A face recognition method of integrated technology

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Abstract

In this paper, based on the study of the Two-Dimensional Principal Component Analysis (2DPCA), Two-Dimensional Principal Component Analysis (2DPCA) and fuzzy set theory, we propose a new face recognition algorithm integrating 2DDCT, 2DPCA and fuzzy 2DLDA. This method can make good use of the advantages of each single method, and also can make up for the defect of each other. The comparison of the results of the different methods identification effect on the ORL, YALE and FERET face database show, the integrated method proposed in this paper improves the recognition rate, and it also reduces the training and classification time as well.

Keywords: face recognition, 2DDCT, Two-Dimensional Principal Component Analysis (2DPCA), Two-Dimensional Linear Discriminant Analysis (2DLDA), fuzzy set theory

1 Introduction

In recent 20 years, face recognition has become a hot topic in the research field of computer vision and pattern recognition [1], and it is through the modern information processing technology and computer technology to complete the understanding and recognition of the facial image [2]. The commonly used face recognition methods can be divided into several categories [3]: the method based on geometric features, the method based on model, the method based on the statistical, the method based on neural network method and the method of combining multiple classifiers, this paper mainly focuses on the method based on statistics. The method based on statistical faced the image as random vector, thus using some statistical methods to analyze the face model, the most representative methods include the eigenface method based on principal component analysis which proposed by Turk [4] and the fisherfaces method based on linear discriminant analysis which proposed by Belhumeur et al [5]. But the PCA and LDA methods have a common disadvantage, the two methods both need deal with vector data, and they can not directly deal with image data, so before using these two methods it need transform the image data to vector data firstly, but the dimension of the processed data often is very high. In addition, the two methods both need decompose the matrix feature value, but computation for high dimensional data is very difficult and time-consuming. In order to overcome these shortcomings, Yang et al proposed 2DPCA method [6], Li et al proposed 2DLDA method [7]. They are the extension of one-dimensional PCA and LDA, the main idea of them is to construct the image covariance matrix and the image discrete matrix from the original image data matrices directly, and identification and analysis. These two methods need not do the vector operation process to the

image matrix, so 2DPCA and 2DLDA greatly reduce the computational time complexity of PCA and LDA. Later, some researchers have proposed 2DPCA+2DDLA method [8], (2D)2PCA [9] method and (2D)2LDA [10] method one after another. According to 2DLDA method, some researcher has proposed Fuzzy 2DPCA [11] and Fuzzy 2DLDA (F2DLDA) method [12], these methods made the fuzzy set theory into the 2DLDA method, so it can effectively consider the sample structure information and fully add the distribution information of the overlapped samples to the definition of the discrete degree matrix, so this method can improve the accuracy of classification. Ergun G et al had analyzed the combination method between wavelet subspace techniques and the PCA method [13], Angle et al had analyzed the advance of the face recognition using wavelet subspace [14].

This paper compared and analyzed the above methods, and proposed an integrated face recognition method based on wavelet transform during the analysis result. This method retains the advantages of the original method at the same time, and used the integrated advantages to make up for the deficiency of the original method, so this method will achieve a good recognition effect.

2 Describe about the relevant principles and methods

2.1 THE THEORY OF 2DDCT (DISCRETE COSINE TRANSFORM)

Discrete cosine transform as a compression technology in the field of image processing is very common, and its main effect is selectively discarded some redundant information after the transform processing about the images, and can not produce a wrong interpretation to the original image. For a digital image of $m \times n$ $f(x, y)$, its two-dimensional

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discrete cosine transform:

$$F(u,v) = \left[a(u)a(v) \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y) \right] \times$$
$$\cos\left[\frac{(2x+1)u\pi}{2M} \right] \cos\left[\frac{(2y+1)v\pi}{2N} \right], \tag{1}$$

where $u = 0, 1, 2, …, M − 1, v = 0 , 1, 2, …, N − 1$; at the same time $F(u, v)$ is the coefficient of DCT, $a(u)$ and $a(v)$ can be obtained by the following equation:

$$a(u) = \begin{cases} \sqrt{1/M} & u = 0 \\ \sqrt{2/M} & u = 1,2,...,M-1 \end{cases},$$

$$a(v) = \begin{cases} \sqrt{1/N} & v = 0 \\ \sqrt{2/N} & v = 1,2,...,M-1 \end{cases}.$$

The corresponding inverse discrete cosine transform (IDCT):

$$f(x,y) = \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} a(u)a(v)F(u,v) \times$$
$$\cos\left[\frac{(2x+1)u\pi}{2M} \right] \cos\left[\frac{(2y+1)v\pi}{2N} \right], \tag{2}$$

where $x = 0, 1, 2,…, M − 1, y = 0, 1, 2, …, N − 1$.

