IOT based Real-time Drowsy Driving Detection System for the Prevention of Road Accidents

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***Abstract*— At present time, drowsy driving has become one of the major issues of the traffic collision. According to statistics, a large number of road accidents occur due to drowsy driving which results in severe injuries and deaths. For this reason, various studies were done in designing systems that can examine the driver fatigue and alert him beforehand, thus preventing him to fall asleep behind the wheel and cause an accident. Some traditional approaches used vehicle-based measures to design their system, however, such measurements are highly influenced by the structure of the road, type of vehicle and the driving skill. Other approaches used psychological measures for their system that tend to provide better accuracy in monitoring the drowsiness of the driver. However, such techniques are usually intrusive as electrodes are required to be placed on the head and body. Furthermore, there are few existing researches in which subjective measurements are used as the input for the system, but, such methods can distract the driver and lead to an ambiguous result. In this paper, we proposed a system that is absolutely non-intrusive and real-time. Our proposed system used the eye closure ratio as input parameter to detect the drowsiness of the driver. If the eye closure ratio deteriorates from the standard ratio, the driver is alerted with the help of a buzzer. For our system, a Pi camera is used to capture the images of the driver's eye and the entire system is incorporated using Raspberry-Pi.**

Keywords*— *Drowsy Driving; Eye Aspect Ratio; Facial Landmark; Computer Vision; Raspberry Pi; Pi Camera Module

I. INTRODUCTION

Among many other issues concerning traffic accidents in this busy world, drowsy driving is one of the major issues that is highly required to be brought into consideration. According to [1], 846 deaths have occurred due to drowsy driving in the year 2014. An estimated average of 83,000 crashes per year was identified with drowsy driving between 2005 and 2009. This annual average incorporates approximately 886 deaths, 37,000 injuries, and 45,000 property damage only due to car crashes. Drowsy driving occurs when the driver is extremely worn out while driving, making him impossible to stay alert. This usually occurs when the driver does not get sufficient amount of sleep or is under medications. This can also occur when he suffers from sleep disorders such as insomnia or shift work sleep disorder (SWSD). As a result, the driver tends to have a mild cognitive impairment and also slow reaction times. In the most pessimistic scenario, the driver may fall asleep behind the wheel [2].

Several attempts were taken to detect the drowsiness of the driver by considering various parameters. Many existing methods implemented vehicle-based measures which involve mounting sensors on various components of the vehicle [3, 4]. The sensors are usually placed on acceleration pedal and steering wheel, to evaluate the intensity of the drowsiness. The process of implementing vehicle-based measures can be further broken down into two categories. The evaluation can be performed based on two approaches, namely Steering Wheel Movement (SWM) and Standard Deviation of Lane Position (SDLP). In order to measure SWM, an angle sensor is utilized to determine the driver's level of drowsiness based on his steering pattern [5-7]. On the other hand, SDLP implements an external camera which is used to determine whether the vehicle is drifting out of its lane [8]. However, evaluations based vehicle-based parameters highly rely on the physical aspects of the surrounding environment and the driver himself. These factors basically involve the structure of the road, the type of vehicle used and the driving pattern of the driver which affect the accuracy of the evaluation [9]. Besides, such measurements are also used to detect other sources of traffic accidents such as the drowsiness based on alcohol consumption. As a result, vehicle-based measurements would not be able to detect the cause of the drowsiness particularly [10, 11]. Apart from this, some approaches implemented psychological measures to monitor the drivers' fatigue status which is executed by recording psychological signals using either electroencephalogram (EEG), electrooculography (EOG), electromyography (EMG) or electrocardiography (ECG) [12-15]. One advantage of using psychological measurements is that the evaluations based on such parameters can predict drowsiness with better accuracy since the psychological signals can well represent the cognitive activities of the brain [16]. However, such techniques are intrusive since sensors are required to be placed on the driver's body in order to collect the data. This may make the driver feel uncomfortable and also divert his attention from driving [17]. Few existing approaches used subjective measurements which are conducted through self-rating of the driver or through questionnaire [18]. Nevertheless, such techniques can lead to anomalous result as the self-assessment method can alert the driver subconsciously, decreasing the intensity of drowsiness [17]. Moreover, the most

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prominent drawback of subjective measurements would be that one might fail to precisely predict his own level of drowsiness merely on the basis of self-assessment in a real-time situation. Some existing work provided model-based movement tracking based on optical flow by analyzing the eye state and the head position of the driver [19]. This approach proposes high accuracy rate with acceptably low errors and false alarms for people of various ethnicity and gender. However, this has a disadvantage of higher computing capability requirement and the side-effect of being sensitive to noise [20].

