Combining Multiple Features for High Performance Face Recognition System

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Abstract-*This paper proposes the combination multiple facial feature extraction methods and probabilistic neural network for facial recognition. Firstly, we use horizontal projection of 2-D image to obtain accumulated energy profile signal. Secondly, we obtain the statistical distribution of facial gray images. Finally, we adopt wavelet transform to extract low frequency coefficients from 1-D energy profile signal and statistical distribution of face gray level values as feature vectors, which is applied with probabilistic neural network in facial identification and facial matching. Thus, the proposed method is evaluated on the ORL face database for face recognition. Besides, the face recognition system is also built on PC, and it is evaluated on real data set by the proposed algorithm. The experiment results show that the proposed method possesses the excellent performance. Because of low complexity, it is also suitable for a hardware-friendly and resource-constrained embedded environment.*

Keywords : face recognition; wavelet transform; probabilistic neural network

1. Introduction

Face recognition [1] is the process of automatically differentiating the people on the basis individuality information from their facial images. The technique is used to verify the identity of a person accessing a system. It is favorable for reliable authentication system that the use of automatic identity verification systems based on biometric products.

Two types of face recognition system are depicted in Figure 1, which is face identification and face verification. Both face identification and face verification use a store data set based on reference patterns (templates) for N known face image. Both involve similar analysis and decision techniques. Verification is simpler because it only requires comparing the test pattern against one reference pattern and it involves an alternative decision: Is there a good enough match against the template of the claimed face images? The error rate of face identification can be greater because it requires choosing which of the N face images known to the system best matches the test image or " no match" if the test image differs sufficiently from all the reference templates.

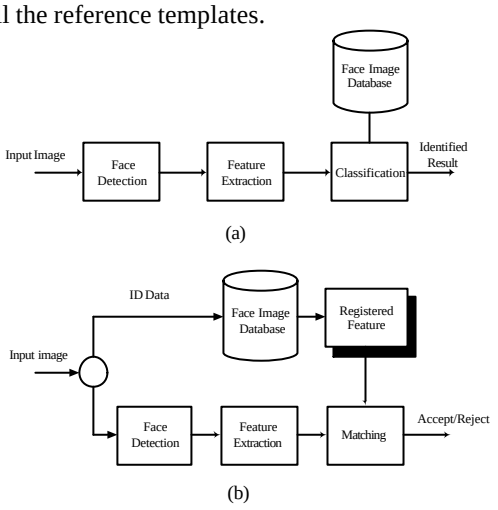


Fig 1. Face recognition scheme (a) Identification; (b) Verification.

The face recognition system consists of three sub-system: a face detection system that include detecting and locating faces, feature extraction system that composes of the proposed algorithm, and a probabilistic neural network (PNN)[12] used as pattern classifier and applied successfully for different applications. However, as the increasing dimensionality could lead to higher computational cost, a dimensionality reduction procedure that eliminates information redundancy and allows for further information transform through limited channels is performed. For the purpose of dimensionality reduction procedure in face images space is performed by implementing 1-D wavelet transform for face

image features extraction and as the consequences.

There are many traditional algorithms [3-7], [14-17] successfully applied to face recognition, but they are too complex to be applied in real-time face recognition. To address these problems related to computational and memory requirements, we focus our investigation on low complexity and high accurate face recognition system. Firstly, to reduce system complexity, we use horizontal projection of 2-D image to obtain 1-D accumulated energy profile signal. The face image is replaced with 1-D energy profile signal. But the 1-D energy profile signal is affected by rotation, shift of facial images. To address the problem, we propose a method combining the previous algorithm and the information of face gray level as two sets of feature vectors, because the information of face gray level are against the rotation, shift of facial image. The combination of two facial features can provide much better recognition performance. Secondly, we adopt 1-D discrete wavelet transform to extract low frequency coefficients as feature vector from the two facial features. In our experiments, the wavelet permits to further reduce the system complexity and obtain discriminant feature vectors. PNN [12-13] is a very simple classifier model that has proved to be effective for face recognition. Finally, the combination of the new method and PNN is evaluated on the ORL face database [11] for face recognition. The basic conclusion drawn from our experiments is that the proposed method is well suitable for a low complex computation and low power devices.

2. Low complexity face recognition system

The proposed method is different from traditional 2-D face feature extraction method [17]. Firstly, 2-D image is transformed into 1-D energy profile signal and the distribution of facial gray information is also extracted. The 1-D wavelet transform is applied in the two facial features. Finally, the PNN is selected as the pattern recognition classifier because of its high performance and high efficiency.

