IJCSET – Volume 2, Issue 2 –August 2016. ISSN: 2455-9091 Pages: 25-34

International Journal of Computer Science Engineering & Technology
Approved by
National Science Library (NSL)
National Institute of Science Communication and Information Resources (NISCAIR)
Council of Scientific and Industrial Research (CSIR)– New Delhi. India.
ISSN :2455-9091

# AN EFFICIENT EYE GAZE TRACKING SYSTEM ON DESKTOP MODEL

[1] Sherin Banu Pookkuth
[1] M. Tech Scholar
[1] Dept. of ECE
[1] MEA Engg. College
[1] Kerala, India

[2] Abdul Raouf Khalid MT
[2] Asst. Professor
[2] Dept. of ECE
[2] MEA Engg. College
[2] Kerala, India

**ABSTRACT-**Eye gaze tracking has been an active research field in past years as it is useful in variety of applications. The purpose of this project was to create a low cost desktop model eye gaze tracking system. Several different approaches have been proposed for eye tracking and used to implement different algorithm for these technologies. An eye gaze tracking system can be divided in to five steps head tracking, face detection, pupil and iris detection. Iris detection was an included as a unavoidable processing step for eye tracking. One of the most important problems with many of this eye tracking methods propose so far is the sensitivity of system to changing lighting conditions and because of the poor camera resolution the captured image is of poor quality. Gaze detection with poor quality images increases complexity and reduces the accuracy sometimes. Here presents a simple, accurate and less processing time method for iris detection in eye tracking. An Integro object function is used to find the iris boundary which can be used in low contrast images to detect the iris center. The proposed method reduces the complexity of finding eye gaze. In addition, experiments for gaze tracking are performed in real-time video sequences under a desktop environment. The proposed method is not sensitive to the light conditions. Experimental results show that visible imaging video type eye gaze tracking system our method out perform as compared to other methods.

**Keywords-** gaze tracking, head tracking, video based gaze system, point of gaze

## I. INTRODUCTION

Eye gaze tracking is the process of estimating the direction of point of gaze of a person and it has been topic on research for many decades because of its potential usage in various applications, such as human computer interference, virtual reality, eye disease diagnosis, human behavior studies etc. Movement of eye is important in identifying person's desires, needs and emotional states [1].both eye and head movement is detected in eye gaze tracking system in order to locate the gaze point in visual scene.

Many eye tracking techniques are presented in past years they can be categories in to intrusive and non-intrusive [2]. Former one report the direction of gaze relative to the head or a fixed position of the eyeball and later one doesn't require any physical contact with the users gaze. Non- intrusive type is also called remote systems [3]. There are many methods introduced in literature on eye tracking. They can act as a base to develop an eye gaze tracking system which achieves the highest accuracy, better performance and lowest cost. Head movement tracking is also been growing rapidly as well.

Until recently, the eye- gaze tracking was a very expensiveandcomplex task used only for laboratory research. However, latest technological advancements (better processor speed, advanced digital video processing) have let down the cost and affectedlyimproved the efficiency of eye - gaze tracking system. The eye gaze tracking system starts with image acquisition of prerecorded video or from web camera. From the recorded video face portion is detected. After that there is a calibration phase where eye gaze is initialized for the cursor pointer on the screen. This whole process is based on image processing.Each stages of system can be done using different methods. Overall efficiency of the system depends upon the method used in each step.

In this paper, we implement a desktop model eye gaze tracking system using a web camera using visible imaging. First we extractthe human face from a real time video to detect the eye region. Than we use Integrodifferential object to detect the iris center. In order to compensate the head movement causing error, here we adopt asinusoidal head model to stimulate the 3-d head shape. Lastly, eye gaze tracking is performed by the integration of the iris center and head movement.In this paper, we focus on gaze estimation methods based on analysis of the image data. The main contribution of this paper is as follows.

The proposed approach can tolerate light change and give a accurate method for the gaze tracking.

An In teg ro differential object function provides a low complex method to detect iris center and processing time is less.

The remainder of this paper is organized as follows: section II describes the related studies. Section III explains the details of the proposed gaze tracking system. In section IV, we explain the application of gaze tracking. In section v we briefly explain the performance of the proposed method. Section V is the conclusion.

