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Detection of Partially Occluded Face using Support Vector Machines

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Abstract

Partially occluded face detection is need, because although the technology of the Automated Teller Machines and face detection is increased, we cannot control the people who wear sunglasses or mask for the crime. To reject the occluded face, we first trained the features of the normal faces and the occluded faces that wear sunglasses or mask using Principal Component Analysis and Support Vector Machines to reduce the dimension and classify efficiently. Then we decide that the detected face is normal or partially occluded face using the scheme that integrates the Principal Component Analysis and Support Vector Machines. In the experiments, we trained the 3200 normal face images that have the variations of illumination and expression and each 2900 and 4500 partially occluded face images that wear the sunglasses or mask with 60*25, and 60*35 resolution. We get the 95.2% and 98.8% partially occluded face detection ratio after face detection and 2.5% and 0% false alarm ratio from the experiments based on the Purdue University Face DB. The proposed algorithm which is incorporated the face detection system can help the security using the Digital Video Recorder System and face recognition

1 Introduction

Recently, the use of Automated Teller Machines (ATMs) has been increased because of popularization and variety of services at the ATMs and staff reduction of the back. With increasing of the popularity of the ATMs, the researchers are developing the security system to protect the depositors. Most ATMs use the credit card and secret number for guarantee person's identification. As the technologies related to ATMs have improved very fast, the crimes of credit card's loss or exposure of the secret number to other people are growing nowadays. For preventing the crime, the Digital Video Recorder (DVR) system and face detection/ tracking algorithms are supplemented at ATMs to identify the user's particulars. But the most people who commit the crime wear the sunglasses or mask to harbor their identity.

In the last ten years, Face detection has become an important area of computer vision such as video surveillance, human-computer interface, and identity authentication. But much more research still remains to be done in the occluded face detection. Previous DVR system records the difference images to detect the human motion. But this system stores the unnecessary images that are not existent human face and cannot know the identity of partially occluded faces that wear the sunglasses, or mask. To control the access of the occluded face to commit the crime, we proposed the intelligent algorithm to classify the normal face and occluded face. And this will help to the security systems that are related to access control of unidentified person.

Linear subspace analysis has been used as representative methods, linear Principal Component Analysis (PCA) or Fisher Linear Discriminant Analysis (FLDA), and eigenface because of its simplicity and efficiency. Support Vector Machines (SVM) is a very powerful supervised learning algorithm that is rooted in statistical learning theory[1]. SVM that is used very popularly in the computer vision area plays an important role in this system. And this system helps to prevent the crime at the ATM and waste of the hardware better than the previous DVR system.

In section 2, we show the definition of the partially occluded face. We then present in section 3 the training and test method to detect the partially occluded face using PCA and SVM. At that section, we will present the roles of the PCA and SVM. We will describe the experiment results at section 4. Our conclusion remark is presented at section 5. Figure 1 depicts the total flow diagram of the envisioned system. This system is divided of 3 parts: One is face detection and size normalization, the second is feature extraction by PCA and classification by SVM, and the third is the identification and warning of the partially occluded face.

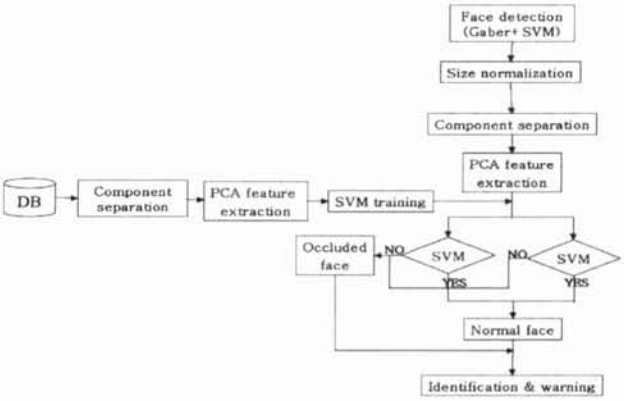


Figure 1. Total flow diagram of system

2 Definition of the partially occluded face

Generally, people have the same features of eyes, eyebrows, nose, and mouth of the face. The shape and location of each component is very similar to each person. But the verification of these features has an important role to recognize and identify one's face. If one component of face's feature points is covered with an obstacle, we cannot know one's identification. To know one's identification from the image, we must see all features of the face. Eyes and eyebrows are gathered at the upper part of the face, and mouth and nose are gathered at the lower part of the facial image. We define that the partially occluded face is not able to classify one's identification because of being covered with an obstacle such as hat, sunglasses, mask, or mufflers. And we define that the face that can identify is normal face. It is necessary for the person who wears these obstacles to prevent the use of ATM. As control the access of ATM, we can reduce the crime and increase the detection ratio of the normal face.

3 Detection of the partially occluded face

To detect the partially occluded face, we train the normal face and partially occluded face. Normal faces are composed of the faces that have change of illumination, expression, and rotation. Partially occluded faces are composed with the faces that wear the sunglasses, mask, and muffler. Changes of illumination and expression are included to the partially occluded face DB too.

