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Techniques for Face Detection & Recognition System- a Comprehensive Review

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Abstract: *Face detection and Facial recognition technology has emerged as a striking solution to address many contemporary prerequisites for identification and the verification of identity prerogatives. It brings together the potential of supplementary biometric systems, which attempt to link identity to individually distinctive features of the body, and the more acquainted functionality of visual surveillance systems. In current decades face recognition has experienced significant consideration from both research communities and the marketplace, conversely still remained very electrifying in real applications. The assignment of face detection and recognition has been dynamically researched in current eternities. This paper offers a conversant evaluation of foremost human face recognition research. We first present a summary of face detection, face recognition and its solicitations. Then, a literature review of the predominantly used face recognition techniques is accessible.*

Clarification and restrictions of the performance of these face recognition algorithms are specified. Here we present a vital assessment of the current researches concomitant with the face recognition process. In this paper, we present a broad range review of major researches on face recognition process based on various circumstances. In addition, we present a summarizing description of Face detection and recognition process and development along with the techniques connected with the various influences that affects the face recognition process.

Keywords: *Face Detection, Face Recognition System, Biometric System, Review Research.*

I. INTRODUCTION

For obvious reasons, the visual organs and the human brain is one of the best existing face recognition machine ever and will be forever. Fusiform face area- a specific are of brain has found to be the totally dedicated part for this task.

As the face recognition is considered to be the most natural thing for humans, biometric techniques are considered to be most suitable for this purpose. Human face recognition is the most authenticated and widely used step for identity proof. A simple example of this can be seen in our wallets, driving license, membership cards etc.

The apparent use of face recognition led to many fantasies, difficulties and inconsistencies while implementing automatic face recognition in technical field. This is because the technology always will have brain as the outstanding competitor trained from birth to do exact things somehow.

An exponential growth in this field has thus has involved the sophisticated features of almost all the biometric techniques up to point where it is on the verge to compete with greatest competitor: the human brain is the best face recognition machine ever and may be forever. Still, in order to deliver its full efficiency, a number of caveats have to be taken into account during implementation, feature extraction is also a main component of a face recognition system, and an example of Eigen face based face recognition system is shown in figure below:

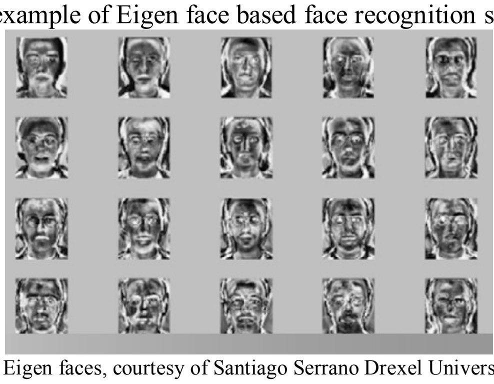

Figure 1. Eigen faces, courtesy of Santiago Serrano Drexel University, USA.

Face detection has direct relevance with the face recognition because before recognition the image must be analysed and the location of the face must be detected. The whole process of face detection consists of four steps:

i. *Input:* **-** An image passed to the system as input .The image may vary in format, size and resolution.
ii. *Pre-processing:-*The image is pre-processed to remove the background noise. This is also called image normalization.
iii. *Classifier:* **-** it takes decision whether the image belong to the face or non-face class.
iv. *Output:* **-** This indicates the location of the face in the original image input.

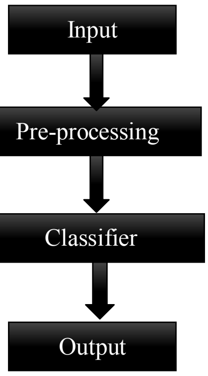

Figure 2. Basic building of face detection system

The block diagram of a typical face recognition system can be shown with the help of Figure 2.The face detection and face extraction are carried out simultaneously. The complete process of face recognition can be shown in the Figure 2. The face recognition system works in three stages: face detection, feature extraction and face recognition. The face recognition systems are divided into three regions; holistic approaches in which original image used as input means the face is used as the raw data. Second category is of feature based techniques in which the local features are first extracted and the localized image is used as raw input to next stage. The third category belongs to hybrid approaches in which both the local features and face region are used as input.

