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Eye Detection Using Composite Cross Correlation from Face Images in Varied Head Pose

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ABSTRACT

This paper presents a Composite Cross Correlation technique for detecting eye in varied head pose of face images. The proposed composite template consists of two single templates; the first template is created by taking the left half of a left eye and the second template by flipping the first template horizontally. We suggest other composite templates of entire face template to determine how many eyes should appear, one in profile face image and two in frontal face image. The experimental result was conducted on Psychological Image Collection at Stirling (PICS) database. The database has face images with five head poses in the range -90°, -45°, 0°, 45° and 90°. The results obtained using the proposed technique shows significant improvement in terms of detection rate compared to single cross correlation or using eye template of entire eye images.

Keywords: Composite Cross Correlation, Psychological Image Collection at Stirling, Eye detection, Head poses

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INTRODUCTION

In the field of computer vision, facial feature detection is an essential step to implement face recognition system. Facial features detection methods are classified as geometric based, appearance based, statistic based, color segmentation based and template match based methods. Most previous studies related to facial feature detection focus on eye detection as the first phase of extracting the detailed information that is needed [1-2]. The main advantages of templates match based methods over others are; it does not require negative training examples or facial feature points. Creating eye template from face images requires only cropping eye images and then calculating a correlation value between the eye template and all parts of face images. Templates match based methods are also well suited for both high and low-resolution face images [3].

Eye detection is subject to a large variety of effects such as shapes, textures, colors, makeup and eyeglasses. Thus, various templates can be used to approach and adapt to changing conditions. For instance, resizing templates is considered a reasonable solution to detect facial feature in varied size of face image [4]. Alternatively, using multi-scale templates produce satisfying results in analyzing upper facial expression [5]. Eye shape is subject to change according to face expression or stress condition, detecting eye in both open and semi-open status was proposed using template match based method proposed by Dong and Wu [6] while detecting eye in both open and close status was proposed using template match based method proposed by Bhoi and Mohanty [3]. To detect eye using template match based method, most previous studies assumed that the head region is first detected and localized. The problem lies when the head pose does not correspond to the eye template. In this case, the efficiency of template match based methods decreases due to the differences in shape of an eye through head pose. Therefore, using iris template instead of eye template may help to overcome this problem [7]. Another solution is using eye template with a suitable head pose as suggested by Murphy-Chutorian and Trivedi [8] in their survey study.

Detecting face region by template match based method was also proposed in [9] where a half horizontal face image is utilized as templates. A better result was obtained in the case of differences in the face poses between the face

template and face image. On the other hand, detecting face is computationally expensive than detecting eye due to the size of face template compared to that of eye template. Therefore, two templates of half eyes in this paper and utilized the composite cross correlation [10] to detect the eyes.

PROPOSED METHOD

Detecting eyes from face image using Composite Cross Correlation based method employs several templates of eyes. Usually, these templates are created from same eye image but in a different size or from different eye image but in the same size. In the proposed method, we create eye templates from half part of the eye in order to detect eyes in varied poses of face images.

Applying Composite Cross Correlation

Detecting eyes using cross correlation based method has restricted efficiency in the case of varied head poses in face images due to difference in the shape between eyes through face poses. That is the difference in shape between eyes in face image and eye templates. For instance, only half eye appears in profile face image while full eyes appear in frontal face image, in addition to other effects such as changes in the size and orientation of eyes. To reduce these impacts, we employed two eye templates of eye. These templates are created from the half single eye image in such a way that the first template T1 is the left half of left eye image and the second template T2 is the right half of right eye image. Consequently, the template T2 can be produced by flipping the template T1 horizontally. Figure 1 shows both templates proposed in this study where the template T2 is produced by flipping the template T1 horizontally.

From the figure above, both templates have same size q × p but the center of the two templates do not correspond to the center of eye iris. A number of shifts on X-axis are q/2 and –q/2 for the templates T1 and T2 respectively, while there are no shifts on Y-axis. Furthermore, these shifts should be taken into account while formulating the correlation as shown in Equation 1.

$$Co(I,T)_{(X,Y)} = \prod_h^k Co'(I,[T_h])_{(X-shift_{h,x},Y-shift_{h,y})} \quad (1)$$

Where $T = [T_1, T_2, \dots\dots, T_k]$; $h \in [0,k]$; $Co'_{(x,y)} = \frac{Co''_{(x,y)}}{\max(|Co''_{(i,j)}|)}$;

$$Co''_{(x,y)} = \frac{\sum_s \sum_t \delta_{I_{(x+s,y+t)}} \delta_{T_{(cx+s,cy+t)}}}{\sqrt{\sum_s \sum_t \delta^2{}_{I_{(x+s,y+t)}}} \sqrt{\sum_s \sum_t \delta^2{}_{T_{(cx+s,cy+t)}}}};$$

$$\delta_{I_{(x+s,y+t)}} = I_{(x+s,y+t)} - \bar{I}_{(x,y)}; \quad \delta_{T_{(cx+s,cy+t)}} = T_{(cx+s,cy+t)} - \bar{T};$$

$$s \in \left[\frac{-q}{2}, \frac{q}{2}\right]; \; t \in \left[\frac{-p}{2}, \frac{p}{2}\right];$$

$$x \in \left[\frac{q}{2}, n - \frac{q}{2}\right]; \; y \in \left[\frac{p}{2}, m - \frac{p}{2}\right];$$

$$cx = round\left(\frac{q}{2}\right); \; cy = round\left(\frac{p}{2}\right);$$

$$\bar{I}_{(x,y)} = \frac{1}{q \times p} \sum_s \sum_t I_{(x+s,y+t)}; \quad \bar{T} = \frac{1}{q \times p} \sum_s \sum_t T_{(cx+s,cy+t)}.$$

