Driver Assistance System using Raspberry Pi and Haar Cascade Classifiers

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Abstract The research mainly focuses on developing a cost-efficient integrated driver assistance system for automobiles using embedded devices and signal processing. To implement this, a variety of software algorithms, input and output extraction hardware tools have been employed in a collaborative way. The system developed consists of three inter-linked modules which are firstly, driver drowsiness detection using Haar cascade classifier and OpenCV, followed by alcohol content detection using MQ3 sensor and lastly the accident/crash detection using Piezoelectric sensor alongside control to constantly monitor the driver's physiological condition which will affect the stability of the vehicle. To detect the onset of fatigue or loss of vigilance of the driver, within the close vicinity of the driver multiple sensors are embedded on this prototype.

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Key words: Drowsiness Detection Alcohol Vehicle crash Physiological parameters Face and Eye recognition sensors Alerting

1 INTRODUCTION

Fatigue or Drowsiness can be defined as the impulse to fall asleep. A driver in this state will tend to lose their vigilance over the steering of the vehicle which ultimately leads to road accidents and far more undesirable consequences especially during the afternoon and midnight hours. A drowsy driver can manifest several symptoms like frequent eye-closure and yawning, nodding, shaking head etc. It is obligatory to develop and design a system that has the competence to both detect and monitor the drunken or drowsy driver and inform the designated users of the current situation. This system needs to be robust and effective under various circumstances such as dim lighting, thermal and vibratory shocks, damp humidity etc. Composed of the three modules, the underlying principle governing the drowsiness detection phase is the object detection framework concept which is simultaneously applied for both face and eyes at the same time. These two target objects are subjected to localization and tracking. Going with the second module, the alcohol content detection mechanism relied on the concepts of electrochemistry. The principle of breath analyzer used by the traffic police is used here. The gas sensor has an in-built electrode which performs either oxidation or reduction on the ethanol gas molecules in its close proximity. As a result of an electrochemical reaction, voltage is generated and is sent as information to the Raspberry Pi board. The final module being the vehicle crash detection mechanism depends on the piezoelectricity completely. In this scenario when an automobile undergoes an accident, the huge amount of mechanical energy in the form of jerks and vibrational shocks is converted into DC electrical energy by the piezoelectric sensor in the prototype. It is able to generate the required voltage and passes the information to the Raspberry Pi minicomputer. The Internet of things was chosen as the right end phase system which performs those actions. Now that all the inputs have been extracted to perform the analysis of alertness deficiency, we design a fast and durable output end system. The end module is an IoT based system, having the facility to inform the designated users about the prevailing situation via android app through messages and mail without any discrepancies .

2 RELATED WORKS

In the precursor techniques, driver monitoring systems used physiological data and these were analog in nature just like the ECG (Electrocardiogram), EEG (Electroencephalogram), Galvanic skin response, blink amplitude, Skin temperature, Heart rate variability and many more [1][2]. These signals were utilized in a collective way to enhance the accuracy of the monitoring systems. The main issue with these systems was that they used a lot of wires and complex hardware connections. Aside from the physiological analog signals, PERCLOS [4] was one metric which was widely utilized in facial recognition and eye tracking. The classifier used in this work is a collaboration of the Haar cascade algorithm which is highly associated with the Viola-Jones algorithm and OpenCV [5].Some techniques also involved the usage of LEDs and multiple cameras to perceive the facial expressions [6]. But these methods faced setbacks when the cameras were subjected to variable lighting and running backgrounds. Finally, the eye openness estimation process was performed by other techniques like the application of Spectral regression embedding (SR) on the segmented eye image to learn the model of the eye shape [7]. The earlier techniques for alcohol content detection were mainly based on the analysis of driver effects like rapid closing of eyes, Over-speed, Lane maintenance, intoxication due to drinks and much more. There was one prototype which performed alcohol content detection using Water-Cluster detecting (WCD) breadth sensors [8]. The extraction part handling the vehicle crash detection mechanism also had many precursors which involved components like sensors and smart phones. One such prototype was designed and implemented using OBD-II Devices and android based Smartphones [9], where the OBD (On-board diagnostics) Interface was used to detect vehicular or automobile collision.

