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Research on Face Recognition Based on Back Propagation Neural Network

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Abstract. A new method, face recognition based on back propagation neural network, is presented in this paper. The proposed method extracts feature from face image with differential projection and geometrical features into eigenvector which is classified by back propagation neural network. Besides our method, the principal component analysis (PCA)-based method, the linear discriminated analysis (LDA)-based method and the Markov Random Fields (MRF)-based method were also tested for comparisons. The experimental results on ORL face database show that the proposed method achieves an average recognition accuracy of over 98% by using only 13 features. Moreover, the recognition accuracy is enhanced effectively, and the computational complexity and feature dimensions are reduced greatly.

Keywords: face recognition; back propagation neural network; image eigenvector

1. Introduction

Face recognition technology is a research focus in the current digital image processing and pattern recognition, which has important applications in many departments and commercial security systems. Various face recognition methods and systems have been proposed, though most of them are successful in terms of recognition performance in well-controlled environments. Among others, two major challenges remain: the illumination variation and the pose variation [1]. Usually, face recognition systems accomplish the task through face detection, facial feature extraction and face recognition [2]. The overall process is depicted in Figure1.

At present, rapid detection based on color and template-based matching approaches are the two major classes of face recognition methods. These two kinds of methods are naturally different and have respective advantages and disadvantages. In general, the former are applied to the scene by the strong constraints of face detection in images, and the latter are applied to the scene by the weak constraints of face detection in images, which has a greater potential and robust performance [3]. This paper proposed a new recognition technology - face recognition based on back propagation (BP) neural network technology.

This paper is organized as follows. System structure and a short theoretical analysis are given in section 2. The proposed method and simulations are described in section 3. Finally, conclusions and future work are drawn in section 4.

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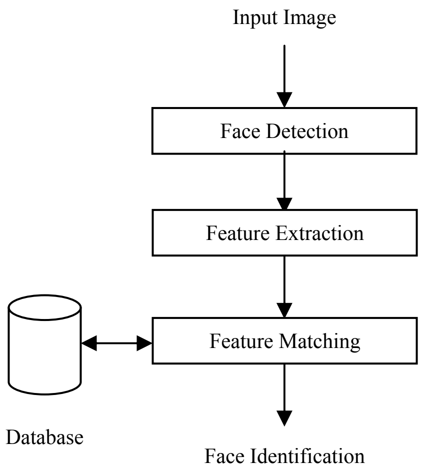

Figure 1. Face Recognition System

2. System Structure and Theoretical Analysis

Artificial Neural Networks, referred to as ANN, is a data classification method based on distance measure. ANN is formed by a series of the identical and interrelated cells (neurons). Links between different neurons can enhance or inhibit the signal. Enhancement or inhibition is implemented by adjusting the weight coefficient between links. Neural networks can achieve classification and regression under the conditions of supervised or non-supervised learning, which is achieved by adjusting appropriate weight coefficients. Output of neural network can converge to the correct target through the weight factor adjustment mechanism. Its important function to analyze the input vectors for obtaining the results their objects belong to. Key issues of face recognition obtain an output vector through the input feature vector of face, and obtain the most similar face by analogy with face image database sample output. Therefore, neural network classifier is very appropriate for a face recognition system. At present, most of the neural networks model uses BP neural network and its variations in the practical application of artificial neural networks.

2.1 System structure

Minsky and Papert showed in 1969 that a two layer feed-forward network can overcome many restrictions, but did not present a solution to the problem of how to adjust the weights from input to hidden units [4]. An answer to this question was presented by Rumelhart, Hinton and Williams in 1986, and similar solutions appeared to have been published earlier [5]. The central idea behind this solution is that the errors for the units of the hidden layer are determined by back-propagating the errors of the units of the output layer. For this reason, the method is often called the back-propagation learning rule. BP neural network is one of multilayer feed forward neural networks based on BP algorithm. BP network model is formed by an input layer, one hidden layer (sometimes two or more) and one output layers under normal circumstances. The network model is shown in Figure 2.