The correlation matrix indicates high correlation values in the pixels corresponding the eyes position, whether in profile or frontal face images. Figure 2 shows the correlation matrices for the single and composite templates. The bright pixels indicate high correlation value of the template. As a result, there exists some pixels corresponding to eye position which does not have high correlation value through the correlation matrix. In addition, there is a problem of not determining the proper position of the eyes in a given frontal or profile face image. In order to overcome this problem, five results were obtained which represent the pixels for the five head poses in the range -90°, -45°, 0°, 45° and 90°.

Selecting the Most Appropriate Eye Position

After selecting the best five pixels from the correlation matrix, composite cross correlations were applied on the five selected pixels as shown in Figure 3. These are $Co(I_{x,y}, [T_1, T_2, TF_1])$, $Co\left(I_{x,y}, [T_1, T_2, TF_2]\right)$ and $Co\left(I_{x,y}, [T_1, T_2, TF_3]\right)$.

The templates TF1, TF2 and TF3 are shown in Figure 3, where we determined the shifts from center template and left eye for TF1 and TF3 templates, as well as the shift from center template and right eye for TF2. The templates

represent the full face image in the cases of left profile, right profile and frontal face image. The final result is given by the maximum correlation value of these triple templates. The template $Co(I_{x,y},[T_1,T_2,TF_3])$ having the highest correlation was applied to detect right eye taking into consideration the shift of center in TF3 and the right eye position.

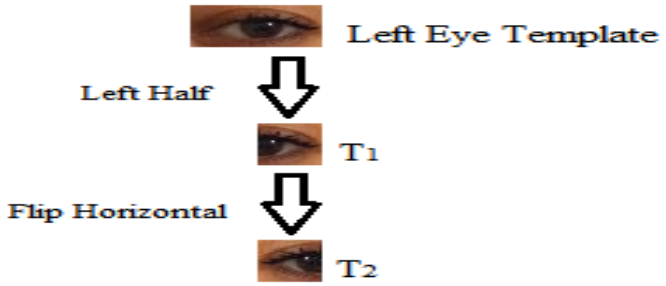

Fig. 1 Creating two eye templates from half eye image

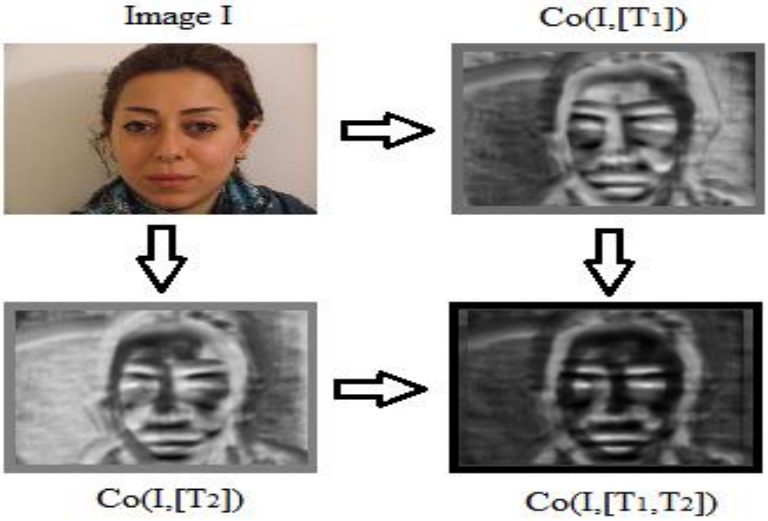

Fig. 2 Correlation matrices for single and composite templates

Fig. 3 Profile and Frontal face templates

RESULTS AND DISCUSSION

The experimental result was conducted on 2D face Iranian woman sets, Psychological Image Collection at Stirling (PICS). This database has 369 images; the size of each image is 1200 × 900 pixels, 34 women, mostly with a smile and neutral in each of five orientations [11]. For the experiment purpose, Matlab software was used on a personal computer with the following specifications; Intel Celeron 2.0 GHz processor and 2.00 GB DDR3 RAM. Figure 4 shows samples of the results in five head poses in the range -90°, -45°, 0°, 45° and 90°.

