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Face Recognition Hybrid Algorithm Based on Improved PCA

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Abstract

As it is simple and convenient to operate face recognition system, and this kind of system is without invasive, making face recognition technology become an important research direction of biometric identification. Face recognition technology involves digital image processing, pattern recognition, computer vision, neural networks and other research areas, has important research values. PCA algorithm is a common method for face feature extraction and recognition. In this paper, an improved PCA algorithm for face recognition is designed for the defect of PCA, traditional PCA algorithm combines with the processing of enhancing local mean and standard deviation of image. The improved PCA algorithm mixed with LDA and 2DPCA algorithm respectively, expands the application scope of PCA algorithm. Experimental results on ORL face database show that the methods designed in this paper have good recognition performance, have certain robustness on the uneven illumination and expression changing human faces.

Keywords: PCA Face Recognition; Enhancing Local Mean and Standard Deviation of Image; LDA; 2DPCA

1. Introduction

With the rapid development of technology and the needs of social security, the requirement of social sectors for the automatic and accurate real-time authentication is everywhere and increasingly urgent. After 911 terrorist attack of the United States, people have a more profound understanding of great challenges of national security. In addition, traditional methods(such as personal identification, certificates and passwords, etc.) used in the application of identification of current social have many security vulnerabilities and are difficult to meet the demand for safety of all areas of society. Therefore, various types of identification technology get extensive attention and support of national governments and scientific communities , biometrics based on inherent properties of human has strong stability and individuality, so this is the ideal basis for authentication, get a lot of manpower and material resources and access to tremendous growth. Compared with sound, fingerprint, iris and other biometric, face images can be obtained in non-contact environment, achieves the purpose of non-invasive for the use of authentication technology. Therefore, face recognition technology has good concealment, its direct, friendly, convenient features can be accepted by users more easily, has become an important research topic in the field of pattern recognition and artificial intelligence. However, face recognition has many problems in practice[1], Face is a natural structure with very complex changes in details, recognition performance often affected by the subtle changes of expression , age, illumination, imaging angle , distance and background. This paper

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designs an improved PCA face recognition algorithm, and then combined with 2DPCA algorithm and LDA algorithm, through experimental validation, the methods designed by this paper get a good face recognition performance.

2. PCA Algorithm Review

PCA (principal component analysis) [2-3] is a common method for linear transformation statistical areas, also known as K_L transform, is a very effective method for dimension reduction. The basic idea is: The high dimensional images vector are changed into low-dimensional vector by K_L transform, and form low-dimensional subspace, then projected face onto the low-dimensional space, get the features which are the basis for identification. When recognizing faces, just compare the characteristics coefficient of the samples to be identified with the characteristics coefficients of the training samples.

Set M as the total number of training samples of human face images, The size of each training sample image is N=w $\times$ h pixels(w rows, h columns), then each training image can be constituted into N-dimensional column vector, namely $x_i = [\cdots\cdots]^T, i = 1, \cdots, M$. So face training samples can be expressed by a matrix: $X = [x_1, x_2, \cdots, x_M] \in R^{N \times M}$. Set μ as the mean vector of all training samples (namely average face), that is $\mu = \frac{1}{M}\sum_{i=1}^{M} x_i$, the covariance matrix of the sample collection:

$$\Sigma = \frac{1}{M}\sum_{i=1}^{M}(x_i - \mu)(x_i - \mu)^T \tag{1}$$

Where use Σ to generate the principal component vectors.

The specific steps of face feature extraction and recognition using PCA algorithm are as follows:

(1) Get principal component vectors by calculating the training samples of face images (eigen faces), define the corresponding eigen-space. Covariance matrix can be expressed as:

$$\Sigma = \frac{1}{M}\sum_{i=1}^{M}(x_i - \mu)(x_i - \mu)^T = \frac{1}{M}AA^T \tag{2}$$

Where $A = [x_1 - \mu, x_2 - \mu, \cdots, x_M - \mu]$, compute the eigenvalues λ_i and eigenvectors μ_i of $\frac{1}{M}AA^T$, select k corresponding eigenvectors of eigenvalues with most characteristic expression to form subspace.

