

A Survey on Eye Tracking and Detection

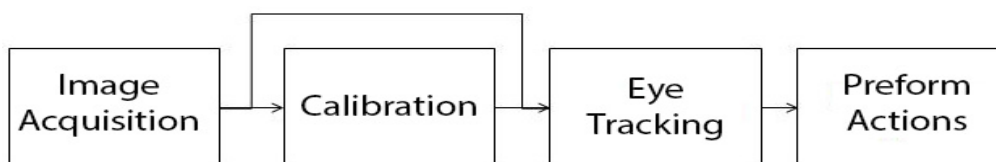
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ABSTRACT: Study of eye movement is widely being employed in Human Computer Interaction (HCI) research. Eye detection and tracking has been an active research field in the past years as it adds convenience to a variety of applications. Eye-gaze tracking is been considered as untraditional method of Human Computer Interaction. Eye tracking is considered as the easiest alternative interface methods. For eye tracking and eye detection several different approaches have been proposed and used to implement different algorithms for these technologies. Generally, an eye tracking and detection system can be divided into four steps: Face detection, eye region detection, pupil detection and eye tracking. One common problem with many eye tracking methods proposed so far is their sensitivity to change in lighting condition. Under changing lightning conditions and because of poor resolution cameras the captured images are of poor quality. Eye detection with blurry and poor quality images increases complexity and sometimes reduces the accuracy. Despite the amount of research done on both eye tracking and eye detection, researchers are still trying to find robust methods to use effectively in various applications. This paper presents a survey for eye tracking and eye detection methods proposed in literature. Examples of different fields of applications for both technologies, such as human computer interaction, Biometric Security, Eye gaze tracking, Driving assisting systems, and assistive technologies are also investigated. This paper is very useful for new researchers for study various approaches and different algorithms for eye tracking and eye detection.

KEYWORDS: Eye tracking, Eye detection, Eye-gaze, Eye Movement, OpenCV, Blink Detection, Eye centre localization, Feature extraction

I. INTRODUCTION

Eye's and their movements are important in expressing a person's desires, needs and emotional states [1]. Method of recording eye position and movements is called oculography. Eye movement provides a rich and informative window into person's thought and intentions. The motion and geometric characteristics of eyes are unique which makes pupil localization, gaze estimation, and eye tracking important for many applications such as biometric security, human attention analysis [10]. Hence robust eye detection and eye tracking are considered to play a crucial role in the development of Human Computer Interaction, Biometric security and in wide range of applications [2]. Eye gaze detection system is natural form of interaction, accomplished by identifying where person is looking [3]. Eye gaze system is based on laptop web camera, enabling a more natural form of human-machine interaction [11]. This eye gaze can be used on PC's, Smart phones or Tablets.



Fig(1)Eye gaze system block diagram

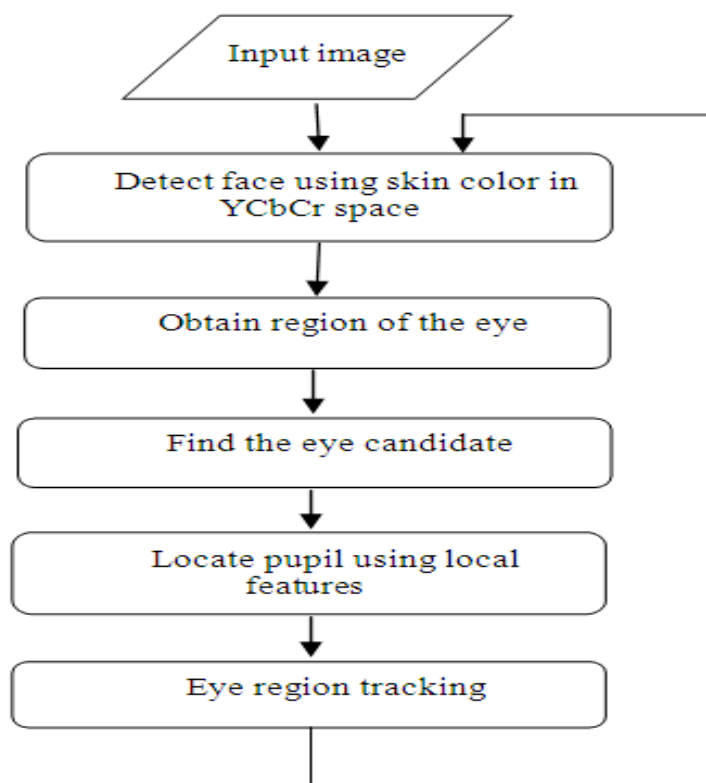
The eye gaze application starts with image acquisition, from web camera or pre-recorded video [11]. After image acquisition there is calibration block where image where eye gaze is initialized for pointer position on screen. The system is based on image processing toolbox OpenCV [12], Open computer vision library [3]. To detect and track eye images with complex background, distinctive features of user eye are used[2].

