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Face recognition and its various techniques: a review

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Abstract

Face recognition is an interesting application of pattern recognition and recently it has received significant attention. Face recognition involves comparison of an image with a database of stored faces in order to identify the person in that input image. The whole process covers in three stages face detection, feature extraction and recognition and various techniques are needed according to the requirements. Various techniques have been proposed and much work has been done in recognizing face under small variations in face orientation, expressions, lighting, back-ground. This paper contains the complete study of various techniques used at different stages under different conditions.

Keywords: Canny edge detector, face detection, face extraction, face recognition, ICA, LDA, PCA, Prewitt edge detector, SVM, Sobel operator.

I. INTRODUCTION

Face recognition is an interesting application of pattern recognition and recently it has received significant attention. The task is can be done by matching a selected face to one of many faces present in the dataset. It is a most reliable method of biometric personal identification. Various techniques have been proposed and much work has been done in recognizing face under small variations in face orientation, expressions, lighting, back-ground [11]. Face recognition systems can be used in various human -machine interfaces and automatic access control systems. User-friendly systems that can secure our privacy without losing our identity are strongly needed.

The face recognition system works in three stages: face detection, feature extraction and face recognition. There are two types of face recognition, the first one is intrusive the second one is non-intrusive. The intrusive kind of face recognition includes the participation the user. Means user is aware about the recognition. But in the non-intrusive face recognition**,** there is no user's co-operation.but it can be able to recognize the user as authenticated person or not. 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 [10].

A. Face detection

Face detection is the first step in face recognition systems. Face detection part indicates whether the input image contains a face or not. And also detect the location of the face. Face detection is mandatory part in face recognition because images must be analyzed and faces identified before recognition. It is a complex task because it is influenced by various factors complex environment, changes in lighting, pose, facial expressions.

B. Feature Extraction

Feature extraction is an important task to collect the set of features from an image. According to the author, Feature extraction/transformation is a process through which a new set of features is created [6]. It involves the extraction of relevant features from the localized image. [10] This localized image obtained after the face detection process. Face detection systems detect the face in the input image and determine the location of the face.

C. Face recognition

Face recognition is the last stage in the face recognition process. It involves the classification of facial images based on the feature vector obtained [10].

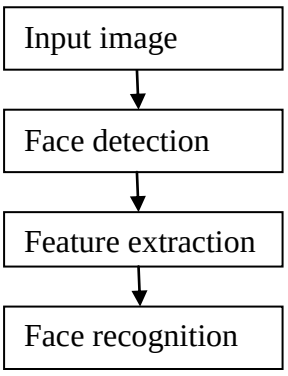

Fig.1 Basic building block of face recognition system

II. FACE DETECTION AND ITS VARIOUS APPROACHES

It is a fundamental part of the face recognition system because it has ability to focus computational resources on the part of an image containing face. Face detection involves the separation of image into two parts; one containing the face and the other containing the background. It is difficult because although commonalities exist between faces, they can vary considerably in terms of age, skin colour and facial expression [11].an ideal face detector must be able to detect the faces under any set of conditions. Face detection has direct relevance with the face recognition because before recognition the image must be analyzed 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 decides 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.

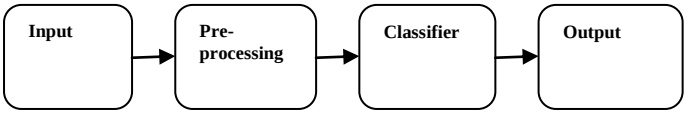

Fig. 2.Basic building of face detection system

A. An overview to face detection techniques

For face detection each technique takes a slightly different approach and produces good results. Each technique has its own limitations.Hjemal and Low [1] divides the face detection techniques into two categories named feature based techniques and image based techniques.

B. Feature based techniques

The feature based approaches use the facial features to their detection process.Hjemal and Low [1] further divides these techniques into three categories: low level analysis, feature analysis and active shape model.