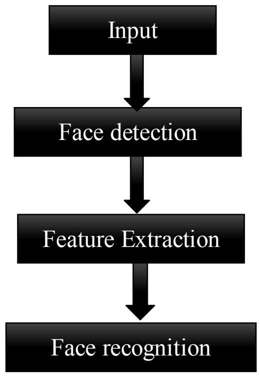

Figure 3. Basic building of face recognition system

The first step in face recognition system is to detect the face in an image. The main objective of face detection is to find whether there are any faces in the image or not. If the face is present, then it returns the location of the image and extent of the each face. Pre-processing is done to remove the noise and reliance on the precise registration.

There are a lot of factors due to which the face detection is a challenging task.

- Pose
- Presence or absence of structural components
- Facial expression
- Occlusion
- Image orientation
- Imaging conditions

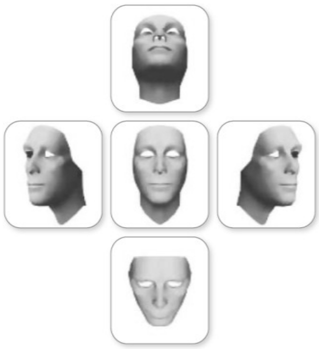

Figure 4: examples of pose angles for a face in a biometric system.

A. Face As biometric

Face recognition is superior than other biometric techniques in certain circumstances, and also the corresponding weakness that renders it unsuitable choice as a biometric technique for other applications. Face recognition came as a biometric derives a major advantage of being the primary biometric used by humans to recognize each other.

The main drawbacks to face recognition are its current relatively low accuracy (compared to the proven performance of finger print and iris recognition) and the relative ease with which many systems can be defeated. Finally, there are many attributes leading to the variability of images of a single face that add to the complexity of the recognition problem if they cannot be avoided by careful design of the capture situation. Inadequate constraint or handling of such variability inevitably leads to failures in recognition. These include:

- Physical changes: for ex. facial expression change; aging; personal appearance (make-up, glasses, facial hair, hairstyle, disguise).
- Acquisition geometry changes: change in location, scale and in-plane rotation of the face (facing the camera) as well as rotation in depth (facing the camera obliquely, or presentation of a profile, not full-frontal face).
- Imaging changes: camera variations; lighting variation; channel characteristics (especially in compressed images, or broadcast).

Figure 5: Sample variations of a single face: in pose, facial appearance, age, lighting and expression.

Face recognition today has to overcome some prominent challenges like broad lighting change and handling rotation in depth, together along with personal appearance changes. Accuracy needs to be improved even under good conditions.

B. Robustness and Fraud

All biometric recognition systems are susceptible to accidental errors of two types which both must be minimized: False Accept (FA)errors where a random impostor is accepted as a legitimate users and False Reject (FR) errors where a legitimate user is denied access. Designers of biometric systems must also be very conscious of how the system will behave when deliberately attacked..

It is also possible for some people to impersonate others with a high degree of similarity (an important vulnerability in 'cooperative' applications like physical access control). A couple of years ago, few systems had a test to detect authenticity (rejecting objects that looked too flat to be faces rather than photographs), but a recent PC Magazine test found that both systems tested could distinguish a real person from a photograph. More sophisticated shape algorithms could be devised, and elastic deformation can be used to prevent simple photograph replay attacks. (One system allows the option of requiring a change in facial expression during verification.) With computing power more abundant, the technology for detecting fake biometrics will keep improving.

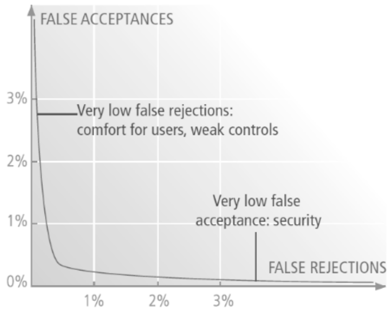

Figure 6: False acceptance – false rejection graph.

C. Structure of Assessment

The association steps of this paper are as follows. The Introductory Section ends with a brief introduction of Face detection and recognition process and its necessity in biometric system. The part **A and B** in introduction shows a brief explanation about principle of face as biometric and its robustness factor.

