Class Specific Threshold Selection in Face Space Using Set Estimation Technique for RGB Color Components

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Abstract. In conventional face recognition techniques, any query image is always classified to one of the face classes irrespective of whether the query image is a face or not. Most of the recognition algorithms are dissimilarity based, and one needs to put a proper threshold on the dissimilarity value for the sake of classification. In this paper, we have introduced a novel thresholding technique for classification, where the query image is not necessarily classified to one of the classes in the training set. The theoretical formulation of the thresholding technique and its utility are demonstrated on color face and non face datasets with RGB color components as features in the subspace. The proposed threshold selection is based on statistical method of set estimation and is guided by minimal spanning tree. Experiment shows that the proposed class specific threshold based technique performs better than the non threshold based systems using subspace algorithms.

Keywords: Feature extraction, Color components, Minimal spanning tree, Intra-class threshold, Set estimation.

1 Introduction

Among the popular algorithms for face recognition, subspace methods [1, 2]are generally based on dissimilarity, where the query image is put in the class for which the dissimilarity is minimal. This is a classical approach of identification and known as closed test identification where the test face always exists in the gallery dataset. However, in a real life scenario the identification system may face a situation where the query face image may not be present in the database, i.e. often referred by the biometric researchers as the open test identification [3]. A way of achieving such a task is to put a threshold on the dissimilarity value at the identification stage. On the basis of the decision threshold, a biometric recognition system should be in a position to accept the query image as client or reject it as imposter. The selection of proper threshold of a given class in a dataset is an open question.

S. Chaudhury et al. (Eds.): PReMI 2009, LNCS 5909, pp. 351–356, 2009.

As found in literature Mansfield [4]et. al proposed equal error rate (EER),the point on ROC curve where FAR = FRR, to be selected as the operating threshold. Martin [5] proposed the use of detection error trade-off (DET) curve which is a non-linear transformation of ROC curve. In reality, the common practice is to use the global threshold for a system rather than using user dependent versions of ROC. In the current problem we are interested in finding the threshold values using set estimation method for color face identification system. The set estimation method in literature has been mainly used to find the pattern class and its multi-valued boundary from its sample points in $\Re^2$ and higher dimensional spaces. Some investigations on estimation of α- shapes for point sets in $\Re^3$ had been proposed by Edelsbrunner [6]. Later Mandal et al. [7] developed and extended their method to $\Re^m$ and found it very useful in developing a multi-valued recognition system. As one can get the shape or boundary of a given set then that procedure of set estimation also generates the intuition for determination of the class thresholds of the set. As a tool of set estimation, minimal spanning tree (MST) is proposed to calculate threshold value. For the purpose of recognition, we proposed two types of threshold values (i) global (ii) local (or user specific) for each face classes. Here two types of decisions can be made by the system. Local threshold of a class is used to conclude whether the given query image belongs to the given class. Global threshold is a general threshold which can be used to conclude whether the query image belongs to the given collection of face classes. These two types of thresholds will satisfy a biometric system in both the closed and open test identification cases.

In this paper we assume the frontal color views are available. Color information is commonly used for detection of faces but its discriminating power is still in question. Role of color in face verification needs to be explored since, generally, it is considered to be a low level feature. This feature is surprisingly effective in race classification. The common approach in most of the face recognition systems is to convert the color images to monochromatic form using simple transformations. There was also another approach where the RGB space has been compared with the YUV and HSV color models by L. Torres [8] for PCA based face recognition. Several studies have been made to evaluate color spaces. They have concluded that RGB space should be suitable for any application on face identification among the other color spaces. In this paper, we considered a few linear combinations of R, G, and B for dimensionality reduction and consequently for classification. To reduce the dimensionality, we need to extract features by using any one of the sub space methods. Two types of feature extraction methods of the images in the face database are explored. These are (i) principal component analysis (PCA) [1, 2, 3] (ii) kernel PCA [1, 2, 3].

2 Mathematical Preliminaries for Threshold Selection

The system assumed to have n images corresponding to a particular expression of a particular person P. If we represent an image of an expression of P by a vector x_0, then the set corresponding to the small variations in the same expression may be assumed to be a disc of radius $\epsilon > 0$ around x_0. The set corresponding to an expression of the same person P may be taken as $\bigcup_{i=1}^{n} x \in \Re^m : d(x_i, x) \leq \epsilon$ where x_1,x_2,$x_n$are the n vectors corresponding to the given n images. The set corresponding to the union of all possible expressions of a person may also be taken as a connected set since for two different images of the same expression, P must be able to provide the intermediary images of that expression (a path connecting the two points is completely contained in the set.). The face class of a person is nothing but the set of all possible expressions of that person. A general formulation of the face class, probably, would have the radius value depending on the center of the disc. The radius value is taken to be independent of the the center of the disc.In the above formulation, as the number of face images of the same person increases, we shall be obtaining more information regarding the face class, and hence the radius value needs to be decreased. Thus the radius value needs to be a function of the number of images.

Usually one may want to estimate a set on the basis of the given finitely many points.Set estimation problem and its utility, methodology, conditions on sets are well documented in the literature [6, 9, 10]. A formulation with only the relevant part used for the class specific threshold selection is presented in this regard. Let $\alpha \subseteq \Re^m$ be the unknown path connected set in m dimensional space and ϵ_n be a sequence of positive numbers such that $\{\epsilon_n\} \rightarrow 0$ and $n\epsilon_n^m \rightarrow \infty$ as $n \rightarrow \infty$.

$$\alpha_n = \bigcup_{i=1}^{n} \{x \in \Re^m : d(x, X_i) \leq \epsilon_n\}$$

where d denotes the Euclidean distance. Then α_n be a consistent estimate of α and ϵ_n's are chosen in different ways for different problem domain.