The characteristic of the discrete cosine transform is follow: through the discrete cosine transform, it only kept the useful information in low-frequency component part, and gave a lot of redundant information in the high-frequency component part at the image reconstruction; the information obtained through inverse transform operation can get a new image approximate to the original image. Although the new image after the processing and the original image were not exactly the same, there are some errors between them, but the significant information of original image is preserved. This not only reduces the dimension of the image, and will not impact on face recognition.

2.2 2DPCA (TWO-DIMENSIONAL PRINCIPAL COMPONENT ANALYSIS) METHOD

The 2DPCA method applied to face recognition can be divided into two parts for feature extraction and pattern classification.

2.2.1 Feature extracting

Suppose that there are c pattern category: ωt ($t = 1, 2, …, c$), each class has n_i matrix of $m×n$, the total number of training samples is N. So the overall image discrete matrix can be defined as:

$$G_t = \frac{1}{N} \sum_{i=1}^{N} (A_i - A)^T (A_i - A), \tag{3}$$

where A is the average value of the training sample, it can be obtained by:

$$A = \frac{1}{N} \sum_{i=1}^{N} A_i . \tag{4}$$

Similar to the PCA, we take the feature vectors corresponding to the K largest feature value of the whole image discrete matrix as the discriminant vector sets of the 2DPCA. Matrix X is made up of K direction vector, we can extract features Y through training samples are projected to the matrix X: $Y=AX$.

Let $B = [y_1, y_2, … , y_K]$, where $y_i = Ax_i$, then we can get the feature matrix B of A.

2.2.2 Pattern classification

For c modes, any two images of Am and An, the projection feature matrix corresponding to them is Bi = $[y_1(m), y_2(m), … , y_K(m)]$ and $B_j = [y_1(n), y_2(n), … , y_K(n)]$, so the distance between Am and An can be obtained by:

$$d(B_i, B_j) = \sum_{r=1}^{K} \left\| y_r^{(m)} - y_r^{(n)} \right\|_2, \tag{5}$$

where $\| yr(m) − yr(n) \|$ said the distance between the principal component $yr(m)$ and principal component $yr(n)$, and the feature matrix are $B_1, B_2, …, B_K$ which correspond to all training samples, and they belong to the class ωt. So for any test sample A, and the feature matrix B corresponding to A, if there exists $d(B, B_i) = \min[d(B, B_j)]$, if B_i belongs to the class ωt, then we can judge that A belongs to ωt.

2.3 FUZZY 2DLDA (TWO-DIMENSIONAL LINEAR DISCRIMINANT ANALYSIS) METHOD

Fuzzy set theory applied in 2DLDA not only can reduce the sensitivity of 2DLDA in face classification, but also can improve the rate of classification. At the same time, it also can make the 2DLDA method more robust in face recognition.

The fuzzy divide problem of sample usually is realized by constructing the membership matrix $U = [u_{ij}]$ ($i = 1, 2, ..., C; j = 1, 2, … , N$), where, u_{ij} said the membership degree of sample j belongs to the class i. Usually u_{ij} satisfies the follow three conditions:

$$\sum_{i=1}^{C} u_{ij} = 1, \ 0 < \sum_{i=1}^{N} u_{ij} < N, \ 0 \le u_{i,j} \le 1, \tag{6}$$

u_{ij} can be obtained through the fuzzy K nearest neighbor algorithm the following:

Step 1: Constructing the matrix $D = [d_{jk}]$, where the d_{jk} said the Euclidean distance between the sample vector j and the sample vector k: $d_{j,k} = \|x_{i,j} − x_{i,k}\|2$, ($j = 1, 2, …, N; k = 1, 2, …, N$);

Step 2: Let the diagonal elements of D is infinite $d_{ij} = +\infty$ ($j = 1, 2, …, N$);

Step 3: Sorting the distance value of the each row of the matrix D according the ascending;

Step 4: Calculating the label vector of the K nearest neighbor samples from the every sample x_{ij}, ($i = 1, 2, \ldots, c$; $j = 1, 2, \ldots, N$);

Step 5: During the calculation to obtain the nearest matrix $H = [h_{ij}]$, where the h_{ij} said the number of k nearest neighbors within the range of the sample which belongs to the sample j in the class i, and ($i = 1, 2, \ldots, c$; $j = 1, 2, \ldots, N$);

Step 6: The fuzzy membership degree matrix can obtained through Equation (7), where $i = 1, 2, \ldots, c$; $j = 1, 2, \ldots, N$:

$$u_{ij} = \begin{cases} \gamma + (1-\gamma)(h_{ij} / k) \\ (1-\gamma)(h_{ij} / K) \end{cases}, \quad (7)$$

where, N said the number of training samples, c is the number of the class, $p \in (0, 1)$ is a parameter to control the change of the $h_{i,j}$ value, $\gamma = (N - c)/2pN$.