In Section II, explains a General review of face detection techniques, this process is difficult because although commonalities exist between faces, they can differ considerably in terms of age, skin colour and facial expression. An ideal face detector must be able to detect the faces under any set of conditions.

Section III provide the information about the review on recent researches in traditional feature extraction based unsupervised approaches, this research therefore has considered a review on existing face recognition techniques based on these approaches, this section consist of some recent researches on Eigen face based methods, Dynamic Graph Matching Algorithms, Geometrical Feature Matching, Template Matching Algorithms, Line Edge Map (LEM) based methods.

Section IV addresses the intelligent supervised approaches in face recognition including neural network, Hidden Markov model, support vector machine, Fuzzy theory etc.

Section V Shows the comparison of different face database used in the field of face recognition and a general conclusion of the paper, discussion regarding review is presented in Section VI.

II. RECENT SURVEY ON AVAILABLE TECHNIQUES FOR FACE DETECTION

Face detection is one of the easiest tasks for human brain. But for the technology it is one of the most complicated tasks. Primary solution includes the segmentation, extraction and verification of faces and its features from an uncontrolled background. But is expected to advance up to a level where it can smoothly function irrespective of camera distance, illumination and orientation.

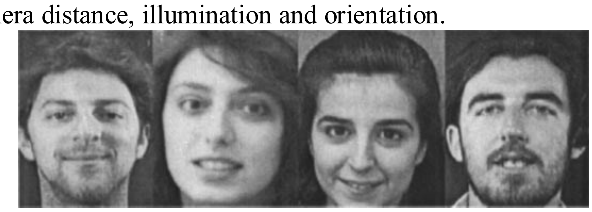
Figure 7: Typical training images for face recognition.

We analyze that Face detection divided into approaches:

Face Detection

- *Feature Based Approaches*
  - *Low Level Analysis*
  - *Feature Analysis*
  - *Active Shape Model*
- *Image Based Approaches*
  - *Linear Subspace methods*
  - *Neural network*
  - *Statical Approaches*

Some methods that fall into each category are edge based, skin color based, gray level based and motion based, point distribution model and deformable template are the type active shape model [1].

Edge is the most primitive feature in computer vision applications and it was applied in some earlier face detection techniques by Sakai et al. [10]. It was based on analyzing line drawings of faces to locate facial features. Craw et al. [2] designed hierarchical method to trace human head outline based on Sakai‘s work. More recent examples of edge based techniques can be found in [3, 4, and 5] for facial feature extraction and in [6, 7, and 8] for face detection. Govinda raju [9] accomplishes this by labeling edges as the left side, hairline, or right side of a front view face and matches these edges against a face model by using the golden ratio [11].

While gray level information gives us basic features about face representation, color information can provide us more face features by extra dimensions of pixel representation. [12, 13, and 14]. The most common color model is RGB representation in which colors are defined by combinations of red, green, blue color components. [12, 14, 15, 16, 17, and 18].

When use of video sequence is available, motion information can also be used to locate moving objects. Moving silhouettes like body and face parts can be extracted by simply thresholding accumulated frame differences [20].

In the literature, most commonly used facial feature is distinct side by side appearance of a pair of eyes [22, 21]. Also, main face axis [24], outline (top of the head) [23, 24], and body (below the head) are searched to detect face regions. After determining features, which are focus on are searched. According to found features' orientations and geometric their geometric ratios, face regions are detected. The facial feature extraction algorithm by De silva et al. [25] is a good example of feature searching method.

III. UNSUPERVISED CLASSIFICATION BASED APPROACHES FOR FACE RECOGNITION

This section discusses the techniques for face detection that are applicable on most of the frontal faces. The advantages and disadvantages are presented after each method.

A. Eigen faces based method for face recognition

Also known as Karhunen- Loève expansion, eigenvector, Eigen picture and principal component, Eigen face is one of the most thoroughly investigated approaches to face recognition. References [26, 27] used principal component analysis to efficiently represent pictures of faces. They argued that any face images could be approximately reconstructed by a small collection of weights for each face and a standard face picture (Eigen picture). The weights describing every single face are obtained by projecting the face image onto the Eigen picture. Reference [28] used Eigen faces, which was motivated by the technique of Kirby and Sirovich, for face detection and identification.

