# Pupil Localizing in Video Images
# The First Step Toward Eye Monitoring

Amir Liaghatdar
Member of Scientific Association of Electrical & Electronic Engineering, Islamic Azad University Central Tehran Branch, TEHRAN, IRAN
e-mail:amir_liaghatdar@yahoo.com

Kaveh Kangarloo[1] , Fardad Farokhi[2]
Assistant Professor of Electrical Engineering Department, Islamic Azad University, Central Tehran Branch, TEHRAN, IRAN
[1]e-mail: kangarloo@iaucb.ac.ir
[2]e-mail: f_farokhi@iauctb.ac.ir

***Abstract*— In this paper we propose a method for pupil localizing in infrared video images. Pupil localizing is the first step toward eye monitoring. The proposed method is based on three phases. At first the pupil is segmented. Pupil segmentation is based on thresholding. The threshold value is estimated on the basis of a genetic algorithm using Otsu thresholding technique. Following, the pupil is modeled. We assumed the pupil as a circle therefore the modeling process is based on circular Hough transform. Finally, the pupil tracking is performed. Center and radius of pupil are the parameters used for tracking. Applying the Kalman filter, pupil movements are estimated in video sequences. Experimental results show promising performance.***

***Keywords- Pupil; Thresholding; Genetic Algorithm; Modeling; Hough Transform; Kalman Filter.***

## I. INTRODUCTION

Eyes and their movements are among major human behavioral characteristics which play significant role in expressing desires and needs as well as in cognitive processing, morale status and passionate relations. Significance of the eye movement for expressing impression of every individual from the visual world and importance of the same impression have already and implicitly been admitted and recognized because it is through the same implicit manner that every individual can get required information on the characteristics of the visual world. Therefore for precise detection and easy tracking of the eye movement for preparing the ground towards further interaction between human beings and computer, precise user interface and understanding of the human passionate situations are of utmost importance.

Several techniques have been proposed for automatic pupil detection and tracking. Pupil detection and tracking has a wide variety of applications in the field of computer vision. Pupil detection is crucial for the development of human-computer interaction, understanding human affective states, human monitoring systems and attentive user interfaces. In eye-gaze detection [1]-[6], head pose detection [7,8], doze detection [9] and iris recognition [10,11], pupil detection plays the main role.

Ali et al. proposed a method which, find the first and last pixels of the row and column, containing maximum number of black pixels. Following, pupil center and radius are estimated [12]. Tisse et al. used integro differential operators with gradient decomposed Hough transform to find the pupil center [13]. Cui et al. applied Harr wavelet and then Hough transform to detect pupil boundary [14]. Theresholding and morphological opening techniques are also applied to detect pupil region and center mass of pupil region [15]. Sung et al. used Canny edge detection method to estimate pupil center [16]. Wildes proposed an iris segmentation method in which gradient based binary edge map is first constructed from the intensity image and then the inner and outer boundaries are detected via Hough transform [17].

Daugman used integro-differential operator for pupil and iris boundary detection [18]. Morimoto et al. presented a robust system based on the image difference method that allows multiple pupil detection under varying illumination conditions and even for people wearing glasses [19]. In [20] an iris tracking scheme based on Kalman filtering is described. The eye region is determined using gray level histogram thresholding and binary search. In order to achieve robustness in an iris identification system, a Gaussian mixture model coupled with Kalman prediction of the pupil position along the sequence was also proposed [21].

In this paper, we propose an approach for Pupil Tracking in Infrared Video images. The propose method is based on three phases. Firstly, the pupil is detected. For this purpose Otsu's thresholding technique along with genetic algorithm is used. In the second phase the pupil modeling is done. Position and diameter of pupil is estimated using circle Hough transform. In the third phase the pupil tracking by use of Kalman filter is done accordingly. In continuation, the methodology for detecting, modeling and tracking phases are discussed. Finally, the experimental results are presented and discussed.

## II. PUPIL DETECTION

For the present research we used an infrared camera fixed in front of the eye. This camera records all eye movements. If the eye is tested from a very close range then the results related to the pupil movement will be more reliable for eye detection. It is possible that pupil and iris become darker than their surrounding areas. If sufficient contrast becomes available and

978-1-61284-774-0/11/$26.00 ©2011 IEEE

more visible then we can use the thresholding method and do the segmentation in due process.

Though it is possible that detection of the dark area is more suitable while using the infrared ray than when we use the visible light. The methods which depend on the visible light are called as passive light approaches.