3.1 Training of the partially occluded faces and normal faces

The performance of this system is influenced by the methods of feature extraction and classification. So selection of the training images is very important in this part. The environments in which ATMs are established are very diverse and the people are not limited to the age and sex distinction. The training images are reflected to the variation of the illumination's direction and strength, face expression, beard, and rotation. Especially, beard and expression can be mistaken as a partially occluded face. Occluded faces are trained by varying the shape and intensity of sunglasses, masks, and mufflers.

We normalize the size of training images with 60*60. Size normalization is based on the eye position that is detected with Gabor wavelet and SVM. We search the candidate region of the face using Gabor wavelet and extract the face by hierarchical classification varying the size of the image. The examples of the trained normal face and occluded face images are shown in figure 2.

(a) Examples of the normal face images

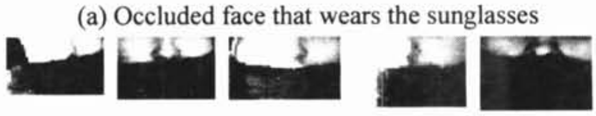
(b) Examples of the occluded face images

Figure 2. Size normalized training images

At next step, we separate the face image component by component: the one is the forehead and eyes and the other is nose and mouth. By separating the image into component, we can reduce the image dimension with 60*25 of the forehead and eyes, 60*35 of the nose and mouth.

Through this process, we can find where occlusion is happened easily and reduce the noise' effect such as hair, background. At the training process, partially occluded face that wears the sunglasses is mis-detected as eyes from the face detection algorithm using Gabor and wavelet. So the position of mis-detected sunglasses is not exact eye position and this can be changed at the continuous input image. So we trained the component of the face that wear the sunglasses with varying the position, scale, and rotation. As varying the position of the eye's position, lower part of size normalized image also have changes. Figure 3 shows the example images used in the training. Figure 3-(a) shows the upper part of partially occluded face and figure 3-(b) shows the lower part of that.

(a) Occluded face that wears the sunglasses



(b) Occluded face that wears the mask or muffler

Figure 3. Training images of occluded face

To extract the feature from the normalized image, we use PCA to the training images and test image. Linear subspace analysis such as PCA has been used more popular than raw image data in the computer vision area because of its simplicity and efficiency. Facial images are not randomly distributed in higher dimensional image space and thus can be described by a relatively low dimensional subspace.

We show the feature extraction process of the normal face and partially occluded face that wears the sunglasses using PCA[2].

$$\Gamma = [r_1, r_2, r_3, \ldots, r_{IJ-1}, r_{IJ}] \tag{1}$$

$$\Gamma' = [r_1', r_2', r_3', \ldots, r_{IJ-1}', r_{IJ}'] \tag{2}$$

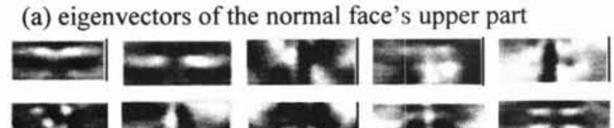
Γ, Γ' are represented as vectors of normalized images of the normal face and occluded face with the size $I \times J$. Total number of the training set of normal face is N and occluded face that wears the sunglasses is M. Averages of each training set is defined as the equation (3), (4).

$$\psi = \frac{1}{L}\sum_{i=1}^{L}\Gamma_i \tag{3}$$

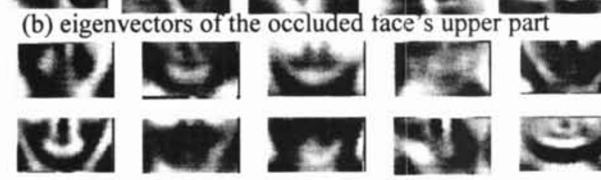
$$\psi' = \frac{1}{M}\sum_{i=1}^{M}\Gamma'_i \tag{4}$$

As shown the equation (1)~(4), we can calculate the eigenvectors u_i, u_i'. Figure 4 shows the examples of the extracted eigenvectors of the normal face of upper and lower part and occluded face of face's upper face part.

(a) eigenvectors of the normal face's upper part



(b) eigenvectors of the occluded face's upper part



(c)eigenvectors of the normal face's lower part

Figure 4. eigenvectors of the training image set

$$w_f = (\Gamma_i - \psi)\times u_k \quad i=(1,2,3...L)$$
$$(\Gamma_i - \psi')\times u'_k \quad i=(L+1,L+2,L+3...L+M) \qquad (5)$$
$$w'_f = (\Gamma'_i - \psi)\times u_k \quad i=(1,2,3...L)$$
$$(\Gamma'_i - \psi')\times u'_k \; i=(L+1,L+2,L+3...L+M) \qquad (6)$$

The weights of the normal face and partially occluded face, w_f, w'_f are calculated as shown in equation (5), (6). By including the eigenvectors of the normal and partially occluded face, weight value of each feature is influenced from each training image. As considering the effect of features of each class, it helps us to have good features to classify the normal and partially occluded face by SVM.

