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Real Time Implementation of Eye Tracking System Using Arduino Uno Based Hardware Interface

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Abstract:

Eye tracking system has played a significant role in many of today's applications ranging from military applications to automotive industries and healthcare sectors. In this paper, a novel system for eye tracking and estimation of its direction of movement is performed. The proposed system is implemented in real time using an arduino uno microcontroller and a zigbee wireless device. Experimental results show a successful eye tracking and movement estimation in real time scenario using the proposed hardware interface.

Keywords — **Arduino based hardware, eye tracking system, Binarization, eye region classification, Hough transform, Viola-Jones algorithm and zigbee wireless device.**

1. INTRODUCTION

Eye tracking is one of the significant way towards measuring either the purpose of look (where one is looking) or the movement of an eye with respect to the head. An eye tracker is a gadget for measuring eye positions and eye development. Eye trackers are utilized as a part of exploration on the visual framework, in brain research, in psycholinguistics, showcasing, as an information gadget for human-PC cooperation, and in item plan. There are various techniques for measuring eye development. The most mainstream variation utilizes video pictures from which the eye position is extricated. Different techniques use look curls or depend on the electrooculogram.

The most broadly utilized current plans are video-based eye trackers. A camera concentrates on one or both eyes and records their development as the viewer takes a consideration at some sort of boost. Most present day eye-trackers utilize the focal point of the pupil and infrared/close infrared non-collimated light to make corneal reflections (CR). The vector between the understudy focus and the corneal reflections can be utilized to process the purpose of respect on surface or the look heading. A basic alignment technique of the individual is generally required before utilizing the eye tracker.

Two general sorts of infrared/close infrared (otherwise called dynamic light) eye following procedures are utilized: enhanced pupil and dim pupil. Their distinction depends on the area of the light source as for the optics. On the off chance that the luminance is coaxial with the optical way, then the eye goes about as a retroreflector as the light reflects off the retina making a splendid student impact like red eye. In the event that the light source is balanced from the optical way, then the student seems dull on the grounds that the retroreflection

from the retina is coordinated far from the camera. Splendid pupil following makes more noteworthy iris/pupil contrast, permitting more vigorous eye following with all iris pigmentation, and incredibly diminishes obstruction brought about by eyelashes and other darkening features.

It likewise permits following in lighting conditions going from aggregate haziness to brilliant. Yet, splendid understudy methods are not powerful to

track outside, as unessential IR sources meddle with monitoring.

Another, less utilized, strategy known to be an inactive light. It utilizes the noticeable light to luminance, which may make a few diversions users. Another test with this strategy is the differentiation of the understudy is not exactly in the dynamic light strategies, accordingly, the focal point of iris is utilized for figuring the vector instead. This count needs to distinguish the limit of iris and the white sclera (limbus following). It introduces another test for vertical eye developments because of block of eyelids.

The following sections in this paper are as follows. The first section gives a brief introduction concerning the significance of the area of interest and the general problems associated with it. A review of literature and related works is given in section 2. The proposed system and implementation concerning the architecture and work flow of the project is given in section 3 and 4 respectively. The obtained results is given in section 5 and finally the conclusion of the overall work along with references is given.

2. LITERATURE SURVEY AND RELATED WORKS

The application which extensively uses the concept of eye tracking include sectors in automotive industries, medical research, Fatigue simulation, Vehicle simulators, cognitive studies, computer vision, activity recognition, etc. The significance of eye detection and tracking in commercial applications has increased over a period of time. This significance of eye tracking applications lead to more efficient and robust designs which is necessary in many of today's modern devices.

An extensive review of literature has been done in the field of healthcare applications concerning the eye tracking system. Some of these methods are mentioned below.

Z. Sharafi et. al [1] performed an evaluation in the metrics concerning the eye tracking in the software engineering. The author brings about different metrics concerning the eye tracking into one common standard to facililate researchers facing difficulty in analyzing the eye- tracking experiment. The work also produces definitions on different metrics used along with suggestions of using the same from other related fields.