In most of researches an infrared source in form of a square with side length of around 780 to 880 nm is used. These wave lengths are invisible to human eyes therefore they do not attract attention of the user not leading to contraction of the pupil. The light generated in the existing systems, whether infrared or the visible one shall necessarily meet all international security standards.

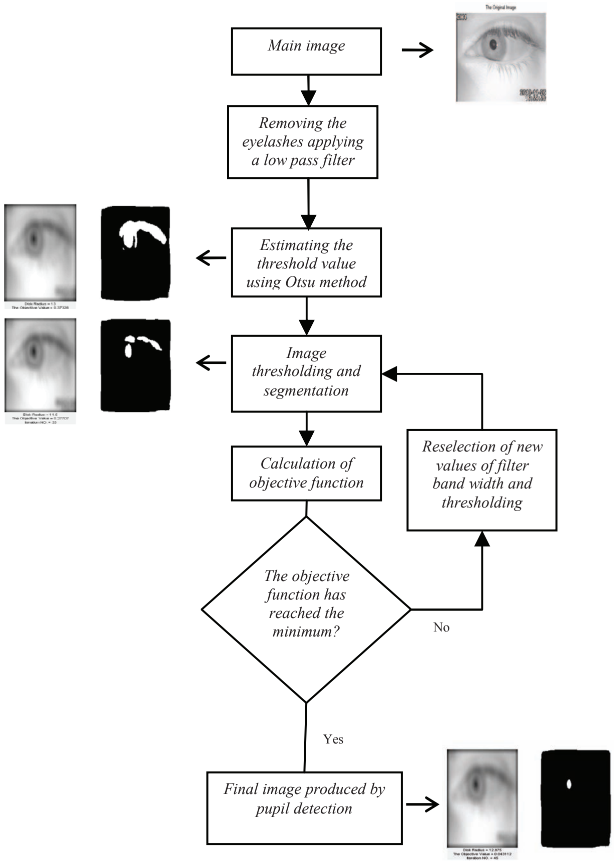



Figure 1. The block diagram of proposed pupil detection Algorithm

Also in the present research pupil segmentation of the video images based on the genetic algorithm-based methods has been introduced. In certain number of researches so far carried out the thresholding quantities have been measured by users. But, certainly, quantity of thresholding in images will not remain unchanged. Based on the method introduced in the present research, by use of a low pass filter (a disk of radius 5 pixel) the eyelashes are removed and then thresholding takes place.

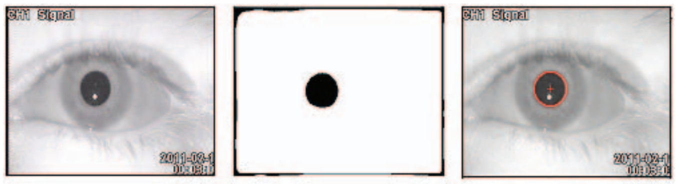
At first, using the Otsu's thresholding method, the proper thresholding quantity is estimated. Then, using the genetic algorithm the filter band width and also thresholding values are determined by minimizing the given energy function. The block diagram of proposed pupil detection method is shown in Fig. 1.

The applied objective function is based on two variables, the number of detected regions and the shape of them. The proposed measure is specially designed to detect a single circular shape in image. On the basis of experimental results, with the increase in the number of variables, probability of finding the minimum is reduced and the correct answer is not calculated.

## III. Pupil Modeling

After pupil segmentation process we need to model the pupil boundary as well. Although iris and pupil regions are observed as an ellipse (based on the view angle) but in this research we assumed the pupil as a circle.

Modeling the pupil as a circle, the pupil center and its diameter are estimated. We used the circle Hough transform for pupil boundary modeling [22]. The circle Hough transform aims to find circular shapes of a given radius R, within an image. The circle Hough transform achieves this detection by a technique that is equivalent to a convolution between the image and a circle operator (fig.2).



(a) (b) (c)

Figure 2. A sample of pupil modeling result. a) Main image, b) Pupil detection result, c) Pupil modeling result

## IV. Pupil Tracking

Conditions such as eye blinking make the pupil invisible. Surely, errors in detection or modeling process cause pupil positioning not to accurately. In such cases, tracking process can be used to improve the estimation results.

