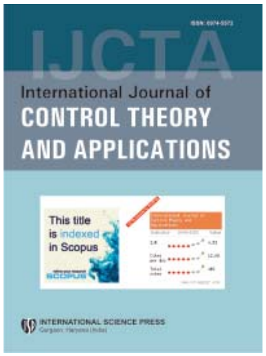

International Journal of Control Theory and Applications

ISSN : 0974–5572

Volume 9 • Number 40 • 2016

Accurate Pupil Positioning for Eye Tracking with Eye Wear Glasses in Natural Desktop Environment

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Abstract: The paper proposes an accurate pupil positioning algorithm for eye tracking technology with eyewear glasses. This non-invasive method accurately locates the pupil position in an eye tracking system under natural lighting condition. Edge strength intensity measurement and ellipse or circle fitting algorithms with edge detection are commonly used to detect pupil. Infra-red illuminators play a vital role in pupil detection for eye tracking and gaze detection to achieve maximum accuracy. This paper focus on morphological operations on binary images with accurate threshold values and use Circular Hough transform with its improvement to detect pupil area. Initially detection of Iris is through binary images, canny edge detector and improved Circular Hough transform. Pupil positioning is localized as the center of the detected iris. The proposed method is explicit to three types of eye glasses and achieved the accuracy of pupil positioning. The proposed method can be modified to fit other type of eyewear glasses with a change in the morphological operations on binary image.

Keywords: *Eye tracking, Pupil positioning, Edge detection, Circular Hough transform.*

1. INTRODUCTION

Eye tracking is a valuable research in the computer vision systems as it has multipurpose applications, being used as an input to a device for human-computer interface device. Iris, Pupil, glint are the various eye features used for eye tracking based on the applications in various fields [1]. Early systems of eye tracking are invasive and had a constrained environment [2 3 4 5 6]. Most of the systems rely on Infra-red illuminators to extract iris and pupil for eye tracking to avoid the specula reflection [7 8 9]. Dissimilarity in the pupil and face contrast improves the accuracy and efficiency of eye tracking methodology. Current advances in eye tracking technology initiated a way to non-invasive methods as more contented and suitable environment within a range head movement [10]. Portable eye trackers for pupil detection are evolving with a new challenge of operating under uncontrolled and varying light conditions [11]. As a final point, pupils give very weak impression in the infrared light withe thick eye glasses. To alleviate some of these problems, pupils are detected based on combing its appearance, the bright pupil effect, and motion characteristics [12]. A real time subtraction and special filter was used to eliminate the external light interferences [13]. Efficiency of pupil detection algorithms is defined in terms of cost, speed and accuracy. Iterative algorithms decrease the speed even though accuracy is achieved. In this paper we proposed real time pupil detection for users wearing eye glasses under natural lighting conditions. The proposed method utilizes bright pupil effect and appearance of eyes for pupil detection [22] in normal lighting conditions. Morphological operations on binary image and improved Circular Hough transform algorithm are used for pupil detection.

2. RELATED WORKS

Pupil localization algorithms were classified under three popular methods [14] Cumulative Distribution Function Algorithm [15], Projection Functions Algorithm [16], and Edges Analysis Algorithm [17]. Fast, robust, low cost pupil detection technique with IR illuminators was developed with the difference in threshold values of bright and dark pupil images [18]. Bright Pupils were used with Kalman filtering for eye tracking [13]. Pupil contour was detected using ellipse fitting algorithm with segmentation [19]. Starburst uses a ray casting method to find points on the border of the pupil (candidate feature points) [20]. Gaze-Tracker followed RANSAC procedure to eliminate possible outliers amongst points in the contour between pupil and iris [21]. A low cost eye tracking solution providing high performance even in challenging outdoor environments was offered by SET [11]. New real-time eye detection and tracking methodology was developed by combining the bright-pupil effect caused from IR light and the conventional appearance-based object recognition technique worked under variable and realistic lighting conditions [22]. A new method of pupil edge fitting with IR illuminators is put forwarded to fit circular objects and remove false points to get accurate position of pupil center in order to improve mapping accuracy[23].Accurate pupil positioning algorithm was developed without IR illuminators under natural environment for users without wearing eyewear glasses [24]. Relative position between centers of pupil and corneal sphere was detected for users wearing eyeglasses using digital video and IR illuminator [25]. Most of the above methods followed the procedure of IR illuminators and in some cases eyeglass and contact lens are considered. Yet, when the user wears eyeglass, the frames and lens produce glass reflections similar to the pupil and the corneal reflection. Misdetection of pupil or the corneal reflection is likely in this situation. We proposed a novel methodology to localize a true pair of the pupil for eye tracking even if the user wears eyeglasses without IR illuminators in real time under natural lighting condition.