## 2. RELATED WORKS

This section outlines the different methods used for video type gazetracking. Numerous eye detection methods have been developed in the last ten years.

Various feature recognition methods, such as template matching and classification, have showed efficient in the field of eye tracking. Raudonis et al. [5] used principal component analysis (PCA) to locate the first six principal components of the eye image to decrease dimensionality problems, which produce when using all image pixels to compare images. Tang and Zhang [6] proposed a technique that uses the detection algorithm shared with gray prediction to provide eye tracking purposes. The process uses low-level data in the image in order to increase speed. Lui et al. [7] proposed robust and fast eye detection and tracking method which can be used with rotated facial images. The camera used by the system is not head mounted. Then a Template Matching (TM) is applied to detect eyes. Zernike Moments (ZM) is used to extract rotation invariant eye characteristics. Chow and Li [8] propose a technique fordetecting the likely iris region Using Hough transform and deformable template technique.

Various computer vision based eye trackers use light reflection points on the cornea to estimate the gaze direction. Yang et al. [9] suggested a method which consists of gray difference between the face, pupils and corneal reflection points for eye detection. This scheme was tried under a cross-ratio-invariant-based eye tracking system.

Another method for eye detection and tracking is to discover the location of the iris or the pupil based on their circular shape or by means of edge detection. Chen and Kubo [10] presented a method where a sequence Gabor filters and face detection is used. The probable face regions in the image are detected based on skin color. Kocejko et al. [11] presented the Longest Line Detection (LLD) algorithm to identify the pupil position. This algorithm is based on the guess that the pupil is arbitrary circular. The elongated vertical and horizontal lines of the pupil are created. The midpoint of the elongated line among the vertical and horizontal lines is the pupil center.Pranith and Srikanth [12] proposed method which finds the inner pupil boundary by using Circular Hough transformation whereas the outer iris boundary is identified by circular summation of intensity from the detected pupil center and radius. Song et al. [13] proposed the binary edge images and intensity data to detect eyes. Their technique contains of three phases: first phase involve extraction of binary edge images (BEIs) from the grayscale face image based on multi-resolution wavelet transform, second phase is the extraction of eye regions and segments from BEIs, and third eye localization based on light dots and intensity information.

There are two reflection based methods used in the literature for pupil estimation: the dark pupil and the bright pupil technique. In the dark pupil technique, the position of a black pupil is estimated in the eye image taken by the camera. Zhu and Ji [14] suggested two new schemes to permit normal head movement for eye tracking and reduce the calibration of the eye tracking system to only one time for each new user. Choi and Kim [15] suggest an eye detection system using the Modified Census Transform (MCT)-based pattern correlation. The method detects two eyes by the MCT-based AdaBoost eye detector over the eye areas.

## 3. PROPOSED METHOD

Eye detection and tracking is a very difficult task due to numerous unique issues, including illumination, viewing angle, occlusion of the eye, head pose etc. Iris Centre is the utmost eminent gaze feature in the face image. When looking at different positions on the screen, eyeball moves in the eye socket. The iris center in the eyeball changes its position that indicates the eye gaze. However, the gaze vector is sensitive to the head movement and produces a gaze error, while the head moves. Therefore, the head pose should be estimated to compensate for the head movement.

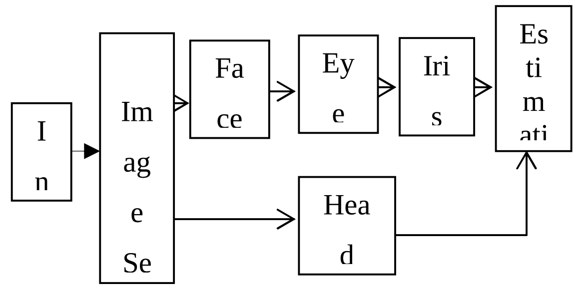


**Figure 1- Eye Gaze Tracking System Block Diagram.**

Fig.1. shows the block diagram of the eye gaze tracking system. We use feature-based eye gaze tracking method to estimate eye features and head pose information to improve the Accuracy of the gaze point estimation. Firstly we extract the eye region that comprises the eye movement information. Then, we identify the iris center and eye corner to form the eye region. In this paper we use feature based visible imaging gaze tracking methods. The first step is to detect the eye location in the image. Based on the information obtained from the eye region and possibly head pose, the direction of gaze can be estimated.

