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# Real time Eye Gaze Tracking for Traffic Safety on Raspberry Pi

ABDUL RAHAMTULLA BAIG
DEPARTMENT OF ECE
HOLYMARY INSTITUTE OF TECHNOLOGY AND SCIENCE

Mr. Y. David Solomon Raju
Associate Professor
DEPARTMENT OF ECE HOLYMARY INSTITUTE OF TECHNOLOG AND SCIENCE

*Abstract*—Most of the automobile accidents are caused by distracted driving. Passively monitoring driver's eyes can help in detecting state of mind and alertness of driver and thus can reduce risk of accidents. Proposed system includes three main parts 1) Facial feature tracking 2) Eye gaze and 3D head pose estimation 3) Eyes off the road and fatigue detection. Video feed from camera installed on car dashboard tracks features of driver in real time (25FPS). Infrared illuminator is used at night time to detect facial features clearly without distracting driver. Image processing algorithm is developed in OpenCV to estimate where the driver is looking by combining 3D head pose estimation and eye gaze estimation. Algorithm is implemented on Raspberry Pi board to make a compact embedded system. Different zones are defined which includes the side mirrors, the rear-view mirror, the instrument board, and different zones in the windshield as points few of which are eyes off the road points. SVM is used to train and classify different combinations of gaze and head pose angles to determine exact point of gaze. Based on algorithm output if driver's eyes are off the road or eyes are closed due to fatigue then accordingly audio and steering vibration warnings are given to driver.

Keywords: Eye gaze tracking, automobile safety, driver monitoring system, head pose estimation, Raspberry Pi.

## I. INTRODUCTION

The main aim of eye gaze tracking based driver monitoring system is to reduce accidents caused by distracted driving. Distraction is mentioned as main cause in 78% of crashes and 65% of near-crashes in NHTSA (National Highway Traffic Safety Administration) study (2013).Distraction is a major factor in more than 20% of all accidents including fatalities and serious injuries.

Distracted drivers tend to decrease attention to important information needed for safe driving which makes them prone to severe car accidents. NHTSA has classified driver distraction into four types which are auditory, visual, biomechanical and cognitive. Reasons for distraction can be driving after drinking alcohol, driving at night time, driving without taking rest, aging, fatigue because of continuous driving, long working hours and night shifts etc. Nowadays another concern for distracted driving is the use of mobile phones and other electronic devices while driving.

NSTHA has stated that texting, browsing, and dialing is the reason for longest time of drivers taking their Eyes Off the Road (EOR) and increase the risk of crash by three times.

Proposed driver monitoring system based Eye gaze tracking and 3D head pose estimation can help in continuously monitoring and alerting driver in case of eyes off the road (EOR) or distraction and drowsiness. Implementing system which will give audio alerts and wheel vibration alerts depending on situation. To reduce number of accidents caused by distraction is the motivation behind this project in order to improve traffic safety

## II. PREVIOUS WORK

### A. Driver monitoring systems

Fatigue/distraction detection can be mainly categorized into three categories [10]. (1) Approaches based on bioelectric measurements (for e.g., ECG and EEG), (2) Approaches based on steering motion, lane departure (3) Approaches based on driver face monitoring (eye closure %, eyelid distance, blinking rate, gaze direction and head rotation etc.)

TABLE I Comparison between Types of Driver Monitoring Systems

| Property | Approaches | | |
|---|---|---|---|
| | Steering Motion | Bioelectric Signal | Driver Face monitoring |
| Fatigue Detection | Yes | Yes | Yes |
| Distraction Detection | Yes | No | Yes |
| Accuracy | Good | Very Good | Moderate |
| Complexity | Moderate | Complex | Easy |
| Speed of Detection | Slow | Very Fast | Fast |

Driver monitoring systems which use driver face monitoring can be classified into intrusive and non-intrusive techniques. Intrusive techniques need special attachments such as electrodes, goggles or head mounted device. These devices are attached to the skin and hence interfere with the user. Intrusive methods interfere with the user and are inconvenient, hence limited for laboratory testing. The systems that do not have any physical contact with the user are called remote systems or non-intrusive systems. These techniques are mostly based on imagprocessing and can be passive image based or video feed based [10].

