A Comprehensive Study of Face Detection and Recognition

Vinita Malik
Assistant Professor, Department of Computer Science Engineering, MSIT, New Delhi, India

Sheetal Srivastava
Student, Department of Computer Science Engineering, MSIT, New Delhi, India

Dheeraj Kaushik
Student, Department of Electronics and Communication Engineering, MSIT, New Delhi, India

Abstract: Over the last decade, face recognition gained magnificent interest in the research field. Face recognition consists of three processes, namely, face detection, feature extraction and recognition. Earlier, face detection is limited to frontal face detection but presently, there are some new algorithms that resolve the problem of side-view detection. In this paper, all the four methods comprising of knowledge-based, template-based, feature-invariant, appearance-based are discussed in detail with the merits and issues they face. Here, we also present short notes on some techniques of face recognition. This includes Haar-like features, Separate Haar, Color-based, PCA, LDA, ICA, SVM, Gabor wavelet, Machine Learning, Neural Networks. This paper also includes a performance comparison of these techniques. To sum up, we have given our conclusion for all the methods of face detection.

Keywords: Face detection, Feature extraction, Face recognition, Haar-like features, PCA, LDA, ICA, Gabor Wavelet, SVM, Machine Learning, and Neural Networks.

I. INTRODUCTION

Face detection is a technique to extract the information such as location and sizes of faces in digital image. It is the very first step towards the face processing systems. One of the main applications of face detection is in the area of face recognition such as verification and identification. The following diagram shows the steps involved in face recognition process:

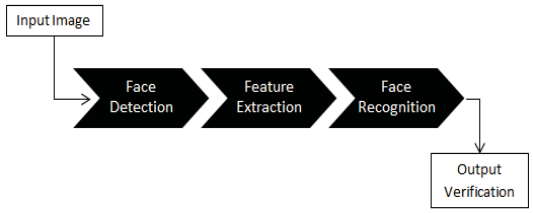

Figure.1 Process of Face Recognition

First of all, face detection is done on the input image. Then, features are extracted with the help of certain techniques and then the recognition techniques are applied. Lastly, output verification or identification is done. Some of the areas where face detection and recognition is used are: Security purposes (CCTV, ATM machines, and email authentication), Identity verification (national IDs, passports, electoral registration etc.), Biometrics (identification of face, fingerprints, veins etc.), Database investigation of images etc. [1].

II. LITERATURE SURVEY

The technology of face recognition is closely related to varied domains such as face detection, feature extraction, pattern matching, image processing, biometric identification etc., and shares a rich literature with many of them. In this section we present a brief understanding of some methods and technologies that have been proposed and used for face detection, feature extraction and face recognition.

Classification: Usually, face detection approaches are divided into 4 main categories:

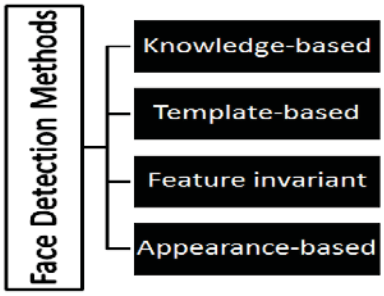

Figure 2. Classification of Face Detection Methods

(a) Knowledge-based methods:

In 2000, Jianguo Wang and Tieniu Tan [2], proposed a new system based on energy functions which was very useful for images with simple background [2]. The basis of this approach is the knowledge about the geometry of human face as well as the facial feature design. There are some rules for face detection from an image are defined and these rules can also be used to detect the face from typical or complex backgrounds in an image. Firstly, facial features are extracted from an image. Secondly, candidate recognition is done with the help of predefined simple rules. A rough estimate of face geometry is used for candidate recognition at higher levels. Natural symmetry of face helps in describing the rules for shape, size, texture and other facial features characteristics like eyes, nose, chin etc. and relative position and distance between them.

(b) Template-based methods:

In this method of face detection, firstly, the head outline is detected using filters or edge detectors. Then, the contours or edges of the facial features are extracted using energy functions and finally their relative locations are matched with the stored predefined templates of facial features by executing pixel intensity which are sensitive to shape, scale, pixel intensity or pose variations. This method is based on the correlation between the features extracted from the input image and those of the predetermined estimate i.e. templates, to determine the possibility of a human face in the given image. Deformable template methods have been proposed by Yuille et al. [3], to detect and describe the facial features using parameterized templates containing priori knowledge about the expected shape of the features to guide the detection process [3].

(c) Feature invariant approaches:

David G. Lowe [4] developed a system that uses a new class of local image features. The features are invariant to image scaling, translation, and rotation etc. [4]. These approaches target to locate the faces with the help of structural features that are present even in the variations in light or distinct viewpoint. Structural features such as facial local features, shape, and texture and skin color are used for this purpose. Some features such as eyes, mouth, eyebrows and nose are known as local features and they are extracted with the help of filters. Then, the existence of face is verified with the help of statistical models, thresholding or edge detectors. Some studies also proved that skin color is considered to be the one of the best feature for face detection as each individual have different skin color and it is clearer when the race of people is also a standard of evaluation [5].

