Two-Dimensional Principal Component Analysis with Local Direction Descriptor

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Abstract. This paper proposes a novel approach using two-dimensional principal component analysis (2D-PCA) and local direction descriptor for face recognition. The proposed method utilizes the transformed image obtained from local direction descriptor as the direct input image of 2D-PCA algorithms. The performance comparison was performed using principal component analysis (PCA) and Gabor-wavelets based on local binary pattern (LBP). The extended Yale B face database was accompanied for performance evaluation of proposed method. From the experimental result, we confirmed the effectiveness of the proposed method under varying lighting conditions.

Keywords: Local Direction Descriptor, Two-Dimensional PCA.

1 Introduction

Face recognition has many applications such as biometrics systems, access control systems, surveillance systems, security systems, credit-card verification systems, and content-based video retrieval systems. This paper presents a new approach for achieving the illumination invariant face recognition by using LDP image. Most of previous face recognition researches based on LBP [1] or local directional pattern (LDP) [2] utilize the descriptor for histogram feature extraction of the face image. However, this paper uses the LDP image as a direct input image of 2D-PCA [3] algorithm for illumination-robust face recognition system. The performance evaluation of the proposed system was carried out using the extended Yale B database, and we will demonstrate the effectiveness of the proposed approach at experimental result.

2 Proposed Method

The LDP assigns an 8 bit binary code to each pixel of an input image. This pattern is then calculated by comparing the relative edge response values of a pixel by using Kirsch edge detector. Given a central pixel in the image, the eight-directional edge response values m_i $(i = 0, 1, \cdots, 7)$ are computed by Kirsch masks. Since the presence of a corner or an edge shows high response values in some particular directions, thus, most prominent directions of k number with high response values are selected to generate the LDP code. Finally, the LDP code is derived by

$$LDP_k = \sum_{i=0}^{7} b_i(m_i - m_k)\times 2^i, \quad b_i(x) = \begin{cases} 1, & x \ge 0 \\ 0, & x < 0, \end{cases} \tag{1}$$

where m_k is the $k\text{-}th$ most significant directional response.

Unlike PCA, which treats 2D images as 1D image vectors, 2D-PCA views an image as a matrix. Consider an m by n image matrix A. Let $X \in R^{n\times d}$ be a matrix with orthonormal columns, $n \ge d$. Projecting A onto X yields m by d matrix $Y = AX$. Suppose that there are M training face images, denoted m by n matrices A_k $(k = 1, 2, \cdots, M)$, and the average image is denoted as $\overline{A} = 1/M \sum_k A_k$. Then, the image covariance matrix, G is given by

$$G = \frac{1}{M}\sum_{k=1}^{M}(A_k - \overline{A})^T (A_k - \overline{A}). \tag{2}$$

It has been proven that the optimal value for the projection matrix X_{opt} is composed by the orthonormal eigenvectors $X_1, X_2, \cdots, X_d$ of G corresponding to the d largest eigenvalues, i.e., $X_{opt} = [X_1, X_2, \cdots, X_d]$. For a given face image A, the feature vector $Y = [Y_1, Y_2, \cdots, Y_d]$, in which Y has a dimension of m by d, is obtained by projecting the images into the eigenvectors as follows:

$$Y_k = (A - \overline{A})X_k, \quad k = 1, 2, \cdots d. \tag{3}$$

3 Experimental Result

For the performance evaluation, we used images from the extended Yale B database [4]. In the extended Yale B database, we employ 2,414 face images for 38 subjects representing 64 illumination conditions under the frontal pose. All face images converted as grayscale and were cropped and normalized to a resolution of 48×42 pixels. To evaluate the performance of the proposed method, we partitioned the extended Yale B database into training and testing sets. Each training set comprised of seven images per subject, and the remaining images were used to test the proposed method. Next, we investigated the recognition performance of proposed approach with conventional recognition algorithms such as PCA and Gabor-wavelet based on LBP [5]. As a result, we showed the maximum recognition rates as various approaches in Table 1. The proposed approach using LDP and 2D-PCA showed a maximum recognition rate of 96.43%, when k is 3. However, the maximum recognition rates revealed 81.34% and 69.50% for PCA and Gabor-wavelets based on LBP approaches, respectively. Consequently, the recognition accuracy of proposed method was better than that of conventional methods, and it also shows performance improvement ranging from 15.09% to 29.63% in comparison to conventional methods.

Table 1. Maximum recognition rates on Yale B database.

Input Images	Recognition Approaches		
	PCA	2D-PCA	Gabor-wavelets based LBP
Raw	30.03%	30.78%	57.14%
Histogram	50.61%	54.09%	**69.50%**
LBP	72.09%	91.54%	X
LDP (K=1)	70.77%	94.60%	X
LDP (K=2)	77.16%	95.72%	X
LDP (K=3)	78.85%	**96.43%**	X
LDP (K=4)	77.96%	96.10%	X
LDP (K=5)	**81.34%**	95.49%	X

4 Conclusion

This paper proposed a novel face recognition approach using LDP image and 2D-PCA. The proposed method has an advantage that the illumination effects can be degraded by LDP descriptor and 2D-PCA is also more robust against illumination variation than global features. The performance evaluation was performed on the extended Yale B database, and the proposed method showed the best recognition accuracy compared to different approaches. Through experimental result, we confirmed the effectiveness of the proposed system under illumination varying conditions.

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