Face Image Detection Methods: A Survey

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Abstract Face detection is an important part of face recognition systems. In this paper, we presented various methods of face detection, which are commonly used. These methods are local binary pattern (LBP), Adaboost, support vector machine (SVM), principal component analysis (PCA), hidden Markov model (HMM), neural network-based face detection, Haar classifier, and skin color models. Each method is summarized along with their advantages and disadvantages.

Keywords Face detection · Adaboost method · Local binary pattern (LBP)
Principal component analysis (PCB) · Hidden Markov model (HMM)
Support vector machine (SVM) · Skin segmentation

1 Introduction

The face detection simply means to determine that the given input is a face image or not, regardless of the size, position, background, etc. The current evolution of computer technologies has boosted in this era; for example, computer vision contributes in face recognition and video coding techniques. Face detection in computer vision involves segmentation, extraction, and verification of faces. Face detection is considered as primary steps toward face recognition. In recent years with the development of artificial intelligence, Internet of Things, e-commerce, and other computer applications, face detection and recognition gain much more importance [1].

Applications of face detection include as follows: **Surveillance**: Surveillance in the form of CCTVs can be proved effective in gathering evidences, e.g., criminal

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evidences or during exams. Face detection is the best biometric for video data too. **General identity verification**: Smart cards are most often used in today's world for maintaining high security, e.g., employee id, driving license, e-registration, voter id card. **Criminal justice systems**: For gathering criminal evidences, forensic analysis and postevent investigation can be surely benefitted by face detection even if the culprit is wearing mask or cloth for distraction. **Image database investigations**: Searching in large number of image databases for any kind of identification purposes like missing children, licence holders, account holders. **Multimedia** environments with adaptive human–computer interfaces; i.e., it is a robust way as well as proved beneficial in various domain areas.

Computational powers and availability of recent sensing is increasing results in human–computer interactive applications such as face detection, which gradually includes authentication, verification, tracking of facial images. Face detection goal is to determine the input contains any face images and provides results regardless of expressions, occlusions, or lighting conditions [2]. Face detection is a first step in human interaction systems which include expression recognition, cognitive state, tracking, surveillance systems, automatic target recognition (ATR), or generic object detection/recognition. Face detection challenges include as follows: out-of-plane rotation: frontal, 45°, profile, upside down, presence of beard, mustache, glasses, etc. Facial expressions occlusions by long hair, hand, in-plane rotation image conditions include as follows: size, lighting condition, distortion, noise, and compression.

Face detection applications in areas such as content-based image retrieval (CBIR), video coding, video conferencing, crowd surveillance, and intelligent human–computer interfaces are gaining popularity. Basically, face detection falls under two categories that are local feature-based ones and global methods. Approaches based on features include: geometrical method, color-based or texture-based method, motion-based method [3].

Figure 1 shows face detection approaches in graphical representation, and detail description is as follows [4].

2 Face Detection Techniques

Generally, prior to basics include following methods:

Knowledge-Based Methods: It encodes what constitutes typical face, e.g., the relationship between facial features. It includes knowledge about some features that could fall into face localization like distance of eyes and mouth or mouth is below nose, etc., thus reducing computational time for detection. It includes top-down approaches and bottom-up approaches.

Feature Invariant Approaches: This approach aims to find structural features of a face that exist even when pose, viewpoint, or lighting conditions vary. Therefore useful in locating face faster, and correct identification of faces is possible even in adverse conditions and include skin color and texture.