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An eye tracking and detection process is divided into four steps: Face detection, eye region detection, pupil detection and eye tracking. For each step different approaches and algorithms are available. To take images of person's face Hough transform algorithm is used [4]. To detect eye Haar-like features are used, Haar classifiers are already available in OpenCV [5]. To detect eye Haar cascade classifier is used which is present in OpenCV API [9][12]. Haar classifiers are trained with a few thousand of sample view images of object and cascade is constructed to detect eye rapidly. Mean shift algorithm is used for segmentation of eye images. Pupil position is not constant always, for accurate pupil localization Kalman filtering is used [7].



Fig(2) Algorithm for eye detection and eye tracking.

Eye tracking is used as alternative interface method; they have achieved higher accuracy and performance [1]. Eye movements are least affected by disabilities. Combining eye tracking and detection can provide a larger number for control commands to be used with assistive technologies such as a Human computer interaction, Biometric security, driving assisting system [1]. There are many issues associated with eye tracking and detection system, because of which such system becomes challenging task. These issues include degree of eye openness, variability in eye size, poor resolution of cameras, blurry images [4]. Detection of eye becomes easy when person is not wearing any lens or glasses, but conflict occurs if direct contact with eye is not possible [2]. The efficiency of eye detection is dependent upon the proper eye tracking approaches and algorithms [6].

There are many methods and algorithm introduced in literature focusing on eye tracking and eye detection. They can be used as base to develop an eye tracking and detection system which achieves highest accuracy, best performance and lowest cost. This paper presents the survey of different eye tracking and eye detection approaches reported in the literature along with examples of various applications employing these techniques.

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II. EYE TRACKING

The geometric and motion characteristics of the eyes are unique which makes eye and eye detection tracking important for many applications such as human attention analysis, human emotional state analysis, interactive user interfaces and biometric security[1].

A. Sensor based eye tracking(EOG)

Some eye tracking system makes use of electric potentials measured with electrodes placed in the region around the eyes called as electroculogram [1]. This is done to detect eye and analyse the movement of eyes. The electrode becomes steady when eyes are in their original states. Eye movements can be tracked by analysing the changes in EOG signal.

B. Computer vision based eye tracking

Many eye tracking presented in literature use computer vision based eye tracking techniques. In these methods camera is set to focus on one or both eyes and record the eye movement. There are two main areas investigated in the field of computer vision based eye tracking. One is eye detection in the image, also known as eye localization. The second is eye tracking, which is the process of eye gaze direction estimation. There are many issues associated with this type of tracking such as degree of eye openness, variability in eye size, head pose, etc. Different applications that use eye tracking are affected at different levels [1].

1. Pattern recognition for eye tracking

Pattern recognition techniques such as template matching and classification are effective in the field of eye tracking [1].Artificial Neural Network (ANN) is used to classify the pupil position. The training data required for ANN is gathered during calibration [8].

2. Eye tracking based on corneal reflection points

Reflection points on cornea are used by many computer vision based eye trackers to estimate gaze direction. Images containing corneal reflection points are also called as Purkinje Images. To compute the gaze direction vector between the centre of pupil and corneal reflections is used [6].

3. Eye tracking based on shape

This is also one of the popular approaches of tracking eye and detecting eye pupil, iris based on the circular shape or edge detection. Hough transform for eye detection is applied to facial images. First step is detection of face based on existing face detection method. Then the eye is searched based on circular shape of eye in a two dimensional image [1].

4. Eye tracking by means of gradients

In this approach the eyes are detected by analysis of vector field of image gradients. In [6] authors have mathematically described the relationship between a possible centre and the orientations of all image gradients. In order to obtain the image gradients they computed partial derivatives [6].

