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Efficient Head Pose Determination and Its Application to Face Recognition on Multi-Pose Face DB

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Abstract

Face recognition is a well-known approach for identity recognition. Variation in head pose is a main factor that interferes with face recognition systems. This paper proposes an efficient head pose determination method and its application to face recognition on a multi-pose face DB in order to solve the pose variation-related problem. The first step is to detect a facial region using Adaboost. Next, after undergoing preprocessing on the detected face, a mask is placed to cover it. At the detected facial region, the pose is determined by relations of the position of the centroid points of the eyes and lip regions detected by using ellipse-fitting method. Finally, face recognition is conducted by applying template matching between a set of facial images in multi-pose face DB pertinent to the determined head pose and the input face image. In experiments, the proposed approach outperformed the conventional PCA-based face recognition approach depending on a single-pose face DB.

***Keywords**: Head Pose Determination, Multi-pose Face DB, Template Matching, Face Recognition, Ellipse Fitting*

1. Introduction

The video security industry has been growing more than 20% every year recently. Face recognition method has grown commercialized and has been applied to the security market due to its safe and non-contact manner [1]. Face recognition has the advantage that it can be used in various fields such as admission control, searching for criminals, security, and so on. However, its disadvantage is that recognition rates are relatively low compared with other identity recognition methods of biometrics [2].

This paper proposes a face recognition method based on multi-pose DB in order to complement the weak point of conventional face recognition approaches. First, we construct a multi-pose face DB, which has three groups of faces according to the head poses of right, front, and left side. After detecting the face region by using the well-known Adaboost algorithm, eye and lip regions are detected by using ellipse fitting method after applying image preprocessing and the mask operation [3-4]. Then, by calculating the relations of the centroid points of the eye and lip regions we can determine the head pose of the input image. Finally, face recognition is conducted using a template matching method between a set of face images in multi-pose face DB pertinent to the determined head pose and the input face image.

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2. Multi-Pose Face Database and Head Pose Determination

2.1. Multi-Pose Face Database

For constructing multi-pose DB for face recognition, we divide face images into three groups of faces, according to the head poses of right, front, and left side. Each facial image in the DB targets images belonging to face angles of a pre-determined threshold, which can be detected by the Adaboost algorithm. Histogram equalization and normalization of the image size are conducted over the detected face area as preprocessing processes, as shown in Figure 1.

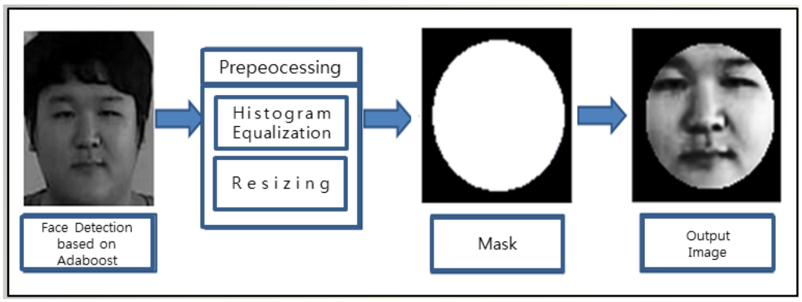

Figure 1. Face Image (Front) after Applying Image Preprocessing and the Mask Operation

Then, a detected face area with ROI (Region of Interest) is appointed and a mask is covered over it, after which the representative images of multi-pose face DB are created [5-6]. As shown in Figure 2, using face images from three viewpoints of the left, front, and right side, a multi-pose face DB with 30 face images was obtained from 10 people.

Figure 2. Face Images of Three Viewpoints Created through the Image

2.2. Head Pose Determination

After constructing a multi-pose DB for face recognition, we need to determine the head pose of the input face image to recognize its identity. The input face image is processed by the same sequences of performing the Adaboost algorithm to detect a face region and the preprocessing and masking described in the previous section, after which we obtain a face ROI image of the input image for face recognition.

In this research, we propose a method of head pose determination prior to conducting face recognition with multi-pose DB. The relations of the position of centroid points of the eye and lip regions are very important in determining the head pose. Figure 3 shows regions of containing eye candidates defined by the given red lines on the y-axis after obtaining face ROI images that have passed the preprocessing and masking.

Then, we apply the ellipse fitting algorithm on the eye candidate region to detect the exact positions of eyes [7-8]. We assume that the shape of eye is close to an ellipse. By using ellipse fitting, we obtain contours from a binary representation of the candidate region using the proper threshold values. Figure 4 shows the ellipse fitting results according to the threshold values, and Figure 5 shows a binary representation of eye region with the given threshold.

