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Glint Detection and Evaluation Using Edge Detectors

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***Abstract*—**Gaze based human computer interaction (HCI) has become a very significant area of research in computer science. Eye gaze estimation is generally done in relation to gaze direction of the eye position and movements of the user. Gaze interaction combines specific eye movements and requires the estimation and detection with high accuracy so as to identify the region of interest (RoI). The eye coordinates are extracted and the relationship between the user's pupil and glint can be determined to ascertain RoI for further detection of the glint and the gaze position. Among other methods, edge detection techniques are also applied to segment the image into different required components for analysis. Different edge detectors with wide range of parameters can be effectively used for detecting the glint coordinates and gaze direction.

In this research paper, a comparative experimental analysis of three standard edge detectors Sobel, Canny and LoG has been done for detecting glint formation. Variation in parameters like threshold T, sigma S_i along with the alpha factor α generates different output patterns. Number of outputs generated for Sobel, LoG and Canny are 90, 176 and 146 respectively. The outputs obtained are studied for estimating the desired RoI and compared for understanding the performance. Analysis of a large image data base shows that the different domain of images require different ranges of control parameters for better results. The analysis of the result shows that Sobel and Canny detectors are better than LoG for the detection of RoI. The Sobel works well without sigma parameter as compared to other edge detectors. LoG edge detector requires large values of α for detecting the required glint boundary. The Canny edge detector works well with comparatively lower values of α than LoG and RoI is gradually refined in the direction of better glint within these values of α. The sigma S_i for the Gaussian filter in case of LoG and Canny detector techniques has also been experimentally analysed. The LoG detector works well with S_i but Canny detector with S_i behaves in a different manner. Smaller the S_i parameter, better the detection of RoI is for Canny detector. The range of α in Sobel detector is less which may help further in faster boundary detection of RoI. These results can be used for effective approximation of gaze direction for further improving the accuracy and performance of different eye gaze based systems.

***Keywords*—**Eye gaze; edge detector; ellipse; glint; pupil.

I. Introduction

Different techniques and algorithmic processes of non physical contact with the computing devices are used to design, evaluate and implement various interactive computing systems [1]. Eye gaze involves measuring of individual's eye movements at any given time and the sequence in which the person's eyes are shifting from one location to another. Eye gaze based methods can be used for executing desired instructions by the user to the computing system for investigation and analysis for meaningful interaction. Various applications of eye gaze based human computer interaction (HCI) techniques are gaze based system controls, understanding intention and desires of the subject, car driver's behaviour, simulators for surgical and medical, interactive dictionary, gaze reactive intelligent tutoring system etc. The advantages include comparatively safer interaction, no requirement of physical proximity, reduction in object selection time and an increase in the interaction speed.

Eye gaze based system requires the estimation and detection with high accuracy so as to identify the region of interest (RoI), a selected subset of an image. The detection of gaze point requires the movement of the eye to be detected [2]. Gaze detection reflects the user's intention, desire, and attention for the selection of any task, icon or menu. The eye gaze based detection system may also be used to point, select, activate and a combination of these tasks. For the analysis of eye gaze, RoI has to be detected and various features can be used like pupil, glint, colour, texture, iris, pupil radius and center, eyelid contours, eye corners etc [3]. The darkest region in the eye image is considered as pupil. The glint or purkinje image is a point of corneal reflection of the light falling from the outside source on the pupil. In terms of image it can be regarded as the highest possible grayscale value located within pupil region or on its circumference. The glint region is identified using standard edge detectors by varying different thresholds. The eye gaze tracking system is highly dependent on the precise detection of iris, pupil and glint. The direction of gaze is generally estimated by mapping reference point of the glint vector and the center of the pupil of these features [4], [5]. Moreover the iris, the pupil etc. move underneath the glint as the user's gaze changes [6]. The estimation of the RoI i.e. glint can be calculated after the exact estimation of the coordinates of the pupil and other required regions. The outer coordinates of RoI are detected by edge detection in image processing. An edge is characterized by an abrupt change in intensity indicating the boundary between two regions in an image. It helps to find out the required RoI to segment the image into different required components for further analysis. Edge detection techniques can further be used to segment the image into different required components for analysis. It helps in extracting the most important shapes in an image, ignoring the identical unwanted regions and remarking the RoI [7].

