Optik 127 (2016) 7408–7417

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Original research article

A new face recognition method via semi-discrete decomposition for one sample problem

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ARTICLE INFO

Article history:
Received 6 March 2016
Accepted 26 May 2016

Keywords:
Semi-discrete decomposition
Singular value decomposition
One sample problem
Face recognition
Fisher linear discriminant analysis

ABSTRACT

Fisher linear discriminant analysis (FLDA) is a popular approach which has been widely used for feature extraction in face recognition tasks. FLDA is seeking optimal projection vectors by maximizing the ratio of between-class scatter matrices vs. within-class scatter matrices. However, the within-class scatter matrices cannot be calculated directly when one training sample each object is available. In this case, image decomposition plays an important role in the reconstructed within-class scatter matrices. So, the performance of image decomposition is crucial. In this paper, a based on semi-discrete decomposition (SDD) method is proposed to solve single training sample image per person problem. First, the original single image and its transpose are calculated via using SDD method in the training set. Then, the within-class scatter matrices are constituted by using the original image and its two approximation images of each person. And meanwhile, the optimal projection vectors are obtained via the FLDA algorithm in the new training set. Finally, we use the nearest neighbor classifier to complete the final classification. The performance of proposed method is evaluated on ORL, Yale and FERET databases. The experimental results show that the proposed method is outperforms singular value decomposition (SVD)-based and QR decomposition with column pivoting (QRCP)-based methods in terms of recognition rates.

1. Introduction

Face recognition is a nature and direct biometric method which is used in crime detection surveillance, passport, security, human computer interaction, etc. Many methods have been proposed and achieved many significant results in face recognition field [1–4]. The performance of recognition system is from two factors. One is to find sufficient and discriminative features for face representation and another is the training sample size [4,5]. However, there are still some tough problems have not been well solved, such as one sample problem which means that only one image per person is available [6]. In this case, the FLDA method cannot be used directly when only one image per person is available because the within-class scatter matrices are all zero. Many researchers from different fields had done a lot of studies and proposed several methods to overcome the shortcoming [1,6–11].

In order to make full use of the information of the single image itself, Chen et al. [7] proposed a partition FLDA method which adopts a set of non-overlapping sub-image blocks from each single image and then constructs a new training sub-set.

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http://dx.doi.org/10.1016/j.ijleo.2016.05.105
0030-4026/

Deng et al. [11] proposed a uniform pursuit approach and obtained more discriminative low dimensional feature representation. In Ref. [1], the SVD based on image decomposition was proposed for the single image per person, and the original image and the approximate image are used to construct the new training data set for each class. In Ref. [2], Koc and Barkana proposed an effective method using QRCP-decomposition for the same single image per person problem. In this method, the original image and its two approximations images are all used to obtain the new training data set for each class. For QRCP-based and SVD-based two methods, the recognition performance of the former is better than the latter in terms of recognition rate and training time.

However, there are three main shortcomings of the QRCP-based and SVD-based approaches: (i) the reconstruction of the approximation image is unconvincing; (ii) for the approximation image contains at least 97% of the whole energy of the original image, there is no theoretical explanation was given in the QRCP-based method. And the basis images play an important role in the SVD-based method, meanwhile the original image and the approximation image makes minute difference when the number of basis images is bigger than four; (iii) for a large image, the decomposition and storage have been neglected in the QRCP-based and SVD-based two methods. Thus, in order to improve the recognition rate and solve the above mentioned drawbacks, we need to explore a new image decomposition method and then reconstruct the approximation image.

In this paper, a new face recognition method based on semi-discrete decomposition is proposed to solve the single sample per person problem. The original single image and its transpose are calculated via using SDD and the within-class scatter matrices are constituted by using the original single image and its two approximation images of each person, and the optimal projection vectors are obtained by two-dimensional FLDA (2D-FLDA) algorithm and final classification.

The remainder of this paper is organized as follows. Section 2 briefly reviews the 2D-FLDA. In Section 3, the derivation process of the proposed method is described in detail. The experimental results are reported in Section 4, and finally Section 5 concludes this paper.

2. 2D-FLDA

The main goal of FLDA method attempts to seek the projection vectors that separate the different classes while compressing the same class. But, the FLDA cannot be directly used when the within-class scatter matrix has zeros eigenvalues. To solve the problem, the 2D-FLDA algorithm has been proposed in Refs. [2,12].

In 2D-FLDA algorithm, the between-class scatter matrix (S_b) and within-class scatter matrix (S_w) can be calculated directly from 2D images, then the optimal projection vectors can be obtained by the fisher discriminant criterion. Mathematical formulas of 2D-FLDA can be briefly as follows.

Let C be the number of object classes in the training set, N be the number of all the training samples $X_k \in \mathbb{R}^{m\times n}$ ($k = 1, 2, \ldots, N$) from each class, N_i be the number of the training samples for the training samples for the ith object class, X_i^j be the jth image of the ith object, $\bar{X}_i$ and $\bar{X}$ be the mean of the ith object and all the training samples, respectively. In 2D-FLDA, the optimal projection matrix $W = [w_1, w_2, \ldots, w_d] \in \mathbb{R}^{m\times d}$ (d is at most $\min(C-1, n)$, [2]) can be obtained via maximizing the following criterion:

$$J(W) = \frac{tr(W^T S_b W)}{tr(W^T S_w W)}, \tag{1}$$

where superscript "T" denotes matrix transpose, tr denotes the trace of a matrix, S_w and S_b are constructed as follows:

$$S_w = \frac{1}{N}\sum_{i=1}^{C}\sum_{j=1}^{N_i}(X_i^j - \bar{X}_i)(X_i^j - \bar{X}_i)^T, \tag{2}$$

$$S_b = \sum_{i=1}^{C}\frac{N_i}{N}(\bar{X}_i - \bar{X})(\bar{X}_i - \bar{X})^T, \tag{3}$$

The maximization of Eq. (1) is equivalent to solve the generalized eigenvalue problem.

$$S_b w_i = \lambda_i S_w w_i. \tag{4}$$

The W consists of the eigenvectors corresponding to the d largest eigenvalues of $(S_w)^{-1}S_b$ if S_w is nonsingular.

The discriminant features of any input image can be extracted by using the optimal projection matrix W. But, the FLDA cannot be employed when each object has only one training image, because S_w degenerates to zero-matrix in Eq. (2). We will propose a new method to solve the issue in the following section.

3. Proposed method

It is an important problem that the S_w cannot be calculated when each object has only one available image in training data set. So, how to obtain the approximate image from a single image is a different problem for face recognition.