Face Recognition Based on Block PCA algorithm and Elman neural network

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Abstract: A method of face image recognition based on Elman neural network and block PCA algorithm is put forward. In this method, the first step is to use block PCA algorithm for the face image processing, and gain the face image features of different block number. These features are the inputs of Elman neural network, the output is the corresponding category. The experiment is based on ORL face images database, the simulation partition of the face images into the different sizes for the testing respectively. Through the above experiment results which show that, face image recognition based on the block PCA algorithm and artificial neural network is effective. The application of block PCA algorithm improves the identification accuracy of face image recognition, and which can be used in the further research.

1. Introduction
With the continuous progress of society, the rapid development of computer technology, network technology, people put forward higher requirements for information security. Biometric identification includes many, such as fingerprints, palmprint, face, iris, human ear, hand vein, and so on. Compared with other recognition methods, face recognition is more natural, convenient, friendly and easy to be accepted, so it has been widely studied and applied in[1]. A face image recognition method based on Elman neural network and block PCA algorithm is proposed in this paper. First, using the block PCA algorithm for processing the face image, face image features in different blocks under. Then the features of the above sub images are connected as the input of the Elman neural network, and the output is the corresponding face category.

In the face of image recognition, a small sample problem is often encountered, and the size of the sample is larger than the sample of the sample image vector. When using PCA discriminant analysis method, when the size of the picture (m1×n1) and the original image is divided into pq block number satisfies m1×n1≤Npq, N is the number of training samples, we can avoid the small sample size problem, then turned into a large sample, so the algorithm and theory can the application in a large sample.

2. Elman Neural Network
Elman neural network is a common feedback neural network, which was proposed by Elman in 1990. The output of feedforward network is only determined by the current input and weight matrix, but has nothing to do with the output results of the network. The feedback neural network input includes a
feedback delay input or output data, because there is a feedback input, so it is a kind of dynamic feedback system. The system change process of learning is the process of neuron state, stable state will eventually reach a neuron, marks the end of the learning process. The Elman neural network model adds a layer of acceptance to the hidden layer of the feedforward network. It acts as a step delay operator to achieve the purpose of memory, so that the system has the ability to adapt to time-varying characteristics, and it can directly reflect the characteristics of the process system directly\(^2\).

Elman neural network is generally divided into four layers: input layer, hidden layer (middle layer), receiving layer and output layer (Figure 1). Input layer, hidden layer and output layer are similar to feedforward network. Input units only play the role of signal transmission, and output layer units play a linear weighting role. The transfer function of the hidden layer unit can use linear or nonlinear functions. The accepting layer is also called the state layer, which is used to memorizing the output value of the hidden layer at the first time and return to the input of the network.

![Elman Neural Network](image)

**Figure 1 Elman Neural Network**

Taking Figure 1 as an example, the nonlinear state space expression of Elman network is

\[
y(k) = g(w_3^T x(k)) \tag{1}
\]

\[
x(k) = f(w_1^T x_c(k) + w_2^T u(k-1)) \tag{2}
\]

\[
x_c(k) = x(k-1) \tag{3}
\]

In the formula, \(y\) is a \(m\) dimension input node vector, \(x\) is the element vector of the \(n\)-dimensional middle layer node, \(u\) is a \(r\) dimension input vector, \(x_c\) is a \(n\)-dimensional feedback state vector. \(w_3^T\) connects the weights to the middle layer to the output layer, \(w_2^T\) is the connection weight of the input layer to the middle layer, \(w_1^T\) is the connection weight of the connecting layer to the middle layer. \(g(*)\) is the transfer function of the output neuron, which is a linear combination of the output of the middle layer. \(f(*)\) is the transfer function of the middle layer neurons, often using the S function. The Elman neural network uses the BP algorithm to modify the weight value, and the learning index function uses the sum of square sum of the error.

\[
E(w) = \sum_{k=1}^{n} (y_k(w) - \bar{y}_k(w))^2 \tag{4}
\]

In the form. Input vector for the target \(y_k(w)\).

3. **Experimental Results**

The first use of block PCA algorithm for processing the face image, face image features in different blocks. Then the features of the above sub images after connecting Elman neural network as input, the output is a category corresponding to the face, and finally analysed and compared to experimental results.

3.1 **Data Preprocessing**

In the experiment of face image database came from the ORL face image database. A total of 40 people, each one of 10 images, the image size is 112 x 92, 256 grayscale level, different attitude (deviation of not more than 20 degrees), different expressions and different facial image details, a total of 400 pieces the 60% of them were randomly selected as the neural network pattern recognition toolbox of the training set, validation set proportion is 20%, the remaining 20% of the image as the
The ORL face database is from University of Cambridge, including 40 people, 10 images per person. There are 400 face images, including some volunteers changing posture and facial expression. They are often used in early face recognition experiments. ORL face image database format to pgm format, after reading the MATLAB batch after data preprocessing. Because artificial neural network data format: the number of samples. Therefore x feature vector for the arrangement of the way, each face image will be arranged in a row to measure, after treatment the sample data of 400 people that is composed of the 400 x 10304 sample matrix, for artificial neural network recognition test. Because the size of the face image used in the experiment is 112 x 92 pixels, in order to get the best recognition effect, we do different block test on the image, compare the recognition accuracy of the different block size artificial neural network.

