Automatic Adaptive Center of Pupil Detection Using Face Detection and CDF Analysis

Mansour Asadifard, Jamshid Shanbezadeh

Abstract—This paper presents a novel adaptive algorithm to detect the center of pupil in frontal view faces. This algorithm, at first, employs the viola-Jones face detector to find the approximate location of face in an image. The knowledge of the face structure is exploited to detect the eye region. The histogram of the detected region is calculated and its CDF is employed to extract the eyelids and iris region in an adaptive way. The center of this region is considered as the pupil center. The experimental results show ninety one percent's accuracy in detecting pupil center.

Index Terms— histogram CDF, Image Analysis, morphology operation, AdaBoost algorithm.

I. INTRODUCTION

Face recognition and facial expression analysis have great degree of applications including identification, authentication, psychology, e-learning, security, marketing, human-computer interaction and so on. The first step in face recognition or facial expression analysis is to detect the face location in an image. In the second step, the important points of face can be recognized by the proprieties of face such as symmetric location of eyes and, different colors of face segments. The identification of key points in face, based on these properties can be applied in face recognition. Among these key points, the center of eyes is the most important than others, because with the use of eye centers one can remove in-plane rotation of face and with calculating the distance between eye centers we can approximately find the size of face in an image. This is a helpful clue to find the location of other key points. As a result, detection of eye centers facilitates detection of other key points.

Some of the facial point extraction algorithms in literature are: Template matching [1], Integral projection [1], Snakes

Mansour Asadifard is a postgraduate student in the field of artificial intelligence, in Department of Computer Engineering at Islamic Azad University, Research and Science Branch in Iran. He is interested in machine vision and image processing and its application on emotion detection for e-learning. (e-mail : asadifard@gmail.com).

Dr. Jamshid Shanbehzadeh is an Associate Professor in the Department of Computer Engineering at Islamic Azad University Science and Research Branch in Tehran, I. R. Iran. He has published over eighty international journal and conference papers in the areas of image processing, computer vision, emotion detection and affective tutoring systems. He is an expert in e-learning and artificial intelligence in education. (Corresponding author. Phone: +98 9121484177; e-mail: jamshid@tmu.ac.ir).

[2], Deformable template [3], Hough transform [4], Elastic bunch graph matching [5], Region growing search [6], Active Shape Models (ASMs), and Active Appearance Models (AAMs) [7]. In template matching a template is constructed for a specified point and, generally it is constructed from some test images. A matching process is applied to find the point in new image. In integral projection, row/column integral histogram is calculated and according to the intensity properties of eye region, the eyes are detected. In elastic bunch graph matching a transform is applied on the image and a model is constructed for feature points in the transformed space by the use of test images. Then the points in the new image are searched to find a match for the model. In region growing search, a rectangle is considered and, its initial position is approximately on the tip of the nose. This rectangle region grows step by step until the difference between rectangle region pixels intensity and new pixels are greater than a threshold. This new pixels are the eye pixels. In ASM and AAM, a model is constructed for predefined facial points by using the test images. Then with the use of this model in an iterative scheme, feature points are detected. Most of the above-mentioned methods for eye localization are sensitive to the variations due to varying face poses, illuminations, expressions and accessories. Therefore, it is necessary to design robust eye localization algorithms respect to various imaging conditions.

This paper presents a robust adaptive algorithm for eye localization that find the center of pupils in a fast and accurate way under varying expression and lighting conditions based on cumulative density function (CDF) framework. Fig. 1 shows the block diagram of algorithm. The first block detects the region of face. The second block works on face region and extracts the region of eye. The third block works on detected eye region and detects the center of pupil. The rest of this paper is organized as follows. Section II describes the face detection scheme. Section III explains the region of interest detection. Section IV describes the center of pupil detection. Section V discusses the experimental results. Conclusions are presented in Section VI.