In mathematical terms, Eigen faces are the principal components of the eigenvectors of the covariance matrix, or the distribution of faces of the set of face images. The eigenvectors are asked to represent different amounts of the variation, respectively, among the faces. Every single face can be represented exactly by a linear combination of the Eigen faces

As the images include a large quantity of background area, above results are influenced by background. The authors explained the robust performance of the system under different lighting conditions by significant correlation between images with changes in illumination. However, [29] showed that the correlation between images of the whole faces is not efficient for satisfactory recognition performance. Illumination normalization [27] is usually necessary for the Eigen faces approach.

Reference [30] proposed a new method to compute the covariance matrix using three images each was taken in different lighting conditions to account for arbitrary illumination effects, if the object is Lambertian. Reference [31] extended their early work on Eigen face to Eigen features corresponding to face components, such as eyes, nose, and mouth. They used a modular Eigen space which was composed of the above Eigen features (i.e., Eigen eyes, Eigen nose, and Eigen mouth). This method would be less sensitive to appearance changes than the standard Eigen face method. The system achieved a recognition rate of 95 percent on the FERET database of 7,562 images of approximately 3,000 individuals. In summary, Eigen face appears as a fast, simple, and practical method. However, in general, it do not provide invariance over changes in scale and lighting conditions.

B. Dynamic Graph Matching Algorithms for face recognition

Graph matching is another approach to face recognition. Reference [32] is about dynamic link structure for any distortion invariant object recognition that employs an elastic graph match to find the closest stored graph. Dynamic link architectures are the extension to classical artificial neural networks. Objects memorized by sparse graphs have edges labelled with geometrical distance vectors. Stochastic optimization of a matching cost function can perform elastic graph matching for object recognition. They reported good results on a database of 87 people and a small set of office items comprising different expressions with a rotation of 15 degrees.

In general terms of rotation invariance, dynamic link architecture is superior to other face recognition techniques; however, the matching process is computationally expensive.

C. Geometrical Feature Matching for face recognition system

Geometrical feature matching techniques are based on the computation of a set of geometrical features from the picture of a face. The face recognition is possible on a course of low resolution of 8x6 pixels [33]. It is hard to determine the single face features which implies that it is sufficient to have overall geometric configuration of face features. The vector which represents the position and size of main facial features can describe the overall configuration such as eyes and eyebrows, mouth, nose and the shape of face outline. One of the pioneering works on automated face recognition by using geometrical features was done by [34] in 1973. Their system achieved a peak performance of 75% recognition rate on a database of 20 people using two images per person, one as the test and the other as the model image. References [35, 36] showed that a face recognition program provided with features extracted manually could perform recognition apparently with satisfactory results. Reference [37] automatically extracted a set of geometrical features from the picture of a face, such as mouth position, nose width and length, and chin shape. There were 35 features extracted from a 35 dimensional vector. Then the recognition was performed with a Bayes classifier. It reported a recognition rate of 90% on a database of 47 people.

Reference [38] introduced a mixture-distance technique which achieved 95% recognition rate on a query database of 685 individuals. The recognition accuracy in terms of the best match to the right person was 86% and 94% of the correct person's faces were in the top three candidate matches. In summary, geometrical feature matching that are based on accurate measured distances between features can be the most appropriate thing to find possible matches in a large database (for ex: Mug shot album). However, the dependency will be a factor of accurate feature location algorithms. Conventional automated face feature location algorithm cannot provide with high degree of accuracy and are also time consuming.

D. Template Matching Algorithms for face recognition

A test image represented as a 2-D array of intensity values compared using a suitable metric represents the simple version of template matching. For example we can say that with a single template Euclidean distance represents the whole face. One can use more than one face templates with different viewpoints to represent an individual's face.

A face from a single viewpoint can also be represented by a set of multiple distinctive smaller templates [37, 39]. The face image of gray levels may also be properly processed before matching [40]. In [37], Bruneli and Poggio automatically selected a set of four features templates, i.e., the eyes, nose, mouth, and the whole face, and for all of the available faces. They compared the performance of their geometrical matching algorithm and template matching algorithm on the same database of faces which contains 188 images of 47 individuals. The template matching was superior in recognition (100 percent recognition rate) to geometrical matching (90 percent recognition rate) and was also simpler. Since the principal components (also known as Eigen faces or Eigen features) are linear combinations of the templates in the data basis, the technique can never achieve better results than correlation [37], but it may be less computationally expensive.

