Noisy faces recognition based on PCNN and PCA

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Abstract *–An efficient method called for noisy human faces recognition is proposed based on Pulse Coupled Neural Networks(PCNN), Principal Component Analysis(PCA) and Support Vector Machine(SVM). Firstly, the method employs PCNN to cluster the characteristic region of noisy human faces image. Then, PCA is used to do dimensionality reduction and extract a feature vector for noisy human faces image. And ultimately, the SVM classifier is embedded to finish the human faces noise recognition. The experiments using the ORL faces database show that the new method has a good recognition performance for human faces image with different noise value and outstanding robustness as well.*

Keywords *–Pulse coupled neural network(PCNN); Principal component analysis(PCA); Support vector machine(SVM); Noisy faces recognition.*

I. INTRODUCTION

Face recognition is one of the most challenging research topics in pattern recognition and machine vision[1]. It also provides technical support for related applications[2].For example, face identification[3], human-computer interaction[4], video surveillance[5],intrusion detection[6]. Because of the overall similarity and local variability of human face, the research on it is more representative in biometrics. The study of face recognition is more concentrated on the study of face recognition without nose, but for noise face is less. Especially when the face data contaminated by noise, the variance of data will be greatly damaged, and facial feature extraction is more difficult. A single algorithm for face recognition can't achieve good results. The traditional filter and its improved algorithm for preprocessing of face data is a certain effect, but the research shows that this method to the noise effect is not ideal. Therefore, this paper provides a new way of noisy face recognition using PCNN algorithm combined with the classical feature extraction algorithm.

WANG Jianguo applied the improved PCNN to filtering function for data noise[7]. And then, ZOU B J used PCNN to achieved the filtering noise detection of spatial proximity and intensity similarity[8]. Then Li dan located the impulse noise pixels and preserved the non-noise pixels based on PCNN[9]. John J L proposed a simple model of PCNN and applied it to image processing[12]. HE Guan-nan proposed a new face recognition algorithm based on the PCNN without considering the noise[13]. These papers used PCNN to improve the effect of image processing and testified the effectiveness of the noise face recognition method with PCNN.

PCNN is a new type of artificial neural network[9], which is based on the phenomenon of synchronous oscillating pulse from cat's visual cortex. In the PCNN network, synchronization pulse characteristics of similar groups of neurons can effectively suppress noise in image processing. Importantly, the effect of noise suppression is clustered in a local area. The experiment shows that PCNN can suppress the noise while concentrating the neuron in the process of clustering the regional synchronic oscillations.

PCA is a data reduction and feature extraction algorithm based on subspace analysis. PCA can effectively eliminate redundant information in the process data and greatly reduce the data dimensionality[10]. In this method, it is applied to facial feature vector extraction. SVM is an excellent algorithm for solving multiple classification problems. SVM adopts the principle of structural risk minimization, which can achieve a balance between the capacity and training error of the classifier, and can successfully solve the problem of small sample learning. It enables the data to construct the optimal hyperplane in the high-dimensional feature space with a low VC dimension as the decision plane, which makes the distance from the data to the plane maximum[11]. So SVM algorithm for face has a high recognition performance.

In this paper, the recognition algorithm includes three steps. Firstly, the feature area is clustered by PCNN to realize a certain degree of feature variance information reconstruction. And then, PCA is used to do the dimensionality reduction for human face data and extract feature. Finally, SVM is embedded to classify facial features.

II. PULSE COUPLED NEURAL NETWORK MODEL

Fig. 1 shows the simple model of PCNN, which consists of three parts, the acceptor domain, the modulation domain and the pulse generator[7,12-13] . An image pixel receives connections and feedback inputs from other pixels, then obtains its modulating signal through the modulation domain, so the modulation domain compares the signal to the threshold value and outputs to Pulse generator. And finally, the pulse

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generator will determine to transmit the pulse signal or not.

