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Drowsiness detection and safety monitoring using image processing

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ABSTRACT

Drowsy driving is a major issue of the traffic collision due to which severe injuries and deaths occur by the way of accidents. Numerous researches were undertaken to carefully design systems which can assess fatigue of the driver and provide an alert prior, hence preventing from sleep avoiding accident. Some conventional approaches employed vehicular measures that are greatly influenced by the road geometry, vehicle model, driving skill etc., behavioral measures like facial expression and psychological subjective measurements that can cause discomfort to the driver and may produce ambiguous results. In this paper, a nonintrusive and real-time approach is proposed that monitors driver's eyes using a high resolution Pi camera. An algorithm is developed to capture the symptoms of driver fatigue through facial and head movements. On detecting abnormal conditions, a buzzer alerts the driver and an alert message will be sent. Raspberry-Pi is used to incorporate the entire system. Experimental outcomes ensures that the system could track the changes in the driver's facial movements and alert the driver from accidents more efficiently with an appreciable accuracy. The system can be implemented at any lighting condition.

Keywords: Feature extraction, Fatigue detection, Supervised learning, Neural network, Classification.

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1. INTRODUCTION

Transport systems have become an integral part of human activity and their usage has increased in the recent years. According to 2019 statistics, nearly 3M new cars were registered in India. Congested road traffic with rise in car transport in India, road safety is one of the key issues to be addressed and given due importance. In India (2017), nearly 1.47 lac people died due road accidents which are equal to the population of Shillong, the capital of a Meghalaya, India. Also, the injury rate in those road accidents is almost 3/4th higher compared to yester years. A study at the Central Road Research Institute (CRRI) revealed that 40 to 45% of the highway road accidents occur owing to driver fatigue. National Highway Traffic Safety Administration (NHTSA) has reported that as many as 1550 citizens lose their lives and several thousands of people suffer severe injuries year on year as a dreadful consequence of drowsy drive. Another survey released by USA's National Sleep Foundation' s Sleep-poll has said that nearly 103 M people have fallen asleep during driving. The driver may get fatigue due to several causes like very short sleep, lengthy trips, mental state etc. These symptoms have an adverse effect reducing the vigilance level of the driver leading to hazardous accidents.

Year on year, there is an increase in the mortality rate and fatality injuries worldwide. At this juncture, it is extremely vital to make use of novel emerging technologies in designing and building systems that monitor driver activities and measure their vigilance level during driving. Drowsiness detection has thus become very crucial in avoiding accidents and saving lives. Parameters that are related to real-time drowsiness detection of the driver rely on either measuring divers' physical features of the face like eye closure, yawn, head posture or activities of the brain like measuring bio-potential signals like EEG, ECG etc. Ratio between eye closure and opening is also taken into account in some cases.

The bio-potential measurement technique, though provide promising results, is unrealistic due to the fact that electrodes are required to be connected to the driver's body that cause discomfort while driving. In addition, the sensors are also prone to depreciate due to high state of usage resulting in perspiration and offer low efficiency. The other method that makes use of driver's behaviors like head posture, facial movements make it applicable to real time as it is non-contact and non-intrusive. A camera is used to record such changes positioned in front of the driver. Easier installation and low cost are some of the advantages of the non-contact method. For example, systems in Smart Eye (2018) use the eye movement of eye and head position of the driver to estimate the fatigue level. By monitoring driver's eye continuously, it is possible to assess one's state and alert

In this work, a contactless method of assessing the driver's fatigue is proposed employing a dashboard mounted camera and related accessories. The system employs every image frame captured in analyzing the driver's state. Our system is suited to adjust the camera settings according to the height and posture of the driver to track the trajectory of head movements.

