Face detection using modified FDA-SVM method

Hanumantha Reddy T.^{1*}, Karibasappa K.¹ and Damodaram A.²

¹Vijayanagar Engineering College, Bellary, Karnataka

²JNTU College of Engineering, Hyderabad, Andhra Pradesh

Email- id: thrbly@yahoo.com, k_karibasappa@hotmail.com, damodarama@jntu.ac.in

Abstract- This paper proposes a method for face detection using Modified Fisher Discriminant Analysis (FDA) and Support Vector Machine (SVM). It is a three layer architecture system that identifies all image regions which contain face. The face detection is a preprocessing stage for an automatic face recognition system. At the first stage, the Modified Fisher Linear Discriminant Analysis (FDA) classifies the input pattern into three classes: a face class, undecided class and non-face class. At the next stage, the SVM classifies the undecided class or non face class as either face or non-face class. In the Final stage, FDA-SVM detects the face class if any sub image region falsely judged as non-face class. This system alleviates the problem of false positive rate. The experimental result shows that the proposed approach outperforms some of the existing face detection methods.

Key words: Face detection; Support Vector Machine; Fisher discriminant analysis

1 Introduction

The face detection and recognition system has drawn considerable importance from researchers for many decades. The SVM is a learning technique based on statistical learning theory that has been applied successfully in variety of application and regression problems [3, 5, 8, 14]. Support vector machine with a binary tree recognition strategy is proposed to tackle the multi-class face recognition problem that gives the pair wise discrimination capability of SVM to the multi class scenario [10]. The stability of SVM in classification task is dealt by decomposing the average prediction error of SVM into the bias and variance terms [2]. The modified kernel based FDA method applied for face detection with low confidence of classification [18]. Masahi Sugayama, high lights a local fisher discriminant analysis for high dimensionality reduction [16]. Shih et al. presented a distribution based DFA-SVM method for face detection, but the amplitude projections of face and non face resembles the same thus reducing the detection accuracy [16]. The hierarchy quarantine method is basis for face and non face classification and hierarchy classifiers analyze the whole image for face class identification and reject the non face image [12, 13]. Character recognition with SVM by using kernel and feature extraction on pair of letters is proposed in [4, 7]. In the paper [9], the visual features of the face like eye, nose etc is modeled for facial expression recognition using SVM. The combined global and local approach for feature extraction is used for face recognition with SVM [17]. It uses linear subspace projection and Euclidean norm for computational speed up for large database. The Bayesian Expectation inference algorithm is proposed for binary classification in the paper [9] by Daniel L and Hernandez Lobatto. The component and two global approaches are presented in this paper [1] for face recognition. In component system, the facial features extracted and combined them into single vector which is used by SVM for recognition. In global approaches, the face image is feature vector which is used by SVM for recognition. The main motivation of this paper is to diminish the

false positive rate of the face detection system. The two parameters that decides the efficacy of the system are high positive detection rate and low or nearest to zero percentage of false positive rate. In this paper, a novel FDA-SVM method is proposed for face detection by kernel based Fisher Discriminant analysis (FDA)-Support Vector Machine (SVM) method, which reduces the dimensionality of the input image by preserving the intrinsic information. The method statistically estimates the sub image is face or non face class. The non face or undecided class is given as input to the SVM for classification of face or non-face class. Finally, the Kernel based FDA-SVM classifies the undecided class as face or non-face class. The SVM classifier is used to recognize the face with optimal hyper plane but recognition accuracy is hindered for large databases. The rest of the paper is organized as follows. Section 2 describes the Modified FDA, SVM and architecture of the proposed face detection system. Experimental results are described in the Section 3. Conclusions are given in the Section 4.

