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Practical Aspects of Face Recognition

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***Abstract*—**Current systems for face recognition techniques often use either SVM or Adaboost techniques for face detection part and use PCA for face recognition part. In this paper, we offer a novel method for not only a powerful face detection system based on Six-segment-filters (SSR) and Adaboost learning algorithms but also for a face recognition system. A new exclusive face detection algorithm has been developed and connected with the recognition algorithm. As a result of it, we obtained an overall high-system performance compared with current systems. The proposed algorithm was tested on CMU, FERET, UNIBE, MIT face databases and significant performance has obtained.

***Keywords*—**Adaboost, Face Detection, Face recognition, SVM, Gabor filters, PCA-ICA.

I. Introduction

IN recent days, a high-demand for new security methods has been increased due to the terrorism, high-jacks, kidnap etc. In the field of security, especially bio-security systems are being more popular than the past since bio-security-based systems are difficult to break. Fujitsu Corp [1] has developed vein recognition system and has already placed it to ATM machines. On the other hand, Oki Electric Corp [2] has already announced that they would release new ATM with embedded face-recognition functionality within 2008. Omron Corp developed a new face recognition system for mobile telephone industry [3].

Face recognition systems are getting popular since they are the only one bio-security system that someone gets authenticated all of a sudden with no touch, with no special operation. Even if someone intends to do something bad, the reaction can be psychologically prevented. Despite those advantages and technological development, it is a common problem of all industry that face recognition systems are weak to environmental factors especially in outside, to the position of the person, angle of the face to the camera, distance etc. Hence, many algorithms and methods have been proposed to cover this lack on detection and recognition since now [4][5]. The researches have done in two major subjects: Face detection and face recognition. Lienhart [6] used Haar detection method for a fast face detection to perform a real time detection in open air. Maydt [7] did a research on face detection based on support vector machines to increase the performance of face finding in short processing time. While those researches are being done, CMU [8] performed some face recognition methods like Principle Component Analysis (PCA), Local Distance Analysis (LDA) and Independent Component Analysis(ICA).

As far as we evaluate those methods, face detection methods are categorized on either image-based approaches which apply a window-scanning technique or face feature-based approaches.

Face recognition can be categorized in two: Eigenface-based methods and pattern-matching methods. Since our work combines both face detection and recognition, we will explain our proposed algorithm separately. First, we propose a new face detection algorithm which mainly uses SSR filters and Haar cascade classifications. Face detection algorithm does not only do a simple detection but also does face tracking by confirming it for every frame which increases the reliability. We do face confirmation for each frame using SVM and Adaboost using a threshold value. We use Adaboost for the face finding at the first stage which generally use a constant threshold value. Finally we test our algorithm for face detection and tracking using 32,000 images from FERET, CMU, CVS, BIO-ID, YALE, UNIBE, MIT, UMIST DB and 18,000 images for recognition which include different face expressions and face poses.

In Section II, we give short explanation about our face extraction using proposed SSR filter structure and Haar features. In Section III, face recognition algorithm will be explained in short. This section will have Principle Component Analysis (PCA), Independent Component Analysis (ICA) algorithms and Face Features comparison (FFC) with video camera images. Section IV will touch on total system composed from Section II~III. Finally, Section V will have experimental results. Some test results done with some major face databases will be given. It will also include Equal Error Rate (EER) ratios to show the performance of the algorithm and Section VI will be conclusion section which concludes the paper.

II. Face Extraction

A. SSR Filter Structure

SSR is a filter structure which Kawato [9] discovered to find a face among many candidates with low processing time. The basic idea comes from cell logic. Since person has eyes, we apply our SSR filter to face to find whether or not there are eyes on the images.

SSR is 6 rectangles and below formula is calculated to

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understand the eye areas:

$$Eul < Nu, Eul < Edl \quad (1)$$

$$Eur < Nu, Eur < Edr \quad (2)$$

$$Nu \cong Nd, Eul \cong Eur, Edl \cong Edr \quad (3)$$

where Eul is Upper Left eye, Eur is Upper Right Eye Edl is lower left Eye, Edr is lower right eye, Nu is Upper Nose Area and Nd is Lower Nose Area. By calculating this relation we extract eye candidates.

Fig. 1 SSR filter application to the face

We use this logic since above relation is invariant against different light conditions. The relation is always satisfied. So, we extract the eyes from many candidates correctly. When we apply SSR filter, we get four local minimums :
Left Eye, Right Eye, Left Eyebrow, Right Eyebrow
Using those four minimum, we calculate the Eye center points. Since we want to find different sizes of faces in real time, we change SSR rectangle sizes with a $1/\sqrt{2}$ ratio. We can find 20x20~180x180 pixel sizes of a face by using approximately 6 different filters to apply to the face. In a 320x240 image, we can find approximately 192 faces at once during the detection period when a filter result returns to a face result.