One drawback of template matching is its computational complexity. Another problem lies in description of these templates. Since the recognition system is supposed to be tolerant to certain discrepancies between the template and the test image, this tolerance may average out the differences that make individual faces unique.

E. Line Edge Map (LEM) based methods for face recognition

Edge information is a useful object representation feature that is insensitive to illumination changes to certain extent. Though the edge map is widely used in various pattern recognition fields, it was neglected in face recognition except in recent work reported in [41].

For object recognition Edge images of objects could be used and achieve similar accuracy as gray-level pictures. In reference [41] edge maps measured the similarity between face images. 92% accuracy was achieved in the paper. Takács stated that the face recognition process may start at a very early stage and for recognition process can use edge images without involving the high-level cognitive functions.

A Line Edge Map approach, proposed by [10], extracts lines from a face edge map as features. This approach can be considered as a combination of template matching and geometrical feature matching. The LEM approach not only have the advantages of feature based approaches, such as invariance to illumination and low memory requirement, but also has the advantage of high recognition performance of template matching.

IV. SUPERVISED LEARNING BASED APPROACHES FOR FACE RECOGNITION

A. Neural Network based methods for face recognition

For face verification, [43] is a multi-resolution pyramid structure. Reference [42] proposed a hybrid neural network which combines a self-organizing map (SOM) neural network, local image sampling, and a convolutional neural network. The quantization of the image samples into a topological space is provided by SOM where inputs of original space and output space are nearby only and hence provide dimension reduction and invariance to negligible changes in the sample.

The authors reported 96.2% correct recognition on ORL database of 400 images of 40 individuals.

The classification time is less than 0.5 second, but the training time is as long as 4 hours. Reference [44] used probabilistic decision-based neural network (PDBNN) which inherited the modular structure from its predecessor, a decision based neural network (DBNN) [45]. The PDBNN can be applied effectively to 1) face detector: which finds the location of a human face in a cluttered image, 2) eye localizer: which determines the positions of both eyes in order to generate meaningful feature vectors, and 3) face recognizer. PDNN. The learning scheme of the PDNN consists of two phases, in the first phase; each subnet is trained by its own face images. In the second phase, called the decision-based learning, the subnet parameters may be trained by some particular samples from other face classes. The decision-based learning scheme does not use all the training samples for the training. Only misclassified patterns are used. If the sample is misclassified to the wrong subnet, the rightful subnet will tune its parameters so that its decision-region can be moved closer to the misclassified sample.

B. Hidden Markov Models (HMMs)based methods for face recognition

Stochastic modeling of non-stationary vector time series based on (HMM) is quite successful for voice applications. In reference [46] authors applied this methodology for human face recognition. Faces were divided in parts such as eyes, nose, mouth, etc. which are to be associated with the states of hidden Markov model. Since only one-dimensional observation sequence and 2-D image sequence are required by HMMs it is required to convert images either to 1-D spatial sequence or 1-D temporal sequence.

In [47], 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 HMMs in the model face database (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.

C. Support Vector Machine (SVM) based methods for face recognition

SVM is a learning technique that is considered an effective method for general purpose pattern recognition because of its high generalization performance without the need to add other knowledge [48]. Intuitively, given a set of points belonging to two classes, SVM finds the hyper plane that separates the largest possible fraction of points of the same class on the similar side, while maximizing the distance from either class to the hyperplane. According to [48], this hyper plane is called Optimal Separating Hyper plane (OSH) which minimizes the risk of misclassifying not only the examples in the training set but also the unseen example of the test set.

In summary, the main characteristics of SVMs are:

1) That they minimize a formally proved upper bound on the generalization error;
2) That they work on high-multi dimensional feature spaces by means of a dual formulation in terms of kernels;
3) That the prediction is based on hyperplanes in these feature spaces, that correspond to quite involved classification criteria on the input data; and
4) Those outliers in the training data set can be handled by means of soft margins.