S. Chandra et. al [2] proposed an application based on eye-tracking and their respective interaction with human beings. The work mainly focuses on the determination of direction of gaze along with their position and their and sequence of movement. The work focuses on three aspects in the eye-tracking experiment. The first objective was to provide the user an insight into the underlying issues present in the eye-movement technology. The second objective was to provide the user a guidance concerning the development of the eye-movement technology. The third objective was to recognize the challenges and prospects in building a Man And Machine Interfacing (MAMI) systems using the principle of eye-tracking. Experimental results show a reduced computational time in with respect to gaze input as compared to mouse input.

Y. Zhang et. al [3] performed a comparative analysis on the stationary and mobile eye tracking wayfinding system considering the EXITs design. A mobile tracking system was used to detect the eye movement where the EXIT design was used in the building. A stationary eye- tracking technique was used for the same purpose. A comparative analysis was performed which resulted in some conclusions which was primarily procured from elements of appearnece, design and placement of the EXIT on the building. Empirical methodologies were introduced in the field of research with respect to wayfinding and space decision.

D. Miyamoto et. al [4] proposed a method for the enforcement of phishing prevention habits using the eye tracking technique. The experiment was performed where the eye movement of 23 participants were analyzed and also considered that the novice participant did not tend to possess a similar habit. A prototype named eyebit was developed which required the participant to look in the address bar and consequently enter some address in the web forms. The system was designed such that it deactivates and reactivates (control parameter) based on the participant eye movement pattern. Experimental results show that the significance in effectiveness of the proposal which

was based on the participant eye movement prediction even though an incovineance was observed in the Eyebit system.

R. G Bozomitu et. al [5] proposed an eye tracking system based on the circular Hough transform algorithm. The experiment was aimed towards producing benefits to the neuromotor disabled patients. The signals were captured using an infrared video camera along with a pc. The process of eye tracking system implemented in this work uses a keyword technology. Experimental results show that the optimal performance of the pupil eye detection movement was based on a trade-off between the algorithms computational time and the precision of detection of the pupil region in the eye-movement.

R. G. Bozomito et. al [6] performed a comparative analysis on the eye tracking applications with respect to its pupil. The experiment was a comparison between two eye-movement detecting algorithms mainly the circular Hough transform and the Starbust transform. A parameter based algorithm was implemented in the circular hough transform and a feature based algorithm was implemented in the in the Starbust transform. In order to improve the curser stability a Gaussian smoothing filter along with appropriate spike removal technique was implemented. Experimental results showed that the Starbust based transformation had a higher accuracy as compared to circular hough based transformation with respect to cursor movement, but due to the notably high disparity of the pupil center position in successive frames the Starbust based transformation had high levels of noise.

O. Mazmar et. al [7] proposed a eye-ball tracking system which was performed in a real time environment. The experiment was aimed towards people having disabled neuromotor systems. The experiment was conducted by developing a human computer interface facilitating the neurological control of the disabled patients by observing only the eye-movement of the patients. A serial communication was performed which sent data from the webcam to a MATALB based simulating tool. A segmentation process followed by a centroid calculation for the pupil was performed which results in producing a control signal from the patient. The conducted experiment resulted in a real time simulation of an eye tracking system.

M. Kim et. al [8] proposed a system of eye movement detection and tracking based on the cardinal direction. The experiment was conducted in such a way that the participants were asked to look towards north in a given cardinal direction and the respective reaction time for each cardinal direction was observed. The experimental results demonstrates that the participant's eye is fixed on the character part, corner of shape and the cross over point. The cardinal direction was observed to be small in range considering the gaze movement. A significant observation proclaimed in this experiment was that the clarity of the cardinal direction confirmed the presence or absence of the character information.

C. Jin et. al [9] proposed a technique based on the gaze point compensation technique using the eye tracking system. The work proposes a length compensation algorithm by considering the gaze point algorithm. Experimental result showed a deviation of less than 1 cm in both the vertical and horizontal directions.