3. PROPOSED PUPIL LOCALIZATION METHOD

3.1. Experimental setup

An 8-bit RGB image (640 × 480 pixels) of the user's face was input into a personal computer or Laptop. Our proposed method for pupil detection is implemented in MATLAB 2013a with the Image Processing toolbox. This paper describes an algorithm for finding and localizing a subject's iris and pupil center given a facial image of the user, *i.e.*, eye within the range of approximately 130 to 160 pixels diameter in a 640x480 image.

3.2. Methods

Even though LED-based IR illuminators have several advantages, it can also be harmful to human eye and installation cost is also high. Precautions are recommended during installation. In order to avoid damaging, reduce costs and improve accuracy, we explore the use of natural light to detect the eyes of human. Our approach uses RGB color space that removes complexity of color space conversion. The input to the algorithm consists of a RGB eye image containing both human eyes. The output of the algorithm is the position of the detected pupil and iris boundaries. The iris boundary is modelled as a circle, described by its center as pupil. Image is captured taken with a webcam embedded in a desktop. The processing was performed using a Laptop with Intel® Pentium® mobile processor T4200, 2 GHz CPU, 3GB of RAM and Windows XP 32-bit operating system. PC with i3processor, 8GB RAM, 3.20 GHz CPU is used for processing with MTALAB 2015. Screen resolution of casted webcam is 1280 x 1024 pixels and produces, moving or still image of user sitting in front of the webcam. Images of 3 participants were taken under a normal lighting condition. After getting the eye from facial segmentation, gray scales of the eye image is obtained with Gary projection. Gray projection shows a clear difference in Iris and Pupil area. As an outcome, the coordinates of pupil can be determined approximately by choosing the circle. Morphological operations are performed on the binary image. Canny operator which applies two thresholds to the gradient detects the eye edges accurately and differentiates pupil and corneal reflection. After detecting edges, it is time to use circular Hough transform to find the Iris exactly and center of the circle is detected as pupil.

The approach used notably does not require the use of the presence and location of any reflections or glints on the eye to assist in the localization of the pupil or iris. Three different types of eye glasses with different frames were tested with our approach.

3.3. Workflow

1. The Get the 8-bit RGB image (640X480) with a webcam
2. Noise removal with pre-processing steps
3. Extraction of the face from the rest of the image using viola jones algorithm [26]
4. Detection of the eyes in the face using Haar cascade classifiers[26]
5. Gray projection algorithm [27, 28, 29] accumulates each pixel by row or column in gray scales.
6. Perform morphological operation on binary image [30, 31]
7. Edge analysis using Canny edge detection
8. Apply Circular Hough Transform (CHT) [32]

4. EXPERIMENTAL RESULTS

A real-time implementation of pupil localization is implemented on a single Pentium processor with an image of resolution 640 X 480 X 8bits. Fig.1 shows the processing steps to localize the pupil with iris.

1. Segmented Facial image from webcam
2. segmented human eyes
3. Edge detected image with canny operator
4. Black and White threshold image after morphological operation
5. Localized pupil with iris boundary.