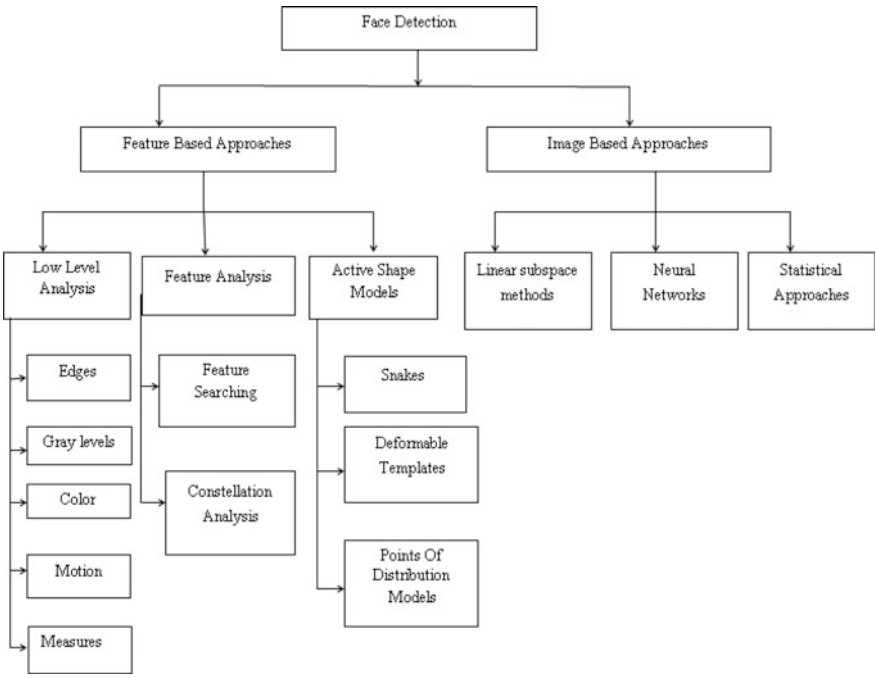

Fig. 1 Face detection approaches

Template Matching: Here, several standard patterns are stored in databases to describe the face as a whole or the facial features separately. So after comparing the input images and stored images, output is provided as match result considering the template of facial images. This technique is used for localization as well as detection of facial images and includes predefined templates.

Appearance-Based Methods: The models are learned from a set of training images that capture the representative variability of faces. Basically, templates are from trained databases and are used for detection purposes, and it includes distribution-based methods, support vector machine (SVM), hidden Markov model.

3 Face Detection Methods

Adaboost: AdaBoost is abbreviated for "Adaptive boosting." It is a machine learning meta-algorithm by Yoav Freund and Robert Schapire who won the global prize in 2003 for their work. It can be used in combination with learning algorithms to improve their performance and accuracy. The output of the other learning algorithms ("weak learners") is combined into a weighted sum that represents the final output of the boosted classifier. Blob filtering results identify ROI region, and

then output is given by adaboost [5]. Also, accurate prediction rule uses visual features to produce classifiers and uses multiple iterations to generate a single strong learner [6]. AdaBoost algorithm includes training samples having weight which is the considered probability for selecting regions and helpful in detecting face and non-face regions. MIT-CBCL database is used for training [7]. Adaboost could be combined with haar-like features and thus optimizing the results by researching weak classifiers by putting threshold parameter [8].

This method could be used as a combination of color segmentation algorithms for accurate detection of facial images, edge lines, and central surrounded features which are used for segmentation, and then color region is detected with adaboost providing robust solution [9].

Principal Component Analysis: Principal component analysis (PCA) is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components those result in dimensional reduction. PCA is widely used in data analysis and for making models of predictions. Principal component analysis (PCA), also known as Karhunen–Loeve expansion, is a classical feature extraction and data representation technique widely used in the areas of pattern recognition and computer vision. Two-dimensional PCA based on 2D matrices is used for reconstruction of image along with support vector machine (SVM) method [10]. The PCA algorithm is applied to check for a face at each pixel in the input image. This search is realized using crosscorrelation in the frequency domain between the entire input image and eigenvectors. A few low-frequency discrete cosine transform (DCT) coefficients are used and then perform PCA on the enhanced training images set, and ORL database is used [11]. Initially, the eigen space is created with eigenvalues and eigenvectors then the input images are classified based on Euclidian distance. Classifier is used for decision-making based on feature vectors; ORL face database is used [12].

Hidden Markov Model: A hidden Markov model (HMM) is a statistical Markov model in which the system being modeled is assumed to be a Markov process with unobserved (hidden) states. Direct states are not visible, but the output is clearly shown. These models are especially known for their application in temporal pattern recognition such as speech, handwriting, gesture recognition, for example, Gaussian distribution. The observation vectors used to classify the states of the HMM are obtained using the coefficients of the Karhunen–Loeve transform (KLT). This method is useful in detecting gray scale images as well. MIT database is used, and both face detection and face recognition are using HMM model [13]. It consists of Markov chain of hidden, invisible, and limited states and a probability density function. Markov chain includes probability distribution function of initial state and probability matrix of transferred state. Probability density function is related to those states [14, 15]. HMM could be used as an expression classifier also. First relative features are extracted based on relative displacement of face muscles [16].