2. REVIEW OF RELATED WORKS

Deng and Wu (2019) proposed "DriCare", that could detect the behavioral fatigue status of drivers, like yawning, eye blinking and closure, with the help of video images, by contactless method. To overcome the drawbacks of previously existing algorithms, a novel face-tracking algorithm was introduced to enhance the tracking accuracy. A 68 key-point detection method for facial region was designed. With the combination of facial features, DriCare was able to give an alert to the driver by using a warning system with an accuracy of 92%. A survey on drowsiness detection methods was reported by Ramzan et al. (2019). The existing techniques were classified into three types based on certain that contribute to behavioral and physiological aspect of the driver and vehicle dynamics as well. A review on supervised methods was also presented. Finally, the merits and demerits of each method with comparative study were reported. Assari and Rahmati (2011) designed a facial expression dependent hardware-based system for detecting driver drowsiness. Infra-red (IR) was used to avoid conditions of poor lighting conditions. From the raw-input images, background subtraction, horizontal projection and template matching were performed to detect facial changes. The system was able to produce appreciable results in case of different driver appearances. In the work done by Saradadevi and Bajaj (2008), the authors proposed a fatigue detection system depending on yawning and mouth analysis. Mouth of the driver was tracked and located using series of classifier training. Support Vector Machine (SVM) classifier was employed. Ahmad and Borole (2015) reported a drowsy detection utilizing head position and eye closures. Viola Jones method was employed in detecting face and eyes. Wavelet network was used to detect the eye status. 80% accuracy was reported by the method. Rahman et al. (2010) developed a method based on eye blinking to assess the driver drowsiness. Video capturing followed by frame conversion was employed in detecting the face. Viola Jones method was used to detect the region of interest (ROI). Eyes were detected using Haar features. Tested under various lighting conditions the system was able to attain 94% accuracy. Similar method was proposed by Khunpisuth et al. (2016). Vehicle based parameters were used to design a system for detecting the driver fatigue and was discussed by Zhenhai et al. (2017); Li et al. (2017); Satzoda and Trivedi (2015); Chieh et al.(2003). Biological parameters of the driver were used to detect the state of the driver such as pulse rate, EEG, temperature etc. Previous studies presented a comprehensive method in analyzing such parameters reported by Li Chung (2013) ; Lin et al. (2005); Leng et al.(2015). A brief summary of the State of art methods based on the three categories is illustrated in Table 1. To put in nutshell, there are merits and demerits of each, and every technique proposed in all the three classes as available in the literature. Behavioral and vehicular parameter-based methods are contactless and are easy to employ in vehicles but at the same time suffer from poor lighting conditions and road geometry respectively. The physiological method though intrusive (drivers' biological parameters are measured by contact sensors) are efficient and highly reliable. Hence hybrid approach is most sort after to obtain high accuracy and reliability. A novel combination of all the three parameters was reported by Lee and Chung (2012), where heart rate, eye closure and speed were studied to detect fatigue of the drivers. HRV model with Fuzzy Bayesian network was employed which achieved 94-99% accuracy. In the proposed system, behavioral features are considered because of the advantages posed by such methods as said in the literatures. A holistic approach on driver drowsiness detection is presented by Ramzan et al. (2019). Contributions to the proposed system is given below

- Video/Image Processing based drowsiness detection system.
- Quick and simple algorithm for facial and eye detection
- Possible implementation on low-cost microcontrollers
- Real time application with simulation and on-field tests

Table 1. Summary of drowsiness detection methods based on different features

Features	Method	Description	Acc (%)	Reference
Eye blinking	Viola Jones, Haar classifier	Non-contact method but failed to work in poor lighting conditions	94	Rahman A et al. (2015)
Yawning	SVM, CHT	Face extraction, mouth movement selection done by SVM, CHT	98	Yan C et al. (2016)
Duration of eye closure, head movement	Viola Jones, WNC Classifier	Drowsiness is detected based on head posture and eye blink	88	Teyeb I et al. (2014)
Steering wheel behaviour	Temporal detection window	Time series analysis of angular velocity of the steering wheel	Not reported	Zhenhai G et al. (2017)
Steering wheel angle and yaw angle	Appr Entropy features, BPNN classifier	Steering wheel and yaw angle is detected	88	Li Z et al. (2017)
Heart rate analysis	SVM, Wavelet	PPG sensor is employed to acquire driver's heart rate and analysed to diagnose the physiological changes	95	Li, G., Chung, W.-Y (2013)
Brain Signals	Bandpass filter, fusion of features	Driver's brain signal collected through EEG sensor is analysed	Not reported	AlZu'bi H S et al. (2013)
Body temperature and pulse rate	Viola Jones, Haar Classifier	Combination of both physiological and behavioural changes of the driver	80	Chellappa Y et al. (2016)