2.1 Horizontal projection

To reduce system complexity, we adopt horizontal projection to obtain 1-D energy profile signal. The exploit the benefits driving from concentrated energy, every column are accumulated as energy signal. This method is evaluated on the face database, which contains a set face images as fig 2 (a) taken at the Olivetti Research Laboratory (ORL) in Cambridge University, U.K. [11]

Let X be an face image of size 112x92

$$\mathbf{X} = \begin{bmatrix} x_{1x1} & \cdots & x_{1x92} \\ \vdots & \ddots & \vdots \\ x_{112x1} & \cdots & x_{112x92} \end{bmatrix}$$

According to the symmetric property of the face, the horizontal signal can be accumulated as 1-D energy signal as fig 2(b).

$$\mathbf{Y} = \begin{bmatrix} y_1 \\ \vdots \\ y_{112} \end{bmatrix}$$

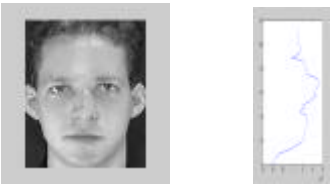


Fig 2. (a) Facial image (b) 1-D energy signal

2.2 Representation of face gray level information

Owing to the 1-D profile signal is affected by rotation, shift of the facial images. In order to improve the recognition performance, we extract the information about the distribution of facial gray level values as fig 3. The range of gray level values is from 0 to 255. But the dimensionality of facial gray image is so large, we adopt wavelet transform to reduce the dimension.

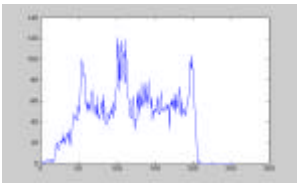


Fig 3. The distribution of facial gray image

2.3 Wavelet transform

The wavelets [9-10] to signal and image processing have provided a very flexible tool for engineers to apply in various fields such as speech and image processing. In a face recognition system, the 2-D wavelet transform is only used for preprocessing. The goal of preprocessing often reduces the dimensions of feature vectors and removes noise. Nevertheless, the computational complexity is comparatively high. Thus, the paper proposes 1-D wavelet transform as filters to extract feature vectors, and it can reduce the computational complexity.

Here, we develop a feature extraction algorithm based on the 1-D wavelet transform. By combining the appropriate wavelet transform coefficients with the PNN gets an excellent result.

The wavelet is constructed from two-channels filter bank as Fig. 4. In wavelet decomposition of 1-D signal, a signal is put through both a low-pass filter L and a high-pass filter H and the results are both low frequency components A [n] and high frequency components D [n]. The signal y [n] is reconstructed by the construction filters $\tilde{H}$ and $\tilde{L}$.

The wavelet filters are used to decompose signal s into high and low frequency by convolution.

$$D[n] = \sum_{k=-\infty}^{\infty} s[k] \cdot H[n-k] \Leftrightarrow D = \langle s, H \rangle$$

$$A[n] = \sum_{k=-\infty}^{\infty} s[k] \cdot L[n-k] \Leftrightarrow A = \langle s, L \rangle$$

In order to construct multi-channel filter, we can cascade channel filter banks. Fig.5 is a 3-level symmetric octave structure filter bank. This is an important concept from multi-resolution analysis (MRA).

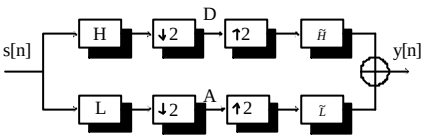


Fig.4. Two-channels filter bank

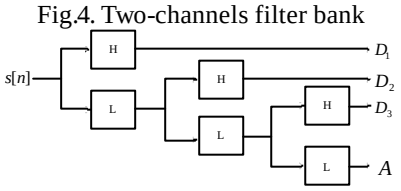
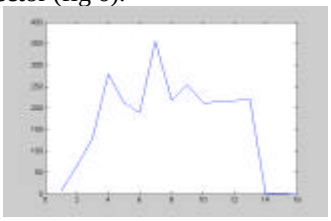
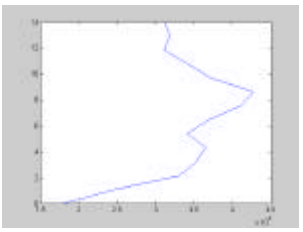


Fig.5. 3-level octave band filter bank

The purpose of the horizontal projection approach is to reduce dimensions of face vectors and to become a 1-D energy profile signal. Besides, the energy is more concentrated in the signal so that the wavelet coefficients are more discriminant. But the energy signal is affected by rotation, shift of the facial images. To cope with this problem, we propose the information of facial gray image as second facial feature. The two facial feature vectors are so large. We resort to wavelet transform to decompose the two facial feature vectors into low frequency as feature vector (fig 6).



