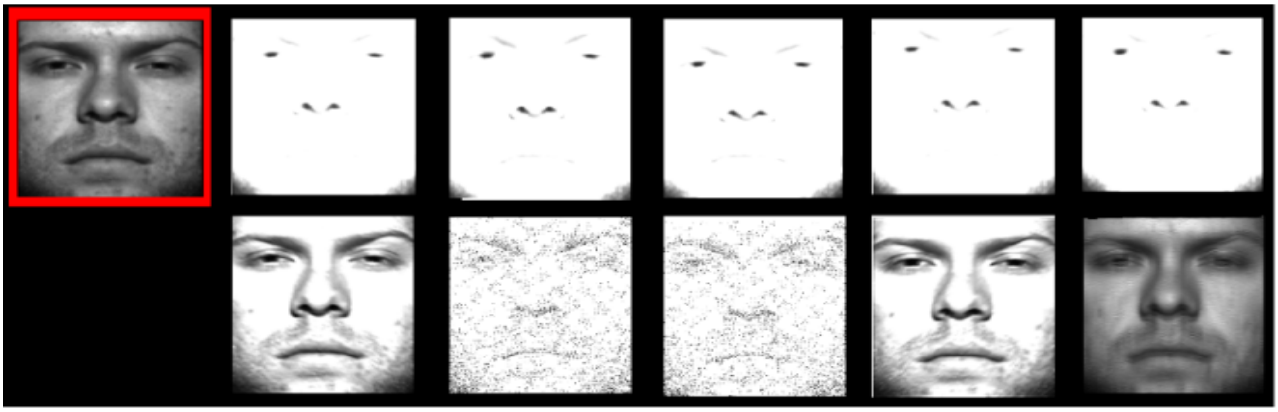

Fig 4. 2D Gabor Representations of Human Face [84]

Since Gabor filters generate redundancy that affects the face recognition i.e. why an algorithm was proposed in which instead of using the Gabor filters alone, a combination of Gabor filters computed by using PCA. These filters were named Principal Gabor filters [85] and they facilitated in eliminating redundancy. These filters were able to identify the faces successfully.

Gabor Wavelet a method is fast in recognition of the faces and requires small training set. Human faces are matched with the features extracted by Gabor wavelet. Comparison of face recognition approaches on the basis of Gabor Wavelet is represented in Table 2.

Table 2. Comparison of face recognition approaches on the basis of Gabor Wavelet

Methods	Year	Database	Approaches	Accuracy		
Barbu, Tudor. et al. [67]	2010	Yale Face Database B	2D-Gabor Filter, Supervised Classifier	90%		
Hyunjong Cho et al. [69]	2014	Yale Face Database B	PCA, Local Gabor Binary Pattern Histogram Sequence (LGBPHS), DPL	PCA		98.3%
				LGBPHS		97.3%
				DPL_6		99.2%
				DPL_{25}		99.7%
Ming et al. [72]	2012	FRGC Database, CASIA Database	3D Gabor Patched Spectral Regression (3D GPSR)	95.80%		
[Shen, Linlin, et al. [73]	2005	FERET Database	Gabor Filter, Improved AdaBoost Learning	95.5%		
Lei, Zhen, et al. [74]	2007	FERET Database	Gabor-Tensor Linear Discriminant Analysis (GT-LDA)	Variations Methods	Expression	Lightening
				GT-LDA	98.24%	89.18%
			Gabor-Tensor Kernel Discriminant Analysis (GT-KDA)	GT-KDA	98.66%	89.69%
Yang, Meng, et al. [75]	2010	Extended Yale B Database, AR Database,	Gabor Feature Based Sparse Representation Classification (GSRC),	Occlusion Method	Sunglasses	Scarves

		FERET Database	Gabor Occlusion Dictionary	GSRC	93%	79%
Shen, LinLin et al. [77]	2007	FERET, BANCA Database	Gabor Wavelet + General Discriminant Analysis		97.5%	
Bellakhdhar et al. [82]	2013	ORL Database, FRGCv2	Magnitude and Phase of Gabor, PCA, SVM		99.9%	
Kar, Arindam, et al. [83]	2009	FRAV2D Database, ORL Database	Gabor Responses, Bayesian PCA	Database	Recognition Rate	
				FRAV2D	99%	
				ORL	100%	
Struc, Vitomir et al. [85]	2009	XM2VTS Database, YaleB	Principal Gabor Filters		-	

5.3 Neural Network (NN)

Because of the importance of the face recognition in several fields, different methods are used to accomplish this task. NN consist on some simple elements that operate in parallel. NN can also be used for Facial Emotion Classification and Gender Classification. NN are used because they reduce the complexity.

