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| **DIGITAL IMAGE PROCESSING-**  **FACE RECOGNITION** |
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Urs

Yatheesh12c5@gmail.com

Abstract:

As one of the most successful applications of image analysis and understanding, face recognition has recently received significant attention, and has an important advantage over other biometric technologies as it is a non -intrusive and easy to use method.

One of the fastest growing areas of advanced security involves biometric face recognition technologies. The art of picking a face out of a crowd is a time honored skill. Applying technology to such a pursuit has to date proven both fruitful and frustrating. Biometric face recognition technology offers great promise in its ability to identify a single face, from multiple lookout points,

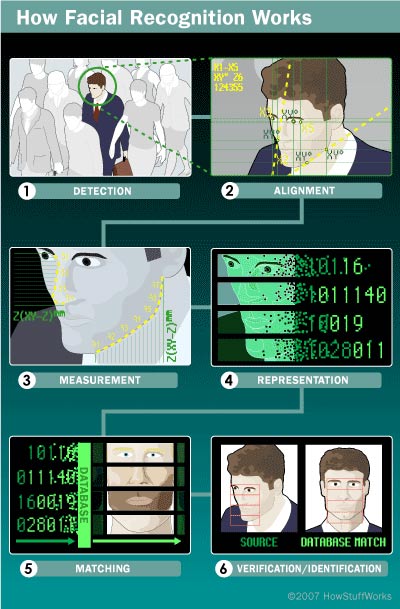
from a sea of hundreds of thousands of other faces. In addition to serving as a information access control tool, biometric face recognition technologies are being used to safeguard international borders, financial ATM transactions, prevent benefits and identity fraud, and help combat terrorism.

The main idea and the driver of further research in this area are security applications and human-computer interaction. Face recognition represents an intuitive and method of recognizing people and this is why it became one of three identification methods used in e-passports and a biometric of choice for many other security applications. However, until the problems (illumination, pose, aging , occlusions) are solved, it is unrealistic to expect that the full deployment potential of face recognition systems will be realized. There are also many technological issues to be solved, some of which have been addressed in recent ANSI and ISO standards.

Face recognition is one of the few biometric methods that possess the merits of both high accuracy and low intrusiveness. It has the accuracy of a physiological approach without being intrusive.

In the general framework of face recognition, a probe still-image is first detected, analyzed and then matched against a collection of images -- the database of the people known by the system. As a result, most of the work carried out in face recognition by computer is limited to the comparison between face images. In these approaches, the overall face detection, facial feature localization, and face comparison is carried out in a single step.

The paper states the generic framework for the face recognition system, and the variants that are frequently encountered by the face recognizer. Several face recognition algorithms, will also be explained. It also throws some light on its important applications areas .It concludes with the current state of the art and some backdrops.



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## 

## Introduction:

***Definition:*** A face recognition system recognizes an individual by matching the input image against images of all users in a database and finding the best match.

Face recognition has received significant attention in the last 15 years, due to the increasing number of commercial and law enforcement applications requiring reliable personal authentication (e.g. access control, surveillance of people in public places, security of transactions, mug shot matching, and human-computer interaction) and the availability of low-cost recording devices.

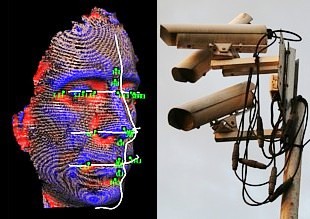
**Comparison with Other Biometrics**: Despite the fact that there are more reliable biometric recognition techniques such as fingerprint and iris recognition, these techniques are intrusive and their success depends highly on user cooperation, since the user must position her eye in front of the iris scanner or put her finger in the fingerprint device. On the other hand, face recognition is non-intrusive since it is based on images recorded by a distant camera, and can be very effective even if the user is not aware of the existence of the face recognition system. The human face is undoubtedly the most common characteristic used by humans to recognize other people and this is why personal identification based on facial images is considered the friendliest among all biometrics.