II. FACE DETECTION

For detection of face region we use the viola-Jones real-time face detector [9]. This scheme made from cascading classifiers trained by AdaBoost algorithm. The integral image and rectangular features are employed by each classifier to detect face. Fig. 2 presents the result of applying

Fig. 1.Block diagram of algorithm
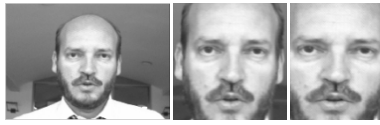
(a)　　　　(b)　　　　(c)

Fig. 2 (a) Input image (b) Detected face region (c) Final face region

Viola-Jones real-time face detector on an image. The outcome of face region is depicted in Fig. 2(c).

III. REGION OF INTEREST DETECTION

The region of interest (ROI) is those areas that contains eye. If we find this region, we can reduce the computational cost by reducing the search space. We can find the region of interest by dividing the face region vertically into top and bottom parts. Then the top part is partitioned horizontally into left and right segments. At this stage we have two regions where each one has an eye. Fig. 3 (a) shows the block diagram of the procedure and, Fig. 3 (b) shows the outcome of the process on a sample image.

IV. CENTER OF PUPIL DETECTION

The center of pupil is detected by an adaptive approach. After finding the ROIs, that each one contains an eye, the following approach is performed on both regions. Fig. 4 shows the block diagram of the approach. At the first step we filter each ROI by the cumulative distributed function (CDF) of that region. We find the CDF by integrating the histogram of each of the ROI by using (1):

$$CDF(r) = \sum_{w=0}^{r} P(w) \quad (1)$$

Where $P(w)$ is the histogram representing the probability of occurrence of gray level w and $0 \leq r \leq 255$. In our experiments, it was found that the pixels of eyelid and pupil have $CDF \leq 0.05$, so ROI is filtered by (2):

$$I'(x,y) = \begin{cases} 255 & CDF(I(x,y)) \leq 0.05 \\ 0 & Otherwise \end{cases} \quad (2)$$

Where $I(x,y)$ is the original eye region and, $I'(x,y)$ is the image that only contains the pixels of pupil and upper eyelid and, those parts that their CDF is less than 0.05. We can see the result of this section in Fig. 4 (b-1).

The result of the first part contains regions rather than iris. We perform morphology to remove these parts. The erosion morphological operation by 2×2 structure element is a suitable candidate for this purpose. Fig. 4 (b-2) illustrates the outcome of this step which is approximately the iris.

The purpose of the third step is to find pupil. We find the pixel with the minimum intensity (PMI) of the ROI in the original image corresponding to the area obtained from the

(a)

(b)

Fig. 3 (a) Diagram of eyes region detection ((b) ROI of each eye

second step. The probability of pixels near to PMI and with low intensity to be the iris is high. We use a 10×10 window with PMI as its center and use the average intensity of this window as a threshold to separate the iris pixels from the rest. Fig. 4(b-3) shows the selection of 10×10 window. There is a reflection and potential noise when we get a face image. To eliminate these noises we employ erosion morphological operator with 2×2 structure element on the eye region. Then a 15×15 window with the PMI as its center is considered as the potential candidate of iris. Fig. 4(b-4) presents the selection of this window. The pixels of this region, with intensity less than the threshold value, are considered as the pixels of iris. The gravity center of these candidates is considered as the potential candidate of the pupil center.

V. EXPERIMENTAL RESULTS

The head and shoulder BioID database [8] is used for evaluation purpose. This database contains 1521 gray scale, frontal-view, and 384×286 resolution images. Different illumination, face size, and complex background are the properties of this database. Some samples have shown in Fig. 5. The BioID database is more complicated than other head and shoulder databases without complex background. We omit the images with closed eye and glasses for evaluation purpose. Because the aim is the evaluation of proposed method to find the pupil center, we consider the images that the face detector detects their face region. Table I presents the results of algorithm. This table shows the detection rate of the pupil center across the pixel difference between the ground truth position and algorithm returned position of pupil center. The results show, we receive up to ninety percent accuracy if the difference pixels of the ground truth position and our result are five pixels. In the case of lower difference pixels, the accuracy decreases. Table II shows the iris detection rate which is about ninety one percents for right eye and ninety five percents for left eye. We compared our algorithm with Z. Niu [12], and Z.H. Zhou, X. Geng [15]. The comparison results have been shown in Table III. If we use the evaluation criteria that used in the [13], [14] and [15], we rich the results that is shown in Fig. 6. There is a general agreement on considering $d_{eye} \leq 0.25$ as SUCCESFULL detection where d_{eye} defined as below:

$$d_{eye} = \frac{\max(||Cl - \widetilde{Cl}||, ||Cr - \widetilde{Cr}||)}{||Cl - Cr||} \quad (3)$$