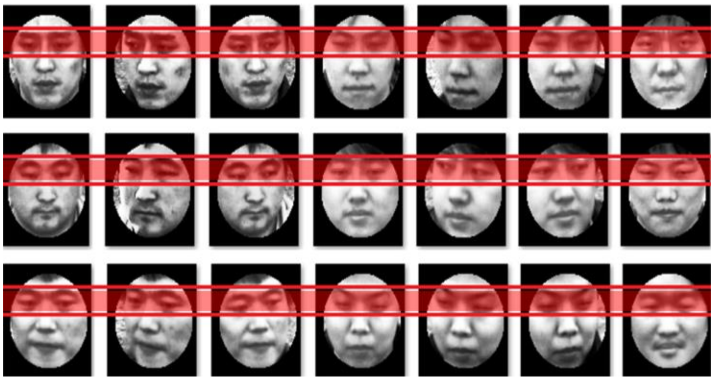

Figure 3. Regions of Containing Eye Candidates on Face Images of Three Viewpoints

Figure 4. Ellipse Fitting Results According to the Threshold Values

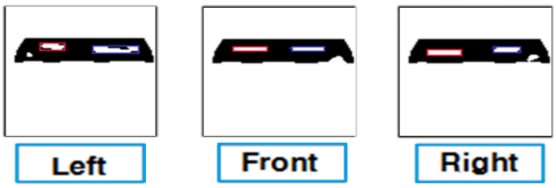

Figure 5. Binary Representation of Eye Region with the Given Threshold

For more reliable eye detection in various environmental conditions, we increase the threshold values until all given conditions are satisfied. As a method for noise reduction, we employ a blob-labeling algorithm and put on labels for regions where they adjacently represent more than 10 pixels according to threshold values. Only the regions are considered as candidate eye regions. Finally, a central point of candidate eye regions are regarded as the center of eyes. In accordance with this procedure, a lip region is also detected by a central point of candidate lip regions. In Figure 6, triangular shapes represent connected lines of central points of detected eyes and a lip.

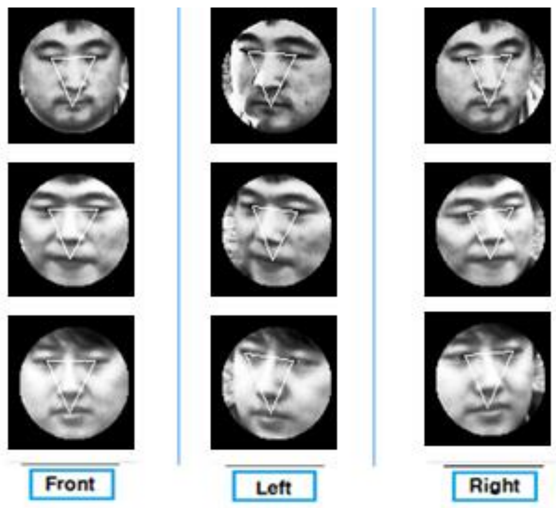

Figure 6. Detected Regions of Eyes and a Lip According to Several Head Poses

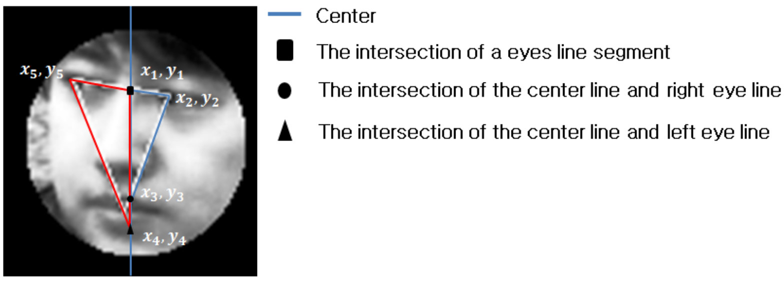

Figure 7. Triangles for Determination of a Final Viewpoint

Next, we determine a final viewpoint. First, we obtain two triangles shown in Figure 7 by using five points, including two eye points and three intersection points, drawn by connected lines of central points and eye lines. The sizes of these respective two triangles are used to determine a final viewpoint, as follows.

$$s_1 = \frac{1}{2}\left|(x_1 y_2 + x_2 y_3 + x_3 y_1) - (y_1 x_2 + y_2 x_3 + y_3 x_1)\right|$$

$$s_1 = \frac{1}{2}\left|(x_1 y_5 + x_5 y_4 + x_4 y_1) - (y_1 x_5 + y_5 x_4 + y_4 x_1)\right| \quad (1)$$

$$\textit{If}\ \ s_1 - s_2 \geq \textit{Threshold},\ \textit{the viewpoint is right}$$

$$\textit{If}\ \ s_1 - s_2 \leq \textit{Threshold},\ \textit{the viewpoint is left}$$

If the size of the right triangle is relatively larger than that of the left triangle, the facial viewpoint is determined to be right.

Figure 8 describes a block diagram for a procedure of determination of a viewpoint and Table 1 represents a result of experiments pertaining to viewpoint determination. In this result, frontal view images showed lower performance compared to left or right views. The frontal view images should organize an isosceles triangle or a regular triangle, but a small measurement error in the central points of the eyes and a lip, caused the incorrect determination in frontal view images.