So, we can obtain the center of every class:

$$\overline{A_i} = \frac{\sum_{j=1}^{N} u_{ij} A_j}{\sum_{j=1}^{N} u_{ij}} . \quad (8)$$

The fuzzy discrete degree matrix between class Sfb and the fuzzy discrete degree matrix within class Sfw can be obtained:

$$S_{fb} = \sum_{i=1}^{C} \sum_{j=1}^{N} u_{ij} (\overline{A_i} - \overline{A})(\overline{A_i} - \overline{A})^T . \quad (9)$$

$$S_{fw} = \sum_{i=1}^{C} \sum_{j=\omega_i} u_{ij} (A_j - \overline{A_i})(A_j - \overline{A_i})^T . \quad (10)$$

The objection function of the fuzzy 2DLDA can be defined as:

$$W = \arg\max_{W} \frac{W^T S_{fb} W}{W^T S_{fw} W} . \quad (11)$$

3 The design principle and structure process of this method

There are a variety of face recognition now, such as PCA, LDA etc, there are some defects in much of these single recognition methods, so it has brought great difficult to improve the recognition rate. This paper has studied the basic characteristic of existing face recognition, and proposed an integrated method for face recognition based on wavelet subspace. Why this paper using the integrated

method is mainly from the following several aspects to consider: A, using the two-dimensional method as the core method of this method is because the two-dimensional method can construct the covariance matrix of the image and the dispersion matrix from the original image directly. Also it is not need to deal with the process of the matrix vector. So it can greatly reduce the time complexity compared with the one-dimensional method. B, there is strong complementarity between 2DPCA and 2DLDA two methods: When 2DPCA method constructs projection feature matrix through the overall dispersion matrix, it can extract the feature information of the face image without know the classification of the face image. But its recognition time is relatively long, does not use the image information which can be used in classification. The 2DLDA method can make up for the lack of 2DPCA method in these aspects; it can do the classification operation on the image information, and its recognition time is relatively short, but its training time is relatively long, this can be made up by the 2DPCA method using the fuzzy set theory into the 2DLDA method, which can effectively consider the structure information of the sample, and also can add the distribution information of the overlapped samples to the definition of scattering matrix, so it can make the classification more efficient D using the 2DDCT technology to treat the face images in the face image database, it can reduce a lot of redundant information, so as to greatly shorten the recognition time. Through the experiment, the integrated method proposed in this paper is better than other methods in the face recognition efficiency and time complexity.

The specific process of the integrated face recognition method proposed in this paper is as follows (Figure 1):

1) Through the 2DDCT method to deal with the original images, to extract the useful information from the low frequency part of the original image, to discard the useless information in the high frequency part of the original image; then we can obtain the new image through reconstruction.

2) Using 2DPCA method to do the feature extraction to the four face image database, and obtain K characteristic value, then obtain the projection feature matrix Y.

3) Using fuzzy 2DLDA method to de the feature selection to the feature matrix Y, and obtain K_1 characteristic value, then obtain the new projection feature matrix Y_1.

4) Using the nearest neighbor classification method of the test sample recognition, firstly calculated the characteristic matrix of all the training samples B_1, B_2, \ldots, B_K, and gave the category which the training samples belongs to ωt. To recognition a existing test sample A, firstly calculated to obtain the characteristic matrix B of the test sample A, and obtained all the distances form A to all the training samples $d(B, B_i)$. Then took the sample Bi which has the shortest distance form B to B_i; if B_i belongs to the category ωt, so we judged that the sample A belongs to category ωt.
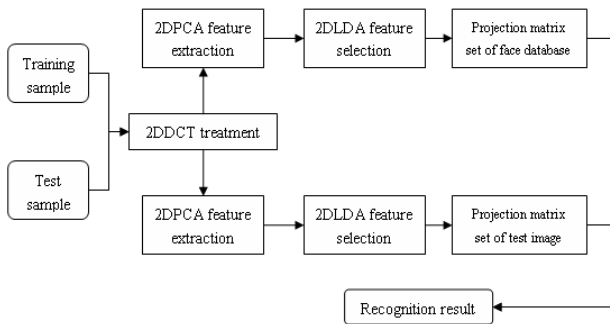
FIGURE 1 The flow chat of face recognition algorithm