Referring to the previously specified issues [9-11, 17, 20]; we have proposed a method, which is based on the behavioral measurements, in which the eye closure ratio is used as the input parameter for detecting driver's drowsiness. Techniques relied upon behavioral measurements involve monitoring the eye blinking pattern, yawning, eye closure, facial movements and head pose via an external camera [21, 22]. Moreover, as the system is designed considering the behavioral parameters, it serves as a non-intrusive technique of determining the driver's drowsiness as it does not require any placements of sensors on the driver's body and thus does not interrupt him while driving. In our proposed system, the face of the driver was continuously recorded in order to detect the eye movements using a Raspberry Pi camera. In order to effectively capture the face, the Pi camera is mounted on the vehicle dashboard and is kept approximately 20 cm away from the driver's face [23]. This Pi camera is connected with the Raspberry Pi with the help of a flexible cable and the Raspberry Pi itself, can be placed anywhere inside the vehicle, out the human eyesight. Initially, the detection of facial landmarks was performed using the Haar Cascade classifier. Once the various areas of the face were detected, the eye regions were extracted to measure the eye closure ratio. If the eye closure ratio of the driver deteriorates from what is considered to be the standard ratio of an individual in a normal state, the driver is instantly alerted with the help of the buzzer. Moreover, to ensure the driver is taking proper measures to not fall asleep, the owner of the vehicle is notified as well through an e-mail which will be sent automatically if the driver is found to be dozing off more than a couple of times. The entire system was integrated using a Raspberry Pi and a Pi camera was used for tracing the eye movements.

The subsequent sections of the paper have been organized as follows: Section II illustrates proposed model with block diagram and flowchart. Section III describe the working of the individual components present in the system. Section IV represents the system implementation of our proposed model. Section V focuses on the experimental results along with the related discussion. Section VI concludes the paper and is followed by the description of future work in section VII.

II. Proposed System

The proposed system has been intended to overcome the drawbacks of the past transportation and drivers management systems and to decrease the number of accidents occurring every day around the world. The objective of our system is to make a smart system that will operate fully automatically for handling the drowsy driver detection problem. This is done by waking the driver up using a buzzer when he is detected with drowsiness and notifying the owner of the vehicle so that the necessary steps can be taken. A human eye without the effect of drowsiness has an Eye Aspect Ratio (EAR) above 0.25, which is the threshold value. When a driver is in a transition to sleep his eyes will automatically tend to shut down thus decreasing his EAR. Once the EAR value falls below the threshold value, the duration of eye closure is considered. In order to distinguish the drowsy eyes of the driver from the normal eye blink pattern, a threshold value, representing the total number of video frames the driver has closed his eyes, is used. If the number of successive frames exceeds this threshold value, the system detects the driver with drowsiness. A buzzer is turned on immediately to wake the driver up. A Pi Camera Module is used to continuously record his eye movements so that the EAR can be calculated in real time. Moreover, a counter is used to detect the number of times he is detected with drowsiness. For our system, the counter limit was considered to be 3. If it exceeds this limit then the owner of the car will be notified to let him/her know that the driver fell asleep for a couple of times while driving. As the system is connected with IOT, it will send an email to the Android device of the authorized owner when drowsiness is detected. This will alert the owner about the driver's driving pattern and will help him to take further decisions based on his driver's actions. Fig. 1 shows the block diagram and Fig. 2 shows the flowchart of your proposed system.

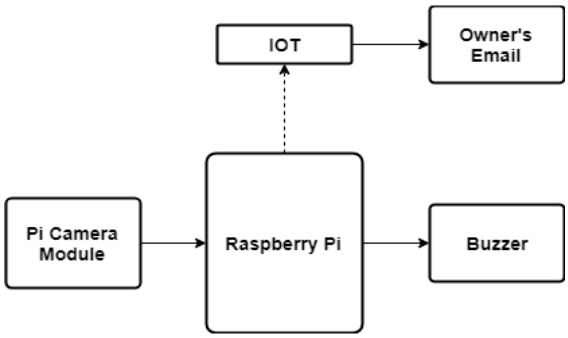


Fig. 1. A Block Diagram of the Proposed System

III. Component Description

The proposed system consists of the following major components:

A. *Raspberry Pi 3 model B*

The Raspberry Pi is a microprocessor that is designed for the Linux operating system. In our proposed system, Raspberry Pi 3 Model B is used with Raspbian OS integrated into it [24, 25].