The neural network learns from experience, it works well on the images with varying lighting conditions and improves accuracy. The major disadvantage of the neural network is a large amount of time required for its training.

ANN [86-87] recognizes the face through learning and previous experience. NN based system is trained to recognize the faces. Neural Network in combination with Incremental Learning Ability was also used for the face recognition purpose [88-89].The Probabilistic Neural Network (PNN) [90] approach was designed by Vinitha and Santosh that detected and recognized the faces from the grayscale images containing the frontal view of the faces. The main advantage of using PNN is that it requires short training time. The Network in the PNN is divided into subnets because its network is not completely connected. Self-Organizing Map Neural Network (SOM) [75-78] having the property of topological preservation is an artificial neural network used in face recognition. SOM is also known as Kohonen Map.

After the feature extraction, the Radial Basis Function (RBF) Network [79-82] which is a neural network classifier can be used for the recognition of faces. Feedforward Neural Network (FFNN) [78] is another classifier of the neural network that can accomplish the face recognition task after feature extraction. In this kind of network, the neurons are organized in the form of layers. Comparison of classification techniques on the basis of Neural Network is given in Table 3.

Table 3. Comparison of classification techniques on the basis of Neural Network

Methods	**Year**	**Database**	**Techniques**	**Recognition Rate %**		
Nazeer et al. [86]	2007	-	Histogram Equalization, Homomorphic Filtering, PCA, LDA, ANN Euclidean Distance, Normalized Correlation	Feature Extractor	Classifier	Recognition Rate
				PCA	E.D	91.85%
					N.C	91.85%
					N.N	92.59%
				LDA	E.D	90.00%
					N.C	92.22%
					N.N	85.56%
Toh, Soon Lee et al. [88]	2003	Japanese Face Image Database	Resource Allocating Network with Long-Term Memory (RAN-LTM), Incremental Linear Ability		-	
Ghassabeh et al. [89]	2007	Yale Face Database	Incremental LDA, APCA Network		-	
Vinitha, K. V. et al. [90]	2009	BioID Face Database	Probabilistic Neural Network, Template Matching Method, VoronoiTessellations		-	
Nagi, Jawad et al. [91]	2008	-	2D-Discrete Cosine Transform (2D-DCT), SOM		81.36%	
Mantri, Shamla et al. [93]	2011	AT & T Database	SOM		92.40%	

Raja, A. S. et al. [94]	2012	IIT-Dehli Database	Neural Network Based SOM for Face recognition	88.25% to 98.3%	
Nandini, M. et al. [95]	2013	-	Back Propagation Networks (BPC), Radial Basis Function (RBC) Network	Network	Recognition Rate
				BPN	96.66%
				BPN+RBF	98.88%
Radha, V. et al. [96]	2011	ORL face Database	RBC Network, Linear Discriminant, Analysis (LDA), Curvelet Transform	98.6%	
Prasad, M. S. R. S., et al. [99]	2011	Yale Face Database	PCA, FFNN	90% Acceptance Ratio	

5.4 HMM

HMM is a statistical model. The observable properties of a signal are characterized by HMM. This Model has two processes. One of them is Markov Chain with a finite number of states that can't be viewed overtly. While in the other process each state has a set of probability density function associated with it [100]. This model is analogous to Eigenface method. Ever since its introduction in the 1960s, this model contributed a great deal to speech recognition. However, in 1994, it was also used to identify the faces by Samaria and Young [101] for the first time. Now HMM [102] is being used for face recognition, face detection, object recognition but earlier HMM were usually used to deal with one-dimensional data only.

Normally 5-state HMM is used in the researches made for face recognition system. 5-state HMM groups the face into 5 facial features i.e. mouth, eyes, nose, chin, forehead for frontal face images [103]. The number of states can be increased or decreased depending upon the system's requirement. Using 7-State HMM [104] adds significant details which enhance the performance of the face recognition system.

The figure shows the significant facial features and states of 5-state HMM

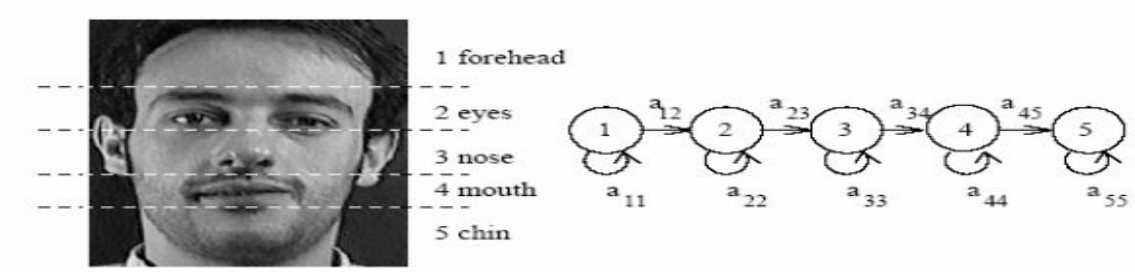

Fig 5. Significant facial features and states of 5-state HMM [105]

