Application of IoT and Machine Learning for Real-time Driver Monitoring and Assisting Device

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***Abstract*—The increasing number of vehicles on Indian roads and low traffic rules enforcement lead to multiple human-error induced crashes and fatalities. In this paper, we propose a driver monitoring and assisting device which employs IoT sensors, like alcohol sensor and air pressure sensor for sobriety check and machine learning algorithms to detect micro-sleep and frequent yawns for drowsiness detection. The device turns on and asks the driver to blow into the mouthpiece. After a clean and proper blow, the driver is allowed to switch the ignition on. Thereafter, the device constantly monitors the driver using a camera for signs of fatigue, and uses the vehicle's sound system or a buzzer to alert the drowsy driver. The goal of our work is to develop and deploy a device that will curb drunk and drowsy driving mishaps and inculcate responsible driving behavior among drivers.**

***Index Terms*—Internet of Things, Sobriety Check, Machine Learning, Fatigue Check, Drowsiness Detection, Yawn Detection, Micro-Sleep Detection**

I. Introduction

With the world's second largest road network, after the US, Indian roads ply over 250 million registered motor vehicles as of 2017. A rapid urbanization and motorization has marked a linear growth in vehicles over the last 70 years [1]. This, unfortunately, increases the road casualties as well, killing sixteen people every hour and twenty children every day on Indian roads [2]. A recent WHO report, among many others, enumerated human errors such as drunk driving, drowsiness and distractions as one of the leading risk factors of road accidents [3]. Surprisingly, the driving under the influence (DUI) incidents are not limited to a certain age group or a section of society. Hence, it is not lack of awareness but disregard for the rules that lead to many DUI casualties [4]. Such incidents strain the lives of affected and associated people, mentally, physically and financially. With the unprecedented advancement of technology, we can now leverage the internet of things (IoT) technology and machine learning (ML) techniques to effectively design a system that curbs the human errors on the road.

A. Background

The current system of random sobriety checkpoints by police officials is insufficient, reducing accidents by only 18% to 24% [5]. Moreover, several countries such as Australia, Austria, Canada, and the US etc. have adopted alcohol based ignition interlock devices (ABIIDs) working on fuel cell technology. The data from these devices are downloaded and checked every 30, 60 or 90-day period, proving ABIIDs a tool for reactive disciplinary action for DUI offenses [6].

B. Our Contributions

However, the proposed proactive approach of deploying IoT sensors for real-time DUI offense alert can help in reducing DUI related casualties. Additionally, real-time camera feed analysis for drowsiness detection to identify micro-sleep and excessive yawning while driving as a result of DUI, fatigue or both, can further help bring down the human-error induced accidents. Overall, our system is an IoT and ML application for reducing road crashes and fatalities due to human negligence.

II. Literature Review

The traditional system of sobriety checkpoints to catch DUI offenders has proved effective but can not keep up with the increasing number of automobiles on road [5]. Being highly human intrinsic, it is prone to errors and biases. The boom in IoT technology has led to many studies to build an alcohol detection device. Reference [6] uses an alcohol sensor and GSM module, on crossing the alcohol content threshold, the driver is alerted via a message. Reference [7], [8] and [9] uses a micro-controller with alcohol sensor, GPS and WiFi modem, but no mechanism is described to differentiate driver's breath from ambient air. Reference [10] uses an Arduino micro-controller with an alcohol sensor to passively detect the alcohol content in the vehicle and sends a message with GPS location, but it poses a major drawback of faulty assumption if anyone else in the car is drunk.

Reference [11] uses an eye blink sensor to detect drowsiness of a driver. The proposed system requires the driver to wear an eye blink sensor frame while driving. Reference [12] and [13] use face and eye localization, followed by facial tracking, and then template matching. However, after facial tracking [14] proposes supervised classification. Reference [15] uses a 3D neural network architecture to train a model for detecting drowsiness. Reference [16] attempts yawn detection based on changes in mouth's geometric features. Reference [17] circular Hough transform based support vector machine for detecting yawn. Reference [18] uses Kalman filter based face tracking followed by analysing mouth features to detect yawn. Reference [19] uses Haar cascades to detect eyes and mouth in a frame and position of lower lip and eye aspect ratio of only one eye to achieve drowsiness detection with higher speed. However, a cost-effective real-time drowsiness detection system should use minimum computational resources.

Hence, the existing sobriety check and fatigue check systems lack usability in the real world. In this paper, we address the aforementioned literature gaps by proposing a system that uses IoT sensors, alcohol gas sensor MQ-3 and air pressure sensor BMP-280 to collect the blow samples from the driver for sobriety check, 5 megapixel (MP) night vision camera for real-time drowsiness detection, Raspberry Pi 3B+ (RPi) microprocessor with 1GB RAM processes this data and outputs the result on a liquid crystal display (LCD) and alerts the driver as well as passenger(s) using vehicle's sound system or a buzzer.

III. Method

A cost effective real-time driver monitoring and assisting system employing sobriety and fatigue check with the help of IoT technology and ML algorithms is a highly usable device for Indian population to curb human-error on roads and develop a responsible driving behavior. The proposed system interfaces with the vehicle closely.

A vehicle turns on in 3 steps. First, the driver inserts the key in the keyhole and turns once, powering up the starter motor. Second, the driver turns the key further, turning the battery on and starting the engine cycle. Finally, on the last turn, spark plug fires, turning the ignition on [20]. Our device takes power from the vehicle and controls its ignition system, hence it fits right between step 2 and 3.

The proposed system uses Raspberry Pi 3B+ microprocessor, depicted in figure 1, at its heart. It processes all the data from IoT sensors and camera; applies small computations and ML algorithms on it to infer the driver's behavior. While RPi provides limited computational resources, they were sufficient for our use case.

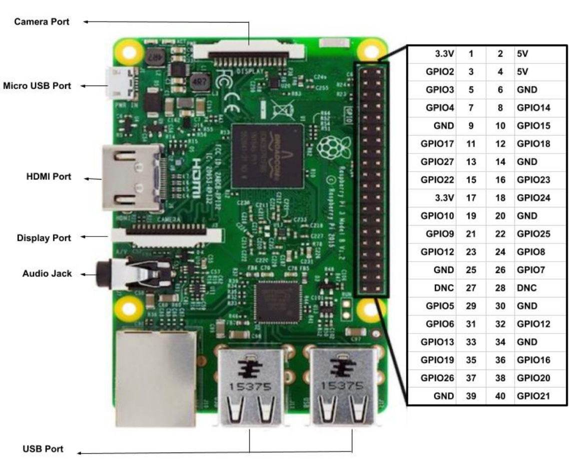

Fig. 1. RPi microprocessor.

The system uses an air pressure sensor BMP-280 and an alcohol gas sensor MQ-3, depicted in figure 2 and 3 respectively, to detect a proper blow and the alcohol content in a driver's blown breath. It also uses an analog to digital converter with MQ-3. BMP-280, MQ-3 and ADC together constitute a movable mouthpiece. The data received from

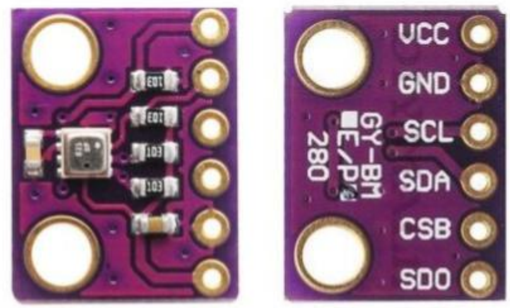

Fig. 2. BMP-280 pressure sensor.

