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Face Recognition in Videos using Gabor Filter

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Abstract: *In the past decade, advances in computer vision have lead automated security applications to high altitude. Human face detection in video sequences is a challenging problem in computer vision. It has wide range of applications in human recognition, human computer interaction (HCI), behavior analysis, teleconferencing, video surveillance etc. Faces serve as an identifying element of human anatomy. In this paper background subtraction is used to detect moving objects in videos. Real-time Viola's Haar face detector is used for detecting faces in moving regions of video frames. The recognition stage uses traditional Gabor Filter for extracting features and Euclidean distance for finding the best match. Efforts are made to minimize processing time for detection and recognition process. Experimental results show successful face detection and recognition in videos of varying scale, pose, expression and illumination for different individuals.*
Keywords: *Background Subtraction, Face Detection, Face Recognition, Gabor Filter, Haar.*

I. Introduction

Face detection has drawn attention of the researchers. It has wide applications in automatic access control system and computer vision, communication, etc. Detecting a face in an image is a preliminary part of face recognition. Face recognition is different from many other object recognition applications as it depends on many factors such as facial position, facial expression, occlusion, image orientation, lightning, and background conditions. With increasing criminal activities and augmenting demand for video surveillance there is need for an efficient and fast detection and tracking algorithm. Many techniques have evolved and developing for face detection and recognition [1,2,3,4].

Face recognition systems are classified as sub-class of pattern recognition systems. Important events detection and finding details of particular individual from such huge video library is tedious task and needs some automated mechanism. The block diagram of proposed system is shown in Fig. 1. The system identifies person in high security premises to restrict the movements of unauthorized person. The first stage in system is background subtraction [5,6] to detect moving objects. The first frame with absence of moving object is modeled as background frame. Background subtraction modeling is an open problem in video scenes with drastic illumination changes and dynamic backgrounds. It represents a fundamental step in several computer vision applications, such as video surveillance, vehicular traffic analysis, object tracking and recently human activity recognition.

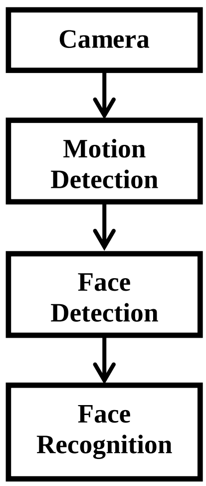


Fig. 1: Proposed System

The second stage in recognition system is choosing the features that uniquely and truly characterizes the target. The literature [7,8] shows that there are many parameters that can be used for human detection. The aim of face detection is to classify the segment of image as face or non-face. The task of describing the human face is difficult due to the fact that the image varies based on external factors like viewpoint, scale, different individual, occlusion, lighting, environmental conditions and internal factors like facial expression, beard, moustache, glasses [9]. The system should be adaptive and robust to these internal and external factors. With concern to video streams, the detection algorithm must be fast and optimized for high performance [10,11]. The last stage is important called as decision making that needs to be highly efficient and reliable.

The purpose of face detection is to identify every face in a surveillance videos. In recent years, face recognition has received substantial attention of the market, but face recognition in real time applications is very challenging. This paper applies Gabor filter technique which is popular for recognition in still images for face recognition in videos. It increases complexity of recognition stage but is efficient in terms of recognition. The paper is organized as follows: Section II gives brief summary of advances in the field. Section III.A describes background subtraction method used to reduce complexity. Section III.B describes Viola's haar face detector. Recognition algorithm is described in Section III.C. Results are given in Section IV. Conclusions are presented in Section V.

II. Literature Survey

Many researchers have studied the face detection in the past decades. There has been vast research in face detection and recognition but still there is scope for improvement in complexity, robustness and efficiency of system. The real-time algorithm has hard limitations to overcome, as any delay in processing may result in loss of important information.