## Organization of a Biometric Face Recognizer:

## Generally consists of 4 parts:

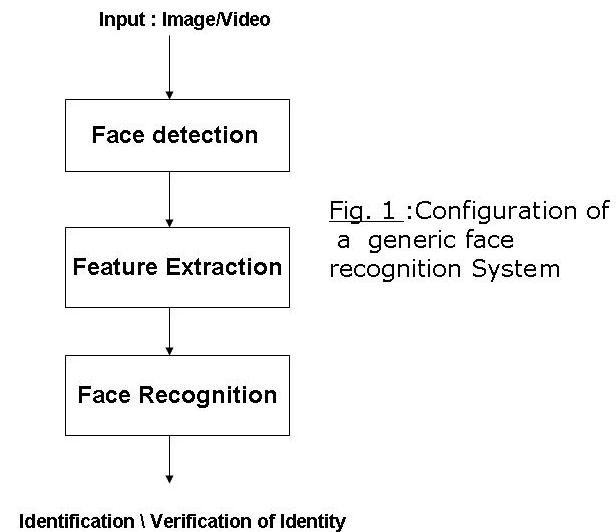
1. **SENSOR**: Hardware that captures face images of an individual. Depending on the sensor modality, the acquisition device maybe a black and white or color camera, a 3D sensor capturing range (depth) data, or an infrared camera capturing infrared images.

fig1: CCTV Cameras



2. **FACE DETECTION AND FEATURE EXTRACTION**: The acquired face images are first scanned to detect the presence of faces and find their exact location and size. The output of face detection is an image window containing only the face area. Irrelevant information, such as background, hair, neck and shoulders, ears, etc are discarded. The resulting face image is then further processed to extract a set of salient or discriminatory, local or global features, which will be used by the face classifier to identify or verify the identity of an unknown face. Such features maybe the measurements of local facial features (such as eyes, nose, mouth, etc) characteristics or global features such as transformation coefficients of global image decomposition (PCA, LDA, wavelets, etc). These features constitute the template or signature uniquely associated with the image.