Various edge detectors reduce the amount of processed data and filter it, preserving the important structural properties like amplitude and location of RoI in an image [8]. These characteristics can be estimated with edge detectors. Several edge detectors that can be used for finding the RoI are Sobel,

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Prewitt and Roberts and Canny, the first order derivatives. The second order derivative includes Laplacian of Gaussian (LoG). These detectors may have different sensitivity to noise, smoothness values and ability to approximate the edges, different computational time and complexity. Sobel operator is the most commonly used edge operator which computes the edge while smoothing at the same time. It places emphasis on the pixel near to the center of the mask. Roberts operator computes the edge at the interpolated point and provides a simple approximation to the gradient magnitude with a 2-D spatial gradient measurement on an image. The Prewitt operator estimates the magnitude and edge orientation. Canny edge detector smooths the image with a gaussian filter. Afterwards it computes the gradient magnitude and orientation. Canny algorithm uses horizontal and vertical gradients. The LoG is a gaussian smoothing filter and is usually used to establish whether a pixel is on the dark or light side of an edge [10]. LoG method finds edges by looking for zero crossings after filtering the image with a LoG filter. Canny and LoG is high sensitive to noise as compare to other methods. These edge detectors require certain thresholds for accurate edge detection as thresholding simplify the data corresponding to the eye image. Variations in the threshold value and other parameters of these detectors result in segmentation of RoI with gradient magnitude, orientation etc. Reduction in the size of the image from a 7-bit grayscale to a 1-bit binary significantly reduces the computational processing requirement [11]. This variation in the threshold values and other parameters generates different binary images for analysis.

The objective of this study is to comparatively analyse the effectiveness for obtaining the glint from a normalized eye image of the subject using three standard edge operators namely Sobel, Canny and LoG. The effectiveness of these operators is observed by varying the different values of thresholds, alpha factor and other parameters of the edge detectors for analyzing the different outputs obtained. By adjusting these different control parameters the appropriate RoI i.e. the boundaries and coordinates of the glint are estimated and analysed.

The remainder of this paper is organized as follows. The literature review is presented in Section II. Section III presents the methodology of the proposed work. Section IV presents the experimental results and discussion. Section V includes conclusion and further research directions.

II. Literature Review

As discussed above a significant research is being done in the area of eye gaze for the working of standard edge detectors. Different standard edge detectors are being used to detect the RoI for eye gaze detection system. Some of the significant algorithms and models including edge detectors, pupil and glint etc. are presented below.

N. Erdogmus et al. presented an efficient method of extracting different eye features like iris, eyelid using different edge detector techniques [3]. A study on the impact of eye locations on 2D face images is done with an automatic technique for eye detection is proposed by P. Weng et al. Various discriminate features has been used to characterize eye patterns [11]. An automatic, non intrusive monocular eye gaze system is proposed by Djeraba et al. using an anthropomorphic model of the human face. The system calculates the face distance, orientation and gaze angle, without any user specific calibration [12]. Gaze estimation algorithm has been presented by J.R. Lewis et al. which work on pupil glint detection and tracking, gaze calibration and mapping to determine eye gaze position [13]. A low cost system is proposed for estimating gaze with a cursor control system irrespective of the real position of pupil center by I.F. Ince et al. The main focus is on the mass center of an eye socket. The pupil is located with no ANN, no calibration and no training process. However lack of auto thresholding affects the system [14]. The paper by J.G. Wang et al. estimate eye gaze with only one eye image and that consequently achieves higher accuracy of eye gaze estimation in less computational time [15]. An inexpensive algorithm is proposed to estimate the eye gaze on the computer screen is by the authors. The algorithm can quickly determine the glint and pupil center of the user with normal lights. These features are further extracted to estimate the gaze of the user for the scaled conjugate gradient based neural network. Different morphological operations are being used in the paper to find the accurate results [16]. In the method proposed by P. Zhang et al. pupil position is obtained by the subtraction of two images, the bright pupil and the dark pupil. The pupil center is located by ellipse fitting with the help of the glint in the dark pupil for detecting the local gaze direction. The method used support vector regression for mapping relationship of the eye parameters to gaze point [17]. The experimental analysis on the working of several edge detectors indicates dependency of glint on parametric variations for finding the RoI [18].