5. Eye tracking using dark and bright pupil effect

There are two illumination methods used for pupil detection, one is dark pupil and another is bright pupil method [4]. In dark pupil method, the location of dark pupil is determined in the eye image captured by camera. The bright pupil method uses the reflection of infrared light from retina which makes pupil appear white in the eye image [7].

6. Eye tracking using eye models

Eye models are used for eye tracking. The cornea of eye is modelled as a convex mirror. Eye's 3-D optic axis is estimated based on the characteristics of convex mirror. The visual axis represents the actual 3-D eye gaze direction of the user. The schemes in this are very complex and hence they are not applicable for real time eye tracking [1].

7. Hybrid eye tracking techniques

Eye tracking can also be performed by using mix of different efficient eye tracking techniques. In this intensity of eye pupil is used for pupil detection. To separate bright objects from pupil, other properties of pupil can be used. Different properties of pupil are pupil size and shape [4]. In hybrid technique support vector is used to locate the location of eye from detected candidates [1]

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III. LITERATURE SURVEY

In area of eye tracking and detection, there are many issues such as lightning conditions, degree of eye openness, variability in eye size, poor quality of cameras. The many authors are working on parameters like eye openness, pupil intensity, dark and bright pupils, image gradients for robust eye detection and eye tracking techniques [6]. That robust technique will be effective and very useful for many real world applications like Human Computer Interaction, Biometric security, driving assisting system etc. [10]. The various properties of pupil are used by authors to make accurate detection of eye.

The author M Azimi Kashani, et al. used colour information in YCBCR environment and Gaussian Mixture Model. Skin colour segmentation along with skin colour model construction is performed. Eye region is detected by Kalman filtering and localization of pupil is done by applying Harris method [2]. The author Rafael Santos, et al. proposed an eye gaze system as human computer interface. The system has proposed requirements such as image acquisition, eye tracking and calibration. The system is based on Open Computer Vision Library which is toolbox for image processing [5][9]. The OpenCV implemented different algorithms like Haar cascade classifier, Hough transform, Mean shift and Kalman Filter [3].

The author Jianbin Xiong, et al. proposed a novel eye gaze tracking system with purposes of high tracking accuracy and low cost of implementation. The system is based on pupil cornea reflection; ameliorated Hough transform algorithm and an efficient eye blink detection [12]. Using eye images as input, the software then localize the pupil position employing a pupil cornea reflection method. The theoretical methods that are used in this system are Hough transform algorithm, Ameliorated Hough transform algorithm, the coarse partitioning method. The image filtering method, canny image detection method [4].

The author Vandna Singh, et al. used Open Computer vision library to implement Haar cascade classifier. For the detection of face Haar features are the main parts of Haar cascade classifier. Two types of images were used the type-1 image contains light background and lightly affected by illumination while the type-2 image highly affected by illumination and have complex background [5]. OpenCV provides Haar cascade implementation with various trained cascade classifier [9]. Authors used default frontal face cascade.

The author Fabian Timm, et al. described a method for accurate eye centre localization by means of gradients. Authors defined a novel approach for eye centre localization which defines centre of semi-circular pattern as the location where most of the image gradients intersect. Derived Mathematical function reaches its maximum at the centre of circular pattern. For evaluation authors selected BioID database. This approach yields accurate centre estimation not only for images containing dominant pupils, but also in the presence of glasses, shadows, low contrast [6]. Author Zhiwei Zhu et al. proposed reliable eye tracking and detection method which can track eyes robustly under various illuminations and face orientations. Authors developed algorithm by combining the bright pupil based Kalman filter eye tracker with the means shift eye tracker. They choose 2D joint Histogram which is derived in the grey level dark pupil and bright pupil [8].

IV. CONCLUSION AND FUTURE WORK

Eye tracking and detection is considered as efficient and reliable method of human computer interaction. In this paper we studied existing methods and presented the art of survey on eye tracking and detection. Many applications can get benefited from effective eye tracking and detection methods. Some aspects need to be guaranteed, one important aspect is the lighting conditions, face and eye illumination, which should be homogenous most natural possible. Second important aspect is camera quality, high resolutions cameras will decrease detection and eye gaze errors. Some eye tracking techniques requires extra hardware. More research and work is needed to make eye tracking reliable for many real world applications.

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