The proposed systems cover the following:

1. If a driver's eyelids are closed for a predetermined amount of time, it is assumed that the driver is tired, and an audible alarm is utilised to alert the driver.
2. When a driver's mouth remains open for an extended amount of time, it is assumed that the driver is yawning, and the driver is given advice on how to avoid drowsiness.
3. When a driver fails to keep his or her eyes on the road, it is detected using facial landmarks, and an alarm is triggered to alert the driver.

3. PROPOSED METHOD

The system comprises of modules like video capture, detection of face and eye and drowsiness. Image is acquired through a Pi camera module. The image acquired goes through series of steps of processing before being detected for face. A credit card sized Raspberry Pi, buzzer is also used in the method for implementation and drowsiness detection. Fig. 1 shows the proposed architecture. Fig. 2 shows the flow chart and explains the overall implementation strategy.

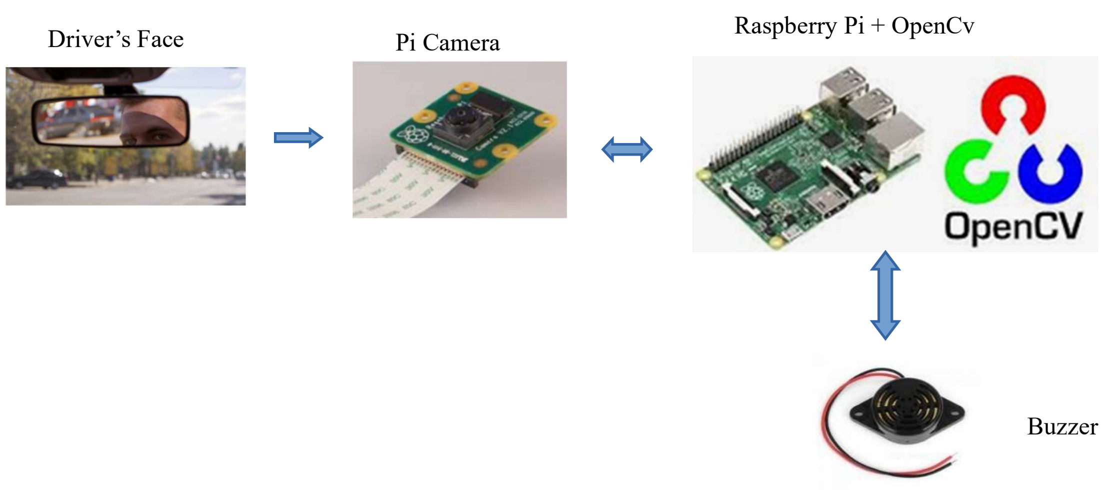


Fig. 1. Proposed architecture