(d) Appearance-based methods:

Appearance-based methods think of face detection as a two class pattern classification problem, one "face" and other "non-face", In 2007, M A Rabbani and C. Chellappan proposed an appearance based method which uses median and give better results in complex images.[6]. The face class contains all the images with faces and the non-face class contains everything that is not a face. This method is mostly used for facial features extraction and recognition as it uses features in the search window and numerous classifies depicting variations in such features like skin color, shape of lips, different mouth positions open/closed. The various face detection techniques based on Appearance-based methods are PCA, Eigen faces, Haar like features, LDA, SVM. Machine learning and statistical analysis can be used to discover the probability distribution of pixel brightness patterns of images belonging to these classes.

Face recognition involves various techniques that are used as per the user's requirement. In the coming section we will discuss some important recognition techniques that are widely used. Next we briefly review the various techniques available for face recognition.

III. VARIOUS TECHNIQUES

(A) Haar like features:

Haar like feature is the most widely used method in face detection after its arrival in 2001. Here, value of all pixels in grayscale image are accumulated which are in black and then they are subtracted from the whole of white boxes and then the result will be compared with the defined threshold. If the result is above the threshold then it is considered as a match or hit [7].

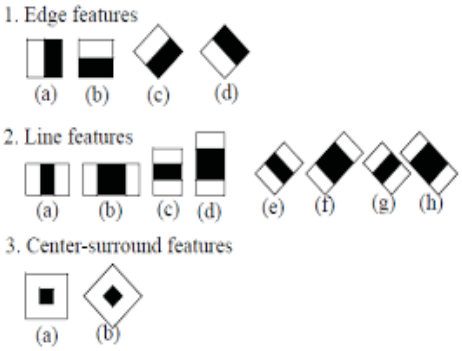

Figure 3. Haar like features

(B) Separate Haar:

There is a possibility of different locations and edges angles between the adjacent rectangles of Haar features in different training face samples. Due to this, feature value is not sufficient to separate from the negative samples. A don't care area between the adjacent rectangles is inserted which is known as Separate Haar Feature [7]. Doing this, we get a significant value for each feature. Therefore, we can use a new threshold for the feature value to separate positive samples from the negative samples. Hence, a more powerful weak classifier.

(C) Color-based model:

By now, skin region can be detected using many color models like RGB etc. Applying skin color statistics, the color image is converted to its grayscale equivalent and then to a binary image with the help of appropriate threshold.

After getting binary image, noise is removed with the certain opening and closing process. Then the facial features are extracted from the binary image with the help of threshold for distinct portions [1].

(D) Principal Component Analysis (PCA):

PCA is a method for feature selection and dimension reduction and is also known as Karhunen-Loeve method. This is one of the popular methods in the field of face detection. PCA was first used by Turk and Pentland [5] for human face recognition. It was first used by Kirby and Sirovich [8] for reconstruction of human faces. Eigen face method known as recognition method, a feature space is defined in which the dimensions of initial data space is reduced and the new space obtained is used for recognition purposes.

(E) Linear Discriminant Analysis (LDA):

LDA provides an efficient way to linearly transform the initial data space into low dimensional space of features where the data is characterized. LDA looks for the data with linear combinations and differentiate the classes of data.

(F) Gabor wavelet:

Gabor function was proposed by Hungarian-born electrical engineer Dennis Gabor in 1946. Face recognition is one of the most important applications of Gabor wavelets where input image is convolved with the set of Gabor wavelets and the output images are then further processed. In recent years, a number of researches on face recognition have been conducted and roughly two approaches are proposed:

(i) Analytic approach: Some feature points are detected (fiducial points) and then theses points are used for face detection.

(ii) Holistic approach: Extracts features from the complete face image. Eigen face based on PCA and fisher faces based on LDA are some common holistic approaches.

(G) Independent Component Analysis (ICA):

Determining factors or components from multidimensional data is done with the help of ICA. This method looks for components that are non-gaussian and statistically independent [8]. In ICA, firstly, each face image is converted into a vector and then independent components are calculated. In 2003, Bruce A. Draper, Kyungim Baek, Marian Stewart Bartlett and J. Ross Beveridge [9] showed that ICA architecture yields highest performance for identifying faces.

(H) Support Vector Machine (SVM):

In 2001, Bernd Heisele, Purdy Ho and Tomaso Poggio proposed a system in which a single SVM classifier is trained for each person in the database [10]. SVMs are known as maximum margin classifiers. When it comes to classification problems, SVM provides a way for face recognition. This method is applied to the space obtained after the application of feature extraction method and the space can be the original appearance space.