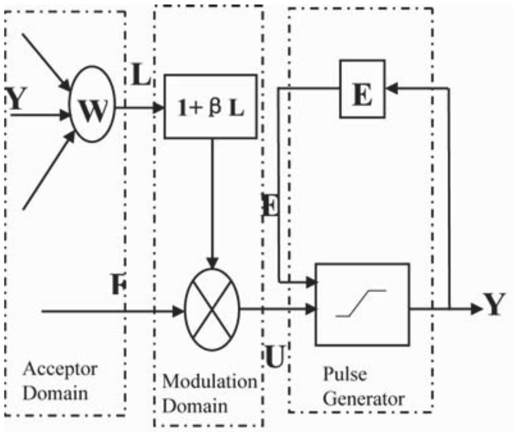

Fig. 1 The simple model of PCNN

The specific PCNN model can be expressed by the discrete iteration equation 1-5[12].

$$F_{ij}[n]=e^{-\alpha F}F_{ij}[n-1]+V_F\sum M_{ijkl}Y_{kl}[n-1]+I_{ij} \quad (1)$$

$$L_{ij}[n]=e^{-\alpha L}L_{ij}[n-1]+V_L\sum W_{ijkl}Y_{kl}[n-1] \quad (2)$$

$$U_{ij}[n]=F_{ij}[n](1+\beta L[n]) \quad (3)$$

$$Y_{ij}[n]=\begin{cases}1, U_{ij}[n]>\theta[n-1]\\ 0, \quad Otherwise\end{cases} \quad (4)$$

$$E_{ij}[n]=e^{-\alpha E}E_{ij}[n-1]+V_E\sum Y_{kl}[n-1] \quad (5)$$

In the accepting domain, the input signal is image's pixel gray-values I_{ij} [13]. It has two channels respectively as the feedback input channel $F_{ij}[n]$ and coupling link input channel $L_{ij}[n]$, The weight matrix of $L_{ij}[n]$ and $F_{ij}[n]$ are W_{ijkl} and M_{ijkl}. Amplification coefficient is V_L at neighborhood coupling links[12-13]. $L_{ij}[n]$ and $F_{ij}[n]$ attenuate exponentially, and their attenuation coefficient are αL and αF [13]. The modulation of the neurons feedback and neighborhood coupling links is $U_{ij}[n]$ called internal state values. The internal activity intensity of neurons is β, which controls the activity intensity of neurons in the vicinity. Dynamic gate of internal state value is $E_{ij}[n]$ [14]. The internal dynamic threshold of the neuron is $E_{ij}[n]$, and its attenuation index and amplitude are αE and V_E. When the internal state signal is larger than the threshold compared $U_{ij}[n]$ and $E_{ij}[n]$, the neuron fires and emits the pulse signal $Y_{ij}[n]$.

III. NOISY FACES FEATURE CLUSTERING OF PCNN

PCNN neurons have the characteristics of dual channel nonlinear modulation and variable threshold exponential decay. These nonlinear parameters of the neuron effectively record the clustering information of the image feature. In this paper, the internal state value of the neuron is used as the image feature region final clustering description.

Figure 2 shows that the face image is processed by PCNN and Wiener filter. The variance of Gaussian noise is σ. Obviously, the noise is well suppressed by PCNN. When the noise variance σ is 0.1, the face image processed by PCNN can clearly show the characteristic contour. And the image quality processed by Wiener filter is not improved obviously. However, in the case of smaller noise pollution, such as $\sigma=0.001$, the image processed by Wiener filtered is more detailed information than the image processed by PCNN. Therefore, the image feature clustering of PCNN is not a general image filtering.

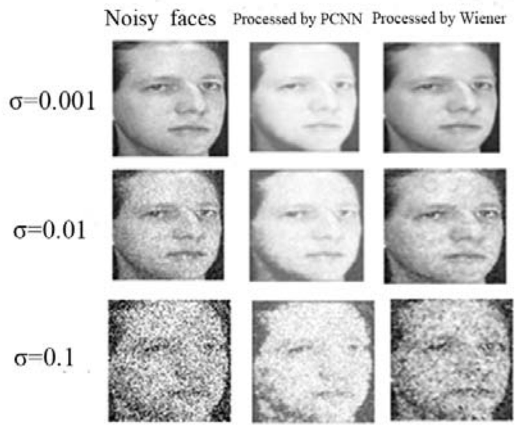

Fig.2 Noisy human face images with different methods

Figure 3 shows the variation of the PCA eigenvector for different noisy faces which is processed by PCNN, in order to illustrate the role of PCNN feature region clustering in faces recognition. Obviously, after the image is polluted by noise, the characteristic value of the image is drastically reduced, that is, the variance information of the image is seriously broken. However, after dealing with PCNN, its eigenvalue is obviously improved, that is, the variance information of the image is partly reconstructed.