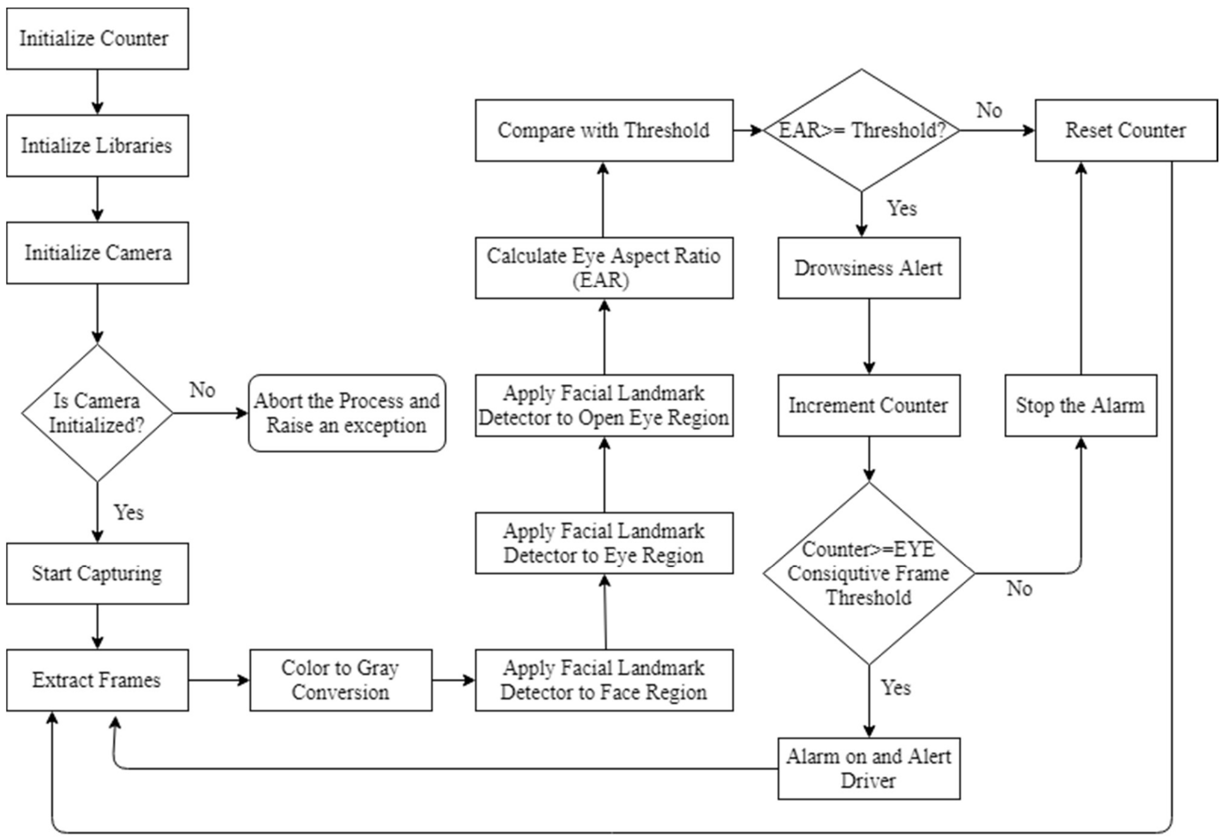


Fig. 2. Methodology flow

The process starts with the video capture by the camera installed in-front of the driver. The acquired video is converted into a series of frames/images. Face detection step starts by where the driver's face is detected every frame which is extorted from the video. Eyes and mouth are detected by processing the facial landmarks and it is able to calculate the eye closure and yawning. If eyes detected are closed for sufficiently long time continuously and is greater than a defined threshold, it is meant that the driver is feeling sleepy or drowsy where an alarm is generated. An alert message is also sent to friends/relatives. Fig. 3 illustrates the process of image acquisition to alarm generation.

3.1 Face Detection

The system captures the each and every video frame at first. OpenCV is used for the purpose as it provides support in processing live frames of videos. The system now detects the face in the frame. Object detection is performed using Viola-Jones method (Viola and Jones, 2001).