Cl, Cr, $\widetilde{Cl}$ and $\widetilde{Cr}$ are the ground truth location of center point of left and right eye, and estimated left and right eye center point, respectively. Fig. 6 shows that the maximum detection rate is 0.96 based on $d_{eye} = 0.25$. Fig. 7 shows some of the detection results. The detected pupil's centers are marked with white spots.
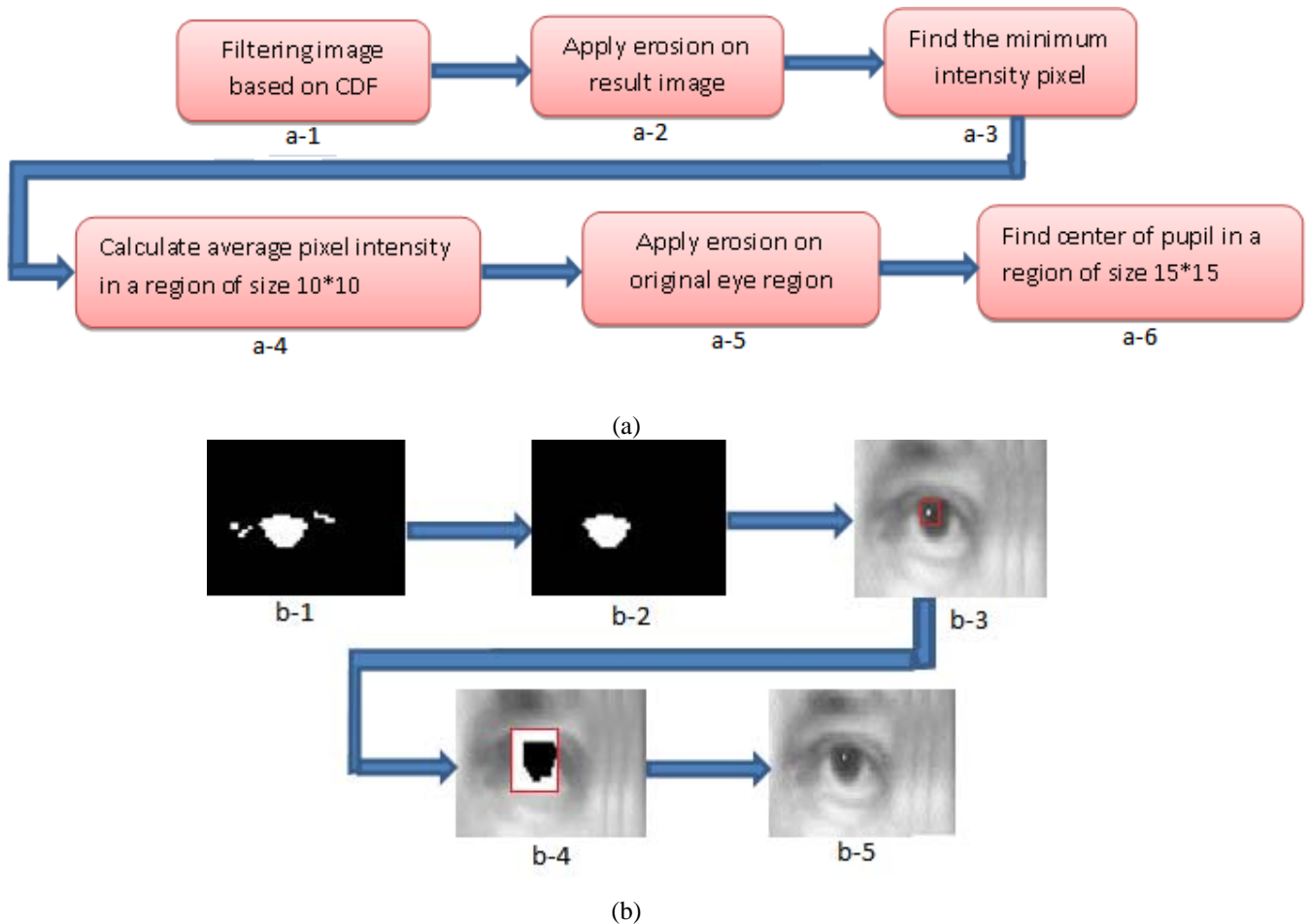
(a)