B. *Pi Camera Module*

The Raspberry Pi camera module can take high-definition video along with still pictures and can support 1080p30, 720p60, and VGA90 video modes [26].

C. *Buzzer*

The buzzer is used to generate beep sound when a voltage is supplied. For our proposed system, the buzzer is used as an alert to generate continuous beep when the driver is detected with drowsiness. [27].

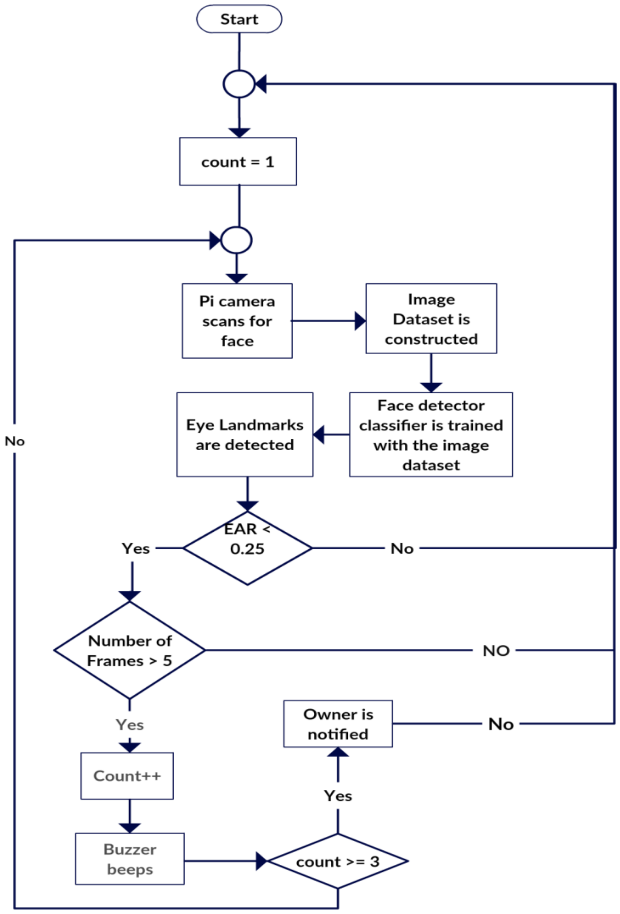


Fig. 2. A Flowchart of the Proposed System

IV. Working Principle

A. Detection of Face

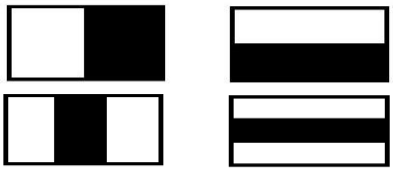
In our proposed system the Raspberry Pi was integrated with the Pi camera module in order to continuously scan for the face of the driver. The face detection and recognition process is carried out in 2 stages.

1) Constructing an image dataset

To construct an image dataset a 300-VW (300 Videos in the Wild) Dataset was used. [28]. The dataset contains 50 videos in which each frame is annotated with a precise set of facial landmarks. The structure of the 300-VW dataset is as follows: a folder containing the compressed video files and a folder containing the corresponding annotated landmark files. For our research, we have only used the video files. The training dataset was constructed on the basis of EAR, using a subset of the 300-VW, containing sample images with both open and closed eyes. To be more precise, 50 frames were taken with eyes wide open (highest EAR), 50 frames were taken with mostly eyes tightly shut (lowest EAR), and 50 frames were sampled randomly. Thus, a training dataset was created by sampling 7500 images. Once that is done, the facial landmarks are detected using a classifier called Haar Cascade classifier. Facial landmarks are nothing but the key features that construct the face of a human and these include the eyes, eyebrows, nose, mouth, and jaw line. In order to detect these features, the Haar Cascade classifier first requires to be trained [29]. For the process of training the classifier, a training dataset was first constructed using 1500 images as described above and afterward, the facial landmarks of these images were labeled indicating the particular 68 (x, y)-coordinates of areas covering all the facial features.

2) Training the face detector classifier with the images in the dataset

After the completion of constructing the training dataset, it was then used to extract the features. Few examples of the simple rectangular features that were extracted from the training dataset of images are shown in Fig. 3 and Fig. 4.