3 Threshold Incorporated Face Classification Using Set Estimation Method

There are several ways in which we can make the estimated set connected. We shall describe a generic way of making the estimated set connected, where only finite union of disks is considered.

Method: (a) Find minimal spanning tree (MST) of $S = \{X_1, X_2, \ldots X_n\}$ where the edge weight is taken to be the Euclidean distance between two points.

(b) Take ϵ_n as Maximum of the (n-1) edge weights of MST.

(c) Take the estimate α_n as

$$\alpha_n = \bigcup_{x \in S} \{y : d(x, y) \leq \epsilon_n\}$$

Note that ϵ_n is the threshold for the set α_n since no point outside the ϵ_n disks is considered to be a member of the set. If we represent an image by a vector $\underline{x}$, then we are considering all possible such vectors corresponding to a human being. Let us represent such a set by α . This set denotes the face class of that human being. It can be noted that we don't know α completely. Only a few points of α like the different expressions of a face are known to us. The proposed set estimation method can be utilized in two ways in face identification problem as described in the next subsection.

3.1 Local Threshold Based Recognition

We assume that we have M classes, each class denoting a human being. Each class consists of N vectors of m dimensions. Here for each class we calculate MST of the respective N vectors and find its maximal edge weight. Let us denote the maximal edge weight of the MST of the i_{th} class by ξ_i for any m dimensional vector $\underline{x}$ in the following way. The total number of given vectors is MN. For each class i, find the minimum distance of $\underline{x}$with all the N points in the class. Let the minimal distance be ρ_i

(a) If there exists an i such that $\rho_i < \xi_i$ then put x in the i_{th} class.

(b) If there does not exist any i such that$\rho_i < \xi_i$ then there the given image does not fall in any one of the given face classes. If the given image does not fall into any of the given face classes, it may still lie within the given face space. In order to analyze this possibility, the global threshold is formulated.

3.2 Global Threshold Based Recognition

In this recognition system, the number of images is large. For determining the global threshold, we have the following algorithm.

(a) Find MST of MN points and find half of its maximal edge weight. Let it be ξ

(b) Find

$$\rho = Min_{i=1,2,\ldots n}\rho_i \tag{1}$$

(c) If $\rho < \xi$ then the image is a face image and will form a new face class in the face space. If $\rho > \xi$ then the given vector x does not belong to the given face space. Here the image is either a non face image or a face image not belonging to the given face space. Note that $\xi_i \leq \xi, \forall i$ is true generally but not for any set of MN points.

4 Experimental Design and Result Analysis on Color Components

The proposed method of threshold based classification has been used for open and closed test face identification and tested over the well known color AR face database [11] and one object (i.e., non face) database namely, the COIL-100 [12]. For AR database we have taken the first 10 images from each of 68 classes and the face portions are manually cropped to dimension 128X128. To form the face space from the image space we have used two well known feature selection methods (i) principal component analysis (PCA), (ii) Kernel PCA The selection of color components on the color dataset have been done in several ways before applying PCA and KPCA on the datasets.In the first procedure we applied the scheme proposed by L. Torres et al. [8] the PCA projection was computed on color components separately and the global distance is measured between test and training images. As procedures 2, 3, and 4, we have used the R, G and B color channels are separately used. In procedure 5, PCA and kpca are applied on (R+G+B)/3, where as in procedure 6, it is applied on (3R+4G+3B)/10. These procedures are denoted by P1, P2,, P6 in the table. The number of color features is 340 for each of R, G, B, and thus the total number of components in feature vector is 340x3. For each of the other procedures, the number of features is 340.

4.1 Open and Closed Test Identification in Color Space

After formation of the face space,the proposed MST based method (discussed in section 3.1) of class specific threshold selection is applied on the each training class of color face points for each procedure. The number of training images for each class of the AR dataset is taken to be 5 chosen randomly. Remaining images for each class are considered for test set. Nearest neighbor (NN) classifier is used to get the non threshold based identification rate.It is observed from Table 1 that for each color components proposed method performs better than the non threshold based systems.

For Open test identification AR used as gallery face points and COIL-100 non face dataset containing 7200 color images of 100 non face objects of size 128X128 are used as probe set. The global threshold formulated in section 3.2 is applied in this case.It is apparent from table 1 that no object image in the COIL-100 dataset is classified to none of the face classes of the training set. Both the results satisfy the theoretical aspects of the proposed local and global threshold selection method.

Table 1. Open and close test identification

Procedure number	closed test identification		open test identification	
	NN classifier	local thresholds	non face points inside global threshold	outside global threshold
P1	96.5(PCA)	98.75	1	99
	91(KPCA)	93.5	0	100
P2	96(PCA)	96.75	0	100
	94(KPCA)	94.5	0	100
P3	96.5(PCA)	98	0	100
	97(KPCA)	98	0	100
P4	92(PCA)	94	0	100
	92(KPCA)	93	0	100
P5	95(PCA)	97	0	100
	92(KPCA)	92	0	100
P6	96(PCA)	98	0	100
	91(KPCA)	94	0	100

5 Conclusions

A method is proposed for threshold selection for subspace based face identification scheme. The method has been applied on the color components of RGB space of the AR databases and it is found to give better results than those methods without threshold. We have also tested the utility of the method, where the training and the test datasets are face and non face datasets using global threshold. One has to take care of several inherent issues regarding the subspace based methods. In all our experiments on the face datasets, we have considered only five points for each class in the training set. We have probably taken the lowest possible such value for the number of training points of each class. It is expected that the results can improve if the size of the training set is larger.

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