Background subtraction employs Gaussian Mixture Model (GMM) [12,13] to segment moving pixels. Apewokin et al. [14] describes advantages of multi-modal mean real-time background modeling. To overcome changes due to small movements of stationary objects in background multi-modal probability distribution functions (GMM) are used [15,16]. Another segmentation method- temporal differencing uses pixel-wise differences between successive two to three frames to extract moving regions [6]. Temporal differencing is dynamic background modeling method. Mario et al. [17] proposed dynamic background moving object detection method. This method is based on a neural-fuzzy model that deals with dynamic background and shadow elimination. Optical-flow-based motion segmentation uses timely directional vectors of moving objects to detect moving objects. Optical-flow-based methods are robust to camera motion [6]. Face detection algorithm is applied to the moving regions that have possible presence of face.

Face detection methods are classified as color based, appearance based, geometry based, pattern based etc. The color information in images is sensitive to the intensity. Skin pixel values for r plane is in the range 0.36 to 0.456 and g value in 0.28 to 0.363. In HSV model pixel is classified as skin pixel if it has values $0 \leq H \leq 50$ and $0.20 \leq S \leq 0.68$ [18]. Complex methods uses depth features to detect face based on geometry and texture pattern. Face is detected using edge maps and skin color thresholding in [19]. Dhivakar et al. [20] used YCbCr space for skin pixel detection and Viola-Jones [21] method to verify correct detection. Mehta et al. [22] proposed LPA and LBP methods to extract textural features with LDA dimensionality reduction and SVM classification. Lai et al. [23] used logarithmic difference edge maps to overcome illumination variation with face verification ability of 95% true positive rate.

Face recognition systems are popular in biometric authentication as they do not require the user intervention. Eigen faces and Fisher faces were proposed in the early 1990s [24]. Eigen faces works well for frontal faces captured in controlled conditions. Rawlinson et al. [25] presents Eigen and fisher face as image based method and Statistical Shape and Active Shape Models as feature based methods for face recognition. Feature based methods achieves robustness to illumination and pose variations with use of non-linear feature spaces. Use of geometric features like face segments, perimeters and areas can be used in recognition process to increase recognition rate. SIFT and SURF has robust performance in unconstrained scenarios [10]. The face dimension can be reduced by principal component analysis before applying Neural Network to enhance recognition process [11,26]. Meshgini et al. [27] proposed a method with combination of Gabor wavelets for feature extraction, direct linear discriminant analysis for dimensionality reduction and support vector machine for classification. The recognition algorithms requires more time as compared to detection stage.

III. Methodology

Face is vital part of human being representing most information about the individual and can be used to identify an individual. Developing a model of face is difficult because face is complex, multi-dimensional visual stimuli. This section describes methods used for background subtraction, face detection and recognition.

A. Background Subtraction

Background model is established with absence of moving object. Adaptive background model is where a series of frames are used and an average is calculated from all of them over a period of time. This approach is useful if there are continuous changes in background scene. Non-adaptive background model is where a frame is taken and saved as the background. This approach is useful in static and indoor environments where there are very less variations in background over a time period. The background is then subtracted from current frame to segment moving objects [15]. The decision of presence of moving object is based on the difference between the two images or frames. This paper uses temporal averaging method [28] for background subtraction. First frame is taken as background frame (Fig. 2) in absence of moving object.

a. Current Frame b. Background Frame c. Difference Frame

Fig. 2: Background Subtraction

For each frame new background model $B_{t(x;y)}$ is estimated as:

$$B_{t+1(x,y)} = \alpha I_{t(x,y)} + (1-\alpha) B_{t(x,y)} \tag{1}$$

where $I_{t(x,y)}$ is current pixel value, t is frame number, (x,y) is pixel location in frame and α is learning rate (speed of updating background model).

The difference between current frame and background is given by

$$D_{t(x,y)} = \left| I_{t(x,y)} - B_{t(x,y)} \right| \tag{2}$$

The pixel whose difference value is greater than given threshold T are classified as foreground pixels given by Eq. 3.

$$M_{t(x,y)} = \begin{cases} 0 & D_{t(x,y)} \le T \\ 1 & D_{t(x,y)} > T \end{cases} \tag{3}$$

B. Face Detection

The detection technique defines the shape of object in terms of a subset of wavelet coefficients [29]. Haar features are computed in constant time using the integral image representation [21,30]. The variance based Haar features are shown in Fig. 3. For a given random variable X, the variance value of X is as follows:

$$Var(X) = E(X^2) - \mu^2 \tag{4}$$

where $E(X^2)$ is expected value of squared of X and μ is expected value of X.