### 1. Eye Region Detection.

In visible imaging, where the ambient light is uncontrolled and normally results in lower contrast images, as a result we require an efficient method to track head, face and eye movements. Here we present a two stage method to detect the eye region.

In the first phase, we use local sensitive histogram [16] to meet various lightning effect.Relatedtonormal intensity histograms, local sensitive histograms implant spatial statistics and decay exponentially with respect to the distance to the pixel position where the histogram is calculated. Examples of the using of local sensitive histograms are shown in Fig.2, in which three images with different radiances have been transformed to ones with steadyradiance through the local sensitive histograms.

In the second phase, we adopt an object detection method using viola jones face detector [17] to extract facial features on image, through which the illumination changes are excluded. To track the eye movement, the face region has to be located first.The Viola–Jones face detection algorithm [19]scans an image with a window detecting for features of a human face. If satisfactory features are determined, then the particularwindowof the image is found to be a face.

(a) (b)

**Figure 2- (a) Input images [18]. (b) Results using local sensitive histograms.**

To understand different sized faces, the window is scaled and the method is repeated. Every single window scale developments through the algorithm independentlyof the other scales. Windows that look not anything like a face will not be evaluated.Fig.2 shows the detected eye region using viola Jones algorithm.

## 2. Eye Features Detection

In the eye region by locating iris boundary we can estimate the gaze direction. Iris localization is a procedure to detect the iris boundary. It is done in two steps. First step is to find the pupillary edge and the second step is to detect the iris edge. Original image is transformed into binary image. Dilation process is used to remove specular reflection in the image, after this highest area regarding pupil is identified which gives the Centre and radius of pupil. A circular contour is drawn withcentre and radius of pupil for highlighting the pupillary border. Next step is to find the iris borderline using Integro-differential Operator which scans the complete image and identifies the iris borderline.The proposed methodology uses Integro-Differential Operator.Wemake use of an Integro-differential operator for locating the circular iris and pupil regions and also the arcs of the upper and lower eyelids.

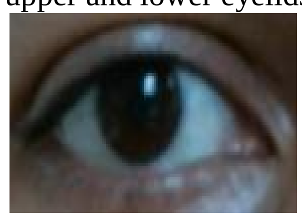

**Figure 3- Detected eye image**

$$\max(r, x_p, y_p) \left| G_\sigma(r) * \frac{\partial}{\partial r} \right| \oint_{r,x_0,y_0} \frac{I(x,y)}{2\pi r} ds (3).$$

Eqn. (3) indicate the Integrodifferentialoperator. The Integrodifferential operators that search over the image domain(x, y) for the maximum in the blurred partial derivative, with respect to increasing radius r, of the normalized contour integral of I(x, y) along a circular arc ds of radius r and center coordinates $(x_0, y_0)$.Here I(x, y), r, $G_\sigma(r)$and sare the eye image, radius, Gaussian smoothing function and the contour of the circle respectively. The operator searches for the circular path where there is maximum change in pixel values by varying the radius and centrex and y position of the circular contour to attain

IJCSET – Volume 2, Issue 2 –August 2016. ISSN: 2455-9091 Pages: 25-34

precise location of eyelids [21]. Fig. 4 shows the complete steps for iris centre detection. Iris detection algorithm is divided into two parts: detection of pupil boundary and detection of the iris boundary [21].

### 2.1 Detection Of Pupil

The process starts for detecting the features of pupil like the centre of the pupil and radius of the pupil. With the help of these features, a contour is drawn which highlights the pupillary boundary. Pupil detection will give a start point for the iris detection. Firstly, the input image is pre-processed to remove the specular reflection from the image.

After removing the specular reflection, next step is to find the centre and radius of the pupil. For this, the binary image is converted into a label matrix to find the maximum area. The maximum area regarding the binary image is the filled white pupil circle given in the Fig. 4. Then the features like centroid and radius of the pupil filled area is obtained. The output of the command is centre coordinate and diameter of the filled pupil circle and a contour is drawn which highlight the boundary of the pupil.