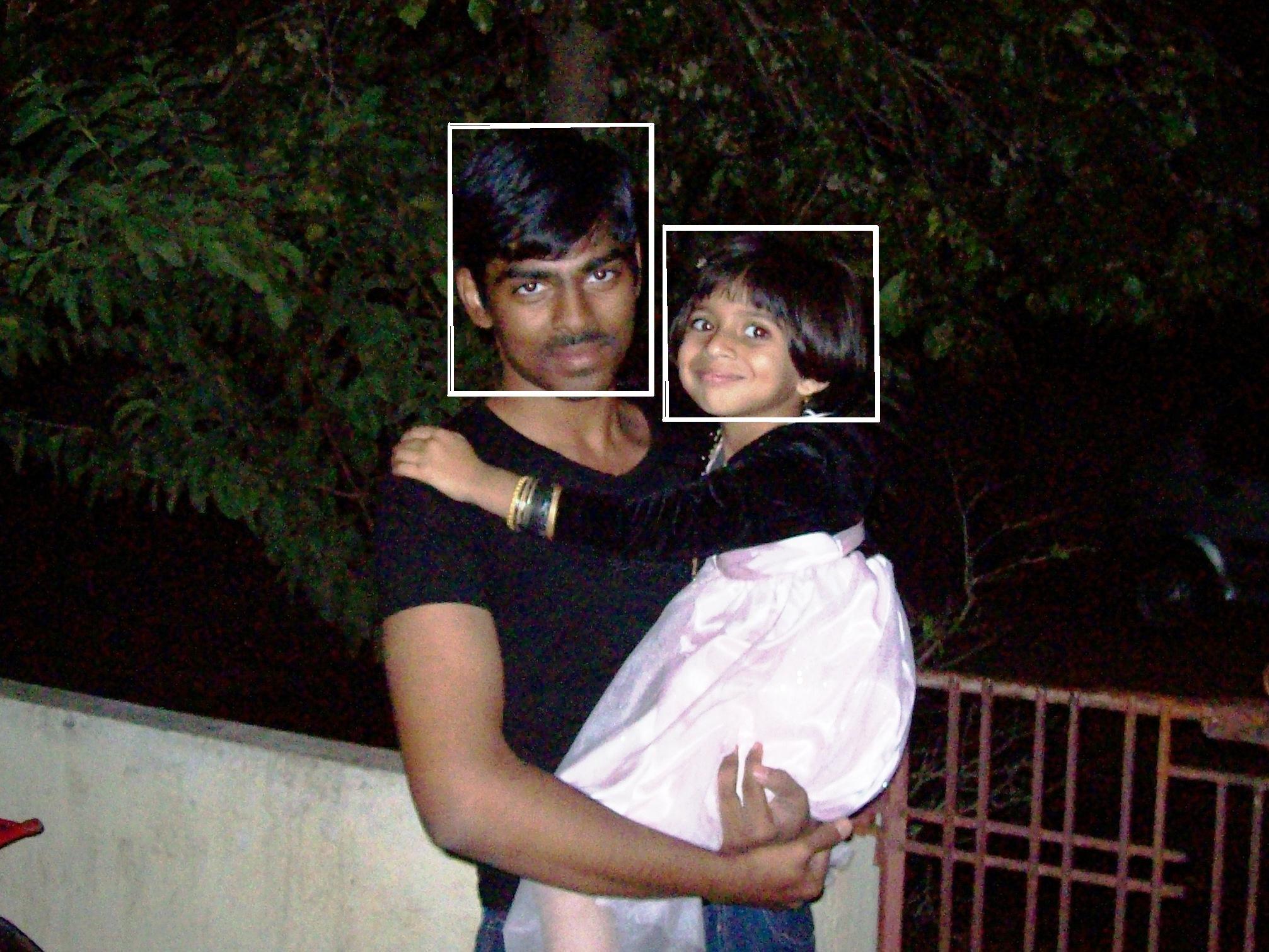
1. **CLASSIFICATION**: In which the template extracted during step 2 is compared against the stored templates in the database to generate matching scores, which reveal how identical the faces in the probe and gallery images are. Then, a decision-making module either confirms (verification) or establishes (identification) the user’s identity based on the matching score
2. **SYSTEM DATABASE**: It is used to extract and store the templates of enrolled users. This module is also responsible for enrolling users in the face recognition system database. During the enrolment of an individual, the sensor module records images of her face. These images are called gallery images and they are used for training the classifier that will perform face recognition. Most commonly, several frontal neutral views of an individual are recorded, but often face images depicting different facial expressions (neutral, smile, laugh, anger, etc) and presence (or non-) of glasses are also acquired. Sometimes gallery images are recorded in more than one session. The time interval between different sessions may result in variations due to hairstyle, beard, make-up, etc being present in gallery images. The presence of such variations ensures a more robust face recognition performance. Given a user’s set of acquired images, a set of features is extracted similarly to step 3 above, and a template that provides a compact and expressive representation of the user based on her images is generated called training. The training algorithm depends on the face recognition method employed by the face recognition system. The aim of the training is to encode the most discriminative characteristics of a user based on the classifier chosen, and to determine the values of the different thresholds.



## Face Detection:

Face detection is the first stage of an automatic face recognition system, since a face has to be located in the input image before it is recognized. A definition of face detection could be: given an image, detect all faces in it (if any) and locate their exact positions and size. Usually, face detection is a two-step procedure: first the whole image is examined to find regions that are identified as “face”. After the rough position and size of a face are estimated, a localization procedure follows which provides a more accurate estimation of the exact position and scale of the face. So while face detection is most concerned with roughly finding all the faces in large, complex images, which include many faces and much clutter, localization emphasizes spatial accuracy, usually achieved by accurate detection of facial features.