3 PROPOSED SYSTEM

The proposed system consists of three modules as shown in Fig.1 namely drowsiness detection mechanism, alcohol content detection, vehicle crash detection.

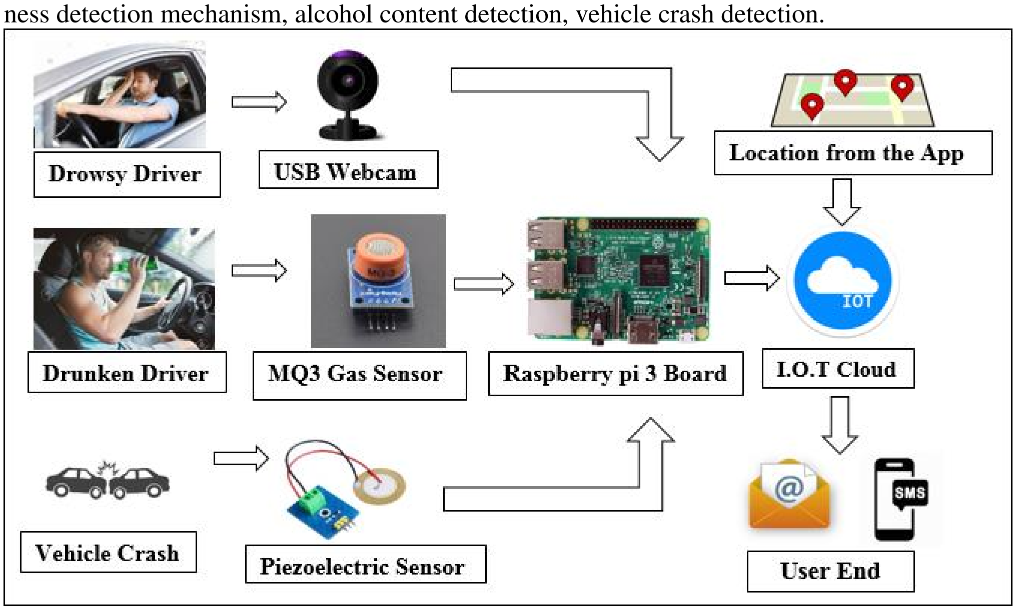

Fig. 1 Architecture of the proposed system

3.1 Drowsiness Detection Mechanism

The USB web cameras are utilized to record the input video which covers the driver's face. The video is loaded into the program in grayscale mode for better performance and it is sampled to obtain the discrete frames where we have applied the Viola Jones algorithm to perform eye detection and tracking [7]. The algorithm has four stages:

1. Haar Feature Selection
2. Creating Integral Images
3. Adaboost Training
4. Cascading Classifiers

The initial step for localization of eyes is the face detection process which is carried out by the Haar features which are widely used in object detection frameworks. Haar features are sequences of rescaled square shape functions which are similar to convolution kernels in the Convolution Neural Networks. They are divided into two classes. The first one is the edge features which can detect edges effectively like the eye brows, lips etc. The second one is the line features which can detect lines like the nose bridge.The Haar Cascade algorithm applies these features on the discrete images and calculates the pixel intensities as shown in Fig 2

Δ = (Sum of Black pixel intensities) – (Sum of white pixel intensities) (1)

$$= \left(\frac{1}{n}\right) * \sum I(x)$$

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Where I(x) – Pixel intensities
n – Number of black or white pixels

