Optik 125 (2014) 5825–5832

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Novel classification rule of two-phase test sample sparse representation

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ARTICLE INFO

Article history:
Received 18 October 2013
Accepted 30 May 2014

Keywords:
Two-phase test sample sparse representation
Coarse *k* nearest neighbor
Face recognition
FKP recognition

ABSTRACT

In this paper, a novel classifier based on two-phase test sample sparse representation (TPTSSR) classifier and coarse *k* nearest neighbor (C-kNN) classifier, called novel classification rule of two-phase test sample sparse representation (NCR-TPTSSR) classifier, is proposed for image recognition. Being similar to TPTSSR classifier and C-kNN classifier, NCR-TPTSSR classifier also uses the two phases to classify the test sample. However, the classification rule of NCR-TPTSSR classifier is different to the decision rule of TPTSSR classifier and C-kNN classifier. A large number of experiments on FERET face database, AR face database, JAFFE face database and PolyU FKP database are used to evaluate the proposed algorithm. The experimental results demonstrate that the proposed method achieves better recognition rate than TPTSSR classifier, C-kNN classifier, nearest feature center (NFC) classifier, nearest feature line (NFL) classifier, nearest neighbor (NN) and so on.

1. Introduction

Biometrics recognition plays more and more important role in our life. A lot of biometric information has been widely used to identify personal, such as face images, fingerprints images, finger-knuckle-print image, and palm print images and so on. Biometrics recognition systems are critically dependent on classifiers. nearest neighbor (NN) [1] classifier and nearest subspace (NS) [2] classifier (i.e., minimum distance between the test sample and mean of each class) are the well-known methods in pattern recognition area. NN classifies the test sample based on the best representation in terms of a single training sample, whereas NS classifies based on the best linear representation in terms of all the training samples in each class.

The number of prototype samples is usually very small, which makes the classification of NN be very difficult. So nearest feature line (NFL) [3,4] was proposed for face recognition [5–8] by S.Z. Li et al. in 1999. NFL attempts to enhance the representational capacity of the limited sample set by using the line passing through each pair of the samples belonging to the same class. After the NFL being proposed, Chien and Wu [9] proposed the nearest feature plane (NFP) in 2002. Zheng et al. [10] proposed the nearest neighbor line (NNL) and nearest neighbor plane (NNP) in 2004, GAO et al. [11] proposed the center-based nearest neighbor (CNN) in 2007. Feng et al. [8] proposed the nearest feature center (NFC) classifier in 2012. Feng et al. [12] proposed the center-based nearest feature plane (CNFP) and line-based nearest feature plane (LNFP) classifier in 2013.

Being different to nearest feature classifier using the samples of class-model, Xu et al. [13] proposed two-phase test sample sparse representation (TPTSSR) classifier, which uses all-class-model to classify the test sample. TPTSSR classifier uses two phases to classify the test sample image. In the first phase of TPTSSR classifier, it uses a simple way to gain "sparse representation" [14–18] of the test sample, which can better represent the training sample space. In the second phase of TPTSSR classifier, it utilizes the new representation for classification. After TPTSSR classifier, some other improved classifiers [19–21] are proposed. Be similar to TPTSSR classifier, coarse *k* nearest neighbor (C-kNN) [19] classifier also uses two phase to classify the test sample image. However, the decision rule of C-kNN classifier is different to that of TPTSSR classifier.

Motivated by two-phase test sample sparse representation (TPTSSR) classifier and coarse *k* nearest neighbor (C-kNN) classifier, novel classification rule of two-phase test sample sparse representation (NCR-TPTSSR) classifier is proposed for image recognition. Be similar to TPTSSR classifier and C-kNN classifier, NCR-TPTSSR classifier also use the two phases to classify the test sample. However, the classification rule of NCR-TPTSSR classifier is different to the decision rule of TPTSSR classifier and C-kNN classifier. A large

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http://dx.doi.org/10.1016/j.ijleo.2014.07.025
0030-4026/

number of experiments on FERET face database, AR face database, JAFFE face database and PolyU FKP database are used to evaluate the proposed algorithm. The experimental results demonstrate that the proposed method achieves better recognition rate than TPTSSR classifier, C-kNN classifier, nearest feature center (NFC) classifier, nearest feature line (NFL) classifier, nearest neighbor (NN) and so on.

2. Review

Let $Y = \{y_i^c, c = 1, 2, \ldots, M, i = 1, 2, \ldots, N_c\} \subset R^D$ denote the prototype set, where y_i^c is the ith prototype belonging to cth class, M is the number of class, and N_c is the number of prototype images belonging to the cth class. Each image is transformed to column vector such as $y_i^c \in R^{a\times b} \to w_i^c \in R^{q\times 1}$, where q = ab.