Z. Zhang et. al [10] proposed a classification method to separate the novice from experienced drivers considering their reflect drivers attention and their skill. The classifier used in this experiment is the binary Gaussian classifier considering a two dimensional data which is obtained from the gaze behavior from the participants. A comparative analysis between the Gaussian based classifier and the Gaussian mixture models were performed. Experimental results show that the performance of the proposed Gaussian based classifier was higher in efficiency as compared to the Gaussian mixture models.

F. B Taher et. al [11] proposed a controller based electric powered wheelchair (EPW) system for certain types of disabled persons based on a combination of EEG (Electroencephalogram) signals with that of the eye tracking system. The proposed technique illustrate the significance of using a multi source control process in the EPW. The first part involves elaboration of separate control techniques involving EEG and the eye tracking system. The second part involves a combination of the previous two techniques by

considering a data fusion algorithm. Experimental results show that by considering only EEG based control signal without the inclusion of eye tracking system, the result was much higher in performance, but the use of EEG devices had a disadvantage of limited energy. Hence by implementing the proposed system this limitation was resolved.

K. Kurzhals et. al [12] proposed an eye tracking system based on computer visualization system. This work mainly deals with the development of tri-dimensional fly through animation system. The technique portrayed an accurate representation of the distribution of the galaxy which was visually and aesthetically pleasing to the observer.

F. Zhou et. al [13] proposed an eye tracking system which was based on the particle filtering algorithm. First an AdaBoost based classifier was implemented to procure the information of the eye region. Performing a comparison of two consecutive frames in a video sequence the eye region information is seeked, for this purpose the particle filtering algorithm was implemented. Experimental result shows an improvement in the computational time between consecutive frames due to the reduced search region for the human eye.

K. Kuzhals et. al [14] proposed an eye tracking mechanism primarily for the application involving Personal Visual Analytics (VSA). This work primarily explains the challenges which arises in real time scenarios in context of VSA along with the prospective of potential research in the respective application. The author also presents a technique for representing the area of interest considering multiple videos

3. PROPOSED SYSTEM

The purpose of the proposed system is to perform detection and tracking of the pupil region of the eye. The application of this system could be found in areas ranging from military applications to healthcare sectors. The proposed system mainly consists of three general modules. The first module is where the video is captured in real time and the eye detection is performed using the Viola-jones algorithm. The second module is used to perform binarization and application of Hough transformation to detect the pupil region of the eye. The third module is used to perform the detection and tracking of the movement of the pupil region of the eye and to set a direction respectively. The obtained direction is then sent to a hardware experimental setup consisting of an Arduino uno microcontroller with a wireless zigbee device for wireless transmission of data.

The general architecture for the proposed system is given in fig 1 as shown below. The purpose of the proposed system is the detection, identification and tracking of the pupil region of the eye in real time scenario. The video is captured from the image capturing device and frames are extracted, for each frame the three module defined in the previous section is performed. The resulting direction data of the movement of the pupil region of the eye is sent to the hardware experimental setup as control signal. The functionalities associated for the proposed eye tracking system are basically divided into three modules which consists of image pre-processing, pupil region detection and pupil detection and movement detection.

4. IMPLEMENTATION

The procedure for the implementation for the eye tracking system is given as follows.

In the first module of image pre-preprocessing, the video is captured from an image capturing device, the respect frame is extracted from the video, the image which is in the RGB format is converted to a single dimension gray scale format. Gamma correction is applied to the image to set the image to an ideal brightness and contrast. The gamma correction is computed by controlling a parameter called the Gamma factor. The eye region is detected using the viola Jones algorithm, In this algorithm the features are extracted using the haar wavelet transformation, An integral image is created and the corresponding training is performed suing the AdaBoost training method and finally the cascading classifiers are used for the detection of the eye region in the face. The threshold is set for which the pixel value of the image will be zero value for value below the threshold and the pixel value will be 1 if the value is above the threshold. The user adjusts this setting until the pupil region is clearly identified and defined in the eye. These parameters is then to Binarization process.