Support Vector Machine (SVM): SVM is a learning model in machine learning that is used for analysis of data and can perform nonlinear classifications.

SVM classifier includes sub-gradient descent and coordinates descent. The SVM algorithm maps the test images into higher-dimension transform space where a hyper-plane decision function is made based on kernel function. Three kernel functions are polynomial, Gaussian radial basis function (RBF), and sigmoidal. ORL database is used [17]. Integration of feature analysis, class modeling, and SVM are used for detection of faces. Input images are represented using 1-D Haar wavelet representation, and its amplitude projections, and then using classification rules face and non-face images are classified. Distribution-based distance and SVM give a novel approach in detection [18].

Skin color segmentation: As name indicates, this method uses skin color detection and segmentation methods for fast retrieval of image detection. Lighting compression is carried out followed by noise removal on YCbCr model then euler computations then put bounding box ratio and eccentricity ratio, thus separating facial and non-facial regions [19]. Color image threshold is provided based on centroid segmentation. Three-dimensional color space is transformed to 2D, and then hexagonal distribution is done, and threshold value is fixed based on centroid segmentation for detection of faces [20]. A robust detector is used which combines skin color, heuristic rules, and geometric features. Pixel-based detection strategy is used and localization of regions of eyes and lips are performed that results in a robust way of detecting faces [21]. Skin segmentation includes locating objects of facial components like eyes, lips. Skin representation is carried out in the chrominance plane and based on rotation of Cg and Cr axis, and boundary box is used for face segmentation. YCgCr model is used, and threshold maximum and minimum is based on Gaussian distribution, thus reducing the processing time [22].

Local binary pattern: Local binary pattern (LBP) is a feature used for classification in computer vision, especially for texture classification. Image texture features extraction is used in fields of image retrieval, texture examination, face recognition, image segmentation, etc. Every pixel has texture value that is useful in finding the key points of the image and then forming a color-texture feature selection [23]. Gradient local binary pattern feature is more discriminative and effective than histogram of orientated gradient (HOG), histogram of template (HOT), and semantic local binary patterns (S-LBP). Combining gradient information and texture information together could result in gradient local binary pattern. INRIA dataset is used [24]. A feature-centric cascade method detector makes use of local binary pattern along with the combination of Haar features. After that, feature-centric detection method is used. Multi-view face detection is possible using this particular method [25].

Neural Network: Firstly, face detection is carried out using a polynomial neural network (PNN) and face recognition using pseudo-2D hidden Markov models; thus, detection of images is even possible in clustered images [26]. Eigen-face algorithm is combined with neural network. Training sets are prepared by eigen algorithm, and then matched blocks are used for detecting the facial image constitute in template-based face detection method [27]. Neural network when combined with adaboost algorithm provides faster processing speed and less computation time.

Table 1 Advantages and disadvantages of various face detection methods

Method	Advantages	Disadvantages
Adaboost method	No prior knowledge is needed	Complex weak classifier, sensitive to noisy data, slow training
PCA	Dimensionality reduction, eigenvalues are used as features	High-dimensional space not having good results, lighting condition varies performance
HMM	Easy to determine hidden states, better compression	Algorithm is expensive and time-consuming
SVM	Nonlinear classification	Training and testing takes time
Skin color segmentation	Detect face and non-face regions	Lighting condition is affecting the results
LBP	Texture classification	Use is restricted
Neural network	High detection rates, less computationally expensive	Less accurate results compared to other methods

Adaboost cascade classifier uses Haar-like features; thus, detection rates are increased drastically [28]. The advantages and disadvantages of above discussed methods are shown in Table 1.

4 Conclusion

The purpose of this paper is to identify face detection issues and challenges and compare various methods for face detection. There is a significant advancement in this area as it is beneficial in real-world application products. Various face detection techniques are summarized, and finally methods are discussed for face detection, their features, advantages, and disadvantages.

There is still a good scope for work to get efficient results by combining or improving the selection of features for detection of face images regardless of intensity of background color or any occlusion.

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