New Algorithms for Human Face Recognition to aid Criminal Investigations

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***Abstract* — Two important algorithms, including face detection and feature identification were studied in this paper for the specific application areas. Through the analysis of a face recognition algorithm using Support Vector Machine technique in the police force system, methods on BP neural network, Principle Component Analysis (PCA) and Support Vector Machine (SVM) were proposed, and a wavelet decomposition method was used in feature extraction. Experimental results indicate that the proposed algorithm has superior performance over traditional methods, and the recognition rate is higher than traditional algorithms.**

Keywords-Facial recognition,Feature extraction,Wavelet decomposition,SVM, criminal

I. INTRODUCTION

Biometric identification technology is a method using the inherent features of human body into status identification, which has the advantages of secure, reliable and effective[1]. There have many kinds of Biometric identification technologies, such as hand shape[2], fingerprint[3], pronunciation[4] and iris[5] were created according to different features. Facial identification, which is used to recognize the criminal suspect and find some specific persons is more and more important in the public security department[6][7] .

There are two methods used in the facial detection. Feature-based method employs the unvariable features in different situations[8]. Classification-based method makes use of the human facial sample set and non-human facial sample set to design a classifier and detect different human faces on neural network learning ability.

Identification algorithm using heuristic models was applied to the facial detection[9].The features including geometric shape, greyscale and texture are extracted, and used to validate the fitting value to the prior knowledge. This method has a fast identification and can achieve a real time detection and tracking. Samples in this method are relative small, so the identification precision will not be guaranteed in some cases. Identification algorithm using statistic considers the facial area as module feature, and a great deal of samples are trained to construct a classifier. Although this method has the disadvantage of complexity and difficulty in facial description, it is taken more seriously now.

The main work of this paper is to apply the wavelet decomposition and SVM into the human facial identification to enhance the criminal suspect detection in public security. This paper is organized as follows. In Section Ⅱ , facial detection and feature extraction technology are introduced. In Section III, facial identification based on BP neural network, PCA and SVM are outlined, and the training algorithm of SMO is selected. The facial identification method using SVM classifier and wavelet decomposition is designed in Section IV. In order to validate the effectiveness of the proposed method, different facial images are tested. Finally, the conclusions are drawn in Section V.

II. FACIAL DETECTION AND FEATURE EXTRACTION

Facial detection and feature extraction is the first step and a pivotal step in the facial identification. The extraction quality plays a big role in the rate and accuracy of the identification.

A. Facial detection

The basic objective of facial detection is to establish a model for the human face, and compare all the possible detecting areas with the model to calculate a fitting value. Two methods are often used. One is based on the statistic algorithm, such as subspace method. The mapping energy of detecting area on the dimension subspace is considered as the detection statistic value. The less the value is, the nearer the object approaches to the model.

Another method is based on the prior knowledge model. The apparatus distribution rule is taken for a example. The rule of grey scale in the face is given firstly. Then images are selected from coarse resolution to precision resolution according to the given rule. At last the fitting value is calculated to take as the criterion of facial detection.

B. Feature extraction

Method of facial feature extraction is classified into two kinds, geometric feature based method and algebraic feature based method. The former uses a geometric vector to denote the human face, thus the unique characteristic must be guaranteed in selecting the geometric feature vector. The vector will not only indicate the contrast between different faces, but has flexibility to eliminate the effect of time span and illumination. The latter method uses an algebraic vector to describe the facial feature, that is, the facial image is a

projection of the eigenface on the dimensionality reduction subspace.

C. Experimental results of wavelet decomposition

The step of feature extraction algorithm based on wavelet decomposition is implemented as follows[10]:

Step 1: The db4 wavelet of Daubechies wavelet family is selected, and a two layer wavelet decomposition for a 64×64 normalized standard facial image is carried out to obtain two low frequency sub-band image I1 with size of 32×32 and I2 with size of 16×16;

Step 2: Matrix in image I2 is lined to vectors according to the row or array, and normalized to vector V1 with the dimension of 256×1;

Step 3: The image I1 is mapped to a vector Vh with the dimension of 32×1 according to the grey integral on the horizontal direction.

Step 4: The image I2 is divided into two parts up and down. The integral projection of two images in vertical direction is obtained respectively, and then vectors Vv1 and Vv2 with size of 32×1 are achieved;

Step 5: Vectors Vh, Vv1 and Vv2 are combined into a new vector and normalized as V2 with size of 96×1;

Step 6: Vectors V1 and V2 are combined into another new vector named x with size of 352×1, which is regarded as the facial feature vector.