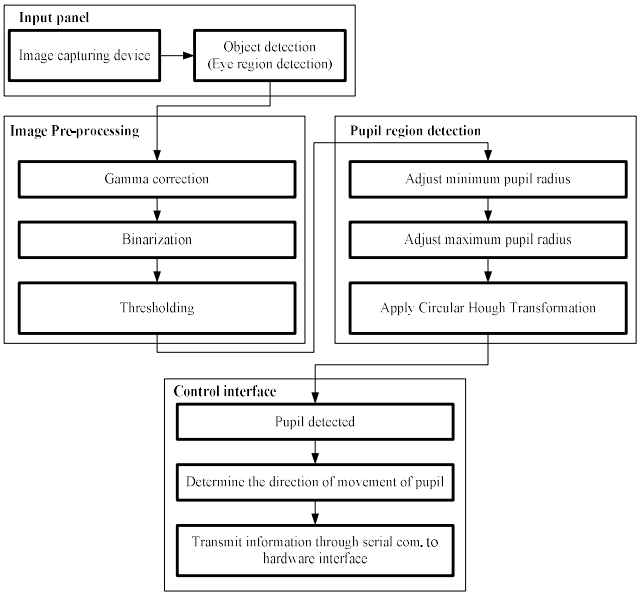

Fig 1: proposed system

The second module consists of the definition of the pupil region of the proposed system, initially a minimum and maximum radii are defined for which the values (or radii value) identified within this range will be termed as circle. The set parameters (i.e the two radii) are then sent to the Hough Transformation which detects and defines the circular region in the eye. (fig. 3)

The third module consists of the detection and movement of the pupil region in the eye. A reference point is set to the pupil region which consists of a matrix having radii and centers as rows and columns. A comparative analysis is performed with respect to previous frame and the current frame considering the pixel position of the pupil region in the eye. The condition given below are set for the direction of movement of the vehicle based pupil movement. (fig.4)

Condition 1: if rows of current frame is greater than the rows of previous frame, then move 'RIGHT'

Condition 2: if rows of current frame is lesser than the rows of previous frame, then move 'LEFT'

Condition 3: if columns of current frame is greater than the columns of previous frame, then move 'FORWARD'

Condition 4: if columns of current frame is lesser than the columns of previous frame, then 'STOP'

The hardware experimental setup is represented as shown in fig. 5.