Edge detectors can be used for finding RoI for gaze estimation. The survey of literature review reveals that edge detectors can be used for finding the RoI like iris, pupil and glint corners in the input image with the help of certain control parameters and other image processing functions.

III. Methodology

As stated above the objective of the research is to comparatively analyse the working of three different standard edge detectors for finding the appropriate RoI. The RoI is the boundaries and coordinates of the glint. These are adjusted to obtain these boundaries and coordinates. In this research work Canny, Sobel and LoG, three standard edge detectors have been selected for experimental evaluation. To achieve the objective an image database *DB* is built for the study containing the selected images taken from different sources [19]. Each image is normalized to a uniform size of 473x170 bmp format. The workflow of the experimental study has been shown in figure 1(a) for the input image figure 1(b). An input image I_i is taken from the *DB*. For experimental analysis, preprocessing of I_i has been carried out which includes cropping and resizing of the image and generates processed image I_P, in the required format. The threshold T is obtained

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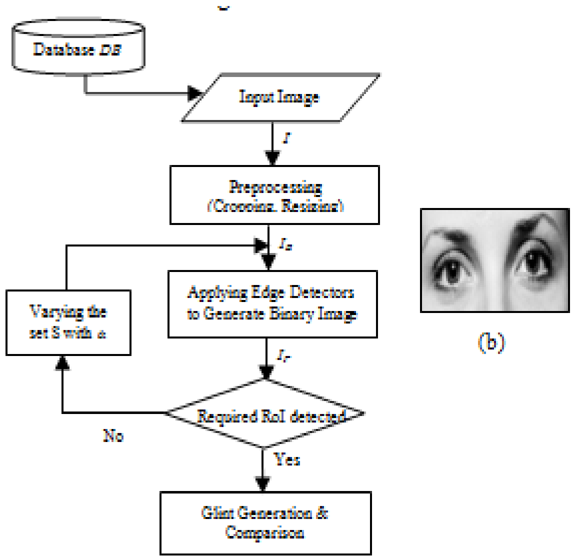
using the inbuilt MATLAB edge function for various edge detectors for detecting RoI.



(a)

Fig. 1 (a). Work flow for glint detection. (b) An input image I_i from *DB*.

Further the threshold value is multiplied by alpha factor α and is selected with a range from 0.5 – 10.5 to form set *S*. The calculated value is again given to the edge function with a uniform incremental interval of 0.5 in the given range to detect the appropriate RoI except in Canny where the interval is 1.0. The binary image I_B is the set of images obtained after applying varying values of *S*. The result has been shown for the input image I_i of figure 1(b). The experiments have been carried out in MATLAB R2013a. The analysis has been done using a variety of normalized eye images selected from a specific domain for the generation of meaningful results. Each image has been tested for each of the above mentioned edge detectors with different *S* values. Some of the significant results for the binary image I_B are shown in figure 2. In case of Sobel, the required RoI is detected at α in the range of 0.5 to 4.5 with an increment of 0.5. The Canny operator doesn't show the required edges with the same *S* values which are being used in the Sobel operator. Therefore the *S* value has to be increased for Canny from 1.5 to 8.5. The sigma parameter S_i is also being considered with Canny for better detection.

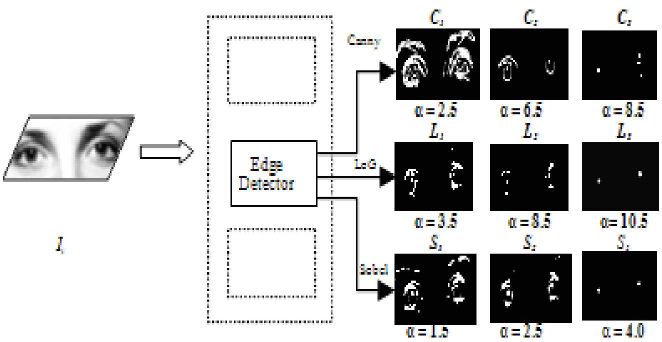


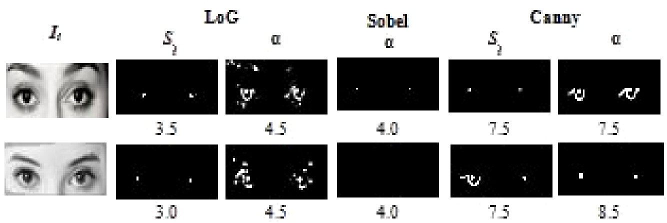
Fig. 2. Working of glint detection model.