D. Fuzzy Theory Based Approaches for Face Recognition System

This approach detects faces in color images based on the fuzzy theory. [49] is a typical example of fuzzy detection category. In this paper Wu et al. made two fuzzy models to describe the skin and hair color, in which used a perceptually uniform color space to describe the color information to increase the accuracy and stableness. Furthermore, the models were used to extract the skin and hair color regions, then comparing them with the pre-built head-shape models by using a fuzzy theory based pattern-matching method to detect face candidates, this part of research is little untouched by researchers and there are only few work that already done in the field.

This approach uses fuzzy theory to representing diverse, uncertain, non-exact, and inaccurate knowledge or information. And information carried in individual fuzzy set is combined to make a decision. Processes of composition and de-fuzzification form the basis of fuzzy reasoning. Fuzzy reasoning is performed to recognize face in the context of a fuzzy system model that consists of control, solution, and working data variables; fuzzy sets; hedges; fuzzy; and a control mechanism. Many paradigms are appeared in [50, 51].

V. COMPARISON OF DIFFERENT FACE DATA BASE FOR FACE RECOGNITION

In Section 3 and 4, a number of face recognition algorithms have been described. In order to compare the performance of various face recognition algorithms presented in the literature there is need for a comprehensive and systematically annotated database populated with face images that have been captured (1) at variety of pose angles, (2) with a wide variety of illumination angles (to permit testing of illumination invariance), and (3) under a variety of commonly encountered illumination color temperatures (Permit testing of illumination color invariance).

Reference [52] presents a method that use the novel set of apparatus to rapidly capture face images in a broad range of pose angles and illumination angles. 4 different types of illumination employed includes the daylight, skylight, flourescent and incandescent. the annotations and the entire set of images along with the experimental results are placed in public domain and were made available for download on www [53].

VI. CONCLUSION & DISCUSSION

Face detection and recognition are both the complicated and in its own part necessary for the recognition techniques. Among all the biometric techniques, face recognition provides friendly features like user-friendliness and satisfying security level. This paper is the introductory survey for face recognition technology. Issues such as generic framework for face recognition, some factors affecting the performance of the recognizer, and several state-of-the-arts face recognition algorithms are studied in this paper.

Face recognition algorithms that were using Description and limitations of face databases are scripted in this paper. Finally, we give a summary of the research results. This is also shown in tabular form in Table I and II. This paper contributes to give details about most well-known techniques for face recognition like, Eigen face based methods, Dynamic Graph Matching Algorithms, Geometrical Feature Matching, Template Matching Algorithms, Line Edge Map (LEM) based methods, neural network, Hidden Markov model, support vector machine, Fuzzy theory etc.

Table 1: Comparison of different face databases

Database	Description	Limitation
AT&T [54] (formerly ORL)	Contains face images of 40 persons, with 10 images of each. For most subjects, the 10 images were shot at different times and with different lighting conditions, but always against a dark background.	(1) Limited number of people (2) Illumination conditions are not consistent from image to image. (3) The images are not annotated for different facial expressions, head rotation, or lighting conditions.
Oulu Physics [55]	Includes frontal color images of 125 different faces. Each face was photographed 16 times, using 1 of 4 different illuminants (horizon, incandescent, fluorescent, and daylight) in combination with 1 of 4 different camera calibrations (color balance settings). The images were captured under dark room conditions, and a gray screen was placed behind the participant. The spectral reflectance (over the range from 400 nm to 700 nm) was measured at the forehead, left cheek, and right cheek of each person with a spectrophotometer. The spectral sensitivities of the R, G and B channels of the camera, and the spectral power of the four illuminants were also recorded over the same spectral range.	(1) Although this database contains images captured under a good variety of illuminant colors, and the images are annotated for illuminant, there are no variations in the lighting angle. (2) All of the face images are basically frontal (with some variations in pose angle and distance from the camera)
XM2VTS [56]	Consists of 1000 GB of video sequences and speech recordings taken of 295 subjects at one-month intervals over a period of 4 months (4 recording sessions). Significant variability in appearance of clients (such as changes of hairstyle, facial hair, shape and presence or absence of glasses) is present in the recordings. During each of the 4 sessions a "speech" video sequence and a "head rotation" video sequence was captured. This database is designed to test systems designed to do multimodal (video + audio) identification of humans by facial and voice features.	It does not include any information about the image acquisition parameters, such as illumination angle, illumination color, or pose angle.
Yale [57]	Contains frontal grayscale face images of 15 people, with 11 face images of each subject, giving a total of 165 images. Lighting variations include left-light, center-light, and right-light. Spectacle variations include with-glasses and without-glasses. Facial expression variations include normal, happy, sad, sleepy, surprised, and wink.	(1) Limited number of people (2) While the face images in this database were taken with 3 different lighting angles (left, center, and right) the precise positions of the light sources are not specified. (3) Since all images are frontal, there are no pose angle variations. (4) Environmental factors (such as the presence or absence of ambient light) are also not described.