Program of facial feature extraction based on wavelet decomposition is compiled and run on the MATLAB 7.01 system. Two layers wavelet decomposition is applied to facial images, and the images are reconstructed using the decomposition parameters. Experimental results show that the identification error is only 4.3887e-009. The low frequency sub-band images are reconstructed on the two layers wavelet decomposition simultaneously, and the results indicate that the facial image reconstruction of different emotion of one person is same approximately. It is proven that there is favorable robustness for the wavelet transform on the emotion change.

TABLE I VARIABLE VALUES UNDER WAVELET DECOMPOSITION EXTRACTION

Name of image variable	Image size	Dimension	Bytes
J initial image matrix	64×64	4096	32768
I1 low frequency sub-band image (one layer wavelet)	32×32	1024	8192
I2 low frequency sub-band image (two-layer wavelet)	16×16	256	2048
LL3 low frequency subband image (three-layer wavelet)	8×8	64	512
HH1 detail variable (one layer wavelet)	32×32	1024	8192
HH2 detail variable (two-layer wavelet)	16×16	256	2048
HH3 detail variable (three-layer wavelet)	8×8	64	512
LH1 horizontal variable (one layer wavelet)	32×32	1024	8192
LH2 horizontal variable (two-layer wavelet)	16×16	256	2048
LH3 horizontal variable (three-layer wavelet)	8×8	64	512
HL1 vertical variable (one layer wavelet)	32×32	1024	8192
HL2 vertical variable (one layer wavelet)	16×16	256	2048
HL3 vertical variable (one layer wavelet)	8×8	64	512

III. MAIN METHODS OF FACIAL IDENTIFICATION

Identification algorithm using statistic method considers the facial area as module feature, and a great deal of samples are trained to construct a classifier. There are three main methods including feature space based method, artificial neural network based method and support vector machine(SVM) based method.

A. Facial identification based on BP neural network

Recently neural network has achieved great effects in function approximation, pattern identification and data compressing. BP and its modified net has been used in most neural network application [11]. A typical BP network is composed of one input layer, one or multiple hidden layers and one output layer, which is shown in Figure. 1.

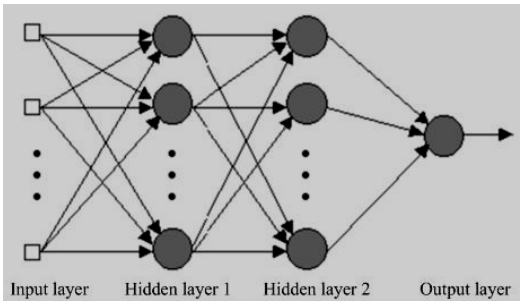

Figure 1. Structure of BP neural network

The transfer function of every node in the BP net is defined as $h(x)$, and the actual output and desired output of the whole net for the ith sample are y_i and o_i respectively. Then the objective function of the net can be written as

$$E = \frac{1}{2}\sum_i \|y_i - o_i\|^2 \quad (1)$$

The error of the BP net output will be transferred from the last layer to the first layer to calculate the error in the hidden layers, and all the weights and thresholds in the net are modified according to the gradient-descent algorithm.

B. Facial identification based on Principle Component Analysis

The basis of Principle Component Analysis(PCA) is the main component variable analysis method[12] which can predigest many objectives into less objectives via the dimension reduction. The initial objective will be substituted by a new integrated linearly independent objective which is obtained from several relevance objectives.

The calculation period of PCA is saved enormously, but the successful identification rate is also reduced. It is a effective method to increase the characteristic vector dimension to improve the rate, however, the storage capacity of facial images will be a great number. The solution of characteristic value and characteristic vector is more difficult because of the large numbers of samples. Moreover, emotion and angle of a face have a great effect on the PCA identification.

The main purpose of this paper is to enhance the identification function of criminal suspects in public security system. The number of samples in the facial identification database of CCICC are tremendous large, so PCA is confined in a certain extent.

C. Facial identification based on SVM

Support Vector Machine(SVM) is a novel learning algorithm proposed by AT&T Bell Lab. In 1990s[13]. The input space can be transferred into a higher dimension space by SVM using a nonlinear transformation defined by inner product function, and obtain the optimal classification surface in this space. SVM has a similar structure as a neural network, which is shown in Figure.2. The output of SVM is linear combination of nodes in hidden layers, and every hidden node is the inner product of a support vector and a input sample.