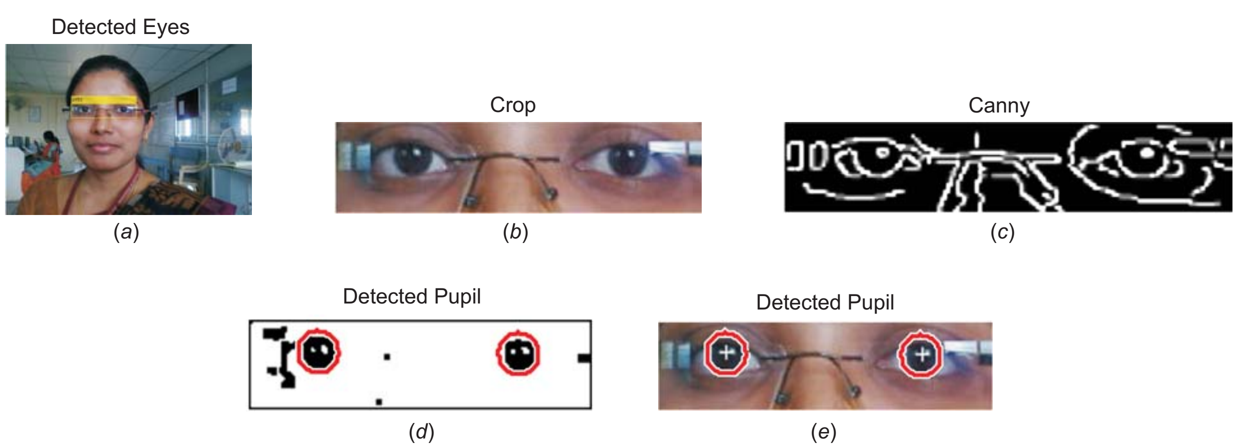


Figure 1: Pupil localization processing steps

Table 1
Eye detection: Eyeglass and Frame Type

Eyeglass Type	*Detected Face*	*Detected Eyes*
Frameless 		
One side Frame 		
Full Frame 		

Table 2
Frame type Vs. Detected Pupil

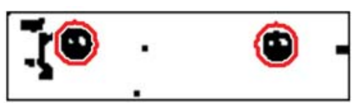
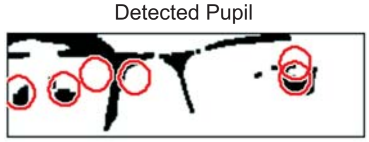
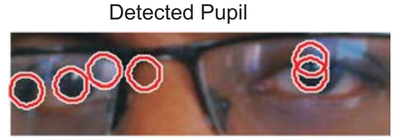
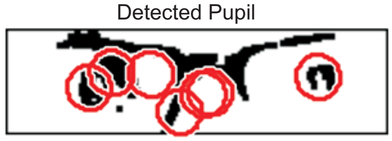
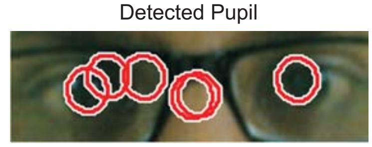
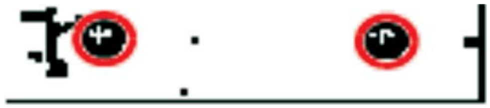
Eyeglass Type	*Binary Image*	*Detected Pupil in Eye image*
Frameless	Detected Pupil 	Detected Pupil 
One side Frame	Detected Pupil 	Detected Pupil 
Full Frame	Detected Pupil 	Detected Pupil 

Table 1 and Table 2 show our experimental results on three types eyeglasses with different frame type.

Fig.2 gives the final result of our approach, with the localized pupils in eye pair for a user wearing eyeglass of frame type 1.



(a)

(b)

Figure 2: Iris and Pupil localization

Our proposed work achieves 100% pupil localization in real-time for users wearing eyeglasses of frameless type. 100% accuracy is not achieved for two types of eyeglasses, as false circles are detected due to frame reflections. Fig. 3 and Fig. 4 show the results of our approach in terms of detected pupils.