(a)



(b)

Fig 6. (a) The 3-level wavelet transform of 1-D energy signal
(b) The 4-level wavelet transform of facial gray image

3. PNN classifier

In 1988, D.F.specht [12] have designed a very efficiency probabilistic neural network (PNN) that is well adapted to manipulate classification problem. The purpose of this paper is for speaker recognition. The experiment reveals it is excellent in efficiency and performance.

The basic concept cited Bayesian classifier to PNN model as fig 7. To probability density function, it has three assumptions:

1. The classification of probability density function is the same.
2. Probability density function is Gaussian distribute.
3. The variance matrix of Gaussian distribute probability density function is diagonal matrix.

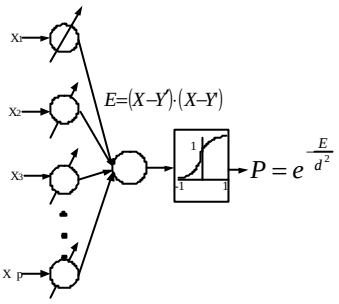


Fig 7. The simplified structure of PNN model

When the external factor is change, the PNN only change the weight of new data. The other neural network needs not to change all network weights.

The PNN model has been used for classification, because of its simplicity, performance and efficiency. Hence, this paper adopt PNN model as classifier.

4. Experiment procedure and its result

In this section, we refer to the proposed method as the feature extraction method for face recognition. The face database used in the comparison is the ORL face database and the

classifier used is a probabilistic neural network (PNN). The database contains 400 face images acquired of 40 individuals (10 images per individual). The images were taken at different times, which contain quite a high degree of variability in lighting, facial expression (open/closed eyes, smiling/nonsmiling etc), pose (upright, frontal position etc), and facial details (glasses/no glasses).

In the following experiments, a total of 200 images were randomly selected as the train set and another 200 images as the testing set, in which each person has five images. Such procedure was carried out 10 times. The experimental platform is the AMD K7 Athlon 750 MHz processor, 384M SDRAM, Windows XP, and the software is Matlab 6.1.

4.1 Evaluation on face identification with the proposed methods

For face identification system, the goal is to determine which one of a group of known face images best matches the input face image samples. Firstly, the feature vectors are extracted from all image samples. All feature data is randomly divided into train data X and test data Y. Train data X directly input PNN as weight of hidden layer. To input a test data Y is to obtain a reference output P in PNN model.

$$P = e^{\frac{E}{d^2}}$$

Where

$$E = (X - Y') \cdot (X - Y')$$

Let j the number of train data. Thus, we set the reference probabilistic values of 1-D profile signal feature is P_{1j}, the reference probabilistic values of face gray level feature is P_{2j}, the threshold of 1-D profile signal feature is T1, and the threshold of facial gray image feature is T2. The decision function P (j) consists of output probabilistic values.

The OR and AND logical operators is adopted as the fusion technique. If P_{1j} is greater than T1 or P_{2j} is greater than T2, then output the P_{1j} into P. If P_{1j} and P_{2j} are greater than threshold, then output probabilistic value P_{1j} into P (j). Finally, P (j) includes one and more output probabilistic values. To select the maximum value of P (j) determines the class of Y.

This method is better than the traditional PNN. In order of the consistence of output probabilistic value, we select the P_{1j} as the output probabilistic value. Besides, it can also provide better parameter estimates and decrease the computational complexity. The face recognition rate R is defined:

$$\mathbf{R} = \frac{\mathbf{N}_1}{\mathbf{N}_2} \times 100\%$$

Where N_1 denotes the number of correct recognition in face images, N_2 the total number of face images.

Our experiment results compare with the different levels of 1-D wavelet decomposition. The results show in Table 1. The represent of db is the different length of Daubechies filters. The represent of db1-1+db1-4 is low frequency component of 1-D energy profile signal extracted by first level wavelet transform and low frequency component of face gray level information extracted by the fourth level wavelet transform.