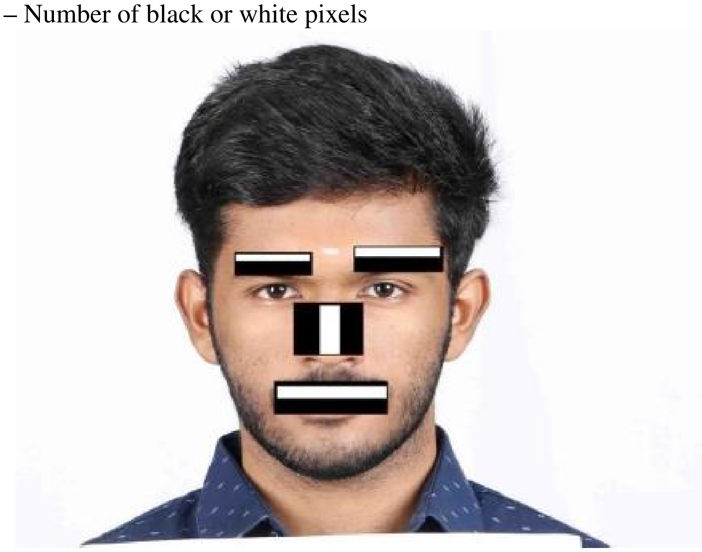

Fig. 2 Application of line and edge features

The intensities of the pixels are separated as black and white segments and are summed up individually and subtracted against each other to determine the delta which forms the integral image. The integral images are used for accelerating the feature evaluation. Adaboost training, which is a boosting algorithm employed to boost the efficiency of the neural networks [7]. It is used to construct strong and weak classifiers and to form a screening cascade classifier to eliminate non-face images and improve accuracy. It selects the best features and trains the classifiers to use them. This algorithm builds a strong classifier as a linear combination of weighted weak classifiers. The weak classifiers are threshold functions based on the features fj.

$$H(x) = \mathrm{sgn}(\ \Sigma\alpha j h j(x)) \qquad (2)$$

$$\begin{aligned} hj(x) &= -\ Sj \text{ if } fj < \theta j \qquad (3) \\ &\quad + Sj \text{ if } fj > \theta j \end{aligned}$$

H(x) – Strong classifier
hj(x) – Weak classifier
Sj – Polarity (either -1 or 1)
αj – Coefficients or weights to boost the performance of the weak classifiers
θj–Threshold value based on features

The final step is to cascade the classifiers.The features are grouped into different stages of classifiers and applied one-by-one.If a window passes at first stage, apply the second stage of features else discard it.The window which passes all stages is a face region. Similarly, repetitive procedure of these steps may manifest a tracking process in the output window. After recognizing the face and eye localization process, the eyes are tracked instantaneously. When the eyes are open, the system keeps on tracking. When the eyes are closed, the classifier can't recognize the target and the system immediately initiates the counter where the user needs to set a particular threshold time limit to determine the basic time for eye closure for tiredness. Once the threshold is set and eyes are closed for more than the threshold, data is sent to the Raspberry Pi board [10]. The data is immediately recognized at the Raspberry Pi3 minicomputer and location available in the phone of the driver to be taken by the Raspberry Pi is sent to the owner of the Vehicle as both SMS and an E-Mail. The data is initially being fetched from the Driver's phone and it is uploaded to the Firebase for processing it.

3.2 Alcohol Content Detection

MQ gas sensors are widely used nowadays to detect liquor content where each of MQ gas sensors detects specific gas molecules. In this project, we have implemented MQ3 gas sensors, since it detects ethanol (alcohol) gas molecules. The sensor is generally active at temperatures between -10°C and 50°C, works on 5V DC and draws around 800mW. It can detect Alcohol concentrations anywhere from 25 to

500 ppm which is basically implemented in the breathalyzer used by the traffic authorities.

The gas molecules diffuse through the porous SnO2 (Tin oxide) membrane to the Au (Gold) electrode where it is either chemically reduced or oxidized. When surrounded by alcohol molecules, the conductivity of Tin oxide increases proportionally with the gas molecules concentration [9]. This electrochemical reaction generates a specific amount of current that passes that alters the resistance of the sensing element and thus, a potential difference is generated. This analog voltage generated is converted into digital data using an ADC and is observed at the Raspberry pi and status as 'Drunken' is sent to the user via email.
Steps involved:

1. Diffusion of alcohol molecules through the oxide membrane
2. Electrochemical oxidation or reduction takes place
3. Voltage is generated through the external circuit
4. Status is sent to the user via email