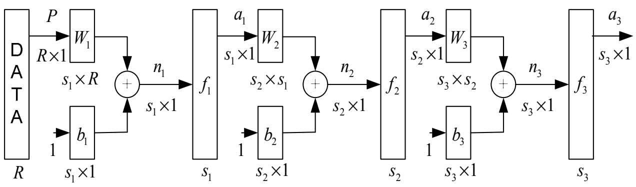

Figure 2. BP network model

2.2 Theoretical analysis

For BP neural network is a supervised learning method, its input is similar to the following sample collection:

$$\left(p_1, t_1\right), \left(p_2, t_2\right), \cdots \left(p_q, t_q\right) \tag{1}$$

where p_i, t_i ($1<i<q$) stands for inputs of network and its outputs respectively.

From figure 1 we know, each layer consists of units which receive their input from units from a layer directly below and send their output to units in a layer directly above the unit. This can be shown as follow:

$$a_{m+1} = f_{m+1}(W_{m+1}a_m + b_{m+1}), m = 0,1,...,M-1 \tag{2}$$

In which M stands for the layer amounts of the network and W stands for the weights matrix. Its input that the first layer's unit receives from directly below is shown as follow:

$$a_0 = p \tag{3}$$

The output of network is the last unit's output, which is shown as follow:

$$h = a_m \tag{4}$$

When a learning pattern is clamped, the activation values are propagated to the output units, and the actual network output is compared with the desired output values, we usually end up with error in each of the output units. The error measure MSE is defined as the total quadratic error at the input P:

$$MSE(x) = E[e^2] = E[(t-h)^2] \tag{5}$$

where t is the desired output and h is the network output.

$$W_m(k+1) = W_m(k) - \partial s_m (a_{m-1})^T \tag{6}$$

$$b_m(k+1) = b_m(k) - \partial s_m \tag{7}$$

where $W_m(k+1)$ is the mth layer's weights matrix after the kth network training, $b_m(k)$ is the mth layer's offset after the kth network training, a_{m-1} is the (m-1)th layer output and s_m is the mth layer sensitivity index for describing the mth layer output error index.

We can input sample vector, adjust W and b, and train the network to minimize MSE. In this way, BP network can achieve the best performance.

3. Simulation Results and Analysis

In this part, a face recognition system based on BP network is presented. Commonly extracting features of face images and the dimension reduction problems is one of key problems of automatic face recognition technology. In this paper, we consider face recognition a task of determining the ID of a given face image using the face images with known ID's. Face recognition process is as follow:

3.1 Collecingt the train set

We test our algorithm on the famous ORL face database which was constructed by AT&T Laboratories at Cambridge. The ORL has 40 distinct subjects; each contributes 10 face images stored in PGM format with slightly varying lightings and different facial expressions [6]. All the subjects are in up-right, frontal position(with tolerance for some pose variation).We use 280 face images selected from the first 7 images of each subject as training and the remaining face images for testing.

In our experiment, we extract 13 geometry feature points of face images such as interpupillary distance, mouth width and so on. Figure 3 shows the 10 images of one object. Train set includes face samples and their eigenvector p. Table 1 shows some images' results.

Figure 3. ORL face database

Table 1 Some samples of train set (1 image per object)

T	1	2	3	4	5	6	7	8	9	10
	32	30	27	34	29	38	26	32	30	30
	23	20	18	23	16	17	18	20	20	16
	50	48	46	48	52	53	54	48	49	50
	13	12	13	11	11	9	14	13	10	10
	13	12	13	11	11	9	14	13	10	10
	52	42	48	53	51	52	49	48	44	48
p	54	43	50	54	52	52	50	52	48	50
	7	9	8	8	11	8	7	7	10	8
	18	20	16	26	20	15	13	13	14	25
	26	38	23	34	30	23	21	20	25	34
	42	38	38	50	46	40	32	33	30	45
	52	49	44	52	53	58	56	58	46	48
	6	4	8	4	6	8	4	5	6	6

3.2 Training network

Under the conditions of supervised learning, training the network with BP algorithm which is described in the II section. The structure of the network is:

- Input layer units:13,face feature after reducing dimension of feature extraction space;
- Hidden layer units:10, values from experience(If the network does not converge in the learning process, we can appropriately increase the number of hidden layer units);
- Output layer units:1, dimension of the network output

We can test the network output selecting a sample from train set. The result is shown in Figure 4.

