Face Authentication System for Information Security

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Abstract

This paper proposes the combination two facial feature 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 facial gray images 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 authentication 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

Security based on possessing tokens (like tickets) or knowledge (such as passwords) is frustrating and inconvenient. Not only can legitimate users be turned away because of their forgetfulness, but also the access codes can be easily stolen and often copied. That is why websites and computer networks are turning to biometric technology that identifies people from their personal features like their faces, irises or their voices. They cannot get lost and can't be copied. Biometric feature is the most secure and convenient authentication tool. It can't be borrowed, stolen, or forgotten, and forging one is practically impossible. Biometrics measure individuals' unique physical or behavioral characteristics to recognize or authenticate their identity. Common physical biometrics include fingerprints; hand or palm geometry; and retina, iris, or facial characteristics. The choice of faces over other biometric technologies was dictated by cost and ease of use. Facial features for website access is equipping users' computers with web camera all over the world.

Face recognition is the process of automatically differentiating the people on the basis of 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 Fig. 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 images. 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.

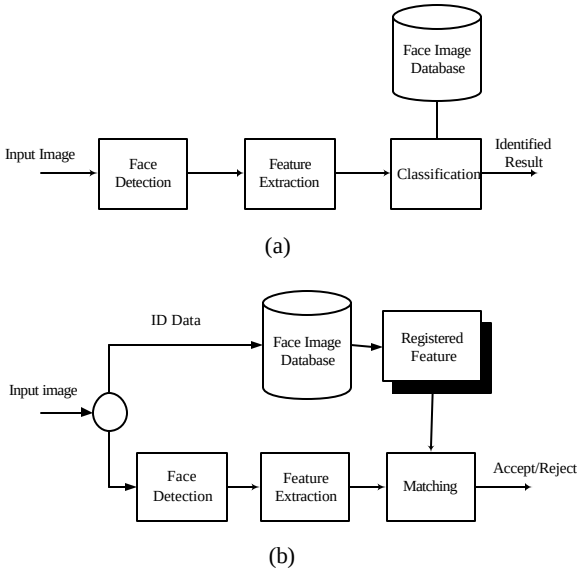

Fig 1. Face recognition scheme (a) Identification; (b) Verification.

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 horizontal projection and 1-D wavelet transform, and a Probabilistic Neural Network (PNN)[11] 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 [3-8], such as eigenfaces [4-5], linear discriminant analysis [6], waveletfaces [8], 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. Secondly, we adopt 1-D discrete wavelet transform to extract low frequency coefficients as feature vector from 1-D energy profile signal. In our experiments, the wavelet permits to further reduce the system complexity and obtain discriminant feature vector. PNN 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 [12] 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 2D face feature extraction method. Firstly, 2-D image is transformed into 1-D energy profile signal, and 1-D wavelet transform is

applied in 1-D profile signal. Finally, the PNN is seen as a classifier in face recognition system.

The purpose of horizontal projection is used as preprocessing to reduce the dimension of face images and obtain 1-D energy profile signal. Each face is projected onto the 1-D energy profile signal. The energy is more concentrated in the signal so that the wavelet coefficients are more discriminant, and the set of coefficients obtained is as feature vectors. The wavelet transform technique has shown as an effective procedure for the reduction of dimensions. Finally, the probabilistic neural network(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. To exploit the benefits driving from concentrated energy, every column is 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. [12]

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 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 2D 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, we obtain an excellent result.

The wavelet is constructed from two-channels filter bank as Fig. 3. 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. 4 is a 3-level symmetric octave structure filter bank. This is an important concept from multi-resolution analysis (MRA).