2 Face detection using Modified Kernel based FDA and SVM

The flow graph of the face detection system is shown in the Fig.1. The input image is first processed by Kernel based Fisher discriminant Analysis (FDA). The multivariate distribution measure of the discriminant feature space is used for classifying the input image as face or non face class. In the next stage, the SVM classifies the undecided class of the input image as face or non face image. In the final stage, the Kernel FDA-SVM classifies the undecided class of the input image as face or non-face image. The performance of the detection depends on the choosing optimal threshold values in decision making process [18].

Fig. 1 Flow graph to detect the face in the input image

2.1 Kernel Fisher Discriminant Analysis (KFDA)

In face detection, it is important to design a two category classifier which can detect whether the given input sub images is face or non face class. The classifier is trained with face and non-face images. It is proved [16, 19] that the Kernel based FDA cannot be applied to classification task because it cannot compensate high dimensional space. In this paper, we have used the FDA as classifier independently and also in combination with Support Vector Machine. The modified kernel FDA is proposed to apply it to classification task. The co-variance of the face is minimized while non-face is maximized. Let face and non-face classes are expressed by,

$$C = \{k(x_i) \mid i = 1, 2, \dots, n_f\} \quad (1)$$

$$\hat{C} = \{k(x_k) \mid k = 1, 2, \dots, n_k\} \quad (2)$$

Where n_f and n_k are face and non-face images. The mean and co-variance of the face class,

$$K_f = 1/n_f \sum_{i=1}^{n_f} k(x_i) \quad (3)$$

$$\sum_f = 1/n_f \sum_{i=1}^{n_f} (k(x_i) - k_f)(k(x_i) - k_f)^T \quad (4)$$

The total mean vector,

$$k_T = w_f k_f + \sum_{i=1}^{n_f} k(x_i) \quad (5)$$

Where $w_f = n_f/N$ with $N =$ Total number of face and non face images ($n_f + n_k$).

The co-variance matrix for with-in class variance and between-class variance are given by,

$$\sum_w^f = w_f \sum_f \quad (6)$$

$$\sum_w^f = w_f(k_f - k_T)^T + 1/N \sum_{i=1}^{n_f} (k(x_i) - k_T)(k(x_i) - k_T)^T \quad (7)$$

The Fisher's Discriminant Criterion,

$$\Omega = \sum_B^f / \sum_W^f \quad (8)$$

The regular matrix is converted in to Eigen vectors and Eigen values. The Euclidean distance between the Fisher's regular matrix and co-variance matrix of the face class is estimated for detection of the face or non-face class. If it is above τ_f then it is face otherwise it is non-face or undecided class.

2.2 Support Vector Machine (SVM)

SVM is a two class realization of statistical learning theory. It describes an approach known as structural minimization [3,5]. The main idea of SVM comes from the mapping of input space to high dimensional space and designing optimal hyper plane in terms of margin.

Let $(x_1, y_1), (x_2, y_2), \dots, (x_k, y_k) \in \mathbb{R}^N$ and $y_i \in \{-1, +1\}$ be the k^{th} training samples in the input space, where y_i indicates the class membership of x_i .

Let ϕ be non-linear mapping $x \rightarrow \phi(x)$.

The optimal hyper plane is defined as below.

$$w_0 \Phi(x) + b_0 = 0 \quad (9)$$

It is proved [6] that the vector w_0 is linear combination of weight vector which are vectors x_i that satisfy

$$y_i(w_0 \Phi(x_i) + b_0) = 1 \quad (10)$$

$$w_0 = \sum_{\text{support vectors}} y_i \alpha \Phi(x_i) \quad (11)$$

The linear decision function,

$$f(x) = \text{sign} \left(\sum_{\text{support vectors}} y_i \alpha \phi(x_i) \cdot \phi(x) + b_0 \right) \quad (12)$$

To increase the efficiency of the operation the dot product is replaced by kernel Gaussian function.

$$k(x_i, x_j) = \phi(x_i) \cdot \phi(x_j) \quad (13)$$

$$k(x_i, x_j) = \exp(-\|x_i - x_j\|^2 / 2\sigma^2) \quad (14)$$

Where, $\sigma > 0$ and $\sigma = 1.2$ [16]