C. Low level analysis

It deals with the segmentation of visual features by using the properties of pixels, gray scale level, and motion information. In [2], implemented an edge representation method for detecting the facial features in line drawings by detecting the changes in pixel properties. In [3], developed this further to detect human head outline. The edge based techniques rely upon the labeled edges which are matched to a face model for verification. There are various operators are present to detect edges like Sobel operator, Prewitt edge detector, canny edge detector.
The gray scale information can be used to identify various facial features. Generally eyebrows, pupils and lips appear darker than surrounding regions, and thus extraction algorithms can search for local minima. In contrast, local maxima can be used to indicate the bright facial spots such as nose tips [11]. Detection is then performed using low-level gray-scale thresholding.

B. Feature analysis

It uses additional knowledge about the face and removes the ambiguity produces by low level analysis.The first involves sequential feature searching strategies based on the relative positioning of individual facial features [11]. Initially prominent facial features are determined which allows less prominent features to be hypothesised (for example a pair of dark regions found in the face area increases the confidence of facial existence). The facial feature extraction algorithm [13], is a good example of feature searching, achieving 82% accuracy with invariance to gray and colour information, failing to detect faces with glasses and hair covering the forehead [11].

C. Active shape model

Active shape models are used to define the actual physical and higher-level appearance of features. These models are developed by Tim Cootes and Chris Taylor in 1995. These models are released near to a feature, such that they interact with the local image, deforming to take the shape of the

feature [11]. ASM are models of the shapes of objects which iteratively deform to fit to an example of the object in a new image. It works in following two steps: Look in the image around each point for a better position for that point, update the model parameters to best match to these new found positions.

There are three types of active shape models such as snakes, deformable templates and smart snakes.

Snakes or Active contours are used to create a head boundary. This model attempts to minimize an energy associated to the current contour as sum of an internal and external energy. The snakes model try to segment the image based on the following energy:

$$E_{snake} = E_{int} + E_{ext} \quad (1)$$

Deformable Templates can be used as an extension to the snake models.Deformable templates give a simple and compact representation highly variable objects. One limitation of such techniques is that they are sensitive to initial placement [11]. Smart Snakes, or Point Distributed Models (PDMs) are compact parameterised descriptions of a shape based upon statistics [11]. The point distribution model is a model for representing the mean geometry of a shape and some statistical modes of geometric variation inferred from a training set of shapes.

D. Image based techniques

Face detection of facial features by explicit modeling is a very trivial approach because it may be troubled by the unpredictability of faces and environmental conditions. So there is a need for more robust techniques, capable of performing in unfriendly environments, such as detecting multiple faces with clutter-intensive backgrounds.

Image based face detection has inspired a new research area and by virtue of this face detection is treated as a general pattern recognition problem. Whereas face recognition deals with recognizing the face, face detectors must recognize an object as a face, from examples. This eliminates the problem of potentially inaccurate models based on incomplete face knowledge and instead focused on the training examples from which the system which learn to distinguish a face.

Window scanning techniques are used by many image based approaches for detecting faces, which due to its extensive nature, increases computational demand [11].The image based approach contains the various approaches like neural networks, example based learning, support vector machine.

Neural Nets can be used to construct systems that are able to classify data into a given set or class, in the case of face detection, a set of images containing one or more face, and a set of images that contains no faces. Neural Nets are essentially networks of simple neural processors, arranged and interconnected in parallel [11].

The example based learning approach is used to locate vertical frontal views of human faces. This technique models the human face patterns by means of a few view-based face and non-face prototype clusters. At each image location, a difference feature vector is computed between the local image pattern and distribution based model. This difference vector is then fed to trained classifier to determine whether or not a human face is present at the current image location [7]. The system can detect faces of different sizes.

In [14], a face detection technique based on SVM is proposed.SVM is a learning approach developed by Vapnik at AT&T .SVM operate on induction principal, called structural risk minimization, which minimizes the upper bound of the generalization error [7].

III. FEATURE EXTRACTION AND ITS VARIOUS TECHNIQUES

Feature extraction stage involves the extraction of relevant features from the localized image. This localized image obtained after the face detection process. Face detection systems detect the face in the input image and determine the location of the face. The resultant image is the raw data for the feature extraction and it is not possible to deal with very high dimensional input data.

A. Statistical approaches for dimension reduction

Dimension reduction is required to extract the structured data and to remove the redundant data. There are many techniques available for mapping of high dimensional data into lower dimensional data. So it becomes easier to do classification in reduced space than original space.