B. *Haar Boosting*

Haar boosting is a fast face finding method. It uses boosted cascade of simple features. To find a face, several rectangles are used to apply to the images. A rectangle is specified in different sizes.
Let X = [W/w] and Y = [H/h] be the scaling factor in two coordinates x,y, then, we can generate the following equation

$$X \times Y\left(W + 1 - w\frac{(X+1)}{2}\right) \times \left(H + 1 - h\frac{(Y+1)}{2}\right) \quad (4)$$

where W is the width and H is height of the image where face is presumed to be there. To find a face, we use several cascade stages shown in Fig. 2. Cascades of classifiers are the degenerated decision trees where each stage is composed of weak classifiers. We train at least 16 stages with a minimum hit rate of 0.9991 and 0.005 false alarm.

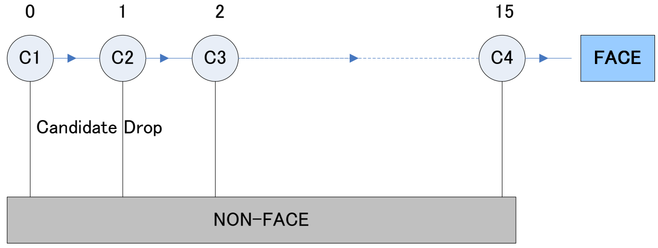

Fig. 2 Face decision by a series of classifiers

The training uses Adaboost algorithm to decide if the candidate is a face or not after each classifier.

C. *SVM*

Support Vector Machine (SVM) is used for face training and face decision. SVM is a powerful learning kernel machine and several forms of it are used by many researchers. We use SVM logic with our algorithm by decreasing the double-type parameters into the int-type which directly affect the calculation time. After we find our face candidates given as Fig. 1 and Fig. 2, we make fast histogram equalization in gray scaled images and apply scale and rotation of the image to evaluate it in SVM. For SVM training we use 35x21 images at a number of 1000 patterns. We use 1000 patterns for positive images and 500 for negative images.

$$W(\alpha) = -\sum_{i=1}^{l} \alpha_i + \frac{1}{2}\sum_{i=1}^{l}\sum_{j=1}^{l} y_i y_j \alpha_i \alpha_j k(x_i, x_j) \quad (5)$$

Where

$$\sum_{i=1}^{l} y_i \alpha_i = 0 \quad (6)$$

l is the number of training samples while α is the vector form of training samples. $k(x_i, x_j)$ is training image. We put our face candidate to an array and trained samples to another array and compare the results. If it is less than 75, we assume that it is not a face.

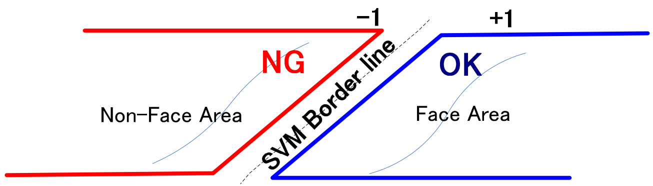

Fig. 3 SVM Face Decision border

For face decision, the result of SVM is evaluated. If the result is +1, it is a face. If the result gives -1, then it means that the candidate is not a face. So, we can drop it off. However, to get a better performance, we assign a threshold in addition to the SVM result. Therefore, if the SVM result is +1 and more than threshold value, we behave it as a face.

III. Face Recognition

Our Face recognition algorithm is composed of gabor filters, PCA, ICA and FFC.

A. *Image Feature Extraction*

To get a high face recognition, we use Gabor filters since Gabors are tolerable against angles, lighting conditions and face expressions. To extract the features of the face, we apply Gabor filter to the face with the size of 40 (8 orientation with 5 scales) with the following equation

$$\varphi_{\mu,v}(z) = \frac{\|k_{\mu,v}\|^2}{\sigma^2} e^{-\frac{\|k_{\mu,v}\|^2 x\|z\|^2}{2\sigma^2}} \left[e^{ik_{\mu,v}^{z}} - e^{-\frac{\sigma^2}{2}} \right] \quad (7)$$

Where μ is gabor orientation, v is gabor scaling

$$z = (x, y), \|.\| \quad (8)$$

is image normalization

As for $k_{\mu,v}$ as depicted in (7),

$$k_{\mu,v} = k_v e^{i\phi_\mu} \quad (9)$$

where

$$k_v = k_{\max} / f^{v}, \ \phi_\mu = \pi\mu/8 \quad (10)$$

Here ," f" is the gabor scaling in Frequency domain.