(2) Project the training face images into the subspace, get the projection coefficient of each face so as to constitute "facial feature database". The k selected feature vector can be expressed as: $U = \{u_1, u_2, ..., u_K\}$, get projection coefficient of the training face images by projecting $\mathrm{P}_i = U^T(x_i - \mu)$, P_i is a K -dimensional column vector, represent the position of training samples in the feature subspace.

(3) Project the face images to be recognized into the subspace and obtain the corresponding projection coefficient.. Set the sample face images to be recognized as g , then get projection coefficients by projecting them into subspace $\mathrm{P} = U^T(g - \mu)$.

(4) Face recognition. The simplest method is to measure the distance between characteristic coefficients

of identifying face images and characteristic coefficients of training samples: $\gamma = Dist(\mathrm{P}, \mathrm{P}_i)$.

3. Improved PCA Algorithm for Face Recognition

The traditional PCA extracts global features, so impacted greatly by lighting conditions and facial expression changes[4], the effect of Recognition is not very good. In this paper, the traditional PCA algorithm combines with the processing of enhancing local mean and standard deviation[5], before taking feature extraction, the improved algorithm can reduce the impact of uneven illumination on face recognition, extends the application conditions of PCA algorithm.

Set the image to be processed by the center point $Q(i, j)$ of the $M \times M$ neighborhood $S_{(i, j)}$, the mean of this neighborhood, that is the local mean can be expressed as:

$$E_s = \frac{1}{M} \sum_{i=1}^{M} \sum_{j=1}^{M} x(i, j) \tag{3}$$

Where $x(i, j)$ is the gray scale of the image to be processed. Local variance can be expressed as:

$$\sigma_s^2 = \frac{1}{M^2} \sum_{i=1}^{M} \sum_{j=1}^{M} (x(i, j) - E_s)^2 \tag{4}$$

The specific standard programs of the processing based on local mean and standard deviation are as follows:

(1) Determine darker areas of the image. If $E_s < k_0 E_g$, k_0 is the normal number and less than 1, this indicates that the region of the image is dark areas, and needs to be further enhanced.

(2) Determine the low contrast areas of the image. If the contrast of the image in a region is too low, it can be found in the region does not contain details, does not need to be enhanced. Therefore, the low contrast region of the image can be assumed as: $k_1 \sigma_g < \sigma_s < k_2 \sigma_g$, $k_1 < k_2$ and k_1, k_2 are normal numbers and less than 1.

(3) Take magnification and contrast stretch processing on the determined gray area.

Based on the above program, then the processing of enhancing local mean and standard deviation algorithm can be expressed as:

$$f(i, j) = \begin{cases} \lambda x(i, j) + \beta x(i, j) , & E_g < K_0 E_s \text{ and } k_1 \sigma_g < \sigma_s < k_2 \sigma_s \\ x(i, j) , & \text{others} \end{cases} \tag{5}$$

Where, k_0, k_1, k_2 are less than the normal 1, E_s, σ_s are the local mean and standard deviation, E_g, σ_g is the global mean and standard deviation, λ is the gray amplification factor, β, γ is contrast stretching coefficient. By the above formula, the algorithm uses the local mean and standard values to determine the area needed to be enhanced (id, low intensity and low contrast areas), and would not enhance the region that do not require enhancement.

PCA algorithm combined with the processing of enhancing local mean and standard deviation algorithm can be well highlighted more important parts of the face image (such as eyes, nose, mouth, etc.), then can

get more discriminative in the process of facial feature extraction, can improve recognition rates, also can eliminate the effect of light factors on face recognition.