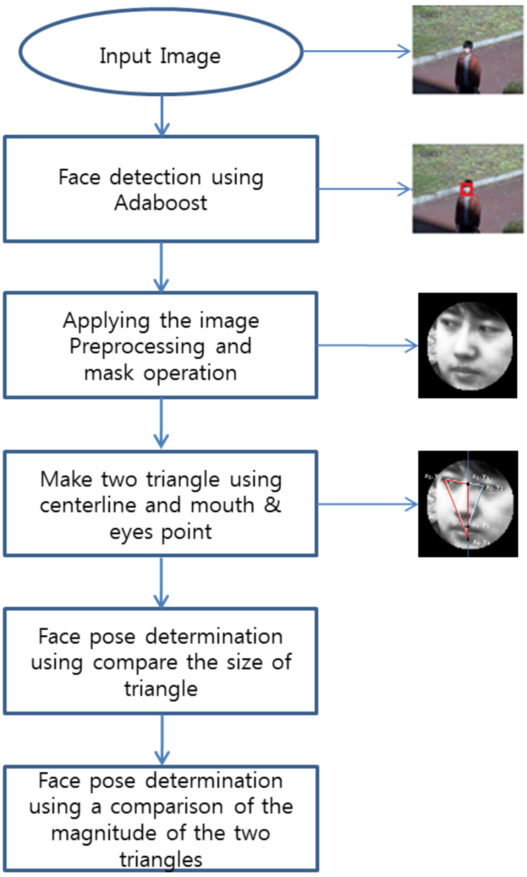

Figure 8. Block Diagram for a Procedure of Viewpoint Determination

Table 1. Result of Viewpoint Determination Experiments

Viewpoint	Times of tests	Results
Front	50	47
Left	50	50
Right	50	50
Total	150	147

3. Face Recognition on Multi-Pose Face Database

We configured our multi-pose DB using only one image for each viewpoint of a subject. Because of insufficient image sources, we adopted the template matching technique as an identity recognition algorithm.

First, a face area is detected from the input image based on the Adaboost algorithm. A viewpoint is then determined by the proposed determination process. Finally, the input template passes through the preprocessing process explained in Section 2. 1.

By the following the template matching formula based on SSD (Sum of Squared Differences), a similarity is measured between the input template and representative images in a multi-pose face DB corresponding to the viewpoint of the input template.

$$R(x,y) = \sum_{x',y'} [T(x'y') - I(x+x', y+y')]^2 \quad (2)$$

In general, the similarity indicates a value between 0 and 1, and the value has linguistic representation, as explained in Table 2.

Table 2. The Linguistic Representation of Similarity Values

Similarity	The linguistic representation
0.80~1.00	Strong correlation
0.60~0.80	High correlation
0.40~0.60	Normal correlation
0.20~0.40	Low correlation
0.00~0.20	A very low correlation

The similarity is compared with an empirically determined threshold (we used 0.8 for this value), and then the final recognition result is obtained.

4. Experimental Results

We targeted facial images captured by a PTZ camera covering the height of about 6m and distance of about 20m to simulate a general closed-circuit television (CCTV) installation environment. The conventional PCA-based face recognition method was applied to the single-pose face DB to compare the performance of the proposed approach using multi-pose face DB.

Table 3 and Table 4 represent the recognition results obtained from several sets of tests. Table 3 shows the performance of the conventional PCA-based approach using single-pose face DB, whereas Table 4 represents the performance of the proposed method using multi-pose DB. Although the PCA-based approach achieved reliable results for the front side viewpoint, the recognition results were significantly deteriorated for other viewpoints. On the other hand, our proposed approach demonstrated reliable performance on all of viewpoints, achieving superior recognition rates in left and right viewpoints. The poor performance of the conventional PCA-based approach in side viewpoints is induced by a reason that the overlap of eigen face in each viewpoint negatively affects estimation of eigenvalues.

Table 3. Recognition Result of the Conventional PCA-Based Approach Using Single-Pose Face Database

Viewpoint	Times of tests	Recognition rate (%)
Front	50	96
Left	50	50
Right	50	56
Total/Average	150	67.3

Table 4. Recognition Result of the Proposed Method Using Multi-Pose Database

Viewpoint	Times of tests	Recognition rate (%)
Front	50	96
Left	50	92
Right	50	90
Total/Average	150	92.7

5. Conclusions

In this study, we proposed a template matching algorithm-based face recognition using the multi-pose face DB for identity recognition in video security environments. In face recognition experiments, the proposed approach outperformed the conventional PCA-based approach using single-pose face DB in all viewpoints.

In future works, we will investigate more sophisticated methods for more reliable detection of eyes and lips, and will employ other learning algorithms that can deal with a large-scale multi-pose face DB.

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