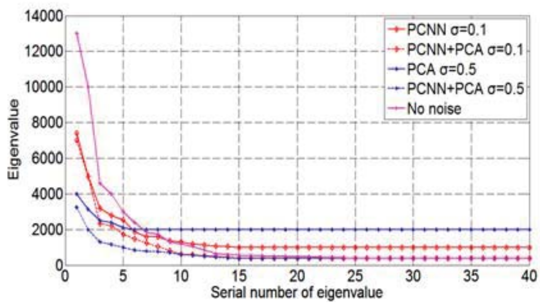

Fig. 3 Comparison of eigenvalues with different methods

IV. THE FACE RECOGNITIONG ALGORITHM OF PCA

A two-dimensional face image can be seen as a vector expressed as X_i .Then we can obtain the face image training set X ($X=[x_1,x_2,x_3,...,x_N]$). The mean image is μ .

$$\mu=\frac{1}{N}\sum_{i=1}^{N}x_i \tag{6}$$

And the mean training set is $\overline{X}$.

$$\overline{X}=\underbrace{[\mu,\mu,\mu,...,\mu]}_{N} \tag{7}$$

Then, we can define the covariance matrix of data X as S_t .

$$S_t=(X-\overline{X})\left(X-\overline{X}\right)^T \tag{8}$$

If the rank of S_t is p , the eigenvalues of S_t are $\lambda_1,\lambda_2,\lambda_3,...,\lambda_p$, the eigenvectors of S_t are $\omega_1,\omega_2,\omega_3,...,\omega_p$. Then we can get the formula.

$$S_t\omega_i=\lambda_i\omega_i \tag{9}$$

The matrix $\lambda_i\omega_i$ constitutes the characteristics of the face image data. Because the vector $\omega_1,\omega_2,\omega_3,...,\omega_p$ is a set of orthogonal vectors, the face image is reduced in the subspace defined by the feature image, and the data is non-correlated in the sense of second order statistics.

V. THE FACE RECOGNITIONG ALGORITHM OF PCNN+PCA+SVM

We have obtained an effective human noisy face recognition method (PCNN + PCA + SVM) shown in figure 4. In the system structure, after the training image and the test image are normalized, they are first sent to the PCNN network in turn to implement clustering processing. Then according to the correlation of the clustering image data, the PCA algorithm uses the covariance calculation of the matrix to realize the variance information extraction of the clustering image data. And the PCA algorithm also uses the orthogonal projection to realize the optimization of the training image feature vector and the test image feature vector extraction in the subspace model. Finally, the one-to-one classification method of SVM algorithm is used to realize the multi-classification of test images, namely faces recognition.

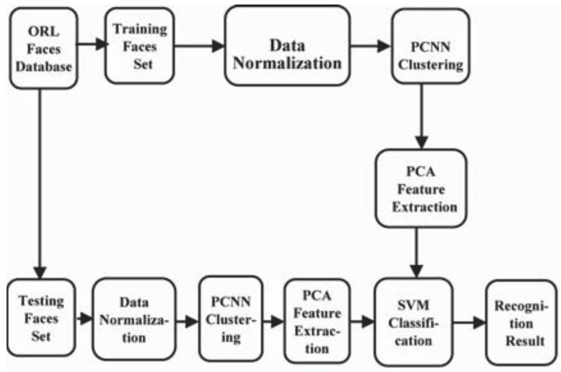

Fig. 4 The flowchart for noisy human faces recognition using PCNN+PCA+SVM

VI. EXPERIMENTAL SIMULATION AND ANALYSIS

The simulation experiments are completed using ORL face database which contains 40 person, whose ages are in the middle of 18-81 years old. Each person has 10 images with the resolution of 112×92[15-16] .The face images are collected at different times, accompanied by changes in expression and appearance [16]. The experiment selects each person's several faces to form the training set, and the remaining several faces compose the test set. To highlight the superior performance of our method, the experimental studies that the face recognition rate is affected by the number of the training sets and different Gauss noise intensity. Especially, the variety of recognition rate under different training sets and different Gauss noise intensity is studied with different recognition methods.

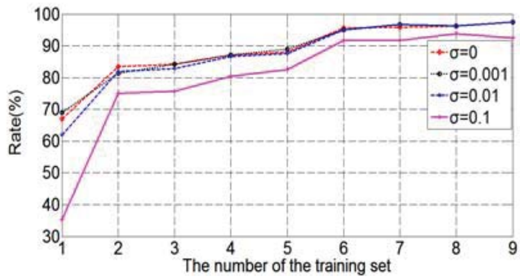

Fig.5 Comparison of recognition rate with different σ

Firstly, we study that the face recognition rate of our method is affected under the training sets when the noise intensity σ is 0, 0.001, 0.01, 0.1. As shown in figure 5, when the noise intensity is constant, the recognition rate increases gradually as the number of the training sets increases. When the number of training sets is greater than 2, the recognition rate has greatly increased and reached a high level. When the number of training sets is greater than 6, the recognition rate is maintained a slight increase. Moreover, no matter how the noise intensity changes, the recognition rate increases with the increase of training sets. Obviously, the recognition rate of our method is also affected by the number of the training sets, which is same as other recognition algorithms.