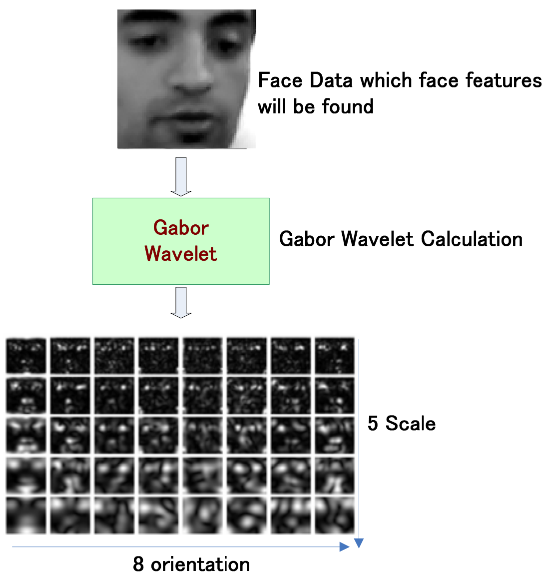

Fig. 4 Face Feature Extraction by Gabor Filters

In Fig. 4, we used $f = \sqrt{2}$, $\sigma = 2\pi$, $k\max = \pi/2$ and $v \in \{0,.....4\}$ and $\mu \in \{0,.......7\}$ Using those parameters, we have 8x5=40 features as shown in Fig. 4.

B. *Dimension Reduction and Feature Analysis*

As a result of Gabor filters, a big dimension of arrays is obtained. Calculation of the whole dimension in real time needs high CPU power with high memory arrays. Therefore, it is needed to reduce the dimensionality of the vector by means of PCA and then further reduce redundancy and represent independent face features explicitly using ICA.

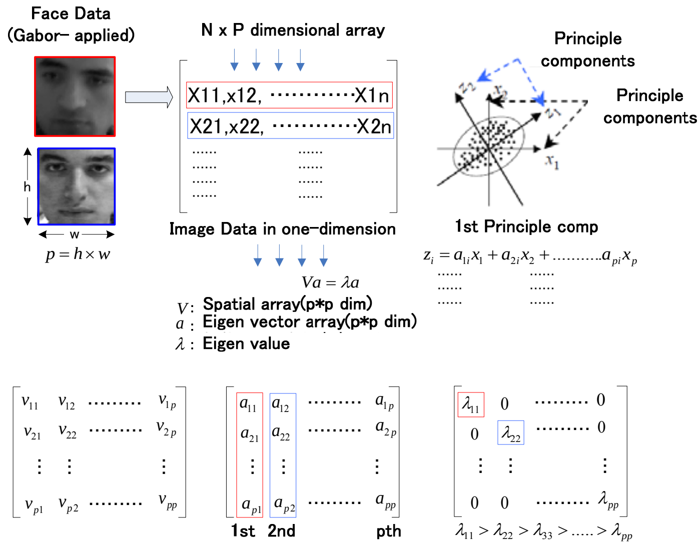

Fig. 5 Dimension Reduction using a different form of PCA

The result of PCA that reduces the image dimension as given in Fig. 5 is analyzed to find the face features explicitly using our ICA techniques. Using it, we extract independent face features in subspace using eq.11 by whitening, rotating, normalizing, transforming

$$x_j = a_{j1}s_1 + a_{j2}s_2 + \dots\dots + a_{jn}s_n \quad (11)$$

where n is the number of linear vectors, $x_1 \sim x_n$ is array components. Independent components $s_1 \sim s_n$ are spatial parameters and have a zero-mean. Finally applying feature component vector transpose using eq. 12 and addition of each gives the total features

$$x = \sum_{i=1}^{n} a_i s_i \quad (12)$$

C. *FFC*

Face classification is done using Bayes linear classifier with the assumption that all class covariance matrices are identical (normalized both in x and y coordinates). Let M_k ,k = 1,2,……,L be the mean of training sample images. Using eq.13, we apply FFC method to the data which is normalized and diagonaled properly.

$$\sum_{i=1}^{m} \frac{(z_i - m_{k_i})^2}{\sigma_i^{\,2}} = \min_j \left(\sum_{i=1}^{m} \frac{(z_i - m_{j_i})^2}{\sigma_i^{\,2}} \right) \quad (13)$$

where $z \in \omega_k$. σ_i^2 is estimated by sample variance in one-dimensional space. For the final comparison, we assign a threshold value by meaning all database training vectors and compare with Gabor-applied test vectors and measure the similarity between train and test data.