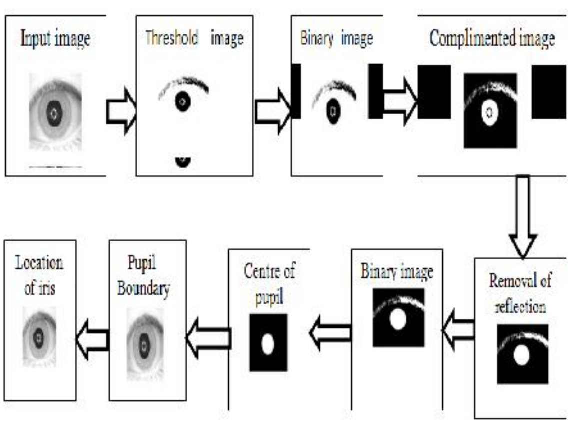


**Figure 4- Complete steps for iris centre detection.**

### 2.2 Detection of Iris Boundary.

Theintegro differential operator creates a circular path at maximum change in pixel values by changing the radius r and the centre (x, y) of the circular contour to determine accurate localization. Let the variables x, y and r belong to the ranges [0; X], [0; Y] [0; R] respectively then this method has the computational requirement of the order [X × Y × R]. Thus, at every pixel, a total of R scans are necessary to compute the circle parameters using this method [22].from this we obtain the coordinate value if centre of iris $(u_x, u_y)$.

### 3. Head Pose Estimation

This section briefly explains on tracking of facial feature and the algorithm for head pose estimation from video frames. Earlier head pose estimation methods generally use a stereo camera [22], [23], accurate 3-D data for head shape [24], or restricted head rotation [25]. Real-time results are limited by the difficult representations or exact initialization for head models [26]. Generally, the human head can be displayed as an ellipsoid or cylinder for simplicity, with the real width and radii of the head for measures. Some use the cylindrical head model (CHM) to estimate head pose [27]–[28], which can perform in real time and roughly track the motion of head.

3-D head shape is stimulated in order to improve the estimation of head pose, SHMis utilized to simulate the 3-D head shape because the ellipsoid and cylinder do not highlight facial features. The SHMcanbe well approximate the shape of dissimilar faces. 2-D facial features can be connected to 3-D positions on the sinusoidal surface. After the 2-D facial features are estimated in all video frames, the 2-D– 3-D conversion procedure can be used to get the head pose data. when a set of 2-D image and 3-D object points are present, we use 2-D–3-D conversion method to get the pose (i.e., rotation and translation) of a 3-D model .2-D–3-D conversion can be done with the method called Pose from orthography and scaling with iterations (POSIT) [29]. For improved estimation of the head pose, we use the AWPOSIT algorithm because the traditional POSIT algorithm considers the uniform contribution offset of 2-D points and 3-D object pointsto estimates the pose of the 3-D model. The overall accurateness of the estimated pose may decrease sharply, if certain features are not detected accurately, with the traditional POSIT algorithm. As for the 2-D facial features, they have Dissimilarsignificancewithrespecttoreformingtheposedue to their reliability. By using key feature information the suggested AWPOSIT can get more precise pose estimations.

The SHMconsidersthat the face is modeled by the sinusoidalsurface and the head is shaped as a 3-D sine (see Fig.5).Hence, the motion of the 3-D sine can be parameterized by the pose matrix M at frame Fi, and that have a rigid motion. The pose matrix contains the translations matrix T and rotation matrix R at the $i_{th}$ frame, i.e.

$$M = \begin{bmatrix} R & T \\ T^T & 1 \end{bmatrix} = [M_1|M_2|M_3|M_4] \quad (4)$$

The head pose at every frame is calculated with respect to the initial pose, and the rotation and translation matrix can be set at 0 for the initial frame (i.e., standard front face). Where $R \in R^{3\times3}$is the rotation matrix, and $T \in R^{3\times1}$is the translation vector with $T = (t_x^i, t_y^i, t_z^i)^T$ , and $M_1$ to $M_4$ are column vectors.