4. Face Recognition Hybrid Algorithm

4.1. Improved PCA + LDA Face Recognition Algorithm

LDA(Linear Discriminant Analysis), the purpose of this algorithm is to extract the most ability to identify low-dimensional features from high-dimensional space[6] , using these low-dimensional features can distinguish different kinds of samples greatly, and can collect the same category together, that is, Select the features and the ratio between its sample between-class dispersion S_b and sample within classes dispersion S_w is maximum.

When using LDA algorithm for face recognition, we often met a problem that the sample dispersion matrix of the class is singular that the problem of small sample size, using the algorithm combined with improved PCA algorithm designed in this paper and LDA[7] to solve the small sample size problem. Its specific application process is: First using the improved PCA algorithm to reduce the dimensionality of the image, and to ensure that sample within class dispersion matrix is non-singular, that is, the improved PCA algorithm projects primitive face images to a face subspace, so that the sample within classes dispersion matrix is non-singular. Then use LDA algorithm to get optimal transformation from second feature subspace, W_{lda} defined as follows:

$$W_{lda} = \arg\max_{W} \frac{\left| W^T W_{pca}^T S_b W_{pca} W \right|}{\left| W^T W_{pca}^T S_w W_{pca} W \right|} \tag{6}$$

Where, W_{pca} is the projection matrix of improve PCA algorithm, after the combination of two methods, the general transformation matrix can be expressed as: $W = W_{pca} W_{lda}$.

For any testing sample images, the extracted features using combined algorithm is: $x' = W^T x = W_{lda}^T W_{pca}^T x$.

So a much lower dimension matrix of full rank can be get after projecting, which also retain the original identification information, will not affect the final output. Improved PCA algorithm can reduce the dimension sample image well, but the consideration of the type of information into the process of training sample is inadequate; LDA algorithm can take full account of the information contained in the training sample, but there is a small sample problem, and it is difficult to solve. Combining the improved PCA algorithm with LDA algorithm, the improved the PCA algorithm can be used on the training image dimensionality, after dimension reduction, LDA algorithm can be used for training a most discriminative classifier. Experiments show that the method combining improved PCA algorithm with LDA algorithm has some robustness for facial expression and illumination.

4.2. Improved PCA + 2DPCA Face Recognition Algorithm

PCA algorithm constructs covariance matrix of sample image through converting the matrix of sample image into a corresponding column vector, but after converting, the dimension of the sample image is relatively high, increasing the amount of computation for image feature extraction, slowing down the speed of feature extraction. 2DPCA algorithm builds covariance matrix by directly using two-dimensional matrix of sample images[8], the dimension of the matrix is much smaller than the matrix samples after image transformation, which can be more intuitive for feature extraction, the overall amount calculation is much less than the PCA algorithm. However, the projection obtained by using 2DPCA is a matrix and the projection obtained by using PCA is a vector, therefore, all the primary for PCA is a factor, but all the principal components 2DPCA is a vector, the dimension of this vector is equal to the number of rows in corresponding, this is an obvious deficiencies for 2DPCA when used in face recognition.

The method combining improved PCA with 2DPCA designed by this paper can use their advantage. After combination, the specific process is as follows: After the sample image processed by enhancing local mean and standard deviation, using 2DPCA to extract feature from the sample images first and get the corresponding feature matrix, then using PCA method for dimension, which can either reduce the dimension of feature data obtained from the sample images, and can make full use of the advantages of two algorithms to obtain good recognition performance. The principle of the new method shows in Figure 1.