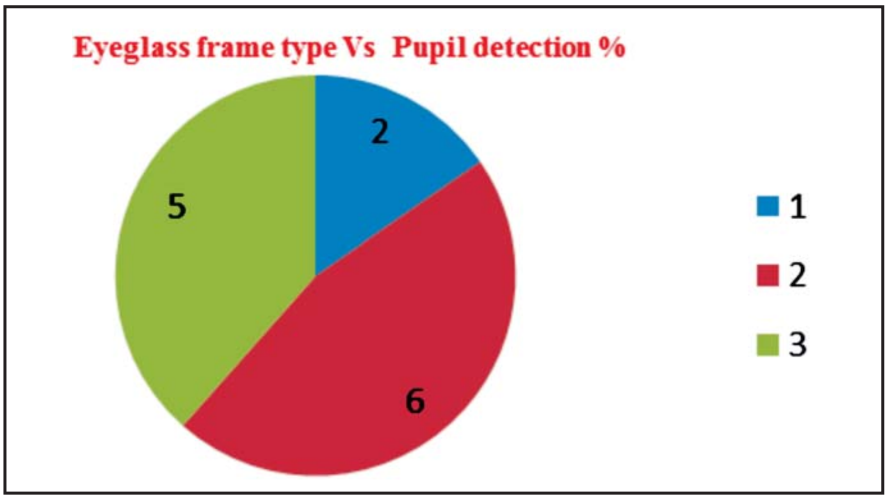


Figure 3: Frame type Vs. Detected pupil

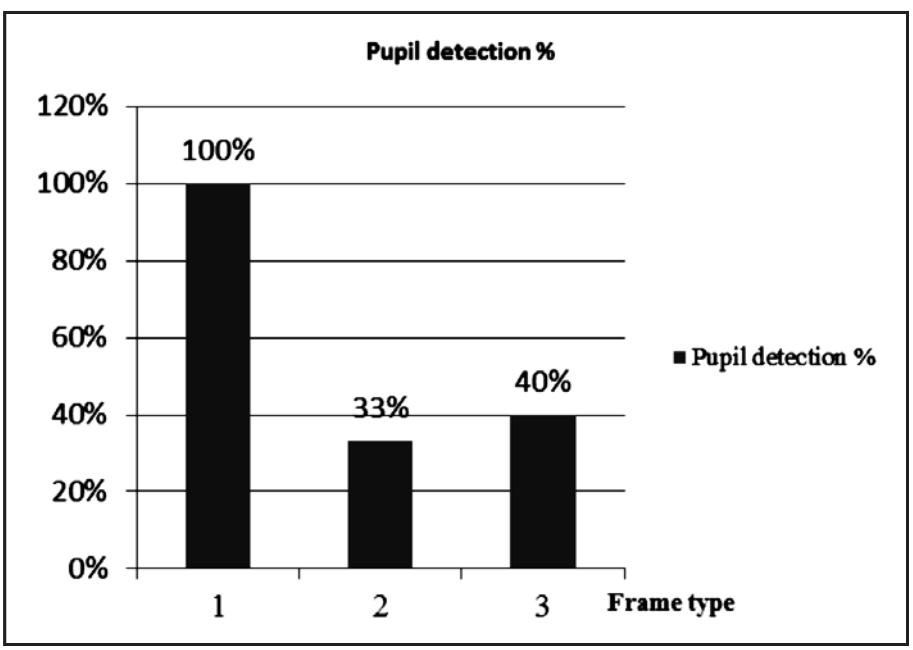


Figure 4: Frame type Vs. Pupil detection %

5. CONCLUSION

This paper has presented a robust, real-time algorithm for localizing iris and pupil center in an eye pair image captured through a webcam. The main feature of the proposed work is non-invasive under natural lighting condition without IR illuminators for users wearing eyeglass. It uses simplified approach on binary image with rapid execution on desktop computer and laptop for frameless eyeglasses. The proposed approach has to be improved for other two types of eyeglasses to achieve accuracy in future. This algorithm can serve as an essential element for gaze direction detection.

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