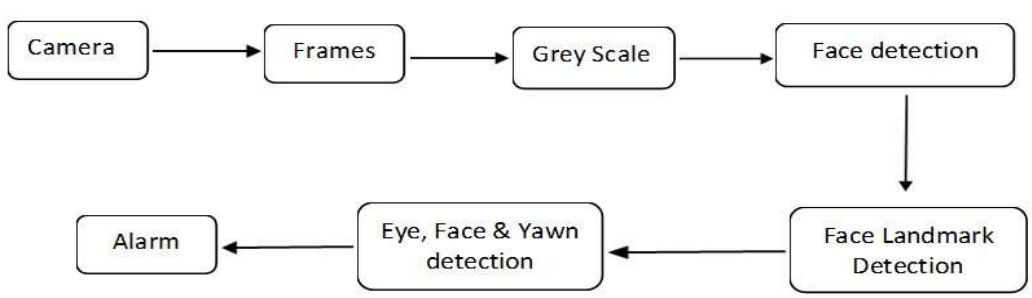


Fig. 3. Flow diagram from video capture to alarm generation

The algorithm has four steps i) Haar Feature Selection ii) Creating an Integral Image iii) Adaboost Training and iv) Cascading Classifiers. This is obtained using Haar algorithm for detecting the face. Haar cascade is a feature-based algorithm that effectively detect the face. By cascading of stages, Haar algorithm removes the non-face candidates. Various Haar features are combined in each stage and the classifier classifies each of the feature in-turn. The inbuilt feature OpenCV xml "haarcascade_frontalface_alt2.xml" file is deployed to search and detect faces in frames individually. This file possesses several facial features and is constructed using several plus and minus samples. Initially the cascade file is loaded. The acquired frame is then passed to an edge detection function to detect all possible objects of various sizes. As the camera captures the entire face of the driver (greater part), the edge detector is specified to detect only particular sized objects i.e. facial features (region of interest). Identification of faces that are located in the frame is performed by storing and comparing the edge detector output with that of the cascaded file.

3.2 Eye Detection

After the face detection phase, eye features are detected using eyes detection function. Facial landmark detection function is used to detect the opening and closing of eyes. Movement of the head and certain facial expressions result in deformations of the face both non-rigid and rigid. This is captured by the landmark points surrounding the face components and contour. This serves as the basis for facial analysis. Facial landmark detection algorithms are categorised into holistic, Constrained Local Model (CLM) and regression-based approaches. These methods vary in their approach of using shape and facial information. Each of the methods have their own merits and demerits. Here, the facial landmark detector is used which is available in *dlib* library, an implementation of the One Millisecond Face Alignment with an Ensemble of Regression Trees (Regression-based Method) by Kazemi and Sullivan (2014) for facial landmark detection. Facial landmark is applied successfully in estimating head posture, detecting facial alignment, face swap detection, blink detection etc. With respect to facial landmarks, the objective here is to detect vital facial structures by employing prediction techniques. The two-step process in detecting face landmarks is:

- Facial image localization.
- Detection of key facial structures (ROI).

A pre-trained facial landmark detector incorporated in *dlib* library is used in estimating the location of 68 (x, y)-coordinates that maps the structures of the face. These 68-point mappings were achieved by training a shape predictor on labelled iBUG 300-W dataset.

The 68 coordinates help in determining the eye and mouth region in the face as shown in Fig. 4. The eye region can be detected and accessed by the following facial landmark index shown below

- Right eye with [37 - 42]
- Left eye with [43 - 48]

Detection of mouth region can be done using the facial landmark index shown below

- Mouth with [49 - 68]

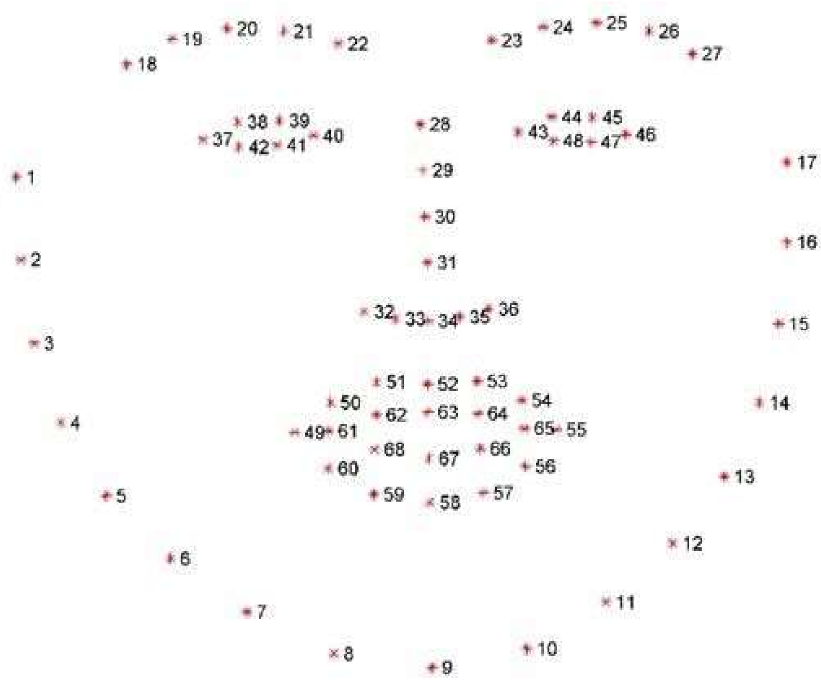


Fig. 4. 68-Facial landmark detection

3.3 Hardware Architecture

The hardware architecture is a view of the physical interrelationship between the hardware components. This description helps to fit the components into the respective positions of the design. The definition of the hardware architecture allows the various effective developments in the project. The hardware components used are listed below,