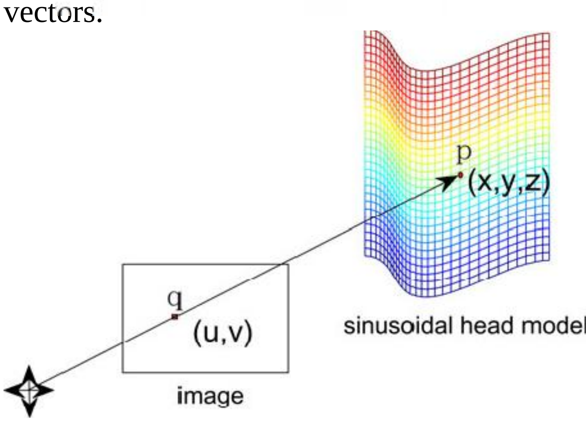


**Figure 5- Perspective projection of 3-D point p onto the image plane.**

The viola jones feature detection method is used to obtain the 2-D facial features. Since these facial features are mapped to the 3-D points on the sinusoidal model, the motions of which are regarded as summarizing the head movements, we develop the perspective analysis through the pinhole camera model for forming the relation between the 3-D points on the sinusoidal surface and their equivalent projections on the 2-Dimage. Fig.9. displays the relation between the 3-D point $p = (x, y, z)^T$ on the sinusoidal surface and its projection point $q = (u, v)^T$ on the image plane, where u and v are find by eqn. (5).the focal length of the camera is f.

$$u = f\frac{x}{z}$$

$$v = f\frac{y}{z} \quad (5)$$

The 2-D facial points are represented as $P_{2D}$ and the 3-D points on the sinusoidal model isrepresentedas $P_{3D}$ . The AWPOSIT algorithm is shown in Algorithm 1.

**Algorithm 1: M= AWPOSIT($P_{2D}, P_{3D}, w, f$)**

Input: $P_{2D}, P_{3D}, w, f$.
$n = size(P_{2D}, 1); c = ones(n, 1)$
$u = P_{2Dx}/f; v = P_{2Dy}/f$
$H = [P_{3D}, c]; O = pinv(H)$
Loop
$J = O \cdot u; K = O \cdot v$
$Lz = 1/(\sqrt{(1/\|j\|) \bullet (1/\|K\|)})$
$M1 = J \cdot Lz; M2 = K \cdot Lz$
$R1 = M1(1:3); R2 = M2(1:3)$
$R3 = \frac{R_1}{\|R_1\|} \times \frac{R_2}{\|R_2\|}$
$M3 = [R_3; L_Z]$
$c = H \cdot M_3 / L_Z$
$uu = u; vv = v$
$u = c \cdot w \cdot P_{2Dx}; v = c \cdot w \cdot P_{2Dy}$
$e_x = u - uu; e_y = v - vv$
if $\|e\| < \in$ then
$M_4 = [M_1(4), M_2(4), L_Z, 1]^T$; Exit Loop
end if
end Loop
output: M

AWPOSIT decides the pose information in the video frames. The tracking mode stop over s and an in itialization identify the 2-D facial features again if AWPOSIT failstoconverge. Then, tracking mode can resume. When the head pose algorithm is available, we can recompense for the gaze error by the head movement. It evaluate the head pose and calculates the corresponding movement ($\Delta u_x.\Delta u_y$) produced by the head movement. Suppose that the initial 3-D coordinate of the head is denoted as ($x_0, y_0, z_0$), and its point of projection on the image plane is ($u_0, v_0$). The coordinate of the head is (x,y,z ) when head movement take place. The corresponding parameters R and T are calculated by the AWPOSIT using eqn.(6).

$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = R \begin{bmatrix} x_0 \\ y_0 \\ z_0 \end{bmatrix} + T \quad (6)$$

Therefore, the displacement ($\Delta u_x$,$\Delta u_y$) can be calculated by eqn.(7).

$$\Delta u_x = f\frac{x}{z'} - u_0$$

$$\Delta u_y = f\frac{y}{z'} - v_0 \quad (7)$$

The $u_x$ and $u_y$ are iris center obtained from using Integrodifferential object. Combining the gaze direction from the iris center and the displacement from the head pose, the final gaze point ( $s_x$, $s_y$) can be calculated with eqn. (8)

$$s_x = u_x + \Delta u_x$$

$$s_y = u_y + \Delta u_y \quad (8)$$

The overall steps for gaze estimation are summarized in algorithm two.