: : fig2 : FACE DETECTION



Face detection algorithms

These can be divided into four categories according to:

1. **KNOWLEDGE-BASED METHODS** are based on human knowledge of the typical human face geometry and facial features arrangement. Taking advantage of natural face symmetry and the natural top-to-bottom and left-to-right order in which features appear in the human face, these methods find rules to describe the shape, size, texture and other characteristics of facial features (such as eyes, nose, chin, eyebrows) and relationships between them (relative positions and distances).

The main issue in such techniques is to find a successful way to translate human knowledge about face geometry into meaningful and well-defined rules. Another problem of such techniques is that they do not work very well under varying pose or head orientations.

1. **FEATURE INVARIANT APPROACHES** aim to find structural features that exist even when the viewpoint or lighting conditions vary and then use these to locate faces. Different structural features are being used: facial local features, texture, and shape and skin color. Local features such as eyes, eyebrows, nose, and mouth are extracted using multi-resolution or derivative filters, edge detectors, morphological operations or thresholding. Statistical models are then built to describe their relationships and verify the existence of a face .Skin color is another powerful cue for detection, because color scene segmentation is computationally fast.

Usually, they use features such as texture, shape and skin color to find face candidates and then use local facial features such as eyes, nose and mouth to verify the existence of a face. Feature invariant approaches can be problematic if image features are severely corrupted or deformed due to illumination, noise, and occlusion.

1. **TEMPLATE-BASED METHODS**. : To detect a face in a new image, first the head outline, which is fairly consistently roughly elliptical, is detected using filters, edge detectors, or silhouettes. Then the contours of local facial features are extracted in the same way, exploiting knowledge of face and feature geometry. Finally, the correlation between features extracted from the input image and predefined stored templates of face and facial features is computed to determine whether there is face present in the image.
2. **APPEARANCE-BASED METHODS**. These methods use large numbers of examples (images of faces and \ or facial features) depicting different variations (face shape, skin color, eye color, open\closed mouth, etc). Face detection can be viewed as a pattern classification problem with two classes: “face” and “non-face”. The “non-face” class contains images that may depict anything that is not a face, while the “face” class contains all face images. Statistical analysis and machine learning techniques are employed to discover the statistical properties or probability distribution function of the pixel brightness patterns of images belonging in the two classes. To detect a face in an input image, the whole image is scanned and image regions are identified as “face” or “non face” based on these probability functions. Well-known appearance-based methods used for face detection are eigenfaces , LDA , neural networks, support vector machines and hidden Markov models.

## Face Recognition Techniques

Face recognition techniques can be roughly divided into two main categories: global approaches and feature based techniques. In global approaches the whole image serves as a feature vector, while in local feature approaches a number of fiducial or control points are extracted and used for classification.

**View Based (Photometric) Approaches for Face Recognition**

Also called as Global approaches or Holistic approaches, model the variability of the face by analyzing its statistical properties based on a large set of training images. Representative global techniques are eigenfaces, Linear Discriminant Analysis (LDA), Support Vector Machines (SVM) and neural networks.

Current View Based (Photometric) Approaches

*Principal-component analysis (PCA)based*

* EIGENFACES: Direct application of PCA
* PROBABILISTIC EIGENFACES: Two-class problem with prob. measure
* FISHER FACES/SUBSPACE LDA: FLD on eigenspace
* SVM: Two-class problem based on SVM(Support Vector Machines)
* EVOLUTION PURSUIT: Enhanced GA learning
* FEATURE LINES: Point-to-line distance based
* ICA: Independent Component Analysis based feature analysis

*Other representations*

* LDA/FLD: LDA/FLD on raw image
* PDBNN: Probabilistic decision based Neural Network

**1. EIGEN FACES :** The first really successful face recognition method (and a reference point in face recognition literature) is a holistic approach based on principal component analysis (PCA) applied on a set of images in order to extract a set of Eigen-images, known as eigenfaces. Every face is modeled as a linear combination of a small subset of these eigenfaces and the weights of this representation are used for recognition. The identification of a test image is done by locating the image in the database, whose weights are the closest to the weights of the test image. The concept of eigenfaces can be extended to eigenfeatures, such as eigeneyes, eigenmouth, etc.