From Figure 4, the first row shows given images; the second row depicts the correlation results of the first template T_1. The third row represents the correlation results of second template T_2 while the fourth illustrate the correlation results of the composite template $[T_1, T_2]$. The eye detection result is displayed in the fifth row, by applying the composite templates $[T_1, T_2, TF_1]$, $[T_1, T_2, TF_2]$ and $[T_1, T_2, TF_3]$ on the best correlation result. In Table 1, the results of eye detection implemented in this paper is summarized, where $Co(I_{x,y},[T])$ is the single cross correlations for the template containing the full eye. Detection rate and false rejection rate are the parame-

ters utilized for evaluating the result. The left half eye template gives a satisfying result for frontal and left head pose as shown in Table 1. Conversely, the right half eye template also gave satisfying results for frontal and right head pose. Similarly, the results demonstrated that applying composite templates produces much better detection rate than applying single template. Finally, applying face template increase the rate of eye detection in the presence of different poses.

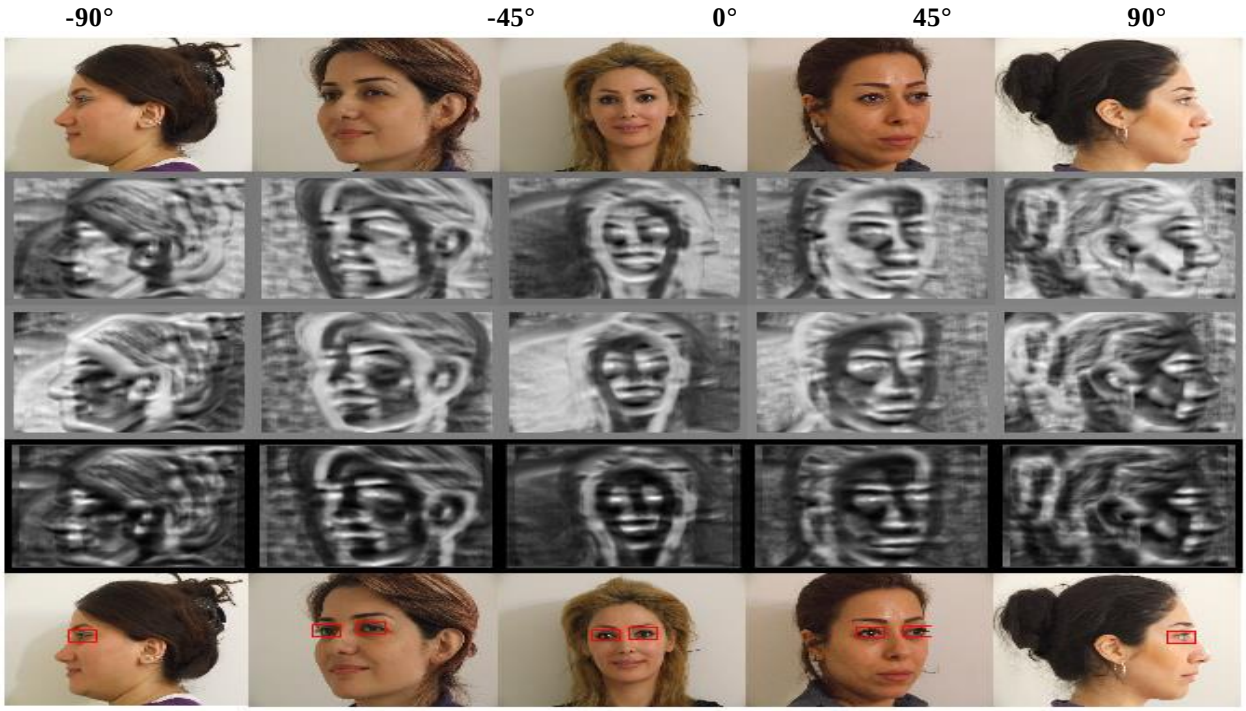

Fig. 4 Sample of template match face detection method to detect the eyes by using two templates of half of the eyes in varied head pose

Table -1 Detection Rate for Single and Composite Template

Correlation	Detection Rate (%)	False Rejection Rate (%)
$Co(I,[T_1])$	69.91	30.09
$Co(I,[T_2])$	68.02	31.08
$Co(I,[T])$	88.61	11.39
$Co(I,[T_1,T_2])$	93.87	6.13
$\text{MAX}(Co(I,[T_1,T_2,TF_i])$	98.83	1.17

CONCLUSION

Cross correlation technique is widely used to detect small part of object from given images depending on template describing the object part. In face recognition field, detecting eye is the essential step to detect other facial features. In this paper, cross correlation technique was utilized to detect eyes from given face image. The objective of this paper is to propose a method to overcome the obstruction of head pose in face images. Two single templates were created to use the composite cross correlation. The first template is the left half of left eye and the second is created by flipping the first template horizontally. The reason to create the template from half part of the eye is due to the low change between the half eye in frontal and profile image while the change is large between full eyes in front and profile images.

The experimental result shows that applying the template of half eye gives a satisfying result in the frontal face image. Furthermore, applying composite template produces better results of eye detection through all orientations. In order to detect head poses in the face image, three templates were generated to represent the entire face; in frontal case and both profile cases. Finally, a detection rate of 98.83% was reported by applying the proposed method on PICS Database while it is 93.87% for the templates which have entire eye image.

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