**Algorithm 2: Pseudo code of eye gaze tracking**

**Initialization:**

– Extracting 2-D facial features using viola jones
– Initialize the 3-D SHM P3D and head pose M
– Get calibration mapping function

**Tracking the gaze through all the frames:**

1. for t = 1 to all Frames do
2. Extract the eye region
3. Detect the iris center p iris
4. Get static gaze point (ux, uy) by mappin
5. Track the face features P2D
6. Obtain head poseM
7. M = AWPOSIT(P2D , P3D , w, f)
8. Get the displacement ($\Delta u_x$ ,$\Delta u_y$)
9. Obtain the final gaze point (sx, sy)
10. **end for**

## IV. PERFORMANCE EVALUATION

The eye gaze tracking system contains a web camera to obtain image sequences. It makes use of a Logitech web camera with a resolution of 960 × 720 pixels, which was connected above the computer monitor. The hardware configuration was an Intel Core i7 CPU 3.40 GHz. With the approximate 70 cm distance between a subject and the screen, each subject is seated in front of the computer screen to make his/her head fully taken by the camera. The experimentations were performed in a desktop environment, in which the light could come from the fluorescents, LEDs, or sunlight. The recognition of the iris center is a difficult task in eye features detection. The accuracy of eye center detection straightly affects the gaze estimation.an evaluation of eye centre detection is presented here. Our proposed iris detection method in eye gaze tracking system will outperform in normal desktop model.

Proposed works given better results than previous work for visible imaging in eye gaze tracking system. This method tends to reduce processing time and improve the accuracy of estimated gaze point. One of the existing methods we have compared with our proposed work is estimation of gaze point by considering eye corner as reference and iris centre is detected by considering its intensity and energy of the image (30) in this section, the performance of our method is compared with the existing method in terms of processing time, and accuracy.

**Figure 6- (a). original frame. (b).detected eye region (c). Estimated gaze Feature detection.**

In order to estimate eye gaze the first step we done is extract the face region from face. After that we estimated eye region. Next step done here is detection of eye features that is iris and pupil region.fig.6 represent the steps involved in detection of iris centre.

Performance of gaze estimation:

Performance of gaze estimation is analyzed here by comparing accuracy and processing time of our proposed method that is using Integro differential function with one of the existing intensity and energy method .for analyzing the performance of accuracy of estimated centre of iris we use a ground truth value. Which act as a reference iris centre it is calculated by assuming iris centre as the centre coordinates of eye centre. fig.7, Shows the accuracy graph for proposed method and existing method. From the graph it can be clear that our proposed method is more near to the ground true values. Processing time is an important factor for the performance of our system. Fig. 8, represent the graph for the time taken by our proposed method and existing system for processing the complete steps for estimating gaze point