In the present research, we used the Kalman filter. We assumed pupil movements on linear basis. In this respect, the Kalman filter is considered as the best method for tracking. Kalman Filter is based on the following pair of equations. Equations 1,2 are process and measurement equations respectively. $F_k$ and $H_k$ are state transition and observation model respectively. $\mathbf{w}_k$ and $\mathbf{v}_k$ are additive Gaussian noise with zero mean.

$$x_{k+1} = F_{k+1,k}.x_k + w_k \quad (1)$$

$$y_k = H_k.x_k + v_k \quad (2)$$

## V. Experimental Results

For testing the proposed method an individual stands within one meter from a 17" monitor. The eye movement is recorded by an infra-red camera (VX56) which is fixed before the eye in a dark surrounding. During the research, three video clips each containing 400 frames are examined. Size of each frame is

320×240 pixels. This algorithm examined for rapid changes in the eye and changes in the amount of light. The experimental result of pupil detection and modeling in a selected clip is shown in fig.3.

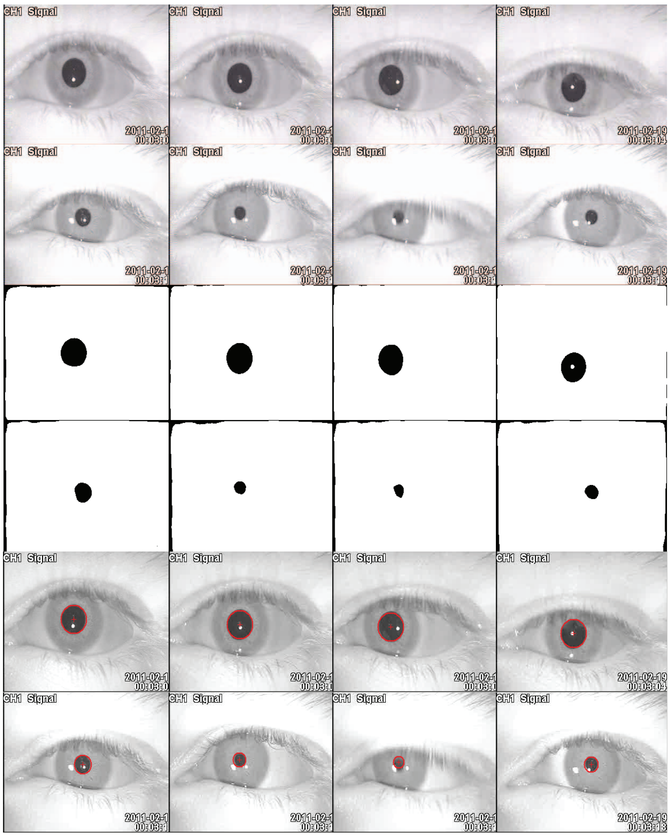



Figure 3. A sample of pupil modeling results Top) main images, Middle) pupil detection results, Bottom) pupil modeling results.

Processing of the imaging data is done in three phases, pupil detection, modeling and finally tracking. The experimental results of proposed pupil tracking method applied to a selected clip are shown in figures 4-7.

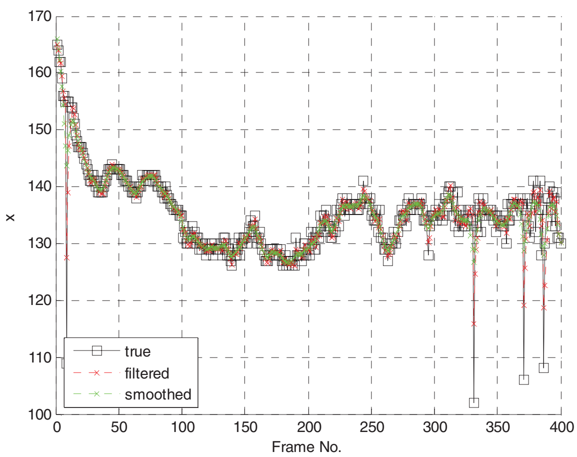



Figure 4. The result of pupil horizontal position estimation in the selected clip based on kalman and smoothed kalman filtering.

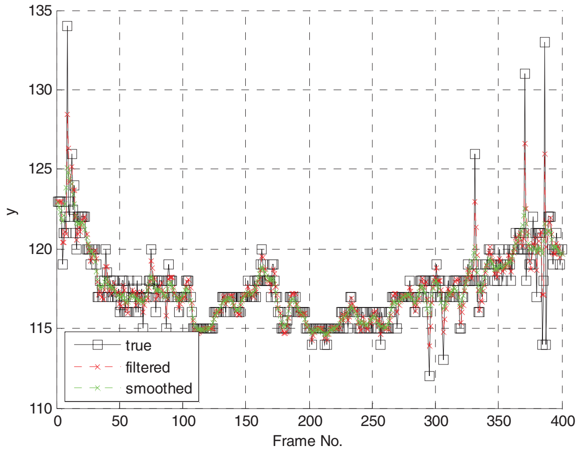



Figure 5. The result of pupil vertical position estimation in the selected clip based on kalman and smoothed kalman filtering.