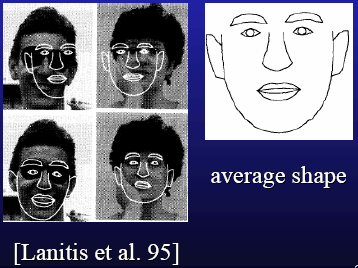
**Fig 3**: Eigen faces



**2. PROBABILISTIC EIGENFACES**: Using a probabilistic measure of similarity instead of the Euclidean distance between weights, the eigenface approach was extended to a Bayesian approach based on image differences Face recognition is viewed as a two-class classification problem. The first class contains intensity differences between images of the same individual (depicting variations in expression, illumination, head orientation, use of cosmetics, etc) and represents the intrapersonal facial variations. The second class contains intensity differences between images belonging to different people and represents the extra personal facial variations due to differences in identity. The distribution probabilities of the two excluding classes are estimated using a large training set. The MAP (Maximum a Posteriori) rule is used for face recognition.

3. **LINEAR/FISHER DISCRIMINANT ANALYSIS (LDA)**: Face recognition techniques using Linear/Fisher Discriminant Analysis (LDA) were also developed. LDA determines a subspace in which the between-class scatter (extra personal variability) is as large as possible, while the within-class scatter (intrapersonal variability) is kept constant. In this sense, the subspace obtained by LDA optimally discriminates the classes- faces. A combination of PCA and LDA was also proposed. Other global techniques include Support Vector Machines (SVM) and neural networks (NN).

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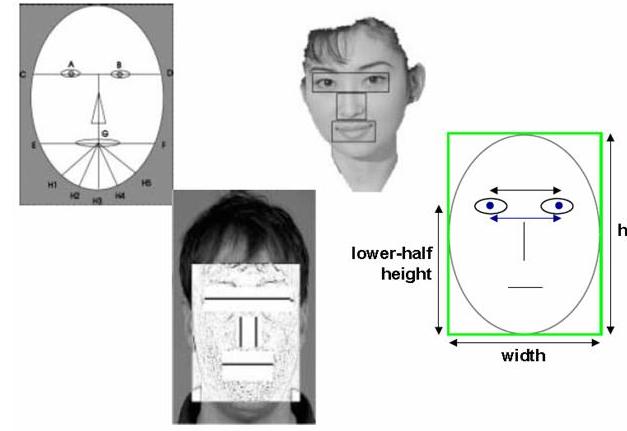
## Feature Based (Geometrical) Face Recognition Techniques

Main idea - discriminate among different faces based on measurements of structural attributes of the face. Most recent approaches are Embedded Hidden Markov Models (EHMMs), the Elastic Graph Matching and Dynamic Link Architecture.