1. Raspberry Pi 3B+
2. Raspberry Pi Camera Module
3. Buzzer

3.3.1 Raspberry Pi 3B+

It is a card-sized computer embedded with Quad Core A53 (ARMv8) Broadcom Videocore-IV, 64-bit CPU, 1 GB RAM, and other accessories. Integration of Raspbian OS and the microprocessor make it suitable for Windows OS. Fig. 5 shows the Raspberry Pi 3B+ used. The specifications are as follows.

- SoC: Broadcom BCM2837B0 quad-core A53 (ARMv8) 64-bit @ 1.4 GHz
- GPU: Broadcom Videocore-IV
- Networking: Gigabit Ethernet (via USB channel), 2.4 GHz and 5 GHz 802.11b/g/n/ac Wi-Fi
- Bluetooth: Bluetooth 4.2, Bluetooth Low Energy (BLE)
- GPIO: 40-pin GPIO header, populated
- Ports: HDMI, 3.5 mm analog audio-video jack, 4x USB 2.0, Ethernet, Camera Serial Interface (CSI), Display Serial Interface (DSI)
- Dimensions: 82 mm × 56 mm × 19.5 mm, 50 g

3.3.2 Pi Camera Module

Raspberry Pi Camera module is employed in capturing high-definition (HD) video with still pictures. It operates with 1080 p with picture resolution 25928 × 1944. The advantages include portability, light weight supporting Raspberry Pi module. Communication with Pi takes place via MIPI camera serial interface protocol. Fig. 6 shows the module used

3.3.3 Buzzer

A buzzer or beeper is an audio signalling device, which may be mechanical, electromechanical, or piezoelectric. If the driver's drowsiness is detected, then a voltage is supplied as an alert to generate regular programmed voice sound. Its operating voltage is 3 – 24 V with sound pressure level 85db and the rated voltage is 12 V (Fig. 7).

4. RESULTS

Drowsiness detection was implemented using Python and OpenCV with the following steps

- Video capturing with successful run time.
- Division of captured video into frames followed by the frame analysis.
- Successful face detection followed by eyes and mouth. If eye closure and yawning for successive frames were detected, then the drowsy state is identified by the system else normal.
- The above steps are repeated to analyze the state of the driver (continuous monitoring)

Fig. 5. Raspberry Pi 3B+

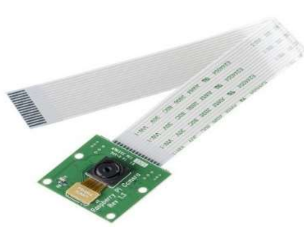


Fig. 6. Raspberry pi camera module

Fig. 7. Buzzer

Initially, the efficiency of Viola Jones algorithm is tested in various settings by finding its accuracy, which will change depending on the brightness, contrast, illumination, movement speed, and other factors. 50 offline images are collected from various sources for testing purpose. They are classified as – looking front, looking left and right, looking up and down. Also, different lighting conditions are set. We compared the viola jones algorithm with Kanade-Lucas-Tomasi algorithm for obtaining a fair comparison and run on the same procedure. Viola jones algorithm detected 96% of the total images as against 91.2% with Kanade-Lucas-Tomasi algorithm. Table 2 illustrate the overall comparison on different categories in terms of accuracy.

The proposed method is tested with 20 real time images for different positions of the head and face like eye closure, yawning etc. 97% of the images are correctly identified the model. Fig. 8 depicts the sample output obtained using real time image.