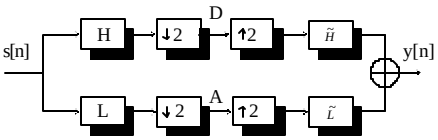

Fig. 3. Two-channels filter bank

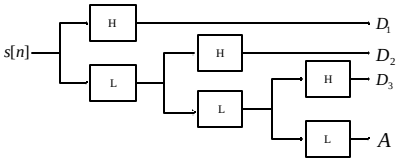

Fig. 4. 3-level octave band filter bank

The purpose of the horizontal projection approach is to reduce dimensions of face vectors and to become a 1-D energy profile signal. Thus, the efficiency of face recognition will improve very much. But the energy signal is still very large. To overcome this problem, we resort to wavelet transform to decompose signal into low frequency as feature vector (Fig. 5).

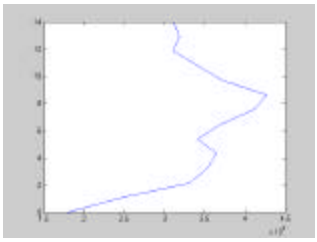

Fig 5. The 3-level wavelet transform of 1-D energy signal

3. PNN Classifier

In 1988, D.F. Specht designed a very efficiency probabilistic neural network (PNN)[11] 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. 6. 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.

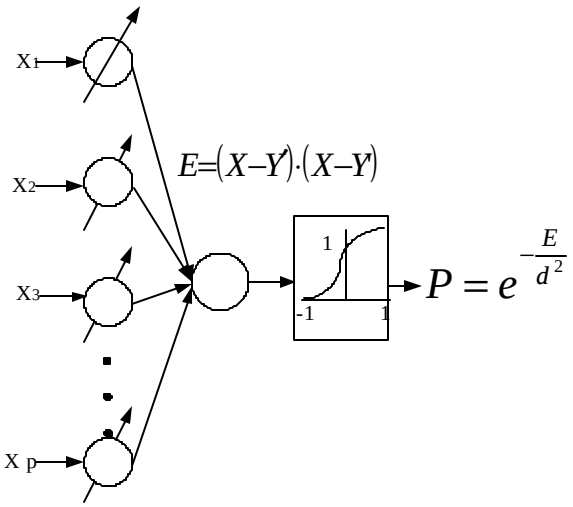

Fig 6. The simplified structure of PNN model

When the external factor is change, the PNN only changes 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 adopts PNN model as classifier.

4. Experiment Procedure and Its Result

In this section, we refer to our method of combining horizontal projection with wavelets 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).

Experiments are divided into face identification and face verification. 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 under Different Levels of 1-D Wavelet Transform Decomposition

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

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

If we have N image samples, then there are N reference output probabilistic values P in PNN model. To determine is whether Y belongs to the image from a variety of images by the maximum probabilistic value P. To select is the maximum P determining the class of Y. 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, Table 2. The represent of db is the different length of Daubechies filters.

Table 1. The average recognition of comparing with different levels of 1-D wavelet decomposition

Different levels of different wavelet filters	Average recognition (%)
db1-1	92.4
db1-2	92.6
db1-3	92
db1-4	86.2
db2-1	92.35
db2-2	93.45
db2-3	95.65
db2-4	91.8
db3-1	92.55
db3-2	93.2
db3-3	93.8
db3-4	91.5

Table 2. The best recognition of comparing with different levels of 1-D wavelet decomposition

Different levels of different wavelet filters	The best recognition (%)
db1-1	95
db1-2	95
db1-3	94
db1-4	91
db2-1	95
db2-2	95
db2-3	99
db2-4	94.5
db3-1	95
db3-2	96.5
db3-3	97.5
db3-4	94.5

From these results of Table 1 and 2, it shows the superiority of using 1-D wavelet transform. The 1-D wavelet transform can achieve the average recognition rate of 95.65 and the best recognition rate of 99 percent using db2-3 wavelet filters. The db2-3 provides the best recognition performance and we select it for subsequent evaluation.

4.2 Evaluation on Face Verification with db2-3 Wavelet Transform Decomposition

Face verification system refers whether the face image samples belong to some specific face image or not. Thus, the result has only two alternatives, accept or reject the identify claim depending on the calculation by a threshold.