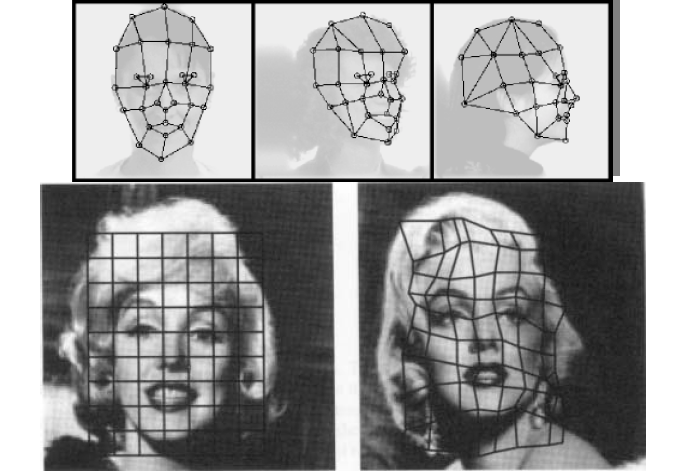
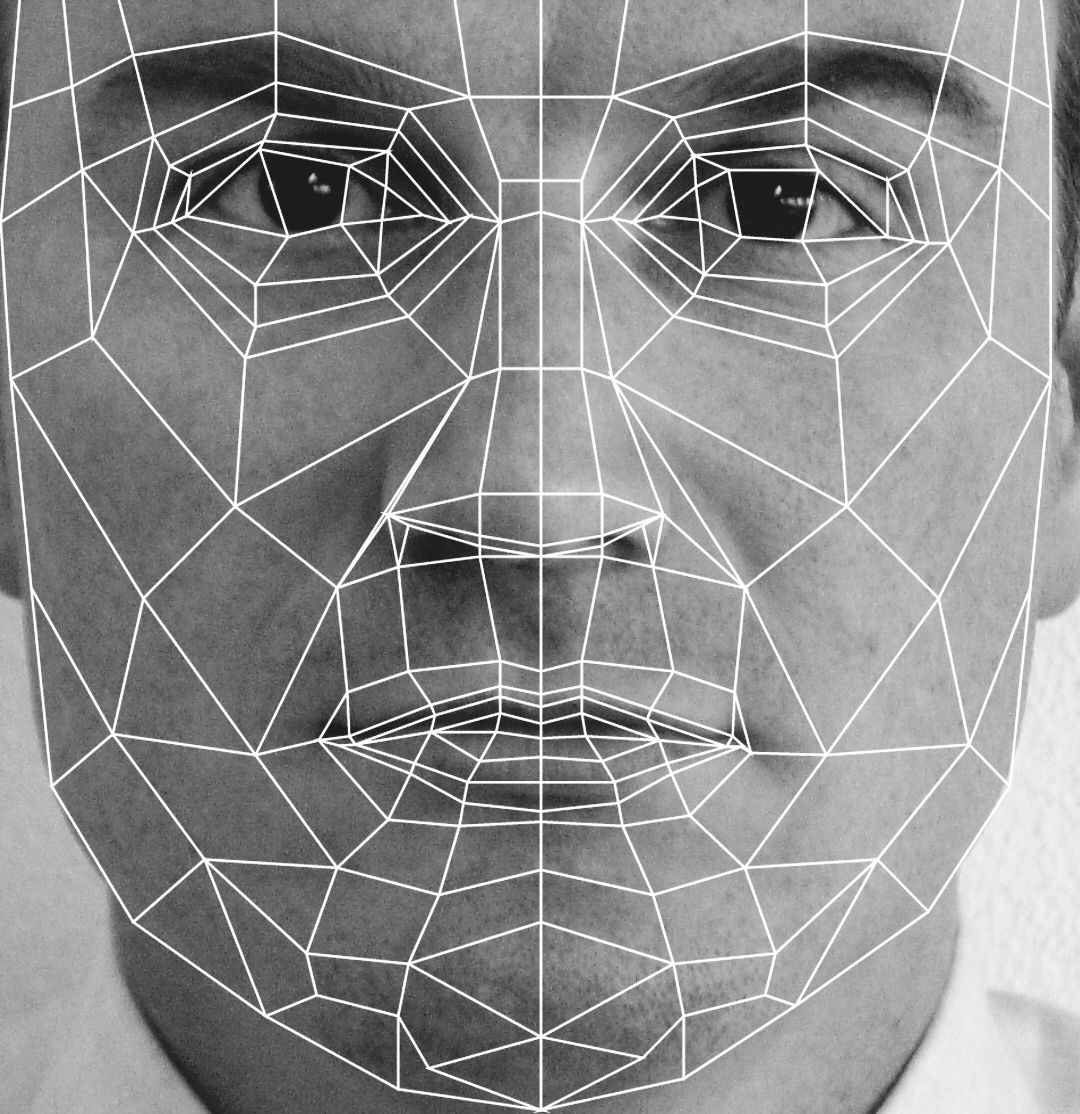
**Current Feature-based methods**

1. Pure Geometry
2. Dynamic link architecture: Graph matching methods
3. Hidden Markov model (HMM) methods
4. Convolution Neural Network SOM learning based CNN methods

**1. EMBEDDED HIDDEN MARKOV MODEL (HMM)**: For frontal views the significant facial features appear in a natural order from top to bottom (forehead, eyes, nose, and mouth) and from left to right (e.g. left eye, right eye). EHMMs model the face as a sequence of states roughly corresponding to facial features regions. The probability distribution functions of EHMM states are approximated using observations extracted by scanning training images from left-to-right and top-to-bottom. To verify a face, first the observations are extracted from the input image and then their probability given the stored EHM model is calculated.