3.2 Image Segmentation

The image is divided into 4 x 4 blocks (Figure 2), and the whole image is divided into sixteen images of equal size as shown in the above image as the input of the PCA calculation. In the same way, the gray matrix of each face image is reconstituted by row priority sorting method. After 400 face images are processed, sixteen image pixels matrix F1, F2,... F15 and F16. The size of the 400 matrices is 400x644, and the sixteen matrices are analyzed respectively. The values of the principal components are calculated by using the princomp function:

The cumulative contribution rate of the first 8 principal components of matrix F1 has reached 80%.

Therefore, in the sixteen block matrix, respectively. Principal component transformation matrix tranMatrix1 = pc(:, 1: 8), so the sample feature matrix after F1=F1×tranMatrix1; tranMatrix2 = pc(:, 1: 7), so the sample feature matrix after F2=F2×tranMatrix2; ... tranMatrix15 = pc(:, 1: 10), so the sample feature matrix after F15=F15×tranMatrix15; tranMatrix16 = pc(:, 1: 12), so the sample feature matrix after F16=F16×tranMatrix16. And then F1, F2,... The sixteen matrixes of F15 and F16 are connected according to the corresponding row rows of the sample. The number of sample features for each face image is as follows:

8+7+11+6+12+18+15+13+18+16+17+20+7+9+10+ 12=199

That is, the face sample data is reduced from the original 10304 dimension to 199 dimension, and the dimensionality reduction data are used for the next Elman neural network classification recognition.

3.3 Elman Neural Network Training

According to the above, the structure of the neural network under the 4x4 block model is set to 199-89-40 (199 input neurons, 89 hidden neurons, 40 output neurons corresponding to 40 different face categories), as shown in Figure 3.
The experimental image is made up of 400 face images. Each person has 10 categories. The training set of neural network, the validation set and the test set are randomly divided into 240, 80 and 80 parts. With the training process, the network error decreases monotonously, while the validation error decreases to a certain point, and then increases (Figure 4). Under the 4×4 block model, the error is minimization when the artificial neural network is trained in the twenty-seventh step, and the validation error is 0.0081 at this time.

Take the 5 test set classification experiment results were analyzed (Table 1), the rate of correct classification according to the classification results, the average 5 times the correct rate of 98.50%. in second and third of the experimental results the correct rate is 100%, that all 80 pieces of test set of image recognition and all. The worst result is fourth experiment results, The accuracy of its classification is also 96.25%. The correct recognition rate shows that with the increase of image blocks, recognition test set accuracy rate increases, And a higher recognition accuracy is obtained. The ROC curve is shown in Figure 5. Almost all the face categories are approximately 1, that is, the recognition effect is excellent. Therefore, face recognition based on artificial neural network and block PCA algorithm is feasible.

| Experiment No | Test set number | Correct identification number | Accuracy   |
|---------------|-----------------|------------------------------|------------|
| 1             | 80              | 79                           | 98.75%     |
| 2             | 80              | 80                           | 100.00%    |
| 3             | 80              | 80                           | 100.00%    |
| 4             | 80              | 77                           | 96.25%     |
| 5             | 80              | 78                           | 97.50%     |
| Average       | 80              | 78.8                         | 98.50%     |

3.4 Contrastive Analysis

According to the experimental results, discuss different blocks under each data index. From the distribution curves of Figure 6 can be seen in the neural network training process, the variance of the validation set increased with the increase of face image blocks mainly showed a decreasing trend. The number is 8, both the minimum variance of the validation set, and then with the number of points increases, variance showed relatively flat trend. With the increase of face image blocks, the complexity of the neural network structure have also increased, The pattern recognition ability is also
increased, so the neural network has a higher recognition precision after the artificial neural network is trained.

![Figure 6]

![Figure 7]

The distribution of the curve can be seen from Figure 7, the neural network recognition test results correct rate is increased with the number of points. Especially the block number from 2, the correct rate of increase in size with stable face image blocks. The number is 16, the correct rate reaches the maximum value, the recognition accuracy is 98.5%. The results show that with the increase of face image blocks, artificial neural network for the test set accuracy is increasing, the human face recognition ability is also increased.

4. Conclusion
This paper is based on artificial neural network (artificial neural network) to study face image recognition. On the basis of experimental and theoretical analysis, test and research are carried out based on block PCA and Elman neural network algorithm. The ORL face image database is used for block PCA test, and the multi block of face image is tested respectively. The test results show that with the increase of face image blocks: the complexity of the Elman neural network is also increasing, which requires more training cycle to complete the training of the Elman neural networks. With the increase of face image blocks, the complexity of the neural network structure have also increased, the ability of pattern recognition is also increased. Therefore, it is feasible to study face recognition based on artificial neural network and block PCA algorithm.

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