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A novel face recognition method: Using random weight networks and quasi-singular value decomposition

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ABSTRACT

This paper designs a novel human face recognition method, which is mainly based on a new feature extraction method and an efficient classifier – random weight network (RWN). Its innovation of the feature extraction is embodied in the good fusion of the geometric features and algebraic features of the original image. Here the geometric features are acquired by means of fast discrete curvelet transform (FDCT) and 2-dimensional principal component analysis (2DPCA), while the algebraic features are extracted by a proposed quasi-singular value decomposition (Q-SVD) method that can embody the relations of each image under a unified framework. Subsequently, the efficient RWN is applied to classify these fused features to further improve the recognition rate and the recognition speed. Some comparison experiments are carried out on six famous face databases between our proposed method and some other state-of-the-art methods. The experimental results show that the proposed method has an outstanding superiority in the aspects of separability, recognition rate and training time.

1. Introduction

Face recognition has attracted much attention in recent years due to its inexpensive, convenient and hassle-free advantages. It has widespread applications, such as smart cards, telecommunication, database security, medical records, and digital libraries [27]. There are two key steps in the face recognition: feature extraction and classification. The aim of feature extraction is mainly to give an effective representation of each image, which can reduce the computational complexity of the classification algorithm and enhance the separability of the images to get a higher recognition rate. While the aim of classification is to distinguish those extracted features with a good classifier. Therefore, an effective face recognition system greatly depends on the appropriate representation of human face features and the good design of classifier.

It is well known that image features are usually classified into four classes: Statistical-pixel features, visual features, algebraic features, and geometric features (e.g. transform-coefficient features), where the latter two are often applied in face recognition system. Up to now, many geometric-feature based methods have been proposed to acquire a higher level of separability through transforming the space-domain of the original image into another domain. At the early stage, wavelet transform is popular and widely applied in face recognition system for its multi-resolution character, such as 2-dimensional discrete wavelet transform [6], discrete wavelet transform [8], fast beta wavelet networks [12], and wavelet based feature selection [9,24,26,29]. Although wavelet transform is suitable for detecting singularities in the image, it fails to represent curved discontinuities. Fortunately, Donoho and Duncan have proposed another transform-based method, called curvelet transform, to improve the directional capability [4]. That is, it can represent edges with singularities well and increase anisotropy with decreasing scale as well. Therefore, curvelet transform has been widely used in face recognition, such as curvelet based moment method [14], curvelet based face recognition [15,16], and curvelet based image fusion [21]. On the other hand, the algebraic features of images can reflect the intrinsic properties of images stably. Therefore, they have been considered as valid features for face recognition [10]. As one of the effective algebraic-feature based methods, singular value decomposition (SVD) method [7] was applied in face recognition to extract feature vectors [3,23]. It can represent algebraic features from space-domain well. However, images usually come from the same class in practical applications, so they are often related to each other. Hence it is not enough to just take SVD method in images as SVD method is applied on each image separately.

As we all know, related literatures only use one of the above features in the process of extracting face features. In this paper, we will propose a new method for extracting compound features that consist of geometric features and algebraic features. At first, we use FDCT to

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extract geometric features from original images. Considering that the obtained geometric features usually contain statistical redundancies, two dimensional principal component analysis (2DPCA) [25,28] is employed to reduce redundancies as well as to reveal the essential features of face image. At the same time, in order to compensate the shortcoming of SVD method, we propose an improved method, called quasi-singular value decomposition (QSVD) method, to extract algebraic features to represent the relation of each image in a unified framework better. Finally, we fuse the dimensionality-reduced geometric features with the algebraic features by Q-SVD method to form the final compound features. Therefore, these compound features possess not only geometric information, but also algebraic information of images, which can increase separability of images and thus improve the recognition rate greatly.

After extracting the compound features, the following work is to design an effective classifier. There have been a lot of classifiers, such as polynomial function, support vector machine (SVM) [22], and feed-forward neural networks (FNNs). Among these classifiers, FNN can be seemed one of the most popular techniques. As we know, perceptron [19] and backpropagation (BP) algorithm [30] are classical methods for training FNNs. But they are often confronted with the slow learning speed in the process of tuning parameters. However, random weight network (RWN) is proposed in some prior articles [11,17,20] to improve the learning speed of FNNs. That is, the hidden weights and biases are chosen randomly and the output weights of FNNs are calculated by the least square. Compared with the traditional BP algorithm and its various modified methods, RWN has a more concise architecture and a faster learning speed. Therefore, RWN has wide applications in many areas. In this paper, we take RWN as a classifier to distinguish those final compound features to improve the recognition accuracy and speed. Comparison experiments of the proposed method with some other state-of-the-art approaches for face recognition have been carried out on five well-known face databases, and the experimental results exhibit that the proposed method for face recognition achieves a higher recognition rate and a faster training speed.