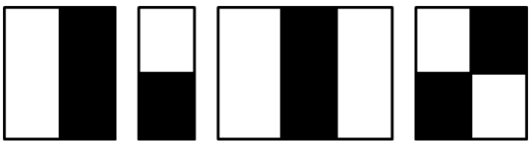


Fig. 3: Haar Basis Features

The value of a rectangle features (Fig. 3) is computed as the difference between sum of variance values in white region and sum of variance values in dark region. The Haar feature classifier multiplies the weight of each rectangle by its area and results are added together. Adaboost algorithm selects the classifier with prominent features. Fig. 4 shows face detection using Haar feature extraction.

Fig. 4: Face Detection using Haar Features

C. Face Recognition

The characteristics of Gabor wavelets (filters) are appropriate for texture representation and discrimination [27,31]. The Gabor filter-based features are directly extracted from gray-level images of objects. In the spatial domain, a two-dimensional Gabor filter is a Gaussian kernel function modulated by a complex sinusoidal plane wave. It is represented as:

$$\Psi_{\omega,\theta}(x,y)=\frac{1}{2\pi\sigma^2}\exp\left(-\frac{x'^2+y'^2}{2\sigma^2}\right)\exp\left(j\omega x'\right) \tag{5}$$

$$\begin{aligned} x' &= x\cos\theta + y\sin\theta \\ y' &= -x\sin\theta + y\cos\theta \end{aligned} \tag{6}$$

where (x,y) is pixel position in spatial domain, x is central angular frequency of complex sinusoidal plane wave, h is anti-clockwise rotation(orientation) of Gabor function, r represents sharpness of Gaussian function along x and y directions and $\sigma \approx \frac{\pi}{\omega}$.

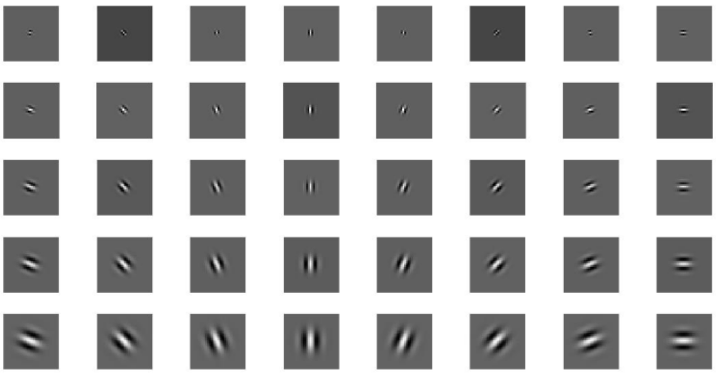


Fig. 5: Gabor Filter with 5 Scales and 8 Orientations

To extract useful features from an face image a set of Gabor filters with different frequencies and orientations are constructed. In most cases, the Gabor filter bank with five frequencies (scales) and eight orientations is used that inculcates all features. Fig. 5 shows the Gabor filter bank with five different scales and eight different orientations. Eq. 7 give five scales and eight orientations for the Gabor filter bank.

$$\begin{aligned} \omega_u &= \frac{\pi}{2}\times\sqrt{2}^{-u} \quad u=0,1,\cdots,4 \\ \theta_v &= \frac{\pi}{2}\times v \qquad v=0,1,\cdots,7 \end{aligned} \tag{7}$$

The Gabor representation of a face image $I(x,y)$ can be obtained by convolution of face image with the family of Gabor filters given as:

$$G_{u,v}(x,y) = I(x,y) * \Psi_{\omega_u,\theta_v}(x,y) \tag{8}$$

where $G_{u,v}(x,y)$ denotes the two-dimensional convolution result corresponding to the Gabor filter at scale u and orientation v. Fig. 7 shows the convolution results of a face image (Fig. 6) with Gabor filters at different scales and orientations.