IV. Authentication System

Our proposed face extraction and recognition system is applied to an authentication system. Authentication system has one video camera with 640x480 pixel size. Computer to implement Authentication system uses Pentium IV 3G with 512MB Ram 30G HDD and Video camera used for recognition as well as registration must support Video for Windows format like in USB and/or Firewire cameras. The environmental conditions will be better to decide beforehand to get a high performance. We implement the authentication system as given in Fig. 6. We detect face using SVM and Adaboost which are explained above. After we locale eyes on Face image, we make some small optimization to the image. After then,

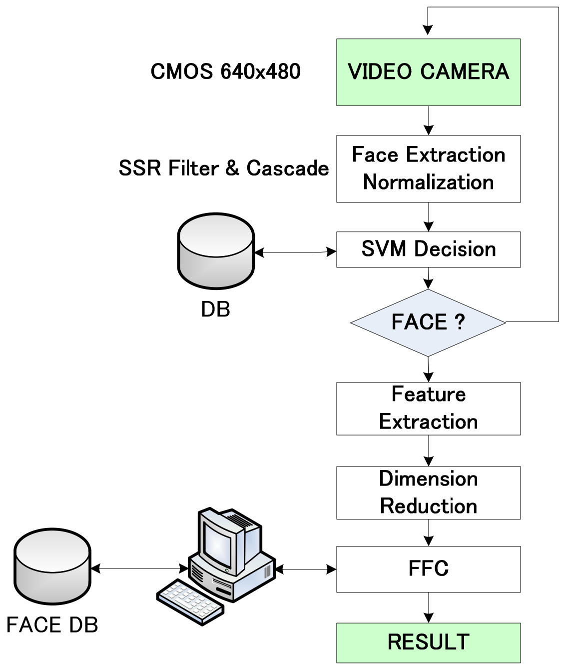

Fig. 6 Authentication system

Image is gray-scaled, normalized, set ROI and then SSR filter is applied after cascaded-classifiers. The decision-maker of the SSR result is done by SVM using our face databases which contain 1000 positive images. Upon finding eye locations, we rotate the face in x,y and then apply Gabor filter. Finally FFC is applied to find if the person face exists in face database via a workstation. If the average value of the test data is higher than that of database, then corresponding face is output.

V. Experimental Results

We tested our face extraction algorithm using 32,000 images from FERET, CMU, MIT, CVS, BIO-ID, YALE, UNIBE, MIT and UMIST DB. Since the images were natural images with no background removed, no cut and rotated. So, we customized our face extraction part to do those and got following results:

TABLE I
Detection Rate

Image form	Detection rate
Single face	98.0%
Multi Face	97.5%
With simple background	96.3%
With complex bacground	92.1%
With Dark environment	94.8%
With bright environment	95.0%
Face with ± 30 angle	97.0%
Face with angle more than ± 30	85.7%

TABLE II
Recognition Rate

Input Resol	Mask size	Rec (ORL)	Rec (Org)	EER
32x32	15x15	98.0%	92.0%	8%
32x32	24x24	98.5%	90.5%	7%
32x32	36x36	99.5%	84.0%	10%
48x48	15x15	97.0%	96.5%	2%
48x48	24x24	99.5%	91.5%	6%
48x48	36x36	99.0%	88.5%	13%

Original DB has 5 images per person with different angles and different face expressions. Algorithm results have shown that recognition rates were not affected by face expressions but affected by angles more than 45degree. As a result, 48x48 size of training image with 24x24 mask size gave the lowest EER ratio with better recognition rate.

VI. Conclusion

We proposed a face extraction algorithm and recognition algorithm and applied it to a total system. Face Extraction algorithm consists of two different algorithms and faces are verified using two powerful learning algorithms: SVM and Adaboost. SVM is used for face verification detected by SSR filters while Adaboost uses Haar-like features. SSR filters find faces among the many objects by calculating white and black information of the face and compute eye-locations of 6 different scales. After S.Kawato proposed SSR filters [9], its angularity and detection policy has been improved and powered with our algorithm. Face extraction algorithm detects faces from 20x20 to 180x180 when using 320x240 USB web camera. In addition to proposed face extraction, we also researched face recognition and developed practical algorithm to fit with our face extraction algorithm. Our proposed Face recognition algorithm uses PCA and ICA methods.

We use Gabor filters since they are famous with their robust behaviors against face angle and face distance. The feature dimensionality is reduced using PCA and then resulted image data is applied whitening and centering. Then it is applied to our ICA algorithm. Finally, the similarity is measured using FFC. FFC takes the distance between the input image and DB images and brings the most nearest image. FFC assumes that the input image is previously registered in DB. Therefore, we use a threshold to adjust the recognition rate. We tested our algorithm using Pentium IV 3G PC machine. Time to extract the faces is approximately 20ms. Total time from camera to the result, when recognizing the faces, is around 1-2 sec. The new registration takes 30sec since it needs database reconstruction. Time for both Registration and recognition is measured when DB has 40 people and 5 images per person (40x5=200 trained images).

Total system performance depends on Face extraction part. Especially trained face database to use with SVM affect the performance. Gabor filtering and feature extraction give good results and do not need processing time. However, face normalization before/after face extraction must be carefully evaluated to increase the recognition performance.

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