(I) Machine Learning:

In the recent years, machine learning is one of the hot topics in research area. The method based on Machine Learning consists of a set of images of different individuals and the classifiers are trained with the help of labels, then a knowledge model is obtained. After this, data for a new individual can be passed in the model so that accuracy identification can be ensured. There are several algorithms for machine learning is used. Some of them are:

K-Nearest Neighbor (KNN), Locally-Weighted Learning (LWL), Naïve Bayes Classifier (NB), Single Decision Tree (SDT), and Decision Table (DT) [11].

(J) Neural Networks:

A neural network is based on multi-layer feed forward algorithm which is capable of pattern matching due to its simplicity. MLP (Multi-Layer Perceptron) is a network in which we have a set source nodes that is at the input layer, one or more hidden layers and the output layer which is of computational nodes.[5].

Table 1: Face Detection Methods

Methods	Merits	Issues & Challenges
Knowledge-based	Relative positions and distances between various facial features can be determined with the rules	An efficient method is needed to translate human knowledge of face geometry into well-defined and meaningful rules Do not work effectively under changing positions or orientation
Template-based	Large number of features such as mouth, nose, eyes and eyebrows. Side view is also possible to implement	Do not represent global face structure Long time complexity description between template and images Dependent on size, scale and rotation.
Feature invariant	Rotation independency Scale independency Quick execution time Contains facial features, skin color, texture and multiple features	Do not yield good results when image features are corrupted or deformed due to noise, illusion or occlusion Feature restoration is difficult
Appearance-based	Since non-face window will be rejected early execution time will be reduced and accuracy will be increased Best performer in facial feature extraction	Need a high quality image for detection process Requires large database

Table 2: Face Recognition Techniques

Techniques	Merits	Issues & Challenges
Haar-like features	Good detecting rate i.e. less execution time	Contribute a lot of false detection Feature value is not powerful enough to separate from the negative samples
PCA	Data compression is achieved by the low dimensional subspace representation No knowledge of geometry and reflectance of faces is required	very sensitive to scale, therefore, a low-level preprocessing is still necessary for scale normalization
LDA	Optimizes the low dimensional representation of the objects with focus on the most discriminant feature extraction	it fails when all scatter matrices are singular A critical issue using LDA, is the Small Sample Size (SSS) Problem
Neural Networks	requiring less formal statistical training ability to implicitly detect complex nonlinear relationships between dependent and independent variables ability to detect all possible interactions between predictor variables, and the availability of multiple training algorithms	Greater computational burden Proneness to over fitting The empirical nature of model development Execution time is more

SVM	SVM classifiers can achieve better generalization performance	Cannot be applied when feature vectors defining samples have missing entries

Table 3: Performance Comparison of Face Recognition Techniques

Author	Technique	Database	Image Resolution	Recognition rate
Zafar G. Sheikh, V. M. Thakare, S. S. Sherekar, (2012) [17]	Haar-like Features	ORL	320x240	92.70% is for detection
Heng Fui Liau, Kah Phooi Seng, Li-Minn Ang and Siew Wen Chin [12]	PCA	ORL (Olivetti Research Laboratory)	32x32	89.50
R.Rajalakshmi, Dr.M.K.Jeyakumar, (2012) [13]		Indian Face database	640x480	90.50
Divyakant T. Meva, C K Kumbharana, (2014) [14]	LDA	ORL	32x32	90.50
Gang Hua Microsoft Live Labs Research [15]		YaleB	37x37	81.30
R.Rajalakshmi, Dr.M.K.Jeyakumar, (2012) [13]	ICA	Indian Face database	640x480	92.50
		Asian Face Database	640x480	86.50
Che-Hua Yeh, Pei-Ruu Shih, Kuan-Ting Liu, Huang-Ming Chang, Ming Ouhyoung , [16]	SVM	AR database	768x576	87.50
Zafar G. Sheikh, V. M. Thakare, S. S. Sherekar, (2012) [17]	Naïve Bayes (Machine Learning)	YALE	640x480	86.60% is for detection
Adnan Khashman [18]	Neural networks	ORL	272input layers, 65 hidden layers, 30 output layers	93.3

V. CONCLUSION

In this paper, we have discussed about four methods of face detection. Face detection and recognition are inter-linked. The knowledge-based method deals with the human face geometry but unable to work well in varying head positions. Template-based methods are able to detect side views but do not represent global face structure. Feature invariant methods are quick in execution but feature restoration is difficult. Appearance-based methods are best in performance but require high quality images. So, from the survey we found that Appearance based methods are best as global face structure can be represented by this method. In this paper, we also provide a comparison between different techniques involved in face recognition.

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