The input vector is written as

$$x = \left(x^1, x^2, \cdots, x^d \right) \tag{2}$$

And the support vector is defined as

$\left(x_1, x_2, \cdots, x_s \right)$

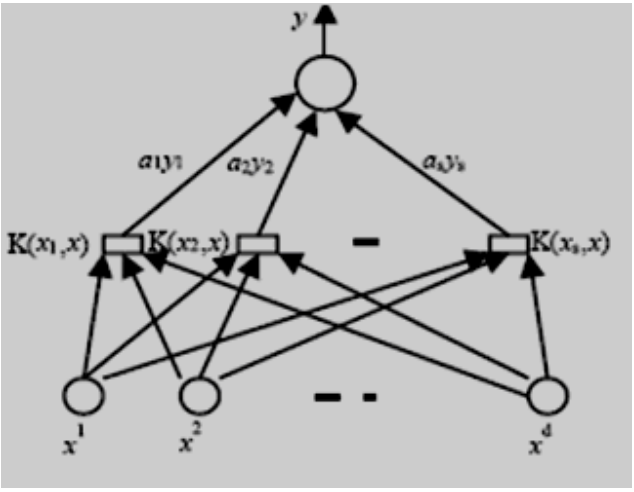

Figure.2 Structure of SVM

Kernel function is utilized in SVM in which the combination of transferring the data into a defined characteristic space via the nonlinear mapping and applying the linear classifier into a characteristic space. The data hidden form is expressed as a characteristic space by the kernel, so it becomes possible for the linear classifier training to resolve the difficulties of characteristic mapping.

Many functions may be selected as the kernel function, but three have been studied in detail and listed as follows

1. Polynomial kernel function is defined as

$$K(x, x_i) = [(x \cdot x_i) +]^q \tag{3}$$

and the q-order polynomial classifier will be obtained.

2. Radial basis kernel function is defined as

$$K(x, x_i) = \exp\left\{ -\frac{\left| x - x_i \right|^2}{\sigma^2} \right\} \tag{4}$$

where the core of every basis function correspond to a support vector, and the output weights are determined automatically, which is different from the classifier obtained by traditional RBF.

3. The inner product is selected as Sigmoid function, which is expressed

$$K(x, x_i) = \tanh(r(x \cdot x_i) + c) \tag{5}$$

The corresponding relationship between the disperse of sample set and optimal classifier is determined firstly in the SVM-based facial identification algorithm, and then the style and parameters of the classifier is set according to the prior knowledge in the training samples. New model can be constructed and optimized in the subsequent training process. A multilevel perception with one hidden layer is implemented by SVM, and the number of hidden node will be confirmed automatically. Local minimum problem which has puzzled the traditional neural network does not exit in this algorithm.

In the algorithm design, initial images will be processed previously, and then trained by SVM. It is found that the identification of facial images can be regarded as two kinds of problems, therefore specified samples are chosen from the whole samples set using the distance formula, and trained by SMO algorithm. The discipline constant C in the training is 1000. The kernel function is selected as RBF, and the kernel constant s 2 is 200, ie. sample number.

IV. EXPERIMENTAL RESULTS

The facial image database in this paper, which is used to verify and evaluate the proposed identification algorithm, is obtained from ORL database of Cambridge University. There are 40 right side grey facial images in this database. The resolution of every image is 100×100, and has a grey scale of 256. 10 images with a black background and different emotion are taken for every person. Some persons have a pair of glasses on their face, and there are also some changes in illumination, size and direction. Several images have slight distortion such as extension in the vertical direction. 10 initial images and normalized standard images of one person are given in Figure.3. All the 10 images are divided into two parts. The first part is used as training and the second part is applied for testing. Images in the training set should be representative which including images with different emotion, direction and illumination. The training set and the testing set have the same image number of 200.

Figure 3. Standard facial images

Normalization is used to the images in advance, and standard image samples of resolution 64×64 is achieved. Then the wavelet transform is applied to compress and extract characteristic of images.

Combination of SVM is needed to resolve the two parts classification problem stated in the previous section. One-to-many strategy is employed in this paper. A specific SVM algorithm for every person is designed to separate sill from others, thus 40 SVM will be determined. Accordingly 40 results obtained from SVM are classified by the nearest classifier. The SVM classification system is the SVM combination, and the kernel function is polynomial function which is written as

$$K(x, x_i) = \left[(x \bullet x_i) + 1\right]^q \tag{6}$$

The Comparison of experimental results between the proposed algorithm and several other method are listed in Tab.2. It is shown that the recognition rate of SVM classifier is higher than other method in facial identification. The SVM classifier which is based on the wavelet decomposition characteristic extraction has less dimension and favorable robustness, and has a higher recognition rate than Eigen-faces+SVM classifier.