In the Sobel edge detector method, the first binary image is generated at value of *S* with α = 1.5 but there is no proper visibility of glint as shown in figure 2. In the LoG edge detector method, the first binary image is generated at value of *S* with α = 3.5 but there is no proper visibility of glint (Fig. 2). However, in certain cases of LoG, α values need to be adjusted up to 10.5 to get better RoI.

IV. Results And Discussion

As explained above, estimation of the RoI i.e. glint in the input image is done using three standard edge detectors viz. Canny, Sobel and LoG. The outputs obtained are compared for understanding the performance. Each image is tested with the three edge detectors by adjusting *S*. Factor α is uniformly varied and the outputs generated are observed to find out the desired RoI. In cases where not very significant results are obtained, the range of α is further increased if required. In the case of Canny, the range of α is 1.5 to 8.5 with an increment of 1.0. In case of Sobel, the required RoI is detected at α in the range of 0.5 to 4.5 with an increment of 0.5. The Canny operator doesn't show the required edges with the same *S* values which are being used in the Sobel operator. Therefore the *S* value has to be increased for Canny. The sigma parameter is also being considered with Canny for better detection. In the Sobel edge detector method, the first binary image is generated at initial value of *S* with α = 0.5 but there is no proper visibility of glint. In order to obtain the glint of an image the value of α is increased for all the detectors. Proper glint for Sobel is obtained at *S* with α = 4.0 as shown in figure. 2. The lower values of α in Canny detector result in extra computation for glint detection. At α = 6.5, a binary image is generated but without proper glint as shown in figure 2. The image at *S* with α = 8.5 generates the exact glint. The output is not very significant at α ranging from 0.5 to 4.5. However, when this value increased beyond 4.5, RoI is gradually refined in the direction of better glint.

Table I. Varying ranges of S_i and α for glint generation using different LoG, Sobel and Canny detectors for input image I_i



As depicted in table I, varying ranges of S_i, and α for glint generation using different LoG, Sobel and Canny detector for different input images I_i are analysed. It is observed that every input image generates different glint on the basis of S_i and α parameters and requires increase in the value of α. Some images also require a range greater than 4.5 for glint detection.

The outputs are also black at some maximum values of S for different detectors (α = 4 for both the images in table 1). The varying ranges of α for glint generation using different edge detectors for input image I_i are shown in table 2.

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Table II. Varying ranges of α for glint generation using different edge detectors for input image i_i

	Sobel	LoG	Canny
No. of outputs	90	176	146
Range of α - Incremented by -	0.5-4.5 0.5	0.5-4.5/10.5 0.5	1.5-8.5 1.0
Glint detected at	2.5 <=α<= 3.5	6.5<=α <=10.5 1.99<=S_i<=2.69	5.5<=α<=8.5 3.69<=S_i<=1.08

The various columns in the table II show the variable increment of α at the different images with or without the S_i parameter. A total of 412 binary images are generated using three different edge detectors. The value of *α* is varies with different detectors. For Sobel and Log it is 0.5-4.5 with an increment of 0.5, however in certain cases of LoG, α values need to be adjusted up to 10.5 to get better RoI. In case of Canny the range of α is 1.5-8.5 with an increment of 1.0. An increase in the optimum range of S_i parameter of the LoG operator is 1.99 to 2.69 which helps in obtaining the desired RoI. A decrease in the range of S_i of Canny from 3.69 to 1.08 also helps in obtaining the desired RoI. In case of Sobel better results are obtained for *α* range of 2.5 to 3.5. In case of LoG for better results the range of *α* is 6.5 to 10.5 whereas the Canny range is 5.5 to 8.5. The Canny and LoG operators with the S_i generate better output as compared to the outputs generated by the other detector. Some outputs also generates only one eye glint at the maximum values of *α*, helpful in eye gaze study. Some images require preprocessing for better detection of RoI. Some images also require a range greater than 4.5 for glint detection. The outputs are also black at some maximum values of *S* for different detectors.