After obtaining PCA features, we build the SVM training set $\{c_i, d_i\}_{i=1}^{l}$ where $d_i = \{1,-1\}$ is the class type of PCA feature c_i. l is the size of the training set. SVM implicitly maps the data into a dot product space via a nonlinear mapping function. Thus the SVM learn a hyperplane which separates the data by a large margin. Generally, SVM has the following form:

$$f(x) = sign(\sum_{i-1}^{l} y_i \lambda_i^{*} K(x, x_i) + b^{*}) \qquad (7)$$

where y_i and x_i are a class label and a training feature vector respectively, λ_i and b are constants which are decided by learning, K is a polynormial kernel. In classification using the non-linear SVM, run-time complexity is very high because it is proportional to the number of support vectors[3][5].

In this paper, we use the kernel as polynormial kernel. Polynormials $K(x, x') = (x \cdot x')^d$ can be shown to map into a feature space spanned by all order d products of input features. This means that support vectors act as templates for normal face and partially occluded face, thus relating non-linear support vector's to vector quantization. Support vector's value is obtained as shown in figure 5. Figure 5-(a) shows the support vector of the upper part of normal face and partially occluded face. Figure 5-(b) shows the support vectors of lower part of the normal and partially occluded face. Blue points are the support vectors of normal face's upper and lower part and red points are the support vectors of partially occluded face's upper and lower part.

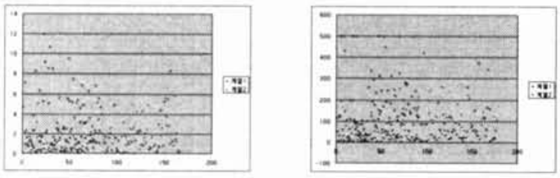


Figure 5. Distributions of support vectors of normal and partially occluded face

3.2 Test of the partially occluded face

Detection of the partially occluded face of the input image has the same process of the training part as shown in section 3.1.

We detect the face region using Gabor and SVM first. From segmented face region, we separate the face region into upper part and lower part. Figure 6 shows the process of separating component of the face.

Figure 6. The process of separating the face from the input image

By applying PCA and SVM schemes to extract the feature points and classify that the feature points are near the normal or partially occluded face. We can reduce the processing time and noise effect because of PCA and SVM. If input image is classified to the partially occluded face, ATMs send the warning message that the users must remove the obstacles of their faces to detect the normal face. When the users ignore that warning message, we control the access and discontinue the service of ATMs.

4 Experiment results

To detect the partially occluded face using PCA and SVM, we used the 3200 images of normal face, 2900 images that wear the sunglasses, and 4500 images that wear the mask, muffler, and non-face. From training images, we extracted the 100 eigenvectors from each trained class. The number of the support vectors and error is shown in the table 1.

	Number of support vectors	Number of errors
Upper part	250	0
Lower part	266	1

Table 1. Number of support vectors and errors

To test this system' reliability and efficiency, we use Purdue Univ. face DB as test image[6]. Purdue Univ. face DB are composed with the normal faces and partially occluded faces images that are included of change of illumination and expression. Figure 7 show the examples of the test images of partially occluded faces.

(a) Test images that wear sunglasses

(b) Test images that wear muffler

Figure 7. Test images of partially occluded faces

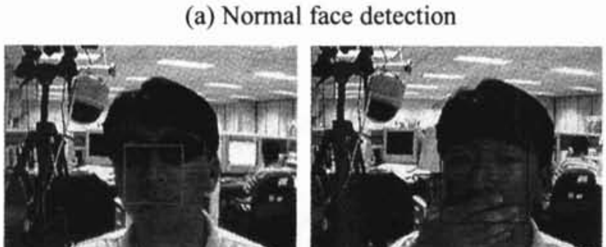
The detection ratio of test images and FAR (False accept Ratio) are reported at the table 2. We test 370 images that wear sunglasses and 390 images that wear mufflers. Each detection ratio and FAR of the partially occluded faces are obtained when the detection ration of the normal face is 98% and FAR of the normal face is 0%.

	Detection ratio	FAR
Upper part	95.2%	2.4%
Lower part	98.8%	0%

Table 2. Detection ratio and FAR of the partially occluded face

We had an experiment of on-line test for detection of the partially occluded face with USB camera that had 320*240 resolution and programmed it using visual C/C++ at Pentium 4 computer. Result images of real-time partially occluded face detection is shown in figure 8. Eye positions and its candidate are painted with green circles. And normal face is painted with blue and partially occluded face is painted green and red square respectively.

(a) Normal face detection



(b) Occluded face detection

Figure 8. Detection results of on-line test

5 Conclusion

In this paper, we have presented a new algorithm that integrates PCA and SVM to detect the occluded face. This system help to prevent the crime related with ATM. At the training process, we include the images that have the change of the direction and strength of illumination and expression. By separating the image with upper and lower component of the face, we reduce the dimension of the image and effect of the noise such as hair and background. And we can obtain more reliable and fast detection of the partially occluded face using PCA and SVM. The proposed system can be used to not only control the access of the people who use the ATM but also guarantee one's identification at the electronic commercial transaction.

References

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