The performance of face verification is estimated with the Equal Error Rate (EER). When FAR is equal to the FRR, the EER is obtained as Fig. 7. False acceptance ratio (FAR) is ratio of accepting an unregistered face image to reject a registered one. False rejection ratio (FRR) is ratio of rejecting a registered face image to accept an unregistered one. The high performance of face verification system is in low EER.

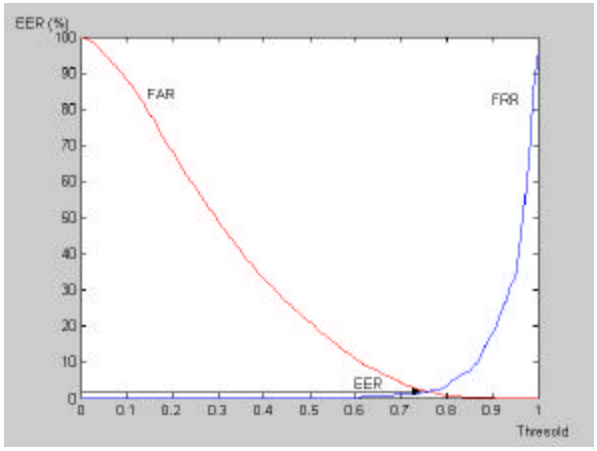

Fig. 7 Equal Error Rate (EER)

In the experiment, we replace the recognition rate with EER. The results show in Table 3.

Table3. The best EER of comparing with third level of db2 wavelet filters

Methods	db 2-3
The best EER (%)	2.37
Feature vector dimensions	16
Feature extraction time (ms) /per image	47.1
Recognition time (ms)/per image	0.25

In these experiments, the best EER is 0.0237, the feature vector dimensions have only 16, and the recognition time per image is shown to be 0.0473 sec. These results further illustrate the superiority of the proposed method. These observations demonstrate that the face recognition techniques can be suitable for real-time face recognition system showing that the complexity of the proposed method is very low. But it has still high performance.

4.3 Evaluation on Face Identification with Existing Methods

The previous methods [3-8] 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 4 gives the results of these methods.

Table 4. The results of comparing with different method

Methods	The best recognition rates(%)	Feature vector dimension
Wavelet +eigenfaces [5]	98	140
discriminant waveletface +NFS [8]	96.4	60
PCA (eigenfaces) [4]	93.5	37
2DPCA [3]	96	(112*3)
The proposed method	99	16

Looking at the results shown in Table 4, we can find the proposed method has the best performance. The dimensionality of the feature vector (16 elements) in the proposed method is very low than the others. That is, the proposed method has very high efficiency and performance.

5. Implementation and Evaluation of 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 subsystem: a face detection system that includes detecting and locating faces,

feature extraction system that composes of horizontal projection and 1-D wavelet transform, and a Probabilistic Neural Network (PNN)[11] 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 with 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 5.

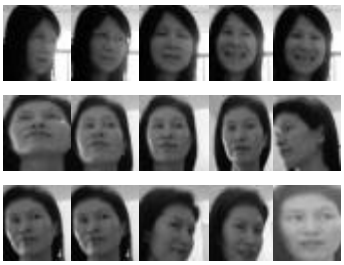

Fig 10. The face image databases

Table5. The results of face recognition system

Method	The best recognition rate (%)	The average recognition rate (%)	Feature vector dimension
db 1-3	100	97.8	23

The face recognition system is implemented on the PC. It has high efficiency and high performance. The system performed very well on our different experiments. Owing to the high recognition performance, the proposed method is proven to possess high efficiency and high performance for Internet security. In the future, the proposed technique will be applied for embedded system.

6. Conclusions

It is well-known that if the dimension of the network input is comparable to the size of the train 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. Firstly, face images are projected onto 1-D signals by the horizontal projection. Then the 1-D signal features are extracted by the 1-D wavelet transform. A novel paradigm, the results of combining the horizontal projection, 1-D wavelet transform, 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 good performance. We have proved the proposed method is suitable for information security, because of its high efficiency and high performance.

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