HMM can also be used in grouping with other methodologies used for face recognition purposes like with wavelet coding [106]. HMM can also be applied to the video sequences for face recognition. Maximum Confidence Hidden Markov Model [107-109] (MC-HMM) is an HMM whose performance for face recognition primarily depends on the selection of model parameters. For the extraction of the discriminative facial features, the transformation matrix is merged. Structural Hidden Markov Model (SHMM) is not usually used for face recognition problems, but, it can also serve the purpose when required [110]. Unlike conventional HMM, the state conditional independence is not executed in the SHMM. The Adaptive Hidden Markov Model (AHMM)[111] is used by the researchers to sort out the issues of identifying the faces from a video sequence. In Sub Holistic Hidden Markov Model [112], a 3-state model i.e. divining face into 3 significant parts is employed for the identification purpose. Comparison of identifying the faces from a video sequence on the basis of HMM is given in Table 4
.

Table 4. Comparison of identifying the faces from a video sequence on the basis of Hidden Markov Model

Methods	Year	Database	Techniques	Recognition Rate %		
Salah, Albert Ali, et al. [100]	2007	BANCA face Database	Gabor Wavelet Filter, DCT Compression Feature, HMM, Gaussian Observation Distribution	Window Size	Average Recognition Rate	Maximum Recognition Rate
				13	95.23%	96.15%
				15	96.85%	98.08%
				17	93.15%	95.00%
Ojo, John Adedapo et al. [102]	2011	AT&T Face Database	2D-Discrete Wavelet Transform, HMM	90%		

Miar-Naimi, H. et al. [104]	2008	ORL Face Database	7 State HMM, Quantized Singular Values Decomposition (SVD)	100%			
Bicego, Manuele et al. [106]	2003	ORL Face Database	HMM, Wavelet Coding	100%			
Chien, Jen-Tzung et al. [107]	2008	GTFD Face Database, FERET Database	Maximum Confidence HMM	95.6%			
Liao, Chih-Pin et al. [109]	2006	ORL Face Database, FERET Face Database	Baseline HMM, Maximum Confidence HMM	Baseline HMM 95.5%	MCHMM 97%		
Nicholl, P., et al. [110]	2008	AT & T Database, Essex Faces95 Database, FERET Database	Discrete Wavelet Transform, Haar Wavelet, Gabor Wavelet, Coiflet Wavelet, Structural HMM	97%			
Liu, Xiaoming et al. [111]	2003	Task Database, Mobo Database	Adaptive HMM	Database	Recognition Rate: Temporal Markov Model	Recognition Rate: HMM	
				Task	98.4%	98.8%	
				Mobo	93%	97%	
Sharif, Muhammad, et al [112]	2013	ORL Face Database, Yale Face Database	Sub-Holistic HMM	ORL Database: Resolution	ORL Database: Recognition Rate	Yale Database: Resolution	Yale Database: Recognition Rate
				112 X 92	99.5%	163 X 240	99.39%
				37 X 23	98.75%	100 X 100	98.78%
				18 X 15	95.25%	30 X 30	94.54%

5.5 Support Vector Machine (SVM)

Different methods are used to accomplish the task of classification. SVM is a method that deals well with the issue of classification. As SVM is a machine learning approach in which the classifier is trained that can to effectively deal with the face recognition problem. From the training data, SVM takes out the related discriminatory information [113]. SVM works to find the classification hyperplane. To apply SVM, the missing entries should not be there in the samples defined by feature vectors. SVM are proposed to deal with the two-class predicament. And Face Recognition is Multi-class problem. SVM can be applied to recognize the faces after facial feature extraction [114-117]or onto the original appearance space. For face recognition, SVM can be applied individually or can be used with the other techniques. Like a Hybrid method can be used in which features can be extracted via Independent Component Analysis (ICA) and then afterward the recognition issue can be resolved using SVM [118]. This approach to face recognition gives a good result but both methods ICA and SVM are slow in feature selection and classification respectively. Multi-class face recognition matter can be cracked by integrating binary tree recognition approach with SVM [119]. To tackle face recognition Fast Least Squares SVM [120] quickly locates the optimization classification hyperplanes by selecting the training sample points with bigger values directly.