3.3 Vehicle Crash Detection

The last input extraction module after the Drowsiness recognition and Alcohol content detection is the Vehicular crash detection mechanism. We have used the piezoelectric sensor also known as vibration sensor to implement this module. The piezoelectric sensor inherently uses piezoelectric effect by converting physical variation in pressure, strain, force or acceleration into an electrical current.
Steps involved:

1. Detect collision as a form of Vibration
2. Measure magnitude of Vibration (ms2 or N)
3. Analog signal is created as per the pressure produced
4. ADC and Data sent to Raspberry pi

The piezoelectric or vibration sensor is an electrical combination of a voltage source and a filter network consisting of capacitances and inductances. The voltage produced is directly proportional to the applied mechanical force. The pressure is usually applied transversely or longitudinally or along the piezoelectric sensor. These pressure or strains cause the occurrence of electric dipole moments in the solids due to the force applied on the piezoelectric material like quartz etc. The amount of charge displaced depends on the dimensions of the sensor and the piezoelectric coefficient. The mathematical expression is given by:-

$$Q_x = d_x * F_y * \left(\frac{b}{a}\right)$$

$$I(t) = {}^{dQ_x}/_{dt}$$

Qx – Amount of charge displaced in the x-axis
dxy –Piezoelectric coefficient
Fy –Force applied on neutral y-axis
a,b –Dimensions of the sensor
I(t) –Current generated during the process