(a)
Edge Feature

(b)
Line Feature

Fig. 3. Examples of recangle Haar-like featurs. Fig. 3(a) is a 2-rectangle feature (edge feature) and Fig. 3(b) is a 3-rectangle feature (line feature)

The rectangle features can be calculated very rapidly using an intermediate representation for the image which was called the integral image [30]. The purpose of introducing the integral image was to reduce the computations for a given pixel to an operation involving just four pixels. Once computed, any one of these Haar-like features can be computed at any scale or location in constant time. For calculating each feature, the sum of pixels under the white rectangle is subtracted from the sum of pixels under the black rectangle. Once the features were extracted, feature selection process was executed to select the important features. For each feature, the classifier finds the best threshold which can classify the faces as either positive and negative. Thus, the features with minimum error rate are selected implying that these can most accurately classify the face and non-face images. For making the classifier more efficient, the concept of cascade of classifiers was used.

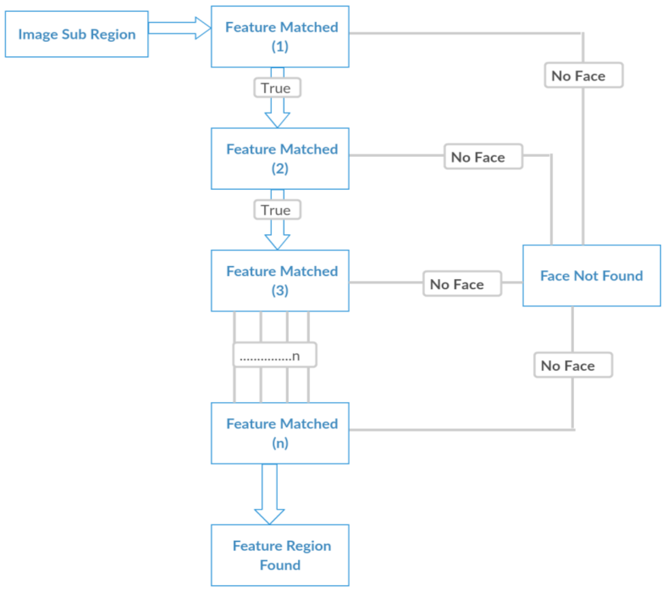


Fig. 4. Finding face from different sub region

In order to discard the background regions of the image, the cascade of classifiers is used so that more calculations can be focused on face-like regions rather than the background regions. This is done by grouping the features into different stages of classifiers and then applying them on the windows consecutively as illustrated in Fig. 4. It can be observed from Fig. 4 that if a window fails to surpass the feature on the first stage, it is immediately discarded without even considering of applying the next feature of the second stage. If a window can successfully surpass all the stages of features, it is considered as a face region.

B. Determining the Eye Aspect Ratio (EAR)

Prior to deducting that a driver is drowsy, the eye aspect ratio (EAR) is calculated to detect the driver with drowsiness.

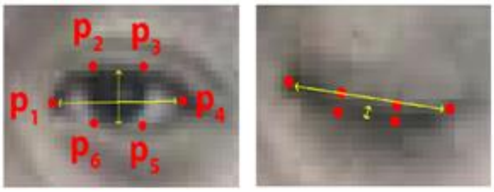


Fig. 5. Six landmarks of the eye before and after closing eyelids [33]

When the facial landmarks are detected, the images of these faces are converted to grayscale format. This is done because the inherent complexity of gray level images is lower than that of the color images [31, 32]. Once the facial landmarks of the driver were detected, the eye regions are extracted using the 6 (x, y)-coordinates of the eye structure as shown in Fig. 5.

We now define the eye aspect ratio function which is used to compute the ratio of distances between the vertical eye landmarks and the distances between the horizontal eye landmarks. In order to calculate distance, the Euclidean Distance of the eye region is used.

$$D(P,Q) = \sqrt{\sum_{i=1}^{n}(Qi - Pi)^2} \qquad (1)$$

where D(P,Q) is the Euclidean distance between points P and Q. In Cartesian coordinates Pi and Qi are two points in Euclidean n-space.

Each eye of a human corresponds to 6 (x, y)-coordinates as illustrated in Fig. 5. The EAR determines how far the eyelids of each eye are apart from each other. However, once a person blinks, the EAR diminishes significantly, moving toward zero. The average duration of single eye blink of each individual ranges approximately from 100 to 400 ms according to [34]. From this statistics, it can be deduced that the duration of eye closure must be greater than 400 ms for a person who is detected with drowsiness. In our work, four frames were considered to represent this 400 ms, indicating that four successive frames with an eye aspect ratio less than 0.25 must occur in order for a blink to be registered. Thus, it is possible to distinguish the eye closure pattern between the eye blink and drowsy eyes.