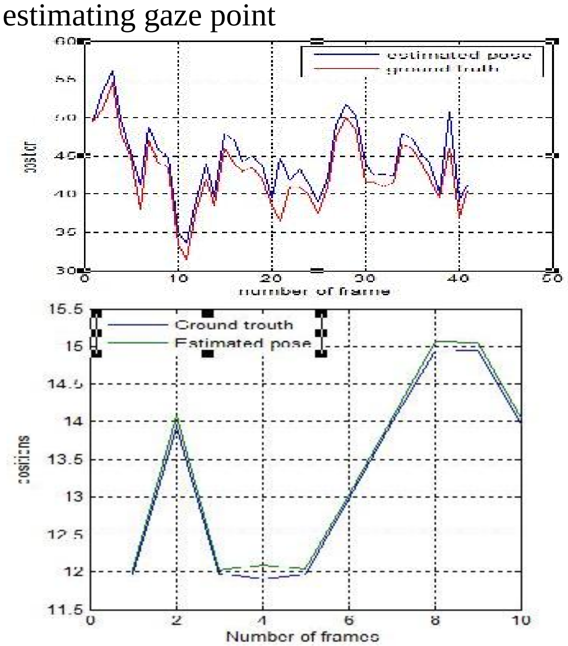


**Figure 7- Comparison of accuracy of gaze point. (a) Intensity and edge method. (b) Integro differential function**

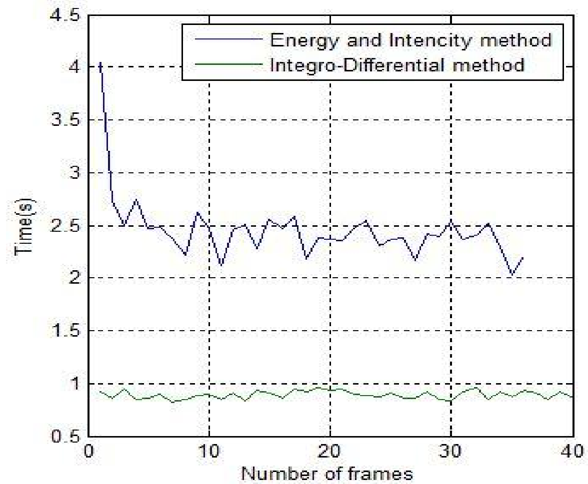


**Figure 8- Comparison of methods in processing Time**

It seems that intensity and energy method take large time for processing initial frame. But as compared to existing method our proposed method takes less time. Alsoproposed model is robust against the light changes and scaling.

## CONCLUSION

An efficient model for gaze tracking has been built using a web camera in a desktop environment. Its main novelty is using Integrodifferential object function to locate the iris center. Further, we have used the AWPOSIT algorithm to improve the accuracy in estimation of the head pose. Therefore, the combination of the eye vector formed by the eye Centre and head movement information can achieve improved accuracy and robustness for the gaze estimation. The experimental results have shown the efficacy of the proposed method. If the iris part of an eye image is not identified correctly then it leads to an error in overall identification method. This work is focus on efficient and accurate iris localization method for developing better eye gaze system in widespread application areas. The method addresses the problem of processing iris images where pupil and iris boundaries are not essentially perfectly circular. To compact with these problems we consider different tasks such as, binary image creation, discovering all joined component, elimination of small connected component, selecting pupil component and finding pupil component for pupil boundary recognition and intensity level conversion, dilation and image thresholding. The processing time for proposed algorithm is 4 sec. while for the iris center and eye corner recognition method require12.4sec. The algorithm shows far better computational .our suggested method has shown out performing results than current other algorithms.

## REFERENCES

[1]. T. Ohno,``One-point calibration gaze tracking method," in Proc. Symp.Eye Track. Res. Appl., 2006, p. 34.

[2]. Duchowsky A, (2007) Eye Tracking Methodology: Theory and Practice. Springer Verlag, Second Edition.

[3]. Morimoto C. and Mimica M. (2005) Eye gaze tracking techniques for interactive applications, Computer Vision and ImageUnderstanding, 98(1): pp. 4-24.

[4]. E. D. Guestrin and E. Eizenman, “General theory of remote gaze estimation using the pupil center and corneal reflections,” IEEE Trans. Biomed. Eng., vol. 53, no. 6, pp. 1124–1133, Jun. 2006

[5]. V. Raudonis, R. Simutis, and G. Narvydas, ``Discrete eye tracking for medical applications," in Proc. 2nd ISABEL, 2009, pp. 1_6.

[6]. J. Tang and J. Zhang, ``Eye tracking based on grey prediction," in Proc. 1st Int. Workshop Educ. Technol. Comput. Sci., 2009, pp. 861_864.

[7]. H. Liu and Q. Liu, ``Robust real-time eye detection and tracking for rotated facial images under complex conditions," in Proc. 6th ICNC, vol. 4. 2010, vpp. 2028_2034.

[8]. G. Chow, X. Li, Toward a system for automatic facial feature detection, Pattern Recognition, Vol. 26, No. 12, pp. 1739-1755, 1993.

[9]. C. Yang, J. Sun, J. Liu, X. Yang, D. Wang, and W. Liu, ``A gray difference-based pre-processing for gaze tracking," in Proc. IEEE 10th ICSP, Oct. 2010, pp. 1293_1296.