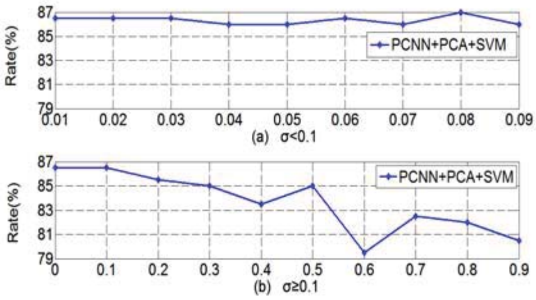

Fig.6 Comparison of recognition rate between σ<0.1 and σ ⩾0.1 using PCNN+PCA+SVM

Secondly, the face recognition rate with different noise intensity (σ) is investigated. Assuming the number of the training set is 5, the experimental result is shown in figure 6. Obviously, as σ increasing, the face recognition rate is generally reduced. Especially, when σ is greater than 0.1, the recognition rate is reduced by a larger range. However, the range of recognition rate is small, when σ is less than 0.1.

In order to investigate the effectiveness of PCNN image feature clustering, we compare the effects of PCNN, Wiener filtering and single PCA algorithm on face recognition. Table 1 show the experimental results of the comparison of the three methods, assuming the number of the training set is 5.

Table 1 shows that PCNN image feature clustering is very effective for noise face recognition. On the one hand, the method proposed in this paper has the highest face recognition rate except when the noise intensity is 0.01. On the other hand, the human face recognition rate of our method reflects the excellent robustness. When the noise intensity is from 0.01 to 0.8, the recognition rate of PCNN method dropped from 86.5% to 79.5%, whose recognition rate decline range is much smaller than the other two methods. On the last hand, although the study at Section 3 found that the images dealt with PCNN lose some detail information compared to the image dealt with wiener filtered, PCNN clustering does not lose the key identification information of face. Because talble.1 shown that the recognition rate of PCNN method is much higher than that of wiener filtering.

Table 1. Comparison of recognition rate among different methods

σ	RATE（%）		
	PCA+ SVM	Wiener+PCA+ SVM	PCNN+PCA+ SVM
0.01	**88**	83	86.5
0.03	86	82.5	**86.5**
0.05	84	82	**86**
0.09	82.5	81.5	**86**
0.1	83	82.5	**86.5**
0.2	76	81.5	**85.5**
0.3	70	81.5	**85**
0.4	69.5	82.5	**83.5**
0.5	59	78.5	**85**
0.6	50	78.5	**79.5**
0.7	43.5	74	**82.5**
0.8	35.5	77	**82**

Finally, we compare the recognition rate of our method and the third-order neighbor method to illustrate the effective role of SVM. Table 2 shows that under different noise intensity, the recognition rate obtained by the SVM classifier is higher than that obtained by the third-order neighboring classifier. In addition, the recognition rate obtained by SVM classifier is more stable. When the noise intensity changes from 0.01 to 0.8, the recognition rate obtained by SVM classifier is only reduced from 86.5% to 82%, what obtained by the third-order neighbor classifier is from 86% to 69.5%.

Table 2 Comparison recognition rate between 3-neighbor classifier and SVM classifier

σ	RATE（%）	
	PCNN+PCA+3-NEIGHBOR	PCNN+PCA+ SVM
0.01	**86**	**86.5**
0.03	**86**	**86.5**
0.05	85.5	**86**
0.09	**86**	**86**
0.1	85	**86.5**
0.2	83	**85.5**
0.3	82.5	**85**
0.4	78.5	**83.5**
0.5	76	**85**
0.6	71	**79.5**
0.7	67.5	**82.5**
0.8	69.5	**82**

VII. CONCLUSION

This paper proposed an effective human noisy face recognition algorithm based on PCNN neural network model, PCA algorithm and SVM classifier. Firstly, the noisy face images are divided to regions by local feature clustering with PCNN which can effectively suppress the noise and partly reconstruct the characteristic variance information of the image. And then PCA is used to extract the feature vector of clustering image. Finally, SVM is employed to realize the classification and recognition of face features. Experimental results based on ORL face database show that the proposed method can obtain better recognition rate and robustness for noise face recognition than the general face recognition algorithm.

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