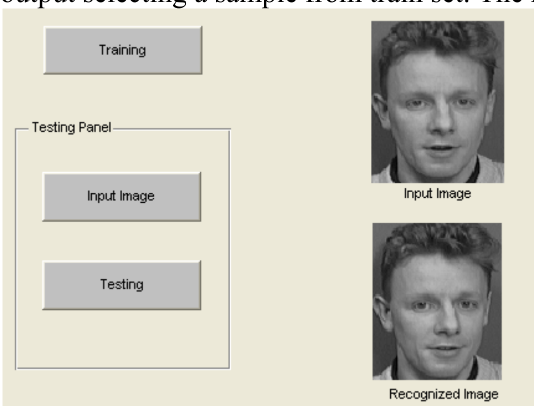

Figure 4. Input image and Recognized image

3.3 Mapping capability testing of network generalization

We can input sample vector and get the network output. Suppose h1 is the network input, h2 is the network output, T is the true value (ID), MSE1 is the total quadratic error between T and h1 and MSE2 is the total quadratic error between T and h2. Table Ⅲ and Figure 5 show the results.

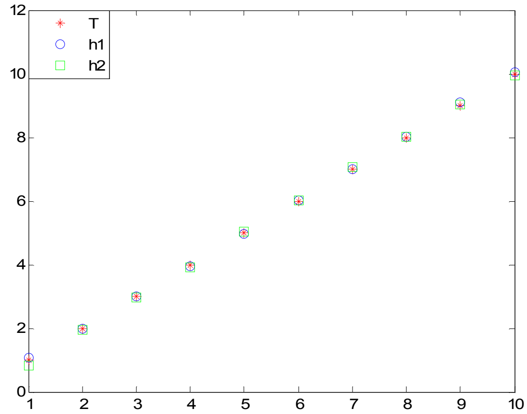

Figure 5. True values, network input and outputs

3.4 Recognition Accuracy

Besides our method, the principal component analysis (PCA)-based method [7], the linear discriminated analysis (LDA)-based method [8] and the Markov Random Fields (MRF)-based method [9] were also tested for comparisons. Table3 shows the result. We tested the recognition accuracy with different numbers of training samples. k (k=1,…, 10) images of each subject were randomly selected for training and the remaining 10-k images of each subject for testing(note that k=1 is not applicable for the LDA-based method). For each value of k, at least 50 runs were performed with different random partitions between the train and test sets, and the average results are displayed. We choose 13 as the final dimension of the PCA- and LDA-based methods according to [8]. Here k is from 1 to 7. The results are shown in Table 2.

Table 2 Result on ORL face database

k	PCA	LDA	MRF	BP
1	56.43	N/A	51.06	57.06
2	71.19	68.84	68.38	69.45
3	79.66	81.74	79.21	80.32
4	84.92	86.74	82.63	83.65
5	88.31	88.87	86.95	85.56
6	90.84	90.86	90.53	95.12
7	94.58	92.62	94.17	98.57

Table 3 True values (IDs), network input, outputs and MSE

T	1	2	3	4	5	6	7	8	9	10
h1	1.0826	1.9817	3.0063	3.9323	4.9551	6.0049	6.9977	8.0199	9.1137	10.0399
MSE1	0.0029									
h2	0.8314	1.9377	2.9647	3.9179	5.0377	6.0268	7.0818	8.0220	9.0200	9.9343
MSE2	0.0054									

4. Conclusions and Future Work

In this paper, we proposed a new method for researching on face recognition technology based on BP NN. Experimental results show that the performance of our method is comparable and sometimes better than other face recognition technology. The advantages of the system achieved are as follow:

- It can be used for face recognition on-line real-time detection. Experimental test shows that network mapping time of less than 1ms;
- High accuracy. Average recognition accuracy shows strong ability to identify the objects;

- It significantly reduced the feature dimension and computational complexity.

In the future, larger and more complicated databases will be tested, and the fluctuations between the different runs could be further analyzed. Computational complexity is still an issue, though a single query needs less than 1ms on the scale of the tested databases.

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