[10]. Y. W. Chen and K. Kubo, ``A robust eye detection and tracking technique using gabor filters," in Proc. 3rd Int. Conf. IEEE Intell. Inf. Hiding Multi-media Signal Process., vol. 1. Nov. 2007, pp. 109_112

[11]. T. Kocejko, A. Bujnowski, and J. Wtorek, ``Eye mouse for disabled," in Proc. IEEE Conf. Human Syst. Interact., May 2008, pp. 199_202.

[12]. A. Pranith and C. R. Srikanth, ``Iris recognition using corner detection," in Proc. 2nd ICISE, 2010, pp. 2151_2154.

[13]. J. Song, Z. Chi, J. Liu, A robust eye detection method using combined binary edge and intensity information, Pattern Recognition, Vol. 39, pp. 1110-1125, 2006.

[14]. Z. Zhu and Q. Ji, ``Novel eye gaze tracking techniques under natural head movement," IEEE Trans. Biomed. Eng., vol. 54, no. 12, pp. 2246_2260, Dec. 2007.

[15]. I. Choi, D. Kim, Eye correction using correlation information, In Y. Yagi et al. (Eds.): ACCV 2007, Part I, LNCS 4843, pp. 698-707, 2007.

[16]. S. He, Q. Yang, R.W. Lau, J.Wang, andM.-H. Yang, “Visual tracking vialocality sensitive histograms,” in Proc. IEEE Conf. Comput. Vis. PatternRecog., 2013, pp. 2427–2434.

[7]. T. Nguyen et al.” A software-based dynamic-warp scheduling approach for load-balancing the Viola–Jones face detection algorithm on GPUs” in journal J. Parallel Distrib. Comput. 73 (2013) 677–685

[18]. K.-C. Lee, J. Ho, and D. Kriegman, “Acquiring linear subspaces for face recognition under variable lighting,” IEEE Trans. Pattern Anal. Mach. Intell., vol. 27, no. 5, pp. 684–698, May. 2005.

[19]. P. Viola, M. Jones, Rapid object detection using a boosted cascade of simple features, in: Proceedings of the 2001 IEEE Computer Society Conference on Computer Vision and Pattern Recognition CVPR 2001, pp. 511–518.

[20]. C.P. Papageorgiou, M. Oren, T. Poggio, A general framework for object detection, in: Proceedings of the Sixth International Conference on Computer Vision.

[21]. J. Daughman," New Methods in iris recognition," Cybernetics, vol. 37, no. 6, October 2007.

[22]. J. G. Daugman, "High confidence visual recognition of persons by a test of statistical independence," IEEE Trans. Pattern Anal. Mach. Intell.,ol. 15, no. 11, pp. 1148–1161, Nov. 1993.

[23]. H.-C. Lu, G.-L. Fang, C. Wang, and Y.-W. Chen, "A novel method for gaze tracking by local pattern model and support vector regressor," Signal Process., vol. 90, no. 4, pp. 1290–1299, 2010.

[24]. L. Morency, P. Sundberg, and T. Darrell, "Pose estimation using 3D viewbasedeigenspaces," in Proc. IEEE Int. Workshop Anal. Model. Faces Gestures, 2003, pp. 45–52.

[25]. P. Martins and J. Batista, "Accurate single view model-based head pose estimation," in Proc. IEEE Int. Conf. Autom. Face Gesture Recog., 2008,pp. 1–6.

[26]. M. a Cascia, S. Sclaroff, and V. Athitsos, "Fast, reliable head trackingunder varying illumination: An approach based on registration of texture mapped

[27]. 3D models," IEEE Trans. Pattern Anal. Mach. Intell., vol. 22,no. 4, pp. 322–336, Apr. 2000.

[28]. J. Xiao, T. Moriyama, T. Kanade, and J. F. Cohn, "Robust full-motion recovery of head by dynamic templates and re-registration techniques,"Int. J. Imaging Syst. Technol., vol. 13, no. 1, pp. 85–94, 2003.

[29]. M. La Cascia, S. Sclaroff, and V. Athitsos, "Fast, reliable head tracking under varying illumination: An approach based on registration of texture mapped 3D models," IEEE Trans. Pattern Anal. Mach. Intel., vol. 22,no. 4, pp. 322–336, Apr. 2000.