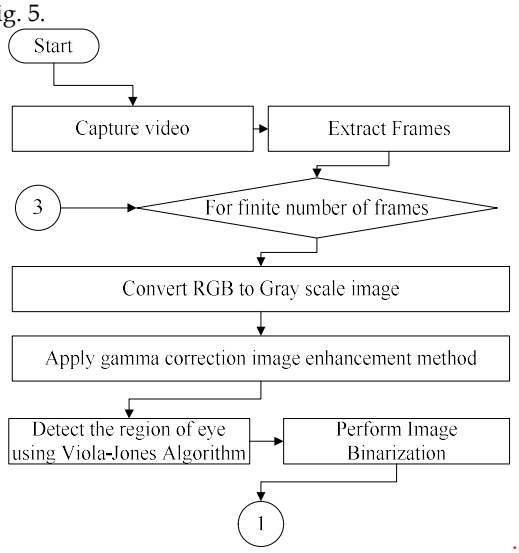

Fig 2: proposed methodology for eye detection and binarization

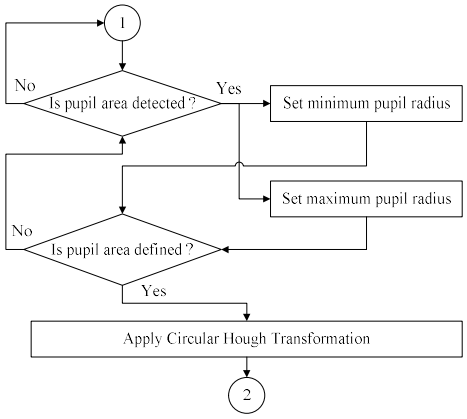

Fig 3: proposed methodology for Hough Transformation

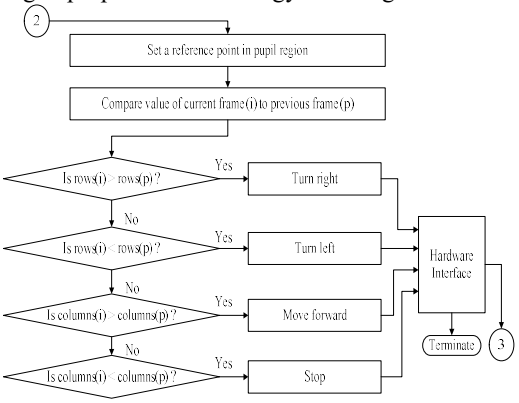

Fig 4: proposed methodology for eye movement detection

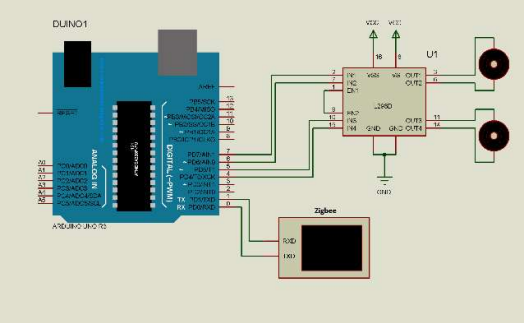

Fig 5: Hardware experimental setup

5. SIMULATION RESULTS AND PARAMETRIC EVALUATIONS

The evaluation performed with respect to image forgery detection is mentioned as follows,

Database

Table 1: database for the proposed eye tracking system

Sl.no	Parameters	Description (value)
1.	Video Device	Integrated webcam
2.	Video format	mjpg 1024X768
3.	Returned colour space	RGB
4.	trigger	Infinite
5.	Frames/trigger	1
6.	n	Number of frames (126)
7.	Image resolution	1024X768X3
8.	Number of frames	126

Parametric analysis

Table 2: parametric analysis for the proposed eye tracking system

Sl.no	Parameters	Description
1.	Video Device	webcam
2.	n	Number of frames
3.	g	Gamma factor
4.	th	Threshold value for binarization
5.	min	Minimum radius for pupil
6.	max	Maximum radius for pupil
7.	dir	Direction of pupil movement

1. **Mean Square Error (MSE):** The MSE is defined as measurement of average of square of the error or deviation between the obtained and reference data. It is mathematically defined as follows,

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(\hat{Y}_i - Y_i)^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, $\hat{Y}_i$ → reference data
Y_i → Estimated data

2. **Peak signal to noise ratio** (PSNR): The PSNR is defined as the log of ratio of power of noise to its respective noise in the image. It is mathematically defined as,

$$PSNR = 10\ \log_{10}\left(\frac{MAX_I^2}{MSE}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where, MAX_I^2 → maximum number of pixels in the image

3. **Sensitivity**: Sensitivity is defined as the ratio of true positive to sum of true positive and false negative. It is mathematically defined as shown in eq.3,

Sensitivity = TP/ (TP + FN) …… (3)

Where, FN → False negative
TP → True Positive

4. **Specificity**: It is defined as the ratio of true negative to sum of true negative and false positive. It is mathematically represented as shown in eq.5,

Specificity = TN/ (TN + FP) …… (4)

Where, TN → True Negative
FP → False Positive

Table 3: Experimental results

parameters	image
Elapsed time	33.82 s
PSNR	14.2 (avg.)
TP	65/126
TN	30/126
FP	20/126
FN	11/126

6. CONCLUSION

For the experiment considering the proposed eye tracking system, a successful interface between the computer and the hardware was achieved. Binarization and Hough transformation was performed for the successful detection, identification and tracking of the pupil region of the eye. The hardware setup was built using an Arduino uno microcontroller and zigbee wireless device. Experimental result show a successful detection and tracking (with respect to direction) of the pupil region of the eye which is serially connected to the hardware interface as a control signal.