In order to calculate the EAR, the eye landmarks are detected for every video frame. The eye aspect ratio (EAR) between height and width of the eye is computed using

$$EAR = \frac{\| p_2 - p_6 \| + \| p_3 - p_5 \|}{2 \| p_1 - p_4 \|} \qquad (2)$$

where p1, p2, p3, p4, p5, and p6 are the 2D landmark locations, as represented in Fig. 5. The EAR is irrespective of the head and body position. Since eye blinking is performed by both eyes synchronously, the EAR of both eyes is averaged.

C. Turning on the Buzzer

The EAR remains constant when the eyelids are kept open, then rapidly approaches to zero on account of the eye closure and then increases again, indicating a blink has taken place. The EAR is constantly monitored to track for a similar pattern implying that the driver has shut his eyes. The threshold value for the EAR is considered to be 0.25 and any value above this would mean that the driver's eyes are open. For our system, the number of video frames is taken into account rather than the duration of eye closure. Initially, the total number of successive frames is preset to 4, representing the eyeblink. If the EAR value drops beneath its threshold value, then the number of frames the person has closed his eyes for is considered. If the number of frames exceeds 4, then the buzzer is turned on.

D. Notifying the Owner

The Raspberry Pi is programmed to operate as a drowsy driving detector system in which it detects the drowsiness of the driver and alerts him with the help of a buzzer. If he falls asleep for more than 3 times then the system sends an email alert to the owner for him to take further action. The subject, message content, and Email ID are all entered into the system through python scripts [35].

In order to send emails, Simple Mail Transfer protocol (SMTP) is used by implementing a native library in Python, smtblib. The smtplib module defines an SMTP client session object that can be used to send mail to any Internet machine with an SMTP or ESMTP listener daemon. MIME protocols are used to send attachments. SMTP connection is put in TLS (Transport Layer Security) mode to ensure security. Port number 587(for smtp.gmail server) is used for sending emails.

V. Results and Discussion

On completion of this work, our system could successfully detect the drowsiness of the driver based on the eye aspect ratio (EAR).

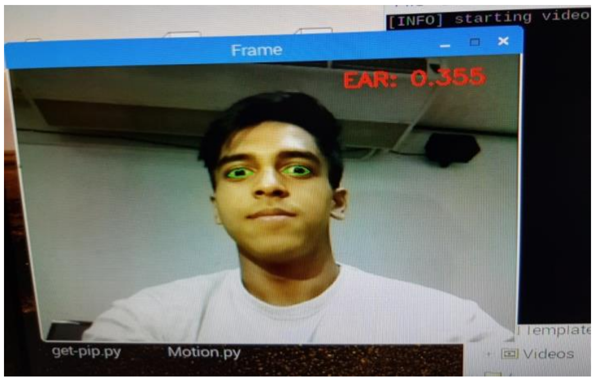


Fig. 6. The EAR value before closing the eyelids

The following figures show the experimental results of how the system could successfully recognize the eye landmarks and then calculate the EAR value before and after closing the eyelids.

From Fig. 6, it can be observed that the system could effectively detect that the eyes are kept open when the EAR value is found to be greater than 0.25. The EAR value can also be graphically represented over the times the eyes are kept open, as shown in Fig. 7.

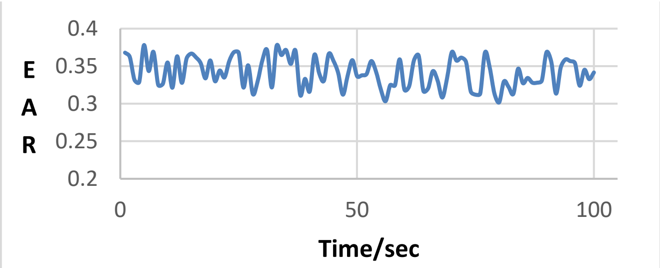


Fig. 7. EAR plotted when the eyes are open

Furthermore, it was observed from Fig. 8 that the system displays a drowsiness alert when the EAR value rapidly falls below 0.25, implying that the eyes are closed. This was also graphically represented over the times the eyes are kept closed, as shown in Fig. 9.

