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Short Paper

Multiple Facial Features Representation for Real-Time Face Recognition

CHIA-TE CHU, CHING-HAN CHEN AND JIA-HONG DAI
Department of Electrical Engineering
I-Shou University
Kaohsiung County, 840 Taiwan
E-mail: cld123@giga.net.tw, pierre@isu.edu.tw, jerome@miat.gotdns.org

The combination of two face feature extraction methods for face recognition is proposed. The proposed approach treats the face recognition problem as a one-dimensional (1-D) problem rather than two-dimensional (2-D) geometry. The horizontal projection and the statistical distribution of facial gray image are adopted respectively as 1-D energy signal representation for each face image. To reduce the dimension of signal and improve the performance, the wavelet transform is proposed. Finally, the probabilistic neural network is used to recognize each individual. The performances of the proposed method are evaluated and compared with other proposed methods on ORL database and IIS database. The experiment results show that the performance of the proposed method is much better than the other methods. Besides, we developed a computer system that can capture face image in a complex background and recognize the person by comparing characteristics of the face to those of known individuals. The proposed algorithm is also evaluated on a real environment database and the results are encouraging. Experimental results show that the proposed method possesses excellent performance as well as low memory requirement.

Keywords: face identification, face verification, wavelet transform, eigenfaces, probabilistic neural network

1. INTRODUCTION

Face recognition [1] 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 the biometric products.

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) [2] used as a pattern classifier and applied successfully for different applications [3-5].

There are many traditional algorithms [6-12] successfully applied to face recogni-

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tion. In 1991, Turk and Pentland [7] presented a well-known eigenface for face recognition. The eigenface approach is based on linearly projecting the image space to a low dimensional feature space. This is achieved by using the Principal Component Analysis (PCA) to find a set of new basis vectors. However, the eigenface does not provide any information for class discrimination. Thus, the linear discriminant analysis (LDA) [9] is proposed for projection of the set of feature vector. The approach finds a subspace for classification in which the ratio of the between-class scatter and the within-class scatter is maximized. Besides, many researchers [3, 10] propose multiresolution wavelet transform to extract waveletface, and perform the eigenface or LDA on wavelet faces to improve the recognition performance. However, these algorithms 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 performance face recognition system. To address these problems, we propose a method combining two kind of face feature extraction method with wavelet transform for face recognition. Firstly, The combination of two face features can provide much better recognition performance than single face feature extraction method. Secondly, we adopt 1-D discrete wavelet transform to extract low frequency coefficients from the two facial feature vectors. In our experiments, the wavelet permits to further reduce the system complexity and obtain discriminant feature vector. Thirdly, PNN [2] is regarded as a very simple classifier model that has proved to be effective for face recognition. Finally, the proposed method is evaluated on the ORL face database [15]. 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 [10-12]. It is possible to improve the performance of face recognition system with the proposed method by the combination of 1-D energy profile [3] signal and facial gray level information. We refer to these traits as soft biometric traits because they provide some information about the individual, but lack the distinctiveness and permanence to sufficiently differentiate any two individuals. Heckathorn *et al.* [16] have shown that a combination of soft attributes like gender, race, eye color, height, and other visible marks like scars and tattoos can be used to identify an individual only with a limited accuracy. Hence, the ancillary information by itself is not sufficient to recognize a user. However, soft biometric traits can complement the traditional (primary) biometric identifiers like fingerprint and face and hence improve the performance of the primary biometric system.

2.1 Representation of Statistics using Facial Gray Images

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 image as Fig. 1. The range of gray values is from 0 to 255. Because the dimensionality of facial gray image is so large, we adopt wavelet transform to reduce the dimension.

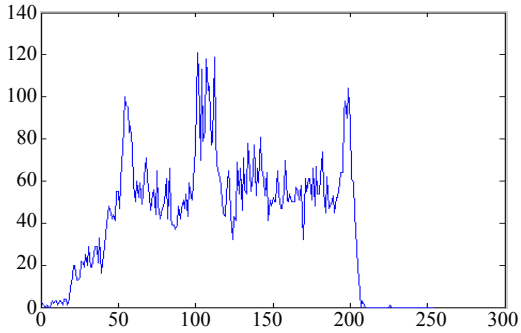

Fig. 1. The distribution of facial gray image.

3. EXPERIMENT PRODURE AND ITS RESULT

In this section, there are two databases used to evaluate the performance of the proposed method. The Database 1 is the ORL database and the Database 2 is the IIS database [10]. They are well-known public domain face databases. The ORL database contains 40 subjects and 400 images. The IIS database contains 100 subjects and 3,000 images. Examples of typical face images from the IIS database are shown in Fig. 2. The experimental platform is the AMD K7 Athlon 2GHz processor, 512M DDRAM, Windows XP, and the software is Matlab 6.1.