Yale B [58]	Contains grayscale images of 10 subjects with 64 different lighting angles and 9 different poses angles, for a total of 5760 images. Pose 0 is a frontal view, in which the subject directs his/her gaze directly into the camera lens. In poses 1, 2, 3, 4, and 5 the subject is gazing at 5 points on a semicircle about 12 degrees away from the camera lens, in the left visual field. In poses 6, 7, and 8 the subject is gazing at 3 different points on a semicircle about 24 degrees away from the camera lens, again in the left visual field. The images were captured with an overhead lighting structure which was fitted with 64 computer controlled xenon strobe lights. For each pose, 64 images were captured of each subject at a rate of 30 frames/sec, over a period of about 2 seconds.	(1) Limited number of Subjects. (2) The background in these images is not homogeneous, and is cluttered. (3) The 9 different pose angles in these images were not precisely controlled. Where the exact head orientation (both vertically and horizontally) for each pose was chosen by the subject.
MIT [59]	Contains 16 subjects. Each subject sat on a couch and was photographed 27 times, while varying head orientation. The lighting direction and the camera zoom were also varied during the sequence. The resulting 480 x 512 grayscale images were then filtered and sub sampled by factors of 2, to produce six levels of a binary Gaussian pyramid. The six "pyramid levels" are annotated by an X-by-Y pixel count, which ranged from 480x512 down to 15x16.	(1) Although this database contains images that were captured with a few different scale variations, lighting variations, and pose variations, these variations were not very extensive, and were not precisely measured. (2) There was also apparently no effort made to prevent the subjects from moving between pictures.
CMU Pose, Illumination, and Expression (PIE) [98]	Contains images of 68 subjects that were captured with 13 different poses, 43 different illumination conditions, and 4 different facial expressions, for a total of 41,368 color images with a resolution of 640 x 486. Two sets of images were captured – one set with ambient lighting present, and another set with ambient lighting absent.	(1) There was clutter visible in the backgrounds of these images. (2) The exact pose angle for each image is not specified.
UMIST [60]	Consists of 564 grayscale images of 20 people of both sexes and various races. (Image size is about 220 x 220.) Various pose angles of each person are provided, ranging from profile to frontal views.	(1) No absolute pose angle is provided for each image. (2) No information is provided about the illumination used – either its direction or its color temperature.
Bern University face database [61]	Contains frontal views of 30 people. Each person has 10 gray-level images with different head pose variations (two front parallel pose, two looking to the right, two looking to the left, two looking downwards, and two looking upwards). All images are taken under controlled/ideal conditions.	(1) Limited number of subjects. (2) The exact pose angle for each image is not specific. (3) There is not variation in illumination conditions.
Purdue AR [62]	Contains over 4,000 color frontal view images of 126 people's faces (70 men and 56 women) that were taken during two different sessions separated by 14 days. Similar pictures were taken during the two sessions. No restrictions on clothing, eyeglasses, make-up, or hair style were imposed upon the participants. Controlled variations include facial expressions (neutral, smile, anger, and screaming), illumination (left light on, right light on, all side lights on), and partial facial occlusions (sun glasses or a scarf).	The placement of those light sources, the color temperature of those light sources, and whether they were diffuse of point light sources is not specified. (The placement of the two light sources produces objectionable glare in the spectacles of some subjects.)
The University of Stirling online database [63]	Was created for use in psychology research, and contains pictures of faces, objects, drawings, textures, and natural scenes. A web-based retrieval system allows a user to select from among the 1591 face images of over 300 subjects based on several parameters, including male, female, grayscale, color, profile view, frontal view, or 3/4 view.	(1) No information is provided about the illumination used during the image capture. (2) Most of these images were also captured in front of a black background, making it difficult to discern the boundaries of the head of those subjects with dark hair.
The FERET [64]	Contains face images of over 1000 people. It was created by the FERET program, which ran from 1993 through 1997. The database was assembled to support government monitored testing and evaluation of face recognition algorithms using standardized tests and procedures. The final set of images consists of 14051 grayscale images of human heads with views that include frontal views, left and right profile views, and quarter left and right views. It contains many images of the same people taken with time-gaps of one year or more, so that some facial features have changed. This is important for evaluating the robustness of face recognition algorithms over time.	(1) It does not provide a very wide variety of pose variations. (2) There is no information about the lighting used to capture the images.
Kuwait University face database (KUFDB) [65]	The in-house built database consists of 250 face acquired from 50 people with five images per face. There is a total 250 gray level images (5 images x 50 people). Facial images are normalized to sizes 24 x 24, 32 x 32, and 64 x 64). Images were acquired without any control of the laboratory illumination. Variations in lighting, facial expression, size, and rotation, are	(1) Limited number of people. (2) It does not include any information about image acquisition parameter, such as pose angle.