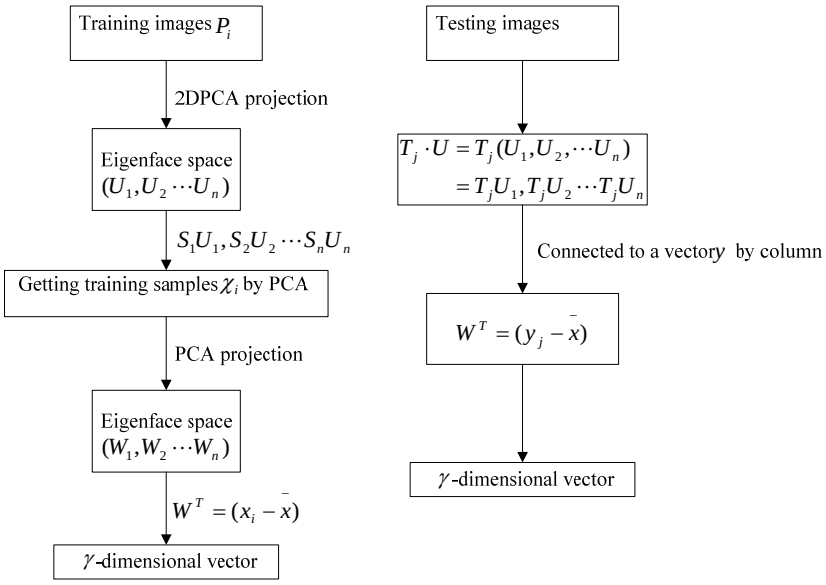

Fig. 1 Flow Chart of Improving PCA+2DPCA

5. Experiment and its Results Analysis

This data used in the experiments is ORL face database[9~10]. ORL face database includes 40 categories of people, each person has 10 images, a total of 400 images, in which the face images are taken in different periods, different perspectives, different facial expressions and facial details, such as eyes closed or eyes open, angry or happy, wearing or not wearing glasses, faces have a great change in attitude and the scale of faces can also have a certain degree of change. The size of each original face image in Yale face database is

100×100 and in ORL face database is 112×92.

For ORL face database, experiment is based on 5 to 8 images of each person as training samples, the remaining 5 to 2 images as the test samples. Figure 2 is the primitive face images in the ORL face image database; figure 3 is face images after treated by improved PCA algorithm, Figures 5 and 7 are average face and eigenfaces obtained by improved PCA algorithm.