The rest of this paper is organized as follows. In Section 2, we propose a novel method for face recognition that contains a method for extracting the compound features and an algorithm for training the classifier. Section 3 gives some experimental comparisons of our proposed method with some other state-of-the-art approaches for face recognition. Finally, conclusions based on the study are highlighted in Section 4.

2. Proposed method for face recognition

In this section, a new method for face recognition is proposed. It consists of two key steps: the extraction of the compound features and a design of an efficient classifier. Specifically, the compound features are made of geometric features and algebraic features. At first, we use FDCT [1] to extract geometric features from original images and employ 2DPCA [25] to reduce their dimensionality for computation. At the same time, in order to compensate the deficiency of geometric features, we propose an improved QSVD method to extract algebraic features to represent the relation of each image in a unified framework better. Finally, we fuse the dimensionality-reduced geometric features with the algebraic features to form the final compound features. At last, we apply the efficient RWN as a classifier to distinguish those final compound features to improve the recognition accuracy and speed. The block schematic diagram of the proposed method for face recognition is shown in Fig. 1.

2.1. Extract geometric features with FDCT and 2DPCA

It is well known that the original face images often need to be well represented instead of being input into the classifier directly because of the huge computational cost. As one of the popular representations, geometric features are often extracted to attain a higher level of separability. Since curvelet transform has an advantage on the directional capability over wavelet transform, here we employ FDCT proposed by Candès et al. [1] to generate the initial geometric features for representing face images.

Suppose that there are m facial images $\{F_i\}_{i=1}^m$, then the process of extracting geometric features with FDCT via wrapping is as follows:

Geometric features extraction with FDCT via wrapping 2.1.1:

Step 1: For each facial image F, compute its coefficients with 2-dimensional fast discrete Fourier transform (2D-FDFT) to get its representative samples $\hat{F}(n_1, n_2)$ on the Fourier frequency, where $\hat{F}(n_1, n_2)$ denotes the discrete Fourier transform of the function F at the point (n_1, n_2), and $-n/2 \le n_1, n_2 < n/2$.

Step 2: At each scale s and angle θ, form the product $\hat{U}_{s,\theta}(n_1, n_2)\hat{F}(n_1, n_2)$, where $\hat{U}_{s,\theta}$ is a localizing window supported on some rectangle of length $l_{s,1}$ and width $l_{s,2}$.

Step 3: Wrap this product around the origin and obtain $\hat{F}_{s,\theta}(n_1, n_2) \; = W(\hat{U}_{s,\theta}\hat{F})(n_1, n_2)$, where the ranges of n_1, n_2 and θ are $0 < n_1 < l_{s,1}$, $0 < n_2 < l_{s,2}$, and $(-\pi/4, \pi/4)$, respectively.

Step 4: Apply the inverse 2D-FDFT to each $\hat{F}_{s,\theta}$ and save the discrete curvelet coefficients to obtain the coarse curvelet coefficients matrix A for the facial image F.

Up to now, we have gotten m coarse curvelet coefficients matrices $\{A_i\}_{i=1}^m$, i.e. geometric features, of original facial images $\{F_i\}_{i=1}^m$. However, the dimension of each feature matrix is still large, it is necessary to reduce its dimensionality for saving computation cost. Here we adopt 2D-PCA [25] to reduce the dimensionality of the extracted coarse curvelet coefficients matrix.

For the m coarse curvelet coefficients matrices $\{A_i\}_{i=1}^m$ extracted from m facial images, let $\overline{A}$ be their average matrix as follows:

$$\overline{A} = \frac{1}{m}\sum_{i=1}^{m} A_i. \tag{1}$$

So the image covariance matrix C can be represented as follows:

$$C = \frac{1}{m}\sum_{i=1}^{m} (A_i - \overline{A})^\top (A_i - \overline{A}), \tag{2}$$

and the generalized total scattered criterion $J(\mathbf{x})$ can be expressed by

$$J(\mathbf{x}) = \mathbf{x}^\top C\mathbf{x}. \tag{3}$$

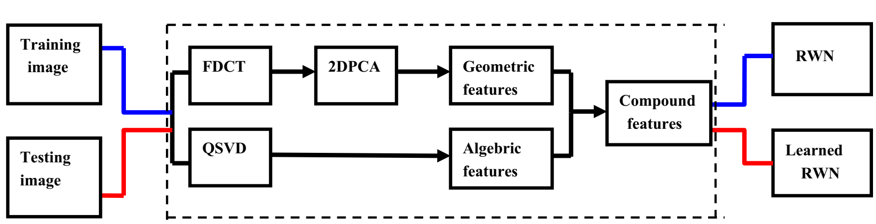

Fig. 1. Diagram of the proposed method for face recognition.