If any other features like head pose estimation is combined with eye gaze tracking can give better accuracy than eye gaze tracking alone especially in cases where spectacles and sunglasses are used by driver [3]. The detection of driver distraction mostly depends on the classification technique [2]. Support Vector Machine (SVM) classifier is widely used for gaze estimation. One or more features are used to design SVM. Real time Hidden Markov Models (HMMs) are also used in some approaches. But SVM are more common and accurate with average accuracy of 82%.

B. Eye gaze tracking methods

The concept of eye-gaze tracking and estimation is hot research topic in last few years. Eye-gaze tracking methods can be categorized into two approaches.

- Appearance based model: It use the position of the pupils and general shape of the eyes and relative to the eye corners for finding the point of gaze [8]. A pre-trained model of the appearance and shape of the eye region is fitted to a sequence of image frames.
- Feature based model: These methods use characteristics of the eye to identify a set of features like contours, eye corners of NIR illuminators (LEDs) [7]. They can be further divided into model-based methods and regression based. The eye-model-based techniques use the geometrical model of the eye along with NIR light sources. In regression based method, vector between the pupil center and corneal reflections is mapped and tracked geometrically with a polynomial regression function to find gaze coordinates on a virtual screen.

C. Head pose estimation methods

The methods for head orientation can be categorized into four categories [9].

- Methods based on shape features with eye position: These methods analyze the geometric arrangement of facial features to determine the head orientation e.g. AAM (Active appearance model) [8].
- Methods based on shape features without eye position: These methods use simpler features like center of the face, left and right borders etc. rather than detailed features of face such as nose, eyes, and face contour. Thus this method is simpler [6].
- Methods based on texture features: These methods identify driver's face in the image and analyzes intensity pattern to determine the head orientation. Many learning techniques such as KPCA, PCA, LDA, and kernel discriminate analysis (KDA) are used to extract texture features. These features are then classified to obtain head orientation [11].
- Methods based on hybrid features: These methods based on hybrid features combine texture and shape features to determine the head orientation. Initial head orientation is determined using texture based features and detailed head orientation is found by using 3-D face model tracking and fitting [6].

## III. SYSTEM DESCRIPTION

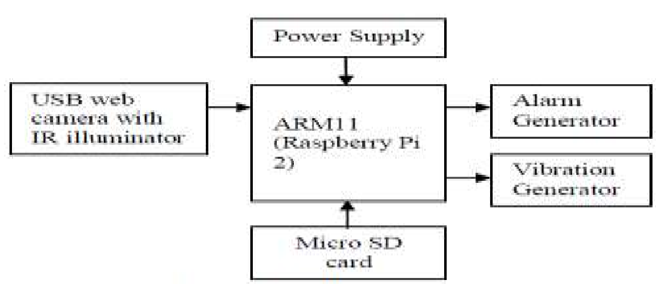


Fig.1.System block diagram

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A. System specifications
Raspberry Pi 2 single board computer is used in the system as central module of complete embedded image capturing and processing system. The main signal processing chip unit used in Raspberry Pi is Broadcom 700MHz Chip in which CPU is a 32 bit ARM11- RISC processor. Camera used in the project is Logitech c270 HD webcam. Raspbian-wheezy operating system image is installed on Raspberry Pi which is a version of Linux. It is a free operating system based on Debian which is optimized specially for the hardware of Raspberry Pi. Operating system is the set of basic utilities and programs that makes Raspberry Pi run properly as a standalone computer. The operating system on the board was installed on a class 4 8GB Samsung Micro SD Card with Micro SD Adapter. Micro SD card is preloaded with the Raspberry Pi NOOBS (New Out of Box Software) package. OpenCV is then installed on Raspbian-wheezy using Micro SD card. Audio alarms can be generated using audio output of Raspberry Pi by either using speaker or headphone. Vibration motor is used to generate steering vibrations depending on the conditions.
B. Image acquisition
The image acquisition module uses a low-cost web camera. USB webcam is used based on CCD mechanism. Camera is interfaced to Raspberry Pi 2 using USB port. Camera is placed on car dashboard above the steering wheel approximately 35-40 cm away pointing straight to the driver. Placing camera in this way makes capturing driver's face very easy. Operation of the camera at night time is achieved using an IR illumination source to provide a clear image of the driver's face without distracting driver. 36 LED IR illuminator is used which is fitted with LDR for automatic on off.