(b)

Fig. 4 (a) Diagram of the detecting the center of pupil (b) Results of applying the algorithm on an image

Fig. 5 BioID face database samples

Table I. Pupil center detection rate

Pixel difference	Detection rate	
	Right eye	Left eye
5 pixel	%90	%94
4 pixel	%89	%91
3 pixel	%81	%87
2 pixel	%64	%68
1 pixel	%31	%35
0 pixel	%05	%07

Table II. Iris detection rate

Iris detection rate	Right eye	Left eye
	%91	%95

Table III. Comparisons with 2D Adaboost [12] and GPF [15]

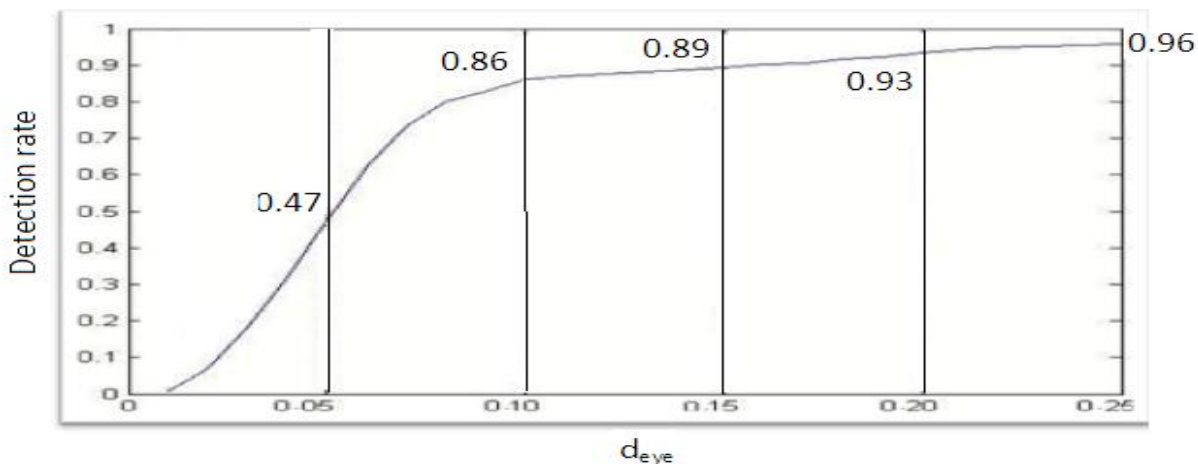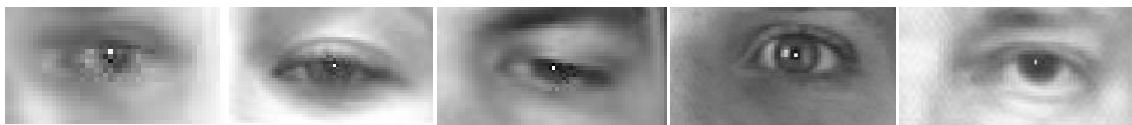| Algorithm	Detection rate
2D Adaboost [12]	%93($d_{eye} \leq 0.1$)
GPF [15]	%94.8($d_{eye} \leq 0.25$)
Ours	%96($d_{eye} \leq 0.25$)

Fig. 6 Detection rate across the d_{eye}

Fig. 7 Samples of detected pupil center

VI. CONCLUSION

This paper presents a coarse to fine adaptive algorithm to detect the center of pupils in different expression and illumination conditions. The contribution of the proposed algorithm is filtering the image segments based on CDF in an adaptive way. We tested our algorithm on public available BioID face database. The experimental results are promising and show 1.5 percents improvement in detecting rate of pupil's center in comparison to similar well known algorithms.

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