	considered.	

Table 2: Summary of the research results

Database	References	Method	Notes
FERET	[31]	Eigen features	This method would be less sensitive to appearance changes than standard Eigen face method. The DB contained 7,562 images of approximately 3,000 individuals.
	[28]	Eigen face	DB contained 2,500 images of 16 individuals; the images include a large quality of background area.
	[47]	Graph matching	
	[55]	Geometrical feature matching and Template matching	These two matching algorithms occurred on the same DB which contained 188 images of 47 individuals.
	[38]	SVM	
	[75]	SVM + 3D morphable model	Face rotation up to $\pm 36^0$ in depth.
	[76]	SVM+PC+LD	DB contained 295 people.
AR	[10]	LEM	DB contained frontal faces under controlled condition.
	[78]	SVM+PCA SVM+ICA	SVM was used only with polynomial (up to degree 3) and Gaussian kernel.
Yale	[78]	SVM+PCA SVM+ICA	DB contained 165 images of 15 individuals. The DB divided into 90 images (6 for each person) for training and 75 for testing (5 for each person)
	[86]	Build face recognition committee machine (FRCM) of Eigen face, Fisher face, Elastic Graph Matching (EGM), SVM, and Neural network	1) They adopt leaving-one-out cross validation method. 2) Without the lighting variations, FRCM achieves 97.8% accuracy.
	[87]	Combines holistic and feature analysis-based approaches using a Markov random field (MRF) method	They tested the recognition accuracy with different numbers of training samples. K(k=1,2,…10) images of each subject were randomly selected for training and the remaining 11-k images for testing
	[88]	Boosted parameter-based combined classifier	The DB is divided into 75 images (5 for each person) for training and 90 for testing (6 for each person)
ORL	[42]	Hybrid NN: SOM + a convolution NN	DB contained 400 images of 40 individuals. The classification time less than .5 second for recognizing one facial image, but training time is 4 hours.
	[47]	Hidden Markov model (HMMs)	
	[47]	A pseudo 2DHMM	Its classification time and training time were not given (believe to be very expensive.)
	[81]	SVM with a binary tree	They compare the SVMs with standard Eigen face approach using the NCC
	[77]	Optimal-Pairwise coupling (O-PWC) SVM	They select 200 samples (5 for each individual) randomly as training set. The remaining 200 samples are used as the test set.
	[80]	Several SVM+NN arbitrator	An average processing time of .22 second for face pattern with 40 classes. On the same DB, PCC for Eigen faces is 90% and for pseudo-2D HMM is 95% and for convolutional NN is 96.2%
	[28]	Eigen face	
	[44]	PDBNN	PDBNN face recognizing up to 200 people in approximately 1 second and the training time is 20 minutes.

	[85]	A combined classifier uses the generalization capabilities of both Learning Vector Quantization (LVQ) and Radial Basis Function (RBF) neural networks to build a representative model of a face from a variety of training patterns with different poses, details and facial expressions	A new face synthesis method is implemented for reducing the false acceptance rate and enhancing the rejection capability of the classifier. The system is capable of recognizing a face in less than one second.

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