Fig. 6: Face Image

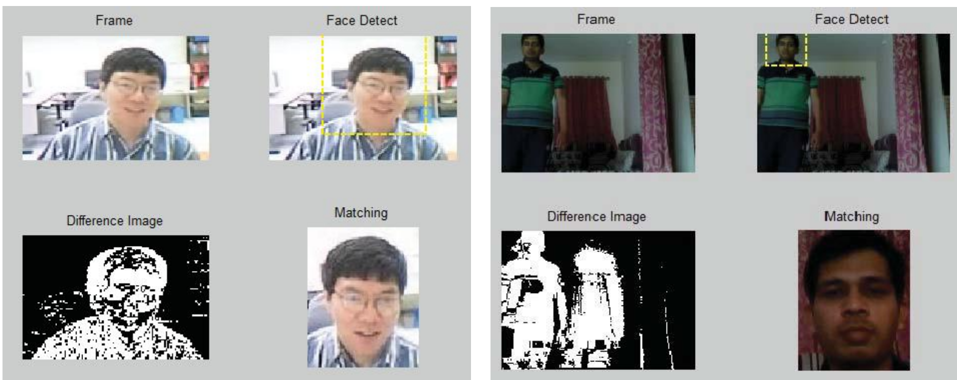
Each image $I(x,y)$ is represented as set of Gabor wavelet coefficients $G_{u,v}(x,y)|\ u=0, 1, \dots, 4; v=0, 1, \dots, 7$. The magnitude of each $G_{u,v}(x,y)$ is down sampled by a factor r, normalized to zero mean and unit variance and turned to a vector $z_{u,v}$ by concatenating the rows [27,32]. A robust feature vector z is derived to represent the image $I(x,y)$ by concatenating those vectors $z_{u,v}$.

$$z = \left[(z_{0,0})^T \; (z_{0,0})^T \cdots (z_{4,7})^T \right] \tag{9}$$

The dimension of the resulting vector is high e.g. for a 112 x 92 image, the vector dimension is (112 x 92) x (5 x 8)/(4 x 4) = 25,760 if down sampling factor is r = 4 x 4 = 16 [27].

IV. Results

The algorithms are applied on video sequences of NRC-IIT Facial Video Database. Table 1 gives summary of results obtained on different videos. Haar face detector works well for frontal faces. Gabor feature method is efficient method for face recognition. Recognition time required is large due to large number of features in feature vector. Out of total 6535 frames of all 21 videos face was detected in 4740 frames. Out of 4740 faces correct recognition was obtained in 1844 frames. The Fig. 8 shows the sample from two different videos. First image in each figure is frame from video, the second image shows detected face, third image shows the difference image (i.e. current frame - background image) and last image is the best match image from data set with detected face.



b. Database Video Frame a. Recorded Video Frame

Fig. 8: Face Detection and Recognition

Table 1: Performance Measures

Video	No. of Frames	Face Detection	Recognition Time	True Detection	False Detection
1.	237	71	28.5168	37	34
2.	329	99	40.03501	31	68
3.	257	223	88.74552	98	125
4.	339	225	90.22506	138	87
5.	448	305	122.0239	7	298
6.	438	283	112.9269	4	279
7.	353	283	112.8361	96	187
8.	404	283	112.7831	195	88
9.	198	191	77.04045	2	189
10.	248	206	81.87446	19	187
11.	78	78	31.17757	65	13
12.	128	124	50.01316	74	50
13.	324	252	106.4006	224	28
14.	353	252	102.756	216	36
15.	258	176	72.21552	82	94
16.	328	191	78.93236	95	96
17.	346	238	99.17065	108	130
18.	426	392	162.7538	289	103
19.	318	392	161.4159	48	344
20.	388	392	162.8405	16	376
21.	337	84	34.63272	0	84

V. Conclusions

The proposed system is intended to segment moving objects in first stage, detect face in second stage and finally recognize detected face. Background subtraction reduces area of interest to larger extend consequently decreasing the complexity in later stages. Haar based face detection is efficient face detection algorithm. It is used for real-time applications. Recognition is done using Gabor filters and matching metric as Euclidean distance. Gabor face recognition is better than many other methods available in the field. It compares large number of features hence requires more time for recognition. Reducing the size of feature vector may reduce this time with small decrease in accuracy of system. The system can serve an intelligent video analyzer to detect occurrence of particular individual. The complexity in system can be reduced further to meet real-time system requirements.

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