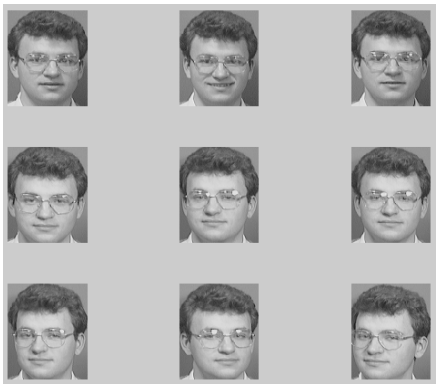

Fig. 2 Original Face Images in ORL

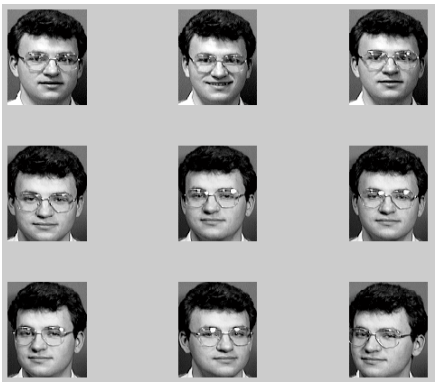

Fig. 3 Face Images in ORL by Improved PCA Algorithm

Fig. 4 Average Face of ORL Obtained by PCA Algorithm

Fig. 5 Average Face of ORL Obtained by Improved PCA Algorithm

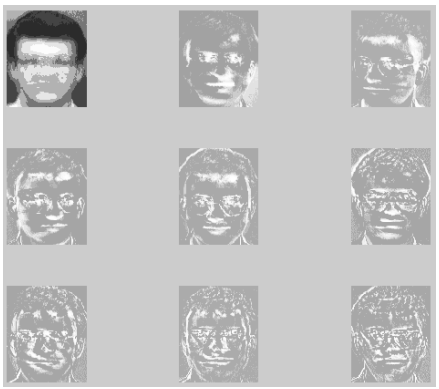

Fig. 6 Eigenfaces of ORL Obtained by PCA Algorithm

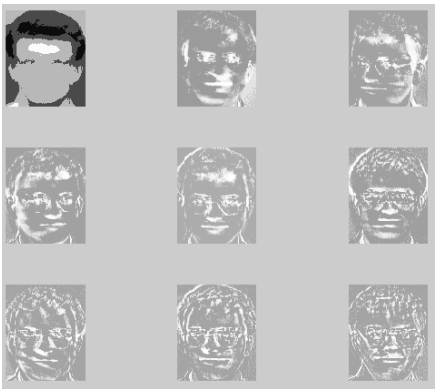

Fig. 7 Eigenfaces of ORL Obtained by Improved PCA Algorithm

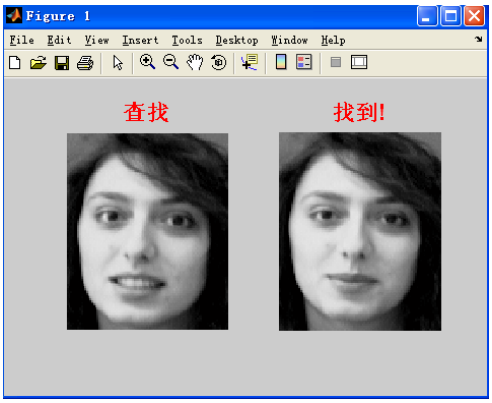

Fig. 8 Recognition Result in ORL by Improved PCA Algorithm

Table. 1 Face Recognition Rate in ORL by PCA and Improved PCA Algorithm

Recognition Rate % \ Training Samples	5	6	7	8
Traditional PCA Algorithm	73.63	77.11	81.56	83.18
Improved PCA Algorithm	80.21	83.53	87.32	90.28
Improved PCA＋LDA Algorithm	83.15	87.76	91.37	94.06

Table. 2 Face Recognition Rate in ORL by 2DPCA and Improved PCA+2DPCA Algorithm

Recognition rate % \ Training Samples	5	6	7	8
2DPCA Algorithm	75.36	78.73	82.92	86.50
Improved PCA+2DPCA Algorithm	81.62	85.00	90.17	93.52

Comparing figure 2 with figure3, figure 3 has a very significant improvement in image clarity. Comparing figure 4 with figure 5, figure 6 with figure 7, improved PCA algorithm can get clearer average face and eigenfaces. The data from table 1 show that face recognition rates is improved very significantly by improved PCA algorithm. Figure 8 is the recognition results after running program.

Table 1 obtained by experiment using ORL database can clearly show that, the algorithm based on improved PCA + LDA has extracted more discriminative feature vectors, which makes its recognition rate much higher than the previous two algorithms, and the recognition rate increasing with the number of training samples increased.

We can see from the data from Table 2, although the face recognition rate of 2DPCA is better than PCA algorithm, and the time needed in recognition has a certain degree of reduction, but the overall recognition performance of 2DPCA algorithm is still not ideal. After the combining improved PCA algorithm with 2DPCA, the recognition rate has greatly improved, that is, after processing the sample images by enhancing local mean and standard deviation, first using 2DPCA for extracting feature from the image needed to be processed, then using improved PCA algorithm to reduce the dimensions of extracted characteristic matrix, combining the advantages of two algorithms skillfully.

6. Conclusion

In this paper, an improved PCA algorithm is proposed combining with enhancing local mean and standard deviation processing first, Based on this algorithm, combining it with LDA algorithm and 2DPCA algorithm and then getting hybrid algorithm for face recognition. Compared with traditional PCA algorithm, face recognition rate has improved very significantly by using improved PCA algorithm, improved PCA+LDA, improved PCA+2DPCA. In the future, I should reduce the impact of facial expression on recognition and make further improvements in real-time face recognition.

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