TABLE II COMPARISON OF EXPERIMENTAL RESULTS(5/5 EXPERIMENT)

Facial identification method	Recognition rate
Algorithm proposed in this paper(SVM classifier)	99.50%
RBF Network	98.00%
PCA	99.00%
Eigen-faces+SVM	98.50%

The order of the polynomial function is also tested and the experimental results are shown in Tab.3. It is indicated that polynomial with 2 and 3 order has the highest recognition rate, and the support vectors are minimum. It is also shown that the polynomial with 4 and 5 order needs less support vector, but the storage and calculating time are increased tremendously. The recognition rate of one order polynomial, i.e. linear SVM is much lower than other methods, which is indicated that the distribution of facial samples is not linear divided.

It is obvious from the experimental results that the sample classification is implemented by less support vectors in SVM. The algorithm is predigested by the combination of transferring data to a characteristic space using nonlinear mapping and applying linear classifier in characteristic space. The SVM facial identification method based on wavelet decomposition will be effective for the criminal suspect.

A whole identification system shown in Fig.4 is designed on the basis of theoretic analysis and experiments proposed previously.

V. CONCLUSION

Two key technologies of facial feature extraction and identification are studied in this paper. To resolve the difficulty of SVM training, a novel algorithm based on wavelet decomposition is proposed. Principle Component Analysis and Support Vector Machine are discussed, and the facial feature extraction is designed. Experimental results show that feature extraction using wavelet decomposition and classifying with SVM has the superiority over traditional methods, and the recognition rate can be enhanced. More experiments should be performed in the near future to improve the proposed algorithm to satisfy the identification request of public security.

REFERENCES

[1] Zhang M H, Zhang Y Y., "The Application of Biometric Identification Technology in ATM System", Applied Mechanics & Materials , pp. 3419-3421, 2013.

[2] Zhai L, Hu Q., "The research of double-biometric identification technology based on finger geometry & palm print", Artificial Intelligence, Management Science and Electronic Commerce, International Conference , pp. 3530−3533, 2011.

[3] Zhai L, Hu Q., "The Research of Double-Biometric Identification Technology Based on Handprints", E-Product E-Service and E-Entertainment (ICEEE), 2010 International Conference onIEEE, pp. 1-3, 2010.

[4] Xiang Z, Sumii T, Iwahashi N, et al., "Correcting phoneme recognition errors in learning word pronunciation through speech interaction", Speech Communication, vol.5, No.1, pp. 190−203, 2013

[5] Shin A K Y, Kim Y G, Kang R P., "Enhanced iris recognition method based on multi-unit iris images", Optical Engineering, vol. 52 No. 4, pp. 602-602, 2013.

[6] Yoshino M., "Facial Image Identification in Criminal Investigation", Technical Report of Ieice Prmu, vol. 99, pp. 67-74, 1999.

[7] Liu C., "The Application of Biometric Identification in Criminal Investigation", Journal of Railway Police College, pp. 34-41, 2010.

[8] Zhao W, Chellappa R, Phillips P J, et al., "Face Recognition: A Literature Survey", Acm Computing Surveys, vol. 35, No. 4, pp. 399-458, 2000.

[9] Rafael C.Gonzalez RichardE.Woods, "Digital image processing", Publishing house of electronics industry, No. 10 , pp. 23-27, 2007

[10] Dong J, Jian M, Gao D, et al., "Reducing the Dimensionality of Feature Vectors for Texture Image Retrieval Based on Wavelet Decomposition", IEEE, vol.1, pp. 758-763, 2007.

[11] Yaermaimaiti Y, Halidan A., "Face Recognition Algorithm Based on Improved BP Neural Network", Computer Technology & Development, pp. 35-42, 2010.

[12] YILihamuYAErmaimaiti., "Human Face Recognition Based on Improved PCA and LDA Fusion Algorithm", Computer Simulation, vol.30, No.1, pp. 415-414, 2013.

[13] Nello Critinini John Shawe-Taylo, "Introductory theory of Support vector machine", Publishing house of electronics industry, vol. 3, pp. 82-128, 2004.