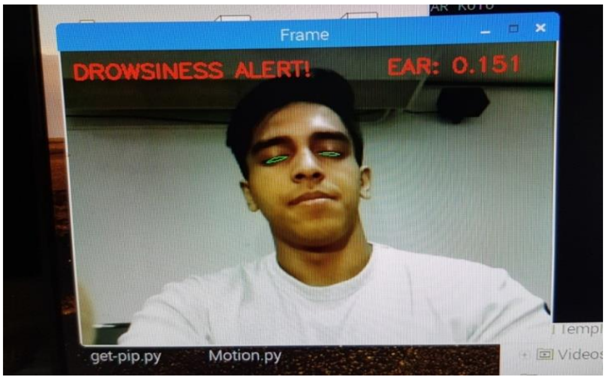


Fig. 8. The EAR value before closing the eyelids

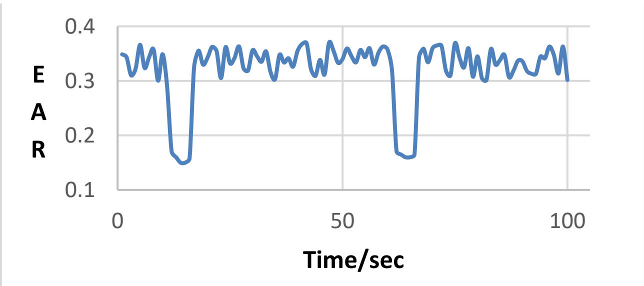


Fig. 9. EAR plotted when the eyes are closed

Once the driver is detected with potential drowsiness, the system alerts him and at the same time, takes an attempt to wake him up with the help of a buzzer. Furthermore, if he tends to fall asleep behind the wheel for more than 3 times, an email notification is sent to the owner of the vehicle as a warning for the driver so that he can recover himself from falling asleep repeatedly. Fig. 10 shows a snapshot of the owner's Gmail account after the email is sent.

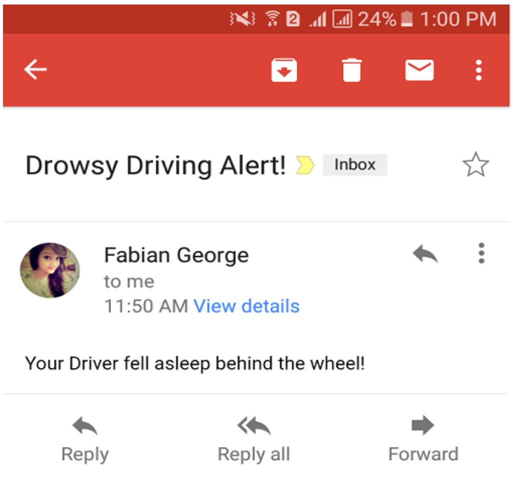


Fig. 10. Result displayed on mobile through email

The training dataset used to train the Haar Cascade classifier was not appropriate for all sorts of environmental conditions. It consisted of images that were taken only in daylight. However, while carrying out the experiment at night, it was observed that the Haar Cascade classifier was unable to detect the facial landmarks from the video frames of the driver. As a result, the system could not calculate the EAR value of the driver's eye. This brought limitations for our system as it could only serve its purpose during the daylight.

VI. Conclusion

The primary motive of this research is to provide a drowsiness detection system and a method that detects the driver's drowsiness in real-time. Existing approaches have used vehicle-based and psychological measurements to detect the drowsiness of the driver. However, such techniques are highly intrusive and depend on the physical characteristics of the surrounding environment. In contrast to the beforehand determined issues, we have proposed a system that implements a non-intrusive technique for determining the driver's fatigue. Our system consists of a Raspberry-Pi and a Pi camera module that continuously keeps scanning for facial landmarks. These landmarks are localized using facial landmark detector and then the eye landmarks are used to calculate the eye aspect ratio (EAR). If the EAR value decreases from the threshold value and the eyes remain closed for too long then the system immediately alerts the driver with the aid of a buzzer. Furthermore, to ensure that the problem has been taken care of, a notification is sent to the owner of the vehicle through e-mail when the driver dozes off for more than a couple of times. This method is useful to people in the car rental and driving business such as truckers and taxi cab drivers. However, there is one issue that remains to be addressed in the system, which is its incapability to serve its purpose at night.

VII. Future Work

In future, we would like to improve our system by attaining a compact design and also by making it appropriate to serve under any physical environments. Apart from this, we would also like to work on recognizing the sleep pattern of the driver for detecting his fatigue level beforehand in the future. We believe, if the sleep pattern can be recognized and combined with the eye closure pattern, it is possible to form a positive correlation between these two patterns which can help us design a near perfect drowsy detection system.

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