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Fast face recognition based on fractal theory

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A R T I C L E I N F O

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A B S T R A C T

Nowadays, people are more and more concerned about accuracy, rapidity and convenience in the process of personal identification. In the field of biology and computer vision, a variety of methods have been proposed, while a proper method for face recognition is still a challenge. Although some reliable systems and advanced methods have been introduced under relatively controlled conditions, their recognition rate or speed is not satisfactory in the general settings. This is especially true when there are variations in pose, illumination, and facial expression. This paper proposed a fast face recognition method based on fractal theory. This method is to compress the facial images to obtain fractal codes and complete face recognition with these codes. Experimental results on Yale, FERET and CMU PIE databases demonstrate the high efficiency of our method in runtime and correct rate.

1. Introduction

Recently, a large number of biological features have been are applied to identity recognition, such as iris recognition, fingerprint recognition, gait recognition and face recognition. These biological features are easy to use, to distinguish and difficult to forge. Compared with other methods, non touching and aggression are the biggest advantages and features of face recognition. As a hot topic, more and more attention has been focused on the face recognition. Face recognition is considered to have broad application prospects in video surveillance, access control system, criminal investigation and other fields [1–7].

General face recognition methods can be broadly divided into two categories of local and global approaches [8]. The task of those local methods is to extract different local features. For another, global approaches process the entire image and make a general template for the face [8]. It should be noted that some deep learning methods such as Convolution Neural Network (CNN) and tensor face also achieve good results.

Global approaches usually adopt a projection technique to manipulate the image as a whole and create a general template for each face pattern. The main work is to find the best template which can describe the test object. Eigenface and Fisherface are the most famous methods in this category. In the eigenface, Principle Component Analysis (PCA) is proposed and can reduce the dimension effectively. It projects images into a low-dimension space and seeks a linear transformation matrix that maximizes the data variance in the projection subspace [9]. Another linear projection is insensitive to variation in lighting direction and facial expression which is implemented by Fisher's Linear Discriminant Analysis (LDA). LDA is a supervised scheme that aims at minimizing the within-class variances as well as maximizing the between-class distances in the projection subspace [9]. However, we often meet the problems of small sample size or high dimensional data in face

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classification and recognition tasks. Therefore, the traditional LDA is not generally available for our direct use due to the fact that the within-class scatter matrix is always singular [6].

Local methods take another path. These approaches process different parts of the image to obtain salient features which are used to learn patterns of different people. Support Vector Machine (SVM) is proposed and used to classify the features extracted from a set of facial components in a component-based system. To extract local topographic representations for objects, Local Feature Analysis (LFA) was mentioned in [8].

For the deep learning methods, CNN is capable of learning local features from the input images and complete recognition. A typical CNN classifier is consisted of a CNN with altering sequence of convolution, sub-sampling layers for feature extraction and a neural network in the last layer for classification [10]. For the tensor face, it is actually used for a multidimensional array. The vector and matrix can be the representation of the first and second order tensors. Higher order tensors have more information, therefore researchers want to use this ability for face recognition and gain better results [11].

In the respect of fractal coding, Tan and Yan have made great contributions in this field. They first put forward the concept of Fractal Neighbor Distance (FND) which is a way of ranging. The definition of the degree of similarity between images which have taken fractal coding is used as the classification and identification criteria [12–14]. In [13], the speed of target recognition is analyzed using the principle of FND is associated with ultimate compression factor of Iterated Function System (IFS). Weighted Fractal Neighbor Distance (WFND) is proposed in [12]. The study finds that the regions of eyes and nose of everyone contain most features of a face and further improve the original method based on different parts of the face with different weighted coefficients.

It should be noted that when the face image is evenly distributed in the frame, it is generally symmetrical. This feature is especially effective for fractal compression, which can help us accelerate the encoding speed. After we complete the process of encoding and get the corresponding fractal codes, Fractal Neighbor Distance based Classification (FNDC) which has the direct connection to FND is presented in this paper and can meet the requirement of rapid identification. Different people are in our training library and each person has several samples under various conditions. The difference between the different samples from the same person is the within-class difference. The difference between different people is the between-classes difference. By these two differences, FNDC can ensure the recognition rate and accelerate the identification speed at the same time.

The remaining of the paper is organized as follows: Section 2 introduces the fractal theory and the steps of fractal encoding. Section 3 describes how to complete the face recognition based on fractal codes and presents the novel method FDNC. Section 4 describes the experimental results and proves the validity of FNDC. Finally, the conclusion is provided in Section 5.

2. Fractal coding theory and method

2.1. Segmentation of range blocks and domain blocks

In the whole process of image segmentation, the range blocks and domain blocks can take any shape, but generally are rectangular. And the area of the domain block is usually larger than the range block to ensure that the corresponding mapping is a contraction transformation.

The whole coding process is to find the fittest domain block for the range block and seek out the corresponding contraction mapping, contrast scaling and luminance shift. Once it is hard to find the most matched object for the current range block, we have to split it into smaller sub blocks. The above operations are repeated until the requirements are met, or the range block cannot be divided.

2.2. Determination of contractive mapping

The matching process between domain blocks and range blocks occupies most of the time of fractal encoding. There are 8 basic affine transformations for each domain block and each range block has to compare with them one by one. The matching process is shown in Fig. 1.

(1) The domain block is compressed to ensure it has the same size as the range block.
(2) The domain block after compression also has to take 8 basic affine transformations.
(3) Calculate the values of contrast scaling and luminance shift in the matching process (least squares method can be used here).

The calculation procedure of values of contrast scaling and luminance shift is introduced as follows:

Supposed $\{d_{ij}(\ \ i = 1, 2, \ldots, n \quad j = 1, 2, \ldots, n\ \ )\}$is the pixel value which is obtained by an affine transformation and $\{r_{ij}(\ \ i = 1, 2, \ldots, n \quad j = 1, 2, \ldots, n\ \ )\}$ is the pixel value of the range block, then the contrast scaling s and luminance shift o under the best conditions should make the R value in Eq. (1) minimum.