2.1. Two-phase test sample sparse representation (TPTSSR) classifier

TPTSSR [13] classifier is described as follows. TPTSSR constitutes a class-specific model X^c by stacking the q-dimensional image vectors

$$X^c = [\,w_1^c \quad w_2^c \quad \ldots \quad w_{N_c}^c\,] \in R^{q\times N_c} \tag{1}$$

Denote by $X^c \in R^{q\times N_c}$ the dataset of the cth class, and each column of X^c is a sample of class c. Suppose that we have M classes of subjects, and let

$$X = [\,X^1 \quad X^2 \quad \ldots. \quad X^M\,] \in R^{q\times MN_c} \tag{2}$$

$\beta \in R^{MN_c\times 1}$ is the vector of parameters, which can be calculated as follows.

$$\beta = (X^TX)^{-1}X^Ty \tag{3}$$

By using the vector of parameters to compute the distance between the test sample and the training sample as

$$e_i^c = ||x - \beta_i^c X_i^x||, \quad c = 1, 2, \ldots, M; \quad i = 1, 2, \ldots, N_c \tag{4}$$

Choose the nearest N samples according to e_i^c. Let each column of J is a sample of N samples.

$$\gamma = (J^TJ)^{-1}J^Ty \tag{5}$$

If the all N samples from the cth class are $J_s^c \ldots J_t^c$. Let

$$g^c = \gamma_s^c J_s^c + \cdots + \gamma_t^c J_t^c \tag{6}$$

We calculate the deviation of g^c from y by using

$$d_c(y) = ||y - g^c\,|| \tag{7}$$

The rule of TPTSSR is in favor of the class with minimum distance

$$\min_{c*} d_c(y)\,, \quad c = 1, 2, \ldots, M \tag{8}$$

2.2. Coarse k nearest neighbor (C-kNN) classifier

C-kNN classifier is described as follows. C-kNN [19] constitutes a class-specific model X^c by stacking the q-dimensional image vectors

$$X_c = [\,w_1^c \quad w_2^c \quad \ldots \quad w_{N_c}^c\,] \in R^{q\times N_c} \tag{9}$$

Denote by $X^c \in R^{q\times N_c}$ the dataset of the cth class, and each column of X^c is a sample of class c. Suppose that we have M classes of subjects, and let

$$X = [\,X^1 \quad X^2 \quad \ldots \quad X^M\,] \in R^{q\times MN_c} \tag{10}$$

$\beta \in R^{MN_c\times 1}$ is the vector of parameters, which can be calculated as follows.

$$\beta = (X^TX)^{-1}X^Ty \tag{11}$$

By using the vector of parameters to compute the distance between the test sample and the training sample as

$$e_i^c = ||x - \beta_i^c X_i^x||, \quad c = 1, 2, \ldots, M; \quad i = 1, 2, \ldots, N_c \tag{12}$$

Choose the nearest N samples according to e_i^c. Let each column of J is a sample of N samples.

$$\gamma = (J^TJ)^{-1}J^Ty \tag{13}$$

Compute the new distance between the test sample and the training sample as

$$r_i^c = ||x - \gamma_i J_i||, \quad i = 1, 2, \ldots, N \tag{14}$$

Choose K samples chosen from N samples according to r_i^c. Let g^c be the number of the cth class of K samples. The rule of C-kNN is in favor of the class with maximum number

$$\max_{c*} g^c, \quad c = 1, 2, \ldots, M \tag{15}$$

3. Proposed method

In this section, the proposed classifier, called novel classification rule of two-phase test sample sparse representation (NCR-TPTSSR) classifier is described as follows.

3.1. Novel classification rule of two-phase test sample sparse representation classifier

NCR-TPTSSR forms a class-specific model X^c by stacking the q-dimensional image vectors

$$X^c = [\,w_1^c \quad w_2^c \quad \ldots \quad w_{N_c}^c\,] \in R^{q\times N_c} \tag{16}$$

Denote by $X^c \in R^{q\times N_c}$ the dataset of the cth class, and each column of X^c is a sample of class c. Suppose that we have M classes of subjects, and let

$$X = [\,X^1 \quad X^2 \quad \ldots \quad X^M\,] \in R^{q\times MN_c} \tag{17}$$

$\beta \in R^{MN_c\times 1}$ is the vector of parameters, which can be calculated as follows.

$$\beta = (X^TX)^{-1}X^Ty \tag{18}$$

By using the vector of parameters to compute the distance between the test sample and the training sample as

$$e_i^c = ||x - \beta_i^c X_i^x||, \quad c = 1, 2, \ldots, M; \quad i = 1, 2, \ldots, N_c \tag{19}$$

Choose the neatest N samples according to e_i^c. Let each column of J is a sample of the N samples.

$$\gamma = (J^TJ)^{-1}J^Ty \tag{20}$$

If the all N samples from the cth class are $J_s^c \ldots J_t^c$. The corresponding parameters of $J_s^c \ldots J_t^c$ are $\gamma_s^c + \cdots + \gamma_t^c$

$$g^c = \gamma_s^c + \cdots + \gamma_t^c \tag{21}$$

The rule of TPTSSR is in favor of the class with maximum value

$$\max_{c*} g^c, \quad c = 1, 2, \ldots, M \tag{22}$$