REFERENCES

[1] Sharafi, Zohreh, Timothy Shaffer, and Bonita Sharif. "Eye-Tracking Metrics in Software Engineering." In *2015 Asia-Pacific Software Engineering Conference (APSEC)*, pp. 96-103. IEEE, 2015.

[2] Chandra, S., Sharma, G., Malhotra, S., Jha, D. and Mittal, A.P., 2015, December. Eye tracking based human computer interaction: Applications and their uses. In *2015 International Conference on Man and Machine Interfacing (MAMI)* (pp. 1-5). IEEE.

[3] Zhang, Y., Zheng, X., Hong, W. and Mou, X., 2015, December. A comparison study of stationary and mobile eye tracking on EXITs design in a wayfinding system. In *2015 Asia-Pacific Signal and Information Processing Association Annual Summit and Conference (APSIPA)* (pp. 649-653). IEEE.

[4] Miyamoto, D., Iimura, T., Blanc, G., Tazaki, H. and Kadobayashi, Y., 2014, September. EyeBit: eye-tracking approach for enforcing phishing prevention habits. In *2014 Third International Workshop on Building Analysis Datasets and Gathering Experience Returns for Security (BADGERS)* (pp. 56-65). IEEE.

[5] Bozomitu, R.G., Păsărică, A., Cehan, V., Lupu, R.G., Rotariu, C. and Coca, E., 2015, November. Implementation of eye-tracking system based on circular Hough transform algorithm. In *E-Health and Bioengineering Conference (EHB), 2015* (pp. 1-4). IEEE.

[6] Păsărică, A., Bozomitu, R.G., Cehan, V., Lupu, R.G. and Rotariu, C., 2015, October. Pupil detection algorithms for eye tracking applications. In *Design and Technology in Electronic Packaging (SIITME), 2015 IEEE 21st International Symposium for* (pp. 161-164). IEEE.

[7] Mazhar, O., Shah, T.A., Khan, M.A. and Tehami, S., 2015, October. A real-time webcam based Eye Ball Tracking System using MATLAB. In *Design and Technology in Electronic Packaging (SIITME), 2015 IEEE 21st International Symposium for* (pp. 139-142). IEEE.

[8] Kim, M., Morimoto, K. and Kuwahara, N., 2015, July. Using Eye Tracking to Investigate Understandability of Cardinal Direction. In *Applied Computing and Information Technology/2nd International Conference on Computational Science and Intelligence (ACIT-CSI), 2015 3rd International Conference on*(pp. 201-206). IEEE.

[9] Jin, C. and Li, Y., 2015, August. Research of Gaze Point Compensation Method in Eye Tracking System. In *Intelligent Human-Machine Systems and Cybernetics (IHMSC), 2015 7th International Conference on* (Vol. 2, pp. 12-15). IEEE.

[10] Zhang, Z., Kubo, T., Watanabe, J., Shibata, T., Ikeda, K., Bando, T., Hitomi, K. and Egawa, M., 2015, July. A classification method between novice and experienced drivers using eye tracking data and Gaussian process classifier. In *Society of Instrument and Control Engineers of Japan (SICE), 2015 54th Annual Conference of the* (pp. 1409-1412). IEEE.

[11] Taher, F.B., Amor, N.B. and Jallouli, M., 2015, September. A multimodal wheelchair control system based on EEG signals and Eye tracking fusion. In*Innovations in Intelligent SysTems and Applications (INISTA), 2015 International Symposium on* (pp. 1-8). IEEE.

[12] Kurzhals, K., Burch, M., Pfeiffer, T. and Weiskopf, D., 2015. Eye Tracking in Computer-Based Visualization. *Computing in Science & Engineering*, *17*(5), pp.64-71.

[13] Zhou, F., Chen, W. and Fang, H., 2014, November. Robust eye tracking and location method based on Particle filtering algorithm. In *2014 IEEE 3rd International Conference on Cloud Computing and Intelligence Systems* (pp. 247-252). IEEE.

[14] Kurzhals, K. and Weiskopf, D., 2015. Eye Tracking for Personal Visual Analytics. *IEEE computer graphics and applications*, *35*(4), pp.64-72.