C. Facial feature tracking
Facial feature tracking algorithm is implemented in OpenCV using Raspberry Pi. Viola Jones algorithm is used which is a four step algorithm 1) Haar feature selection (eyes) 2) Create an integral image 3) Adaboost training on integral image 4) Cascading the classifier. Eyes.xml is the library file used for eye detection. Rectangular frames are used to denote eye. The Haar Classifiers algorithm rapidly detects object using AdaBoost classifier cascades with help of Haar features [4].

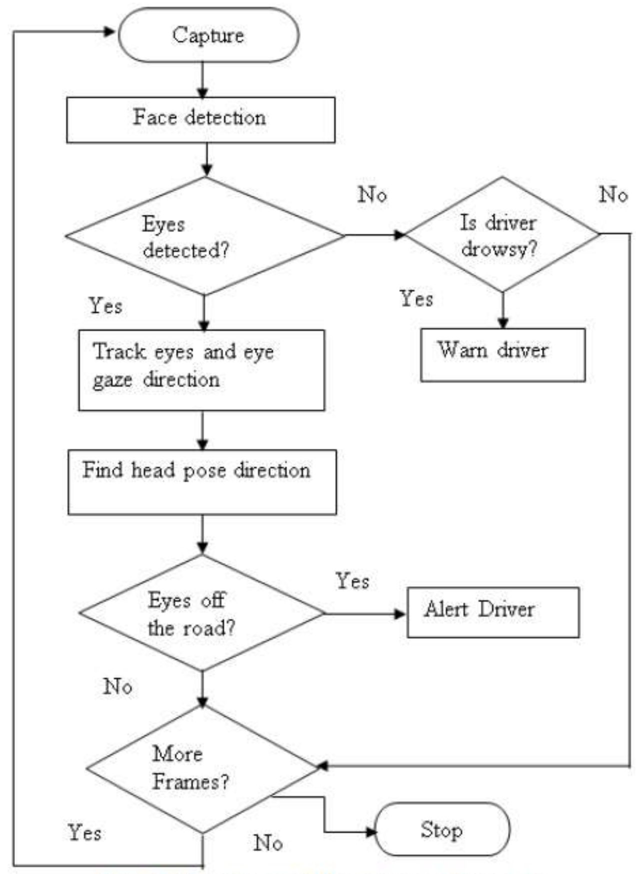

Fig. 2 Flowchart of the proposed system

D. Eye gaze tracking and estimation
Driver eye gaze is constantly changing during driving depending on surrounding conditions. Thus detecting eyes is not sufficient. Eyes need to be tracked in real time. Continuously Adaptive Mean Shift (CAMSHIFT) algorithm is used for real time eye tracking. Pupils of the eyes are tracked.
E. Head pose estimation
Drivers tend to change their head pose while driving. 3D head pose estimation is required to recognize in which direction driver is looking. 3D Head pose is estimation is proposed by combining Active Appearance Models (AAM) and Pose from Orthography and Scaling with ITerations (POSIT). Out of the three Euler angles only yaw and pitch angles are extracted and used and not roll angle. Yaw and pitch angles are sufficient to detect head pose direction.

F. Eyes off the road detection and fatigue detection
Similar to concept used in [3] [6] [9], Different zones are defined in the car as shown in fig.3. Zones are defined in point of view of a driver with left hand drive system. 11 different gaze zones representing the dashboard, the centre console, the rear-view mirror, two side mirrors and six zones on the

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windshield. These defined zones cover most of the possible gaze directions involved in real-world driving.

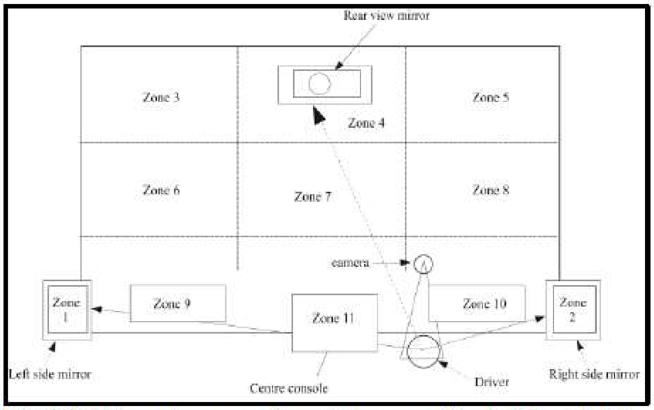

Fig.3.Different gaze estimation zones for left hand drive

TABLE II Shows different on the road and off the road points. Driver's gaze direction lies in which area depends on the combination of eye gaze estimation and head pose estimation calculations. SVM Classifier is defined for different combinations of eye and head pose directions. Then it is decided whether driver gaze lies in off the road and accordingly alerts are generated.