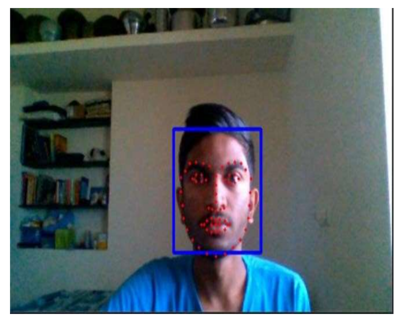
Fig. 9 illustrates the message which will be sent to relatives in case of emergency. Fig. 10 illustrates the complete hardware implementation set up. Our method is able to detect all the positions of the head and face as tested on real time images with a better accuracy.

Table 2. Accuracy of Viola-Jones method

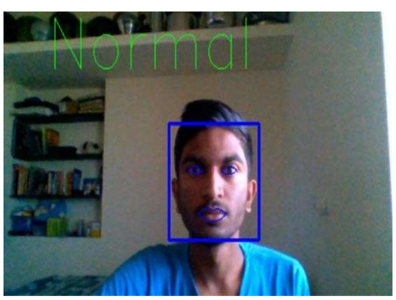
Category	Kanade-Lucas-Tomasi	Viola Jones
Looking front	89%	96%
Looking left	92%	97%
Looking right	94%	98%
Looking up	90%	93%
Looking down	94%	96%
Average	91.2%	96%

(a) No face

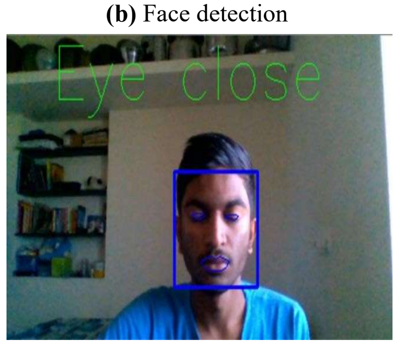
(b) Face detection



(c) 68 key landmark detection



(d) Normal condition



(e) Eye closure detection

(f) Yawn detection

Fig. 8. Sample output obtained using real time image

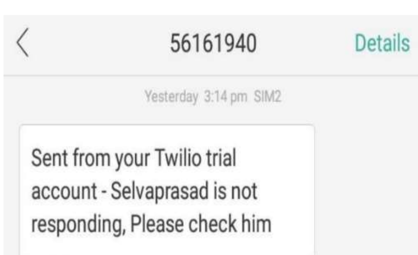


Fig. 9. Message window

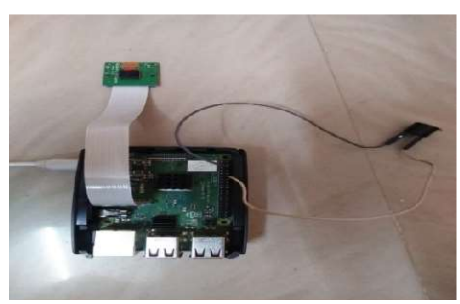


Fig. 10. Hardware implementation

5. CONCLUSIONS

Monitoring driver's alertness is of high importance to prevent great number of incidents. Existing systems makes use of various sensors to monitor or assess physiological parameters like EMG, EEG and EOG which cause discomfort to drivers and in due course it may generate false data owing to perspiration. In the developed system, video of an individual is captured through a camera, processed and is incorporated in Raspberry Pi. The Haar Cascade Classifier is employed in detecting the face and facial key points are predicted using dlib landmark detection. The experimental results show that, whenever the driver closes eye or yawn more than the threshold limit, alarm triggers. Similarly, when the face is not detected, counter starts to increment and at a particular limit, the SMS will be sent to the relatives. The proposed system can be implemented easily on any microcontrollers and do not warrant huge memory. This simple structure results in a low-cost drowsiness or fatigue detection system. The system is also validated through simulation and experiments that demonstrated its applicability in real time applications. Thus, the developed system can reduce many accidents and provide a safe life to the driver and ensure safety of vehicle. Presently in India, only luxury cars have this kind of driver and car security. On the other hand, our model can be implemented in ordinary cars to detect the safety of drivers and thus prevent fatality. In future, this concept could be implemented as a mobile application to save money on hardware. If the driver is caught napping, this can be coupled with an automobile to provide automatic speed control.

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