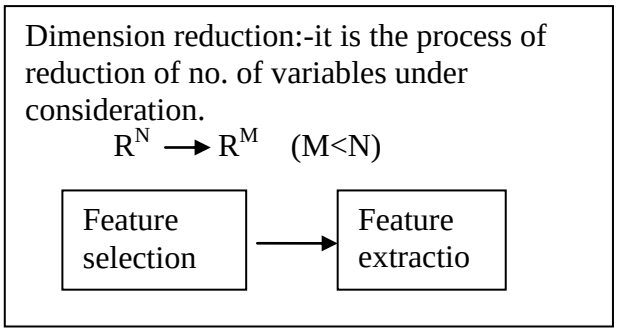

Fig. 3 Dimensionality reduction

Principal component analysis (PCA)

It is used to simplify a data set into lower dimensions while retaining the characteristics of the dataset. It is statistical approach that transforms a no. of possible co-related variables into a smaller no. of uncorrelated variables. [4]

Linear discriminant analysis (LDA)

LDA is one of the most famous linear techniques for dimensionality reduction and data classification. The main goal of the LDA consists in finding a base of vectors

providing the best discrimination among the classes, trying to maximize the between-class differences, minimizing the within-class ones by using scatter matrices [6].

Independent component analysis (ICA)

ICA is the statistical and computational approach for extraction of hidden factors that underlie sets of random variables.ICA algorithm is speeded up by including a "sphering" step prior to learning. The row means are subtracted, and then passed through the whitening matrix, which is twice the inverse square root of the covariance matrix:

$$W_z = 2*(\mathrm{Cov}(X))^{-1/2} \quad (2)$$

This removes the first and the second-order statistics of the data; both the mean and covariances are set to zero and the variances are equalized. Thus, W^{-1} the inverse of the weight matrix can be interpreted as the source mixing matrix and the U=WX variables can be interpreted as the maximum-likelihood (ML) estimates of the sources that generated the data [4].

B. Geometry based method for feature extraction

The features are extracted by using relative positions and sizes of the important components of face. This group method concentrates in two directions. First, detecting edges, directions of important components or region images contain important components, then building feature vectors from these edges and directions [5].

Local binary pattern

In this method, the face image is divided into the regions (blocks) and each region corresponds with each central pixel. Then it examines its pixel neighbours based on the gray scales value of central pixel to change its neighbour to 0 or 1 [5].

Gabor filters

Gabor is a function that satisfies certain mathematical requirements and it is used in the presentation of data, however, it represents data at different scales and orientations. Gabor filters have been applied in many applications such as texture segmentation, image representation, edge detection and face recognition. Extraction information is based on the use of a bank of Gabor filters [10], 8 orientations and 5 resolutions. The 2D Gabor filter is formed by modulating a complex sinusoid by a Gaussian function where each filter is defined by:

$$\mathrm{Gabor}(x, y, \mu, v) = \theta(x, y, \mu, v)\ (\alpha\text{-}\beta) \quad (3)$$

Where:

$$\theta(x, y, \mu, v) = \frac{\left\| {}^{k}\mu v \right\|^{2}}{\sigma^{2}} \quad (4)$$

C. Colour based feature extraction

Colour models such as RGB, YCbCr or HSV with certain range of colour pixels are used to detect skin region .After getting the skin region, facial features like eyes and mouth are extracted. The binarization is done of image obtained after applying skin colour statistics. It is transformed to gray-scale image and then to a binary image by applying suitable threshold to eliminate the hue and saturation values and only consider the luminance part. This luminance part is then transformed to binary image with some threshold because the features for face are darker than the background colours [5]. Opening and closing operations are performed to remove noise after thresholding. These are the morphological operations, which are used to remove holes. Then eyes, ears, nose can be extracted from the binary image by considering the threshold for areas which are darker in the mouth than a given threshold [5]. So triangle can be drawn with the two eyes and a mouth as the three points in case of a frontal face. And it is easy to get an isosceles triangle (i j k) in which the Euclidean distance between two eyes is about 90-110% of the Euclidean distance between the centre of the right/left eye and the mouth. After getting the triangle, it is easy to get the coordinates of the four corner points that form the potential facial region. Since the real facial region should cover the eyebrows, two eyes, mouth and some area below the mouth, this coordinates can be calculated [15]. Due to the diversity of ethnical backgrounds, the performance of such techniques on facial image databases is limited.

