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Modular Two-dimensional Principal Component Regression for Robust Face Recognition ⋆

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Abstract

To improve robustness of Linear Regression (LR) for face recognition, a novel face recognition framework based on modular two-dimensional Principal Component Regression (2DPCR) is proposed in this paper. Firstly, all face images are partitioned into several blocks and the approach performs 2DPCA process to project the blocks onto the face spaces. Then, LR is used to obtain the residuals of every block by representing a test image as a linear combination of class-specific galleries. Lastly, three minimum residuals of every block and fuzzy similarity preferred ratio decision method are applied to make a classification. The proposed framework outperforms the state-of-the-art methods and demonstrates strong robustness under various illumination, pose and occlusion conditions on several face databases.

Keywords: Face Recognition; Block 2DPCR; Liner Regression; Fuzzy Similarity Preferred Ratio Decision

1 Introduction

Face Recognition (FR) has been a concerned issue because of its wide application in information science field in recent years. One of the most challenging problems about FR is how to suppress the influence of illumination, gesture variation and occlusion.

Pattern recognition methods based on subspace have developed rapidly in the past few years. Subspace methods also have been used to achieve successful face recognition which is based on the theory that face images from a specific class lie on a subspace. Images are transformed linearly or non-linearly to low-dimensional vectors with subspace methods in the face space. These approaches could be categorized into two categories, namely, reconstructive and discriminative methods. Classical reconstructive subspace methods are robust to noise including Principal Component Analysis (PCA), Independent Component Analysis (ICA) and Kernel PCA (KPCA). Discriminative methods, such as Linear Discriminant Analysis (LDA) and kernel LDA (KDA) are efficient

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in pure conditions. Although the following discriminative methods, such as Generalized Discriminant Analysis (GDA) [1], the Kernel Direct LDA (KDDA) [2] and Kernel Subspace LDA (KSLDA) [3], can achieve a good performance under illumination and gesture variation, the performance is still not satisfactory for severe variations.

Recently, a few reconstructive approaches were proposed to tackle illumination variations. In 2010, Linear Regression Classification (LRC) [4] has been introduced by assuming that face images from a specific class lie on a linear subspace. Test samples are reconstructed in square sense by training samples of every class, so the regression coefficients can be estimated with the least square method, and then the decision is made in favor of the class with the minimum reconstruction error. In 2012, Huang incorporated LRC with PCA and proposed Principal Component Regression (PCR) [5] by utilizing PCA's ability of data expression. Moreover, Lu proposed Kernel Linear Regression Classification (KLRC) [6] based on LRC and kernel trick in 2014. Experimental results show that the three methods are robust to illumination variations. However, it still could not withstand severe illumination variations.

The good robustness under various illumination of LRC is derived from its reconstructive ability. PCR maintains LRC's advantages and utilizes PCA's strong ability of data expression. Two-dimensional Principal Component (2DPCA) has a stronger expression ability than PCA, so two-dimensional Principal Component Regression (2DPCR) is proposed in this paper. Although strong reconstructive capacity can lower the influence of illumination variations, it will reduce the robustness to pose and occlusion. Modular presentation of face images is helpful to eliminate the error caused by local pollution. Therefore, modular LRC is a valid method to cope with pose and occlusion. Usually, minimum distance or vote is adopted to make decisions in modular approach, but both of them lack effectiveness since few informations are exploited. Final decision can be treated as a fuzzy decision problem due to the existence of residual errors of every class after modular linear regression. Li et al. [7] only use fuzzy membership degree to make decisions and does not make full use of the advantages of fuzzy decision. In this paper, fuzzy similarity preferred ratio decision method [8] is adopted to make decisions.

Based on the above analysis, we proposed a novel face recognition framework based on modular 2DPCR with fuzzy decision.

2 Modular 2DPCR with Fuzzy Decision

2.1 Linear Regression Classification Algorithm

Assume there are N number of classes with p_i number of training samples from the class, $i = 1, 2, \cdots, N$. All training samples constitute a matrix W and every column is a training sample: $W = [W_1, W_2, ..., W_N] = \left[w_1^1, w_2^1, ..., w_{p_1}^1, ..., w_1^N, w_2^N, ..., w_{p_N}^N\right]$, where W_i represents the ith class, and w_j^i is the jth training sample belonging to the ith class, $j = 1, 2, \cdots, p_i$. LRC reckons that face images from a specific class lie on a linear subspace. So, if y belongs to the ith class, we can use W_i to linearly represent y. As shown in Eq. (1):

$$y = W_i\beta_i + e_i. \tag{1}$$

Vector e_i represents the error of the ith class which is perpendicular to linear subspace spanned by W_i. There are two factors causing errors: one is noise of y, and the other one is that the