2.3 Face detection using kernel based Fisher Discriminant Analysis (FDA) and SVM.

The first decision rule separates the input pattern in to face or un decided class or non face class.

$$Y \in \begin{cases} \text{Face class} & \text{if } \|\Omega - \Omega_c\| \geq \tau_f, \\ \text{un decided class} & \text{if } \tau_n \leq \|\Omega - \Omega_c\| \leq \tau_f \\ \text{Non face class} & \text{otherwise.} \end{cases} \quad (15)$$

Where Y is a discriminant measure value and $\|\Omega - \Omega_c\|$ is a Euclidian measure between fisher's and co-variance matrix of the face class. The numerical Dirichlet process estimates the threshold values as $\tau_f = -0.66$ and $\tau_n = -0.68$. The second decision stage is applied with SVM for face detection.

$$Y \in \begin{cases} \text{Face class if } f(x) > 0 \\ \text{Non-face class otherwise} \end{cases} \quad (16)$$

The support vector alone cannot decide the face or non class.

The third decision rule is based on combined FDA-SVM.

$$Y \in \begin{cases} \text{Face class if } f(x) > \tau_f \text{ and } f(x) + \|\Omega - \Omega_c\| > \tau_f \\ \text{Non-face class otherwise.} \end{cases} \quad (17)$$

The face detection accuracy completely depends on threshold values [9].

3 Experimental Results

The accuracy of the face detection depends on the threshold values chosen for the system. The different numerical algorithms support to choose the optimal threshold values. The threshold values chosen in this paper are based on Dirichlet process [18]. The basic search procedure of the modified kernel FDA-SVM is sliding a 20×20 window across all possible locations and scales in a probe image. The window is shifted pixel by pixel with scale factor of 1.5. To detect the face in $k \times k$ scale involves two operations, first resize the image by $20/k$ for window size of 20×20 with scale $k \times k$ and move the window in this resized image for face detection.

The face dataset is chosen with following observations.

1. All images are frontal face images
2. The facial images are such that the distance between the two eyes is same for all images.
3. The images are not occluded by any objects.

For experimental purpose, we use only 10×10 images of 15 people as training data of Yale database, and the remaining images of the other people are used as testing data. The proposed method out performs some of the existing face detection methods. The comparison of the face detection rate of the different methods on CMU face database to the proposed system is shown in

the Table 1. As proposed method addresses only up frontal faces for detection and hence other profile images are not included in our experiments. The FDA-SVM method successfully identifies the faces in the probe image. Fig 2 shows the sample of facial images used in the experiment and the face detected by proposed method is shown in Fig 3. The window sliding approach used in our scheme successfully identifies all faces in the test image. The proposed method identifies all facial images in the test image and is shown in Fig 4. This method identifies non-face class as face but by fine tuning the threshold values the rate of false positives can be reduced and outperforms some of the existing subspace face detection methods.

Fig. 2 Sample Database of Facial Images

Fig.3 Examples of face detected by our proposed system

Fig. 4 Faces detected on test image by the proposed system

Table 1 Comparison of the different Face Detection system

Sl NO	Method	Detection rate %	False positives
1	Henry A Rowley [11]	92.5	862
2	Lutz Goldmann [15]	90.8	4
3	Proposed method	93.2	6

4 Conclusions

In this paper, we have proposed a method for face detection using Modified Kernel FDA and SVM. The modified kernel based FDA classifies the input pattern to face class, non-face class and undecided class. The SVM classifies the processed input pattern as either face or non-face class. Finally, the combined FDA-SVM classifies the undecided pattern as face or non-face class. The detection method outperforms the Discriminant Feature Analysis (DFA)-SVM method which uses probability density measure for modeling the face or non-face class. The primary advantage of the work is to reduce the false positive while improving the positive detection rate. The Yale and CMU database is used for experimentation.

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