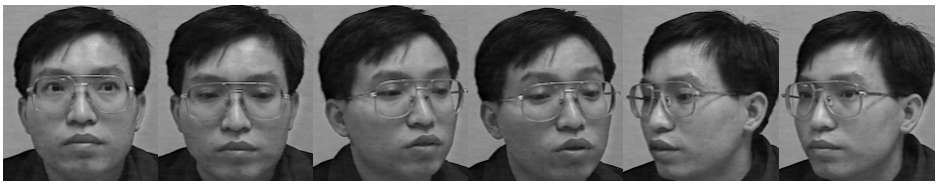

Fig. 2. Sample face images in the IIS database.

To show the statistical robustness of proposed method, the average recognition rates are determined by averaging 100 different rounds of face recognition and the best recognition rate is the best result from 100 different rounds. In experiments, different methods are evaluated in terms of recognition rates or EER.

3.1 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 are randomly divided into train data X and test data Y. Train data X directly input PNN [2] as weight of hidden layer. To input a test data Y is to obtain a reference output P in PNN model.

$$P = e^{-\frac{E}{\delta^2}} \tag{1}$$

where

$$E = (X - Y') \cdot (X - Y'). \tag{2}$$

We set the reference probabilistic values of 1-D profile signal feature is $P1$, the reference probabilistic values of facial gray image feature is $P2$, and P is $P1 \times P2$. To determine is whether Y belongs to the image from a variety of images by the maximum probabilistic value P. The face recognition rate R is defined:

$$R = \frac{N_1}{N_2} \times 100\% \tag{3}$$

where N_1 denotes the number of correct recognition in test data, N_2 the total number of test data.

In experiments, the proposed methods are evaluated on the ORL face database. The face images are sampled from 40 people, each person having 10 pictures with varying lighting, facial expressions (open/closed eyes, smiling/nonsmiling), facial details (glasses /no glasses) and head pose (tilting and rotation up to 20 degrees). The size of each image is 112 × 92. For each person, the five images are randomly sampled as prototypes and the remaining 5 images as queries. The experiment results compare with these proposed methods. The results show in Table 1. In experiments, there are two feature vectors from the information of horizontal projection and facial gray image. They are decomposed by db2 – 3 and db1 – 4, respectively. The represent of db is the different length of Daubechies filters. In Table 1, The DWT is represent of the db2 – 3 + db1 – 4. The represent of db2 – 3 + db1 – 4 is low frequency component of 1-D energy profile signal extracted by third level wavelet transform and low frequency component of facial gray image information extracted by fourth level wavelet transform.

Table 1. Comparison of recognition performance in ORL database.

Methods	Best recognition rates	Average recognition rates
Gray Image Information + PNN	99%	93.99%
Gray Image Information + DWT + PNN	99%	94.67%
Horizontal Projection + PNN	97%	92.01%
Horizontal Projection + DWT + PNN [3]	99%	95.65%
Combination of Horizontal Projection and Gray Image Information + DWT + PNN	100.00%	98.80%

From these results of Table 1, it shows the superiority of using combination of horizontal projection and gray image information + DWT + PNN. The previous method [3] treats 1-D horizontal projection and wavelet transform as a feature extraction algorithm. The best recognition performance is encouraging, but the average recognition is still improved. So as to improve the recognition performance, the information of facial gray image is proposed as the soft biometric trait. Typically, the experimental results show combining the two biometric traits can provide the recognition performance than single

biometric trait. The best recognition performance can achieve 100 percent in the head pose rotating up 20 degree and the dimension of feature vector has only 32. In the following experiments, the proposed method is on behalf of the combination of horizontal projection and gray image information + DWT + PNN.

3.2 Evaluation on Face Identification with Existing Methods

The previous methods [3, 6-12] 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 database. Each person is randomly chosen 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.

Table 2. The results of comparing with different method in ORL database.

Methods	The best recognition rates	Feature vector dimension	Feature extraction time (second/per image)	Recognition time (second/per image)
Wavelet + eigenfaces [6]	98%	140	0.03	1.25×10^{-5}
Discriminant waveletface + NFS [10]	96.10%	60	N/A	N/A
PCA (eigenfaces) [11]	93.50%	37	N/A	N/A
2DPCA [11]	96%	(112×3)	N/A	N/A
The previous method [3]	99%	16	0.015	1.17×10^{-5}
The proposed method	100%	32	0.19	1.48×10^{-5}

Table 3. The results of comparing with different method in IIS database.