Feature Extraction can be done by using any method used for extracting features like PCA, 2DPCA, LDA[121] or angular LDA then for classification SVM can be used [122-124]. Global approaches and component based approach both based on SVM can be used effectively to deal with the problem of face recognition [125]. Least Square Support Vector Machine (LS-SVM) [126-128] is among one of the many types of SVM that can successfully be utilized for face recognition task. This advantage of this method is that it provides fast computational speed with good recognition rate. Component-based SVM classifier [129] is another type of SVM that is in use for face recognition. Comparison of Classification methods based on SVM is given in Table 5.

Table 5. Comparison of Classification methods based on SVM

Methods	**Year**	**Database**	**Methods**	**Recognition Rate %**			
Déniz, Oscar et al. [118]	2003	Yale Face Database, AR Face Database	ICA, SVM	Database	SVM Using Kernel Functions: p=1	p=3	Gaussian
				Yale	99.39%	99.39%	99.39%
				AR	93.33%	92.67%	94%

Kong, Rui et al. [120]	2011	ORL Face Database	ICA, SVM	96%
Le, Thai Hoang et al. [123]	2011	FERET Database, AT&T Database	2D-Principal Component Analysis, SVM	95.1%
Smith, Raymond S., et al. [124]	2006	XM2VTS Face Database	Angular- Linear Discriminant Analysis (ALDA), SVM	-
Jianhong, Xie. Et al. [126]	2008	ORL Face Database	Kernel PCA, LS-SVM	95%
Xie, Jianhong et al. [127]	2009	ORL Face Database	Curvelet Transform, Least Square Support Vector Machine (LS-SVM)	96%
Zhang, Xinming et al. [128]	2008	-	Component Base Support Vector Machine	98%

6 Applications of Face Recognition

As we know the continuous efforts are being made to develop a face recognition system with themost accuracy, it is because of its relevance in many areas. Here some of its applications are exploited including security, access control, person identification, video surveillance and pervasive computing.

6.1 Security

Security is the biggest issue today than ever. For security purpose, face recognition can act as a key. The security system based on face recognition can be deployed anywhere required. Security system based on the face as a biometric is providing better results than other biometric systems. Banks, airports, Schools, Offices and Airports, everywhere security is required. Even our computer system needs to be protected from unauthorized access so that no one can take or make any change to the data. So, to provide security to the computer system face recognition can play a vital role.

6.2 Access Control

Face recognition can be applied to control the access of people to buildings, offices, computer systems, ATM machines, airports, sea ports and email authentication. The success rate for such systems could be very high if the number of people is limited & pictures taken for image gallery are under controlled conditions which make it less dependent upon user contribution. For example, this technique can be used to check continuously who is using a certain terminal and if the user leaves the system for a specified time a screen saver covers up the screen. Access to any unauthorized user is denied while the system resumes from the previous session for the authorized user once he comes back. At ATM machines instead of using ATM card or passcode, the machine would take a picture of the user and will compare it with the picture in the bank database.

6.3 Person Identification

Face recognition can be taken up to diminish duplication and redundancy in data by comparing new facial images with the ones already present in the database. However, if the database is very large it becomes difficult to identify a person, yet search can be narrowed down by imposing other restrictions to get desired results. For illustration, it can be put to use during voting process by spotting the individuals registered more than once under different names for casting votes for than once. And a welfare society has maintained a database of its registered users, now if any new person wants to get registered with the society, its data can be verified from the database to see if he is not an existing member with a different name.

6.4 Video Surveillance

Surveillance is used for protection of people, intelligence gathering & deterrence of crime by the government. A network of Closed Circuit TV (CCTV) cameras can be used to monitor any well-known criminals and authorities are notified if one is located. Criminals also use it for their motives like kidnapping and robbery. Getting results through this system is quite challenging as all the challenges like light illumination, pose variation & facial expression variation etc. are quite manifest in this system.

6.5 Pervasive Computing

Pervasive Computing refers to the increasing drift of setting in the microprocessor in daily life objects. It's a prospective area where face recognition can fit with the passage of time. Although many machines like cars that have a sensor installed in them and the fashion will cultivate as the time goes on. However, most of the devices today possess a very simple user interface with input on the part of the users. Only by adding the touch of human aware would we be able to pick the real payback of the pervasive computing, it means enabling devices to identify the person near it.

7. Conclusion

In this survey the effort is being made to present a review of the face recognition, as it is active research area due to its several benefits. Recent progress in the field of face recognition is covered by conducting a review of a noteworthy number of researchers. Continuous efforts are

being made by the researchers in this area, through which encouraging progress is achieved. But still there is the need to make face recognition system that can achieve accurate results under unconstrained environment. Some researchers have used single method while some used hybrid approaches with the common aim to make a system for face recognition with 100% recognition rate.

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