4 Experimental results and analysis

4.1 THE EXPERIMENTAL DATA DESCRIPTION

To verify the validity of the method, we use three commonly used face image database as test data. The three face databases are ORL face database, YALE face database and FERET face database. The ORL face database contains face images from 40 individuals, there are 10 images each person with different expressions, a total of 400 images, the image resolution is 92×112. Figure 2 is the 6 face images in the ORL face database. The YALE face database contains face images from 15 individuals, there are 11 images each person with different illumination conditions, different expressions, a total of 165 images, the image resolution is 320×243. Figure 3 is the 6 face images in the YALE face database. The FERET face database contains face images from 200 individuals, each person 7 pieces, a total of 1400 images; the image resolution is 80×80. In order to improve the calculation speed, we select face images from 30 individuals for this experiment. Figure 4 is the 6 face images in the FERET face database.

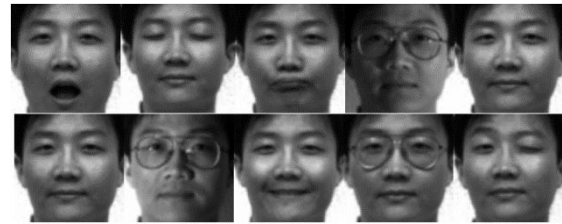FIGURE 2 One person's 10 different images in the ORL face database

FIGURE 3 Part of face images in the YALE face database

FIGURE 4 The six sample images in the FERET face database

4.2 COMPARISON OF EXPERIMENTAL RESULTS

In the experimental process, we used the same test data to test the method of this paper, the PCA face recognition method, the 2DPCA face recognition method, the 2DLDA face recognition method, the 2DPCA+2DLDA face recognition method, then compared and analyzed the test result. Tables 1-3 respectively is the result of recognition in ORL, YALE and FERET database. For convenience of description, the PCA face recognition method is called as method 1, the 2DPCA face recognition method is called as method 2, the 2DLDA face recognition method is called as method 3, the 2DPCA + 2DLDA face recognition method is called as method 4.

TABLE 1 the average identify rates of the different methods on ORL database

	The recognition rate on different number of test sample (%)				
	2	3	4	5	6
Method 1	73.24	78.25	83.05	87.24	90.01
Method 2	74.91	79.12	84.69	88.61	93.52
Method 3	77.36	83.25	88.56	92.56	94.56
Method 4	72.19	75.36	82.64	87.02	89.77
This method	83.22	87.52	91.55	94.42	96.64

TABLE 2 the average identify rates of the different methods on YALE database

	The recognition rate on different number of test sample (%)						
	2	3	4	5	6	7	8
Method 1	86.77	89.53	90.63	91.51	91.13	91.19	92.02
Method 2	87.13	91.23	93.33	94.53	95.09	95.21	95.33
Method 3	90.22	91.42	93.05	93.54	94.93	95.61	96.06
Method 4	85.69	88.79	89.92	90.53	90.69	91.02	91.57
This method	91.12	93.92	95.41	96.29	97.01	97.86	98.44

TABLE 3 the average identify rates of the different methods on FERET database

	The recognition rate on different number of test sample (%)				
	2	3	4	5	6
Method 1	76.76	83.45	88.05	89.02	92.01
Method 2	70.08	75.50	76.24	82.94	86.54
Method 3	75.53	84.25	89.56	90.56	95.03
Method 4	76.02	82.61	87.91	88.67	91.06
This method	83.21	88.52	92.55	94.42	97.86

We can see from the experimental results that the method of this paper is better than other methods in identification efficiency. Firstly we considered the characteristic of different methods, and then it can obtain the effect of the complementary advantages through the integrated approach; at the same time we use the fuzzy set into the 2DLDA method, it fully considered the distribution information o samples, therefore the recognition performance of this paper is better to other methods; at the same time using the 2DDCT method we avoided to calculate the useless and redundant information, so it can short the time of recognition.

5 Summary

Face recognition technology has been put forward 20 years; it has become one of the most popular and the most challenging topics in pattern recognition research fields. With the in-depth study, some scholars have got some achievements about the face recognition technology, and put forward many feasible methods. But many existing methods are still not perfect, they are easy to be disturbed by outside factors, e.g. illumination and pose variation; and much of them has some defects, so it is difficult to make a breakthrough in further improve the recognition rate. This paper fully studied the existing face recognition methods, and mastery of their respective advantages and shortcomings, and learned from each other. So we put forward a face recognition method integrated 2DDCT, 2DPCA and fuzzy 2DLDA method, and described in detail about the principle and the implementation process of the integration method. From the test in the ORL, YALE and FERET face database, we can see that this method is better than other methods in the recognition rate and time complexity, but also has strong robustness against illumination changes.

Acknowledgment

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