Table 1. The recognition performance of comparing with different level wavelet

Methods	The best recognition (%)	The average recognition (%)	Feature vector dimension
db1-1+db1-4	99	97.15	72
db1-2+db1-4	99.5	97.05	44
db1-3+db1-4	100	97	30
db1-4+db1-4	91	86.45	23
db2-1+db1-4	99	96.6	73
db2-2+db1-4	99.5	97.5	46
db2-3+ db1-4	100	98.2	32
db2-4+db1-4	96	92.95	25
db3-1+db1-4	99.5	97	74
db3-2+db1-4	100	97	47
db3-3+db1-4	100	97.9	34
db3-4+db1-4	98.5	95.9	27

From these results of Table 1, it shows the superiority of using the proposed method. The 1-D wavelet transform can achieve the average recognition rate of 98.2 and the best recognition rate of 100 percent using db2-3 +db 1-4. The db2-3 +db1-4 provides the best recognition performance and we select it for subsequent evaluation.

4.2 Evaluation on face identification with existing methods

The previous methods [3-8], [14-18] for face recognition mainly focus on feature extraction and matching. Thus, we only analyze and compare the performance and efficiency of feature representation and matching of these methods. Here, we will present a comparison between the proposed method and their methods described on the ORL databases. Each person randomly chose five images as train set and the other five images as test set. In the same comparison standard, table 2 gives the results of these methods.

Table2. The results of comparing with different method

Methods	The best recognition rates (%)	Feature vector dimension
Wavelet +eigenfaces[3]	98	140
discriminant waveletface +NFS [18]	96.4	60
PCA (eigenfaces)[19]	93.5	37
2DPCA[19]	96	(112*3)
The previous method [20]	99	16
The proposed method	100	32

Looking at the results shown in Table 2, we can find the proposed method has the best performance. That is, the performance of the proposed method is much better than the other methods.

4.3 Implement and evaluation the proposed method for real-time face recognition on PC

In this experiment, we want to prove the proposed method suitable for real-time face recognition system in real life. Our experimental setup is simple: a cheap web camera is plugged into a personal computer. The camera is pointing to a complex background. A person moves in the scene, the facial image is captured and matched with face databases for verification.

The face recognition system is based on builder c++ 6.0. The face recognition system consists of three sub-system: a face detection system that include detecting and locating faces, feature extraction system that composes of horizontal projection and 1-D wavelet transform, and a Probabilistic Neural Network (PNN) used as pattern classifier.

Firstly, the face recognition system is to detect, locate the person's facial image (fig 8). Thus, the facial image is captured shown in fig 9.

Fig 8. Finding the person's facial image

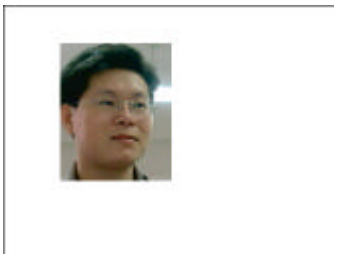


Fig 9. The captured facial image

Secondly, we can perform face verification and the captured facial image is compared to the images in the database.

Finally, we set a threshold. If the PNN output probability is greater than the threshold, the person is accepted. Otherwise, the person is rejected.

We capture 40 facial images from 4 people on fig 10. For each person, we randomly sampled 5 images as train set, and the remaining 5 images as test set. To prove the reliability of the face recognition system, all recognition rates are determined by averaging 1000 different rounds of face recognition. The evaluation is reported in Table 3.

Fig 10. The face image databases

Table3. The results of face recognition system

Methods	The best recognition (%)	The average recognition (%)	Feature vector dimension
The previous method [20]	100	97.8	23
The proposed method	100	99.99	34

From the results, the proposed method can achieve the average recognition rate of 99.99 and the best recognition rate of 100 percent. This is an excellent recognition performance.

The face recognition system is implemented on the PC. From the results, the proposed method can achieve the average recognition rate of 99.99 and the best recognition rate of 100 percent. The advantage of the proposed algorithm is its simplicity and excellent performance. Thus, The proposed technique is very suitable for real-time face recognition system. The system performed very well on our different experiments.

5. Conclusions

It is well-known that if the dimension of the network input is comparable to the size of the training set, which is the usual case in face recognition, the system will easily bring about over-fitting and result in poor generalization. In this paper, a general design approach using a PNN classifier for face recognition to cope with small training sets of high dimensional problems is presented. A novel paradigm, the results of combining the multiple features, and PNN is encountering and has excellent performance and efficiency.

From the simulation results described in experiments, it is clear that the proposed method has excellently high performance and efficiency than the traditional methods. The complexity of feature extraction method for face recognition is excellently low. The recognition time of each image is less than 50 ms. The face recognition has proved to be very effective, achieving a considerable computational reduction while keeping excellent performance. We have proved the proposed method is suitable for embedded system.

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