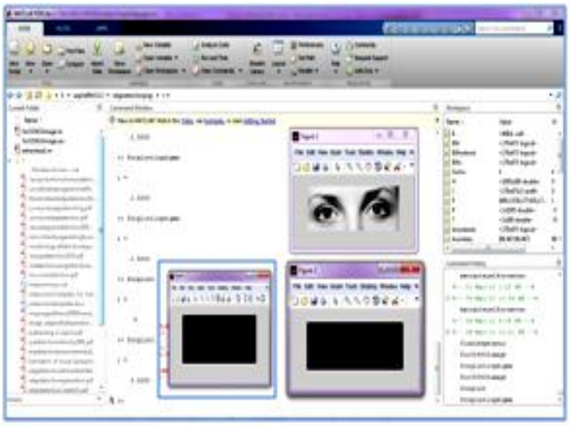

Fig. 3. MATLAB interface generating RoI for different input images.

The MATLAB interface has been developed for implementation of the above comparative model for ascertaining the RoI as shown in figure 3.

V. Conclusion

Detection of various features like pupil, iris and glint are used for estimating the direction of the user's gaze. The objective of this study is to comparatively analyse the effectiveness for obtaining the glint from a normalized eye image of the subject using three different standard edge detector operators. Three standard edge detectors Canny, Sobel and LoG can be used for different parametric variations for obtaining glint from different input eye images. The Sobel, and Canny, first order derivatives and LoG is the second order derivative. Different ranges of control parameters including threshold, alpha factor and sigma parameters have been adjusted to generate different kinds of outputs. The effectiveness of these operators is observed by varying the different thresholds and other parameters of the edge detectors for analyzing the different outputs obtained. By adjusting different control parameters, the appropriate region of interest like the boundaries and coordinates of the glint are obtained. In case of Sobel good results are generated for different input images. Variable increment is done for better RoI detection in different images. Number of outputs for Sobel, LoG and Canny are 90, 176 and 146 respectively. The value of *α* is varies with different detectors. For Sobel and Log it is 0.5-4.5 with an increment of 0.5, however in certain cases of LoG, α values need to be adjusted up to 10.5 to get better RoI. In case of Canny, the range of α is 1.5-8.5 with an increment of 1.0. However, it has been observed that in many of the cases the required RoI is obtained with *α* ranging up to 4.5. Further, it has been observed that better results are obtained in different ranges of *α* parameter. In case of Sobel, better results are obtained for *α* range of 2.5 to 3.5. In case of LoG for better results the range of *α* is 6.5 to 10.5 whereas the Canny range is 5.5 to 8.5. In case of LoG and Canny in addition to *α* parameter, S_i parameter is also varied for optimum results. Optimum range of S_i parameter is 1.99 to 2.69 for LoG, a decrease in the range from 3.69 to 1.08 in the case of Canny.

However, in case of Canny, operator generates the required result but the sigma parameter of the operator behaves in a totally different manner. Lowest the value of sigma, required RoI is generated. The LoG detector also works well with S_i. It has been observed that the value of the suitable threshold that can be used as a general threshold for edge detector Sobel is found to be near 3.5 or 4.0, displaying better results. However, *α* factor value has to be increased to a certain extent for Canny and LoG detector for generating the RoI.

The result shows that different domain of images requires different ranges of control parameters for better results. Different set of images were tested to obtain more than 412 outputs. Sobel generate good results T with α = 4.0. LoG operator with *α* = 0.5 - 4.5/10.5 (in some cases) generate the required results. It has been observed that Sobel and Canny detectors generate better results as compared to LoG but overall Canny generates better output for the detection of glint. The Sobel works well without sigma parameter as compared to other edge detectors. However, Canny and LoG requires sigma parameter which generates a variety of results. The range of *α* in Sobel detector is less which may help further in faster boundary detection of RoI. The study is further used to develop eye gaze based model that accepts the sample images from the given database and approximates the gaze direction.

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