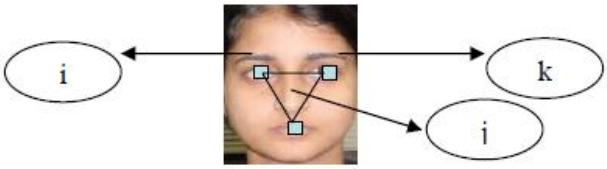

Fig. 4 colour based feature extraction

D. Template based techniques

These techniques are based upon template function and appropriate energy function [5]. There are two methods proposed, deformable template method and genetic algorithms. In an image region, eyes, mouth and nose are appropriate as template image because they will minimize the energy. In the deformable method [9], the eye region is used as template image. An energy function is used to link edges, peaks, and valleys in the image intensity with corresponding properties of the template. Then the template matching is done. Template matching is a technique for finding small parts

of an image which match a template image. In this method, first an eye template is used to detect the eye from face image. The correlation of eye template with various overlapping regions of the face image is found out. The region with maximum correlation with the template refers to eye region. But the template based method cannot represent global structure. The block diagram of the method is shown in Figure.

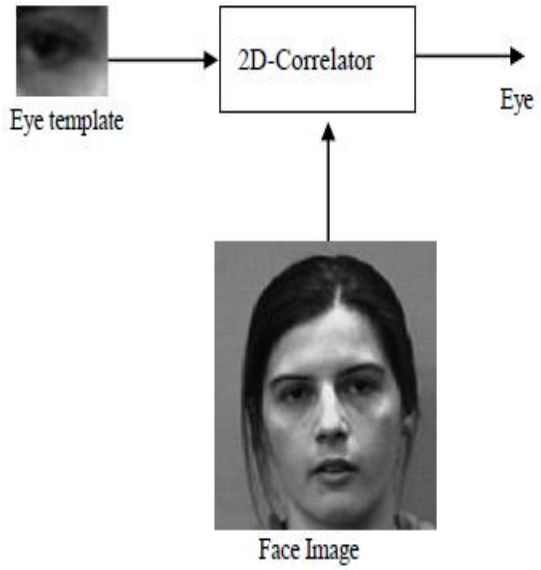

Fig. 5 Template based feature extraction

The algorithm steps are given below [8]:-
Step 1: Eye region of size m × n is taken as template image.
Step 2: The normalized 2-D auto-correlation of template is found out.
Step 3: The normalized 2-D cross-correlation of eye template with various overlapping regions of the face image is calculated.
Step 4: The mean squared error (MSE) of auto correlation and cross-correlation of different regions are found out and stored.
Step 5: The region of the face corresponding to minimum MSE represents eye region.
Step 6: From eye region eyes points are extracted from eye region.
Step7: Now the mouth point can be detected from eye points.

IV. APPLICATIONS

This table lists some of the applications of face recognition systems.

Table. I Applications of face recognition

AREA	SPECIFIC APPLICATION
Biometric	Drivers' Licenses, Entitlement Programs
	Immigration, national ID, Passports, Voter Registration
	Welfare Fraud
Information security	Desktop Logon (windows NT, Windows 950
	Application security ,database security, File encryption
	Intranet Security ,internet Access .Medical Records
	Secure Trading Terminals
Law enforcement And surveillance	Advanced Videos Surveillance ,CCTV Control
	Portal Control , Post –event Analysis
	Shoplifting and Suspect Tracking and Investigation
Smart cards	Stored Value Security ,User Authentication
Access control	Facility Access ,Vehicular Access

V. CONCLUSION

In this paper, we have presented an extensive review of face recognition and various approaches used for face detection and for feature extraction. According to the parameters, different techniques are used and every technique has its own pros and cons. Face detection approaches such as feature based approaches and image based approaches offer promising results. Feature based approaches often applied to real time systems but image based approaches are computationally expensive for real time systems. This paper contributes to give details about most well known dimensionality reduction techniques such as PCA, LDA, and ICA. Template based techniques are easy to implement but they cannot represent global structure. Geometry based techniques produce stable and scale invariant features.

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