FICUDIAL IMAGE POINTS



**Fig 5**: ELASTIC GRAPH MATCHING

**2. ELASTIC BUNCH GRAPH MATCHING** : It is based on the Dynamic Link Architecture (DLA). The basic idea of EGM is the representation of the face using a set of local image features extracted from the intensity images over fiducial image points and the exploitation of their spatial coherence using a connected graph. Each node in the graph is assigned a set of Gabor wavelet coefficients, over different scales and orientations, extracted from the image function. The graph is adapted to each face in the face database by the minimization of a cost function that locally.

## Hybrid Approaches

Approaches that use both global and local features have also been proposed. For example, the modular eigenspace approach uses both eigenfaces and eigenfeatures, while the Local Feature Analysis (LFA) extracts topographic local features from the global PCA modes and uses them for recognition.

**Current Hybrid methods**

* Modular eigenfaces using Eigenfaces and eigenmodules Hybrid LFA Local feature method
* Shape-normalized Flexible appearance models
* Component-based Face region and components

## Application Areas

1. **ENTERTAINMENT**: Video Games, Virtual Reality, Training Programs, Human Robot Interactions.

2. **SMART CARDS**: e Passports, Drivers Licenses, Entitlement Programs, national ID, Voter Registration, Welfare Funds

3**. INFORMATION SECURITY: PERSONAL DEVICE** Login, Desktop Login, Database Security, File Encryption, Intranet Security, Application Security, Medical records, Secure Business Trading Terminals

4. **LAW ENFORCEMENT AND SURVEILLANCE**: Advanced Video Surveillance, Portal control, Post-event control, Suspect tracking and Investigation, CCTV control

## Problems and Considerations

. The main problem of face recognition is large variability of the recorded images due to pose, illumination conditions, facial expressions, use of cosmetics, different hairstyle, presence of glasses, poses, beard,(occlusions), background Lighting etc. Images of the same individual taken at different times, may sometimes exhibit more variability due to the aforementioned factors (intrapersonal variability), than images of different individuals due to gender, race, age and individual variations (extra personal variability)

Another crucial parameter in face recognition is aging. A robust recognition system should be able to recognize an individual even after some years, especially in mug-shot matching forensic applications. This is a very challenging task, which has not been successfully addressed yet.

Recent public facial recognition benchmarks have shown that in general, the identification performance decreases linearly in the logarithm of number of people in the gallery database.

Also, in a demographic point of view, it was found that the recognition rates for males were higher than for females, and that the recognition rates for older people were higher than for younger people.

These tests also revealed that while the best recognition techniques were successful on large face databases recorded in well-controlled environments, their performance was seriously deteriorated in uncontrolled environments, mainly due to variations in illumination and head rotations. Such variations have proven to be one of the biggest problems of face recognition systems.

## Conclusions and Future Developments

The problem of machine face recognition has been an ongoing subject of research for more than 20 years. Although a large number of approaches have been proposed in the literature and have been implemented successfully for real-world applications, robust face recognition is still a challenging subject, mainly because of large facial variability, pose variations and uncontrolled environmental conditions. The use of novel sensors, such as 3D, can help overcome limitations due to viewpoint and lighting variations. On the other hand, it has been acknowledged that there is no perfect biometric and thus the combination of different modalities, e.g. face combined with speaker, fingerprint and/or hand recognition, is required to achieve the desired level of performance.

The computer based face recognition has made much useful advancement in the past decade however the need for high accurate systems remains. Through the determination of industry, government evaluations and organized standard bodies, growth and progress will continue, raising the bar for face recognition.

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