TABLE II GAZE ZONE PARTITIONING

| Zones | Gaze zone type |
|---|---|
| 2,4,5,7,8 | On the road |
| 1,3,6,9,10,11 | Off the road |

A scientific definition for fatigue has not been defined. But there are several relations. There is a relation eye movement, eye closure and fatigue. Eye movement is used to detect drowsiness i.e. fatigue. If closed eyes are detected longer than 3 seconds then driver is supposed to be in drowsy state and wake up alert is generated.

## IV. RESULTS AND DISCUSSIONS

A. Facial feature tracking and fatigue detection

OpenCV allows user to select us region of interest (ROI). In this region of interest is eye region. Eyes are detected with a rectangular box. System is also able to detect eyes when wearing spectacles. Open and close eyes are detected by system. Images shown are the rectangular extraction of the eye area from face.


Fig.4 Open eyes


Fig.5 Closed eyes

Fig 6 shows the open eyes are detected. Both left and right eyes are detected with their x and y coordinate positions. Also for straight view face its showing correct head position.

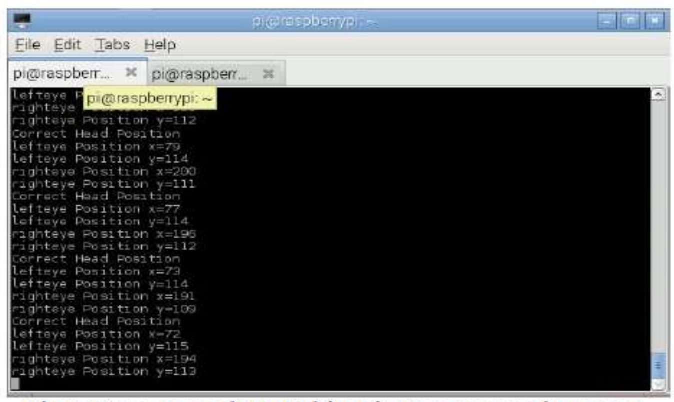

Fig.6 Eyes open detected in Linux command prompt.

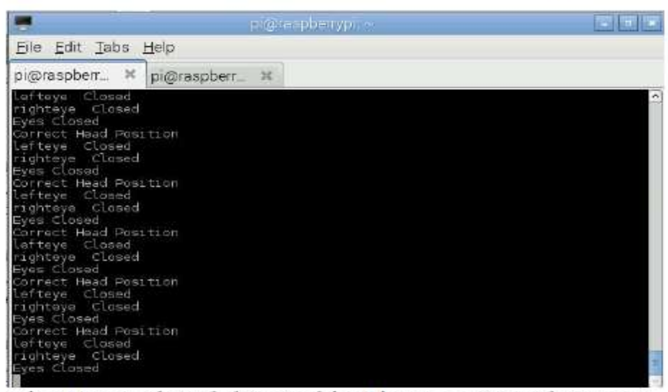

Fig.7 Eyes closed detected in Linux command prompt.

B. Face detection and Eye tracking

Face detection and eye detection can be observed in fig 8

Fig.8 Eyes tracking shown by blue circles

Eye pupil tracking is shown by blue circles and face is shown by a yellow square.

## V. CONCLUSION

The goal of the system is to detect eye gaze direction and head pose direction to detect if eyes off the road. Another goal is to detect drowsiness condition of driver and alert driver in both conditions. Viola Jones algorithm is implemented in OpenCV for rapid face detection with eyes extraction. Real time eye gaze tracking is proposed with CAMSHIFT algorithm. Pupil tracking is achieved Head pose estimation is proposed with AAM and POSIT. Different gaze zones are defined and eyes off the road can be detected by combining eye gaze and head position. Fatigue detection can be achieved by detecting closed eyes. If driver eyes are off the road or if he is drowsy then alert will be generated. System is robust as two methods are combined to find gaze. If one method is failed to detect properly, other will work. System is also robust under night or low light conditions due to use of IR illuminators and build on raspberry pi to be compact and low cost. Future work can include improving driver monitoring system with help of automatic calibration, determining vehicle states, weather conditions, vehicle speed etc.

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