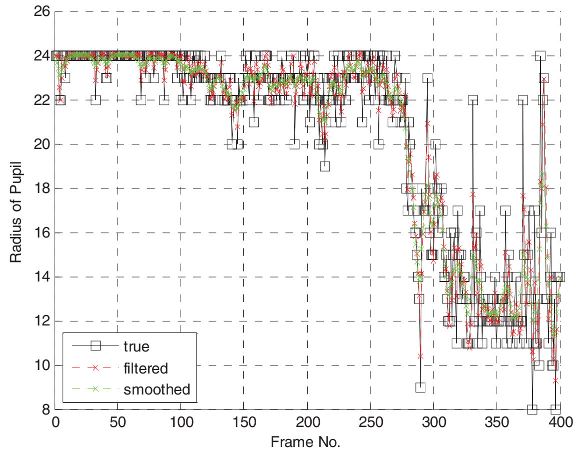



Figure 6. The result of pupil radius estmation in the selected clip based on kalman and smoothed kalman filtering.

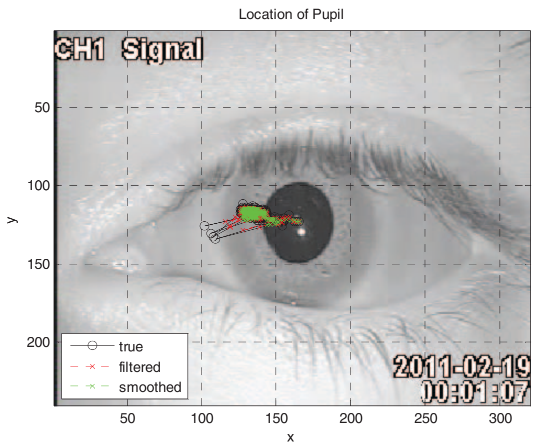



Figure 7. The result of pupil localizing in the selected clip

The results can be classified to the following three possibilities:

***True:*** The pupil has been detected and modeled correctly (fig.8.a).

***Error:*** The pupil has been detected almost correctly but modeled with error (fig. 8.b).

***False:*** The pupil has been detected with error e.g. eye closure or dark eyelashes (fig 8.c).

The summary of experimental results is shown in table I.

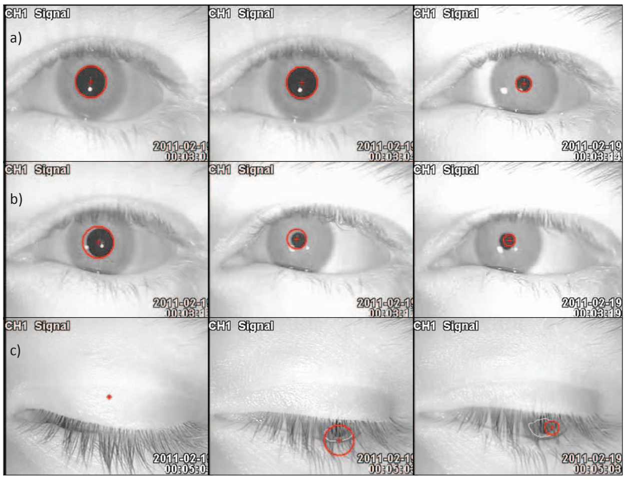



Figure 8. The detection posibilities.
a) True, b) Error (error in modeling), c) False (error in detection)

TABLE I. EXPERIMENTAL RESULTS

| Pupil detection | | | Pupil Modeling | | Pupil Localization | | |
|---|---|---|---|---|---|---|---|
| Missed | Error | Correct | Error | Correct | False | Error | True |
| 0% | 5.83% | 94.17% | 14.5% | 85.5% | 0.5% | 7.5% | 92% |

## VI. CONCLUSION

This paper provided an algorithm for pupil tracking in infrared video images. Pupil tracking is the first step toward eye monitoring. Eye monitoring can be used to analyze the user reaction. The proposed algorithm was in three phases, detection, modeling and tracking. Applying the proposed method on three clips each containing 400 frames of ordinary movement of the eye indicated that the pupil was detected correctly in 92% precision. The pupil detection error is mainly, because of eye closure or covering. Surely, the results could vary with the rate of blinking.

Pupil modeling error is caused because of modeling assumption. We assumed the pupil as a circle while the pupil boundary is seen as an ellipse usually. However, several artifacts such as eyelids, eyelashes, shadows and reflections pose significant challenges in the accurate determination of the pupil centre.

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