Methods	The best recognition rates	Feature vector dimension
Wavelet + eigenfaces [6]	89.67%	120
Discriminant waveletface + NFS [10]	96.4%	60
The previous method [3]	91.17%	24
The proposed method	96.92%	70

So as to verify the proposed methods, we also evaluate the recognition rates on the IIS face database. The face images are sampled from 100 people, each person having 30 pictures with varying viewpoints and expressions. The size of each image is 175×155. For each person, the six images are randomly sampled as prototypes and the remaining 24 images as queries.

Looking at the results shown in Tables 2 and 3, we can find the proposed method has the best performance and high efficiency. That is, the performance of the proposed method is much better than the other methods. Owing to high efficiency and simplicity of the proposed method, it is very suitable for low power applications or HW platforms with small portions of memory available (for example, smartcard).

3.3 Evaluation on Face Verification with Existing Methods

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. 3. 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.

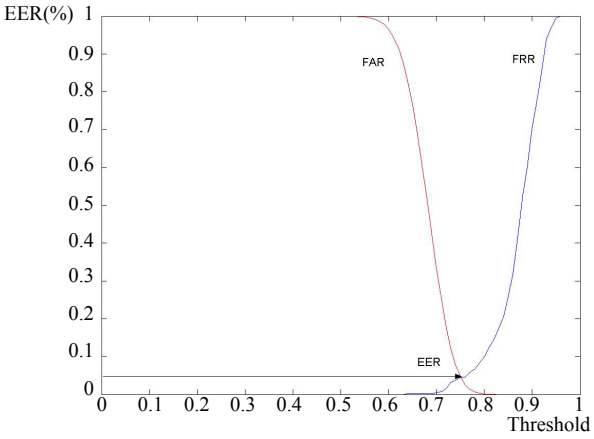

Fig. 3. Equal error rate (EER).

Table 4. The results of comparing with different method in ORL database.

Methods	The best EER	The average EER
Wavelet + eigenfaces [6]	4.58%	6.23%
The proposed method	1.53%	2.25%

Table 5. The results of comparing with different method in IIS database.

Methods	The best EER	The average EER
Wavelet + eigenfaces [6]	10.49%	6.1%
The proposed method	1.81%	2.24%

In the experiment, we replace the recognition rate with EER. The results show in Table 4.

In these experiments, the results further illustrate the superiority of the proposed method. These observations demonstrate that the face recognition technique possesses excellent performance.

3.4 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 database 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.

In face detection system, the Sobel mask is applied on the given image the system retrieves an appropriate edge image and the Hough transform is applied to find the location of face image (Fig. 4). Thus, the facial image is captured shown in Fig. 5.

Fig. 4. Finding the person's facial image.

Fig. 5. 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. 6. 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 1,000 different rounds of face recognition. The evaluation is reported in Tables 6 and 7.

From the results, the proposed method can achieve 100 percent in both the average recognition rate and the best recognition rate and the recognition time is less than 1 ms. The face recognition system can achieve a high efficiency, because the proposed method is very simple and the dimension of feature is very low.

Fig. 6. The face image databases.

Table 6. The recognition rates of face recognition system.

Methods	The best recognition	The average recognition
The previous method [3]	100 %	97.8%
The proposed method	100%	100%

Table 7. The ERR of face recognition system.

Methods	The best ERR (%)	The average ERR (%)	Recognition Time
The proposed method	0.00%	0.70%	< 1 ms

4. CONCLUSIONS

From the simulation results described in experiments, it is clear that the proposed method has excellently high performance than the traditional methods. The complexity of feature extraction method for face recognition is excellently low. The face recognition has proved to be very effective, achieving a considerable computational reduction while keeping excellent performance. In future, the proposed technique will be applied for embedded system.

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Chia-Te Chu (朱家德) was born in Tainan, Taiwan, R.O.C., on January 12, 1974. He received the B.S. degrees from I-Shou University, Taiwan in 2003. He is studying on Ph.D. degree in the Department of Electrical Engineering, I-Shou University. His current research interests include wavelet transform, neural networks, and biometrics recognition.

Ching-Han Chen (陳慶瀚) was born in Kinmen, Fujian, R.O.C., on October 14, 1963. He received the B.S. degree and Master degree in Geophysics from National Central University, Taiwan, R.O.C. in 1986 and 1988 respectively, D.E.A (Diplôme d'Etudes Approfondies) in Informatique, Automatique et Productique in 1992 and Ph.D. degree in 1995 from the Franche-Comte University, France. He is now an associate professor, since 1995, with the Department of Electrical Engineering, I-Shou University, Taiwan, R.O.C. His research interests include multimedia signal processing, biometrics, and embedded system design.

Jia-Hong Dai (戴嘉宏) received his M.S. degree in Electrical Engineering from I-Shou University, Taiwan, R.O.C. in 2000. He currently is pursuing the Ph.D. degree in the Department of Electrical Engineering at I-Shou University. His research interests include computer vision, neural networks, fuzzy theory, and embedded system.