4 EXPERIMENTAL SETUP

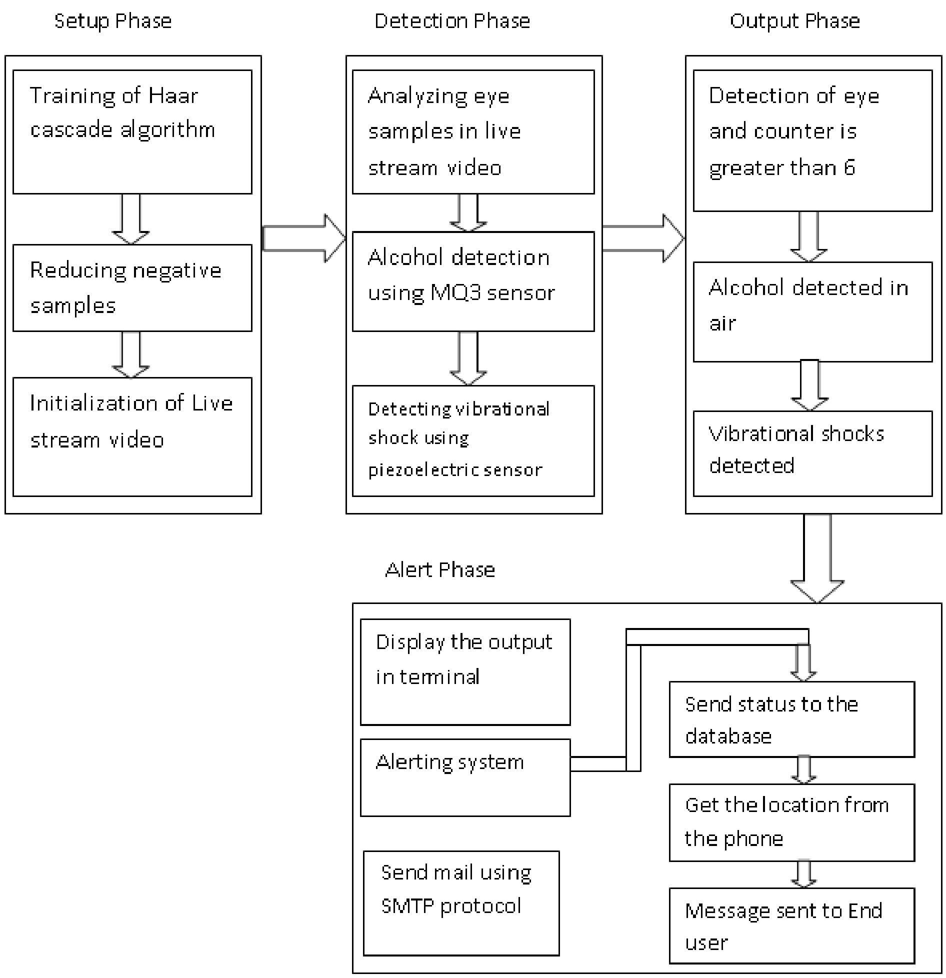

Fig 3. Four phases of the system

The four phases of the system is shown in figure 3. The initial phase being the setup phase used for training the classifiers for drowsiness detection. Next is the detection phase where input is received from all the three modules and physiological state of the driver is closely monitored. The third phase is the output phase where the result of the detection phase is analyzed using Raspberry pi and the information is sent to the alert phase. The final phase is the alert phase where the designated user is alerted using IoT devices.

4.1 Setup Phase

The first phase of the project is used to train Haar cascade classifiers with data sets which consist of human faces and classes are created based on facial and eye features. The data set is stored in the Raspberry pi minicomputer. With help of the modules the OpenCV automatically applies bounding boxes and automatically resizes the images as shown in Fig 4. Initially the images are captured using a USB webcam which is connected to the Raspberry Pi minicomputer in one of its USB ports. The HAAR cascade classifier is applied to this live streaming video to analyze the physiological state of the driver. The MQ3 gas sensor and piezoelectric sensor does not require any initial training.

4.2 Detection Phase

The second phase is Detection phase and its primary focus is to monitor target objects like face and alcohol content in the car. The bounding boxes are used to localize the eyes so that the eyes are closely monitored. In Alcohol detection mechanism, an MQ3 sensor is used to analyze the ethanol content in air. Adsorption occurs when alcohol content in air comes in contact with the sensor. Alcohol molecules are nothing but ethanol particles (C2H5OH). The gas sensor is placed straight to the driver's face so that efficient sensing of Alcohol molecules. The magnitude of the force threshold is set by the user in order to distinguish the vehicle crash force magnitude from the rest.

4.3 Output Phase

The important phase of the prototype is the output phase where the facial elements are closely monitored. Buzzers are activated to alert the passengers and driver if the eye is closed for more than 6 seconds. Buzzers go high if excess alcohol content is present in air or vibration shock greater than threshold is detected. These data are sent to raspberry pi which is the main component of this prototype. The output for each scenario is stored as algorithms in Raspberry pi. The DC motor stops immediately after the buzzers go high indicating that the vehicle has stopped.

4.4 Alert Phase

The final phase is the alerting phase in which the end user is alerted using IoT components. The Buzzer is an internal caution device whereas these Short Message Service (SMS) and Global Positioning System (GPS) location tracking come under cloud computing and are external in this case. SMTP (simple Mail Transfer Protocol) is used to send an email to the end user with the type of event that occurred as shown in Fig 7. The Data is initially being fetched from the Driver's phone and it is uploaded to the Firebase for processing it. The type of alert system can be chosen by the user like whether a mail has to be sent or a SMS is sent or an entry is to be made on the app of the user. The result is projected along with the latitudinal and longitudinal coordinates of the vehicle as shown in Fig 8. Also the app is logged in previously by the driver, so that the agencies/owner can distinguish between their drivers.

5 RESULTS AND DISCUSSION

As the system executes, the popup appears so that the driver can adjust his seating position to face the camera. In a drowsiness detection mechanism, the bounding boxes localize the eyes and start to monitor them as shown in figure 4.

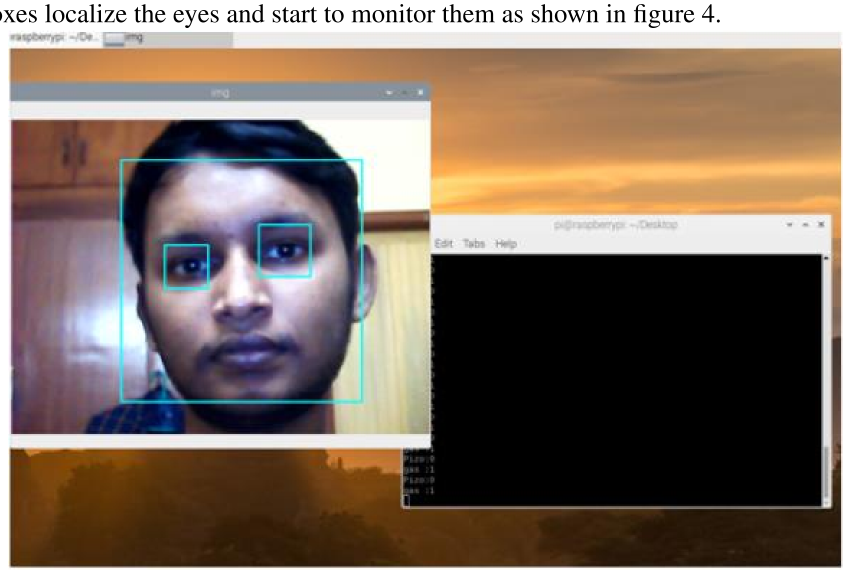

Fig. 4 Eye Closure Detection

After the eye is detected, the USB camera continuously monitors the facial interactions of the driver. A counter is initialized if the eye is closed. If the count in the counter is more than 6 seconds, then the prototype detects that the driver is sleepy and transmits the data to the Raspberry Pi board. From there begins the alert phase where the designated drivers, passengers and users in general are notified of the existing scenario through SMS and email.

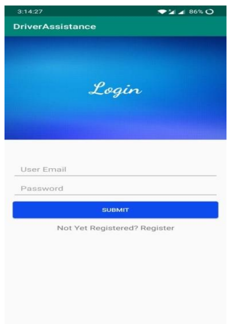

Fig. 5 Login Screen

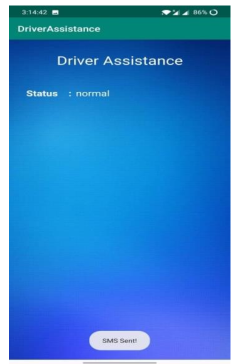

Fig. 6 Driver Status in App

End users can view the information regarding the driver's physiological state and location coordinates during the alert phase. A database in Firebase stores the information regarding the location of the vehicle when an accident occurs. The android application is used to extract the location of the driver which is secured using User Id and Password as shown in Fig 5. The android application is created in Android Studio and it is installed in Driver's mobile to monitor him as shown in Fig 6.

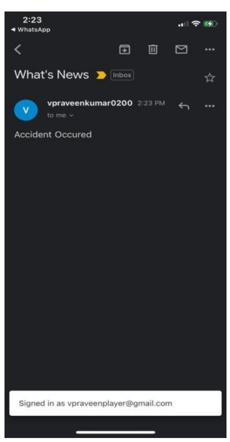

Fig. 7 Email Alert

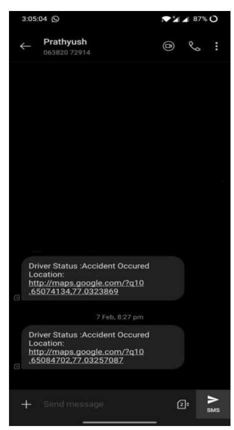

Fig. 8 SMS Alert

6 FEATURES

1. We have implemented an integrated model with multiple sensors and varied functions.
2. This helped us achieve a desirable outcome. This is a cost-efficient model built using optimal and need only basis components
3. This provides the best available features. In this system, to achieve immediate communication, the alert message is sent within a few seconds.
4. Basic internet connection is required for the prototype to run in the vehicle.
5. As the location is sent to the owner, quick recovery in times of crisis and casualties can be reduced in case of accidents

7 CONCLUSION

In this paper, we have given detailed information of how we have designed and implemented the driver assistance system using several hardware components and software algorithms with compatibility and cost efficiency. The main motive of this work is to ensure the safety and security of driver and passengers travelling in the vehicle. There are lots of researches related to this line of work, but our work validates and extracts input from multiple sensors and are digitally processed and delivered instantaneously to the end user. The alert delivery schemes used in the system are compact and fit for daily use. These were possible only because of the underlying foundation of the IoT. The utilization of a much-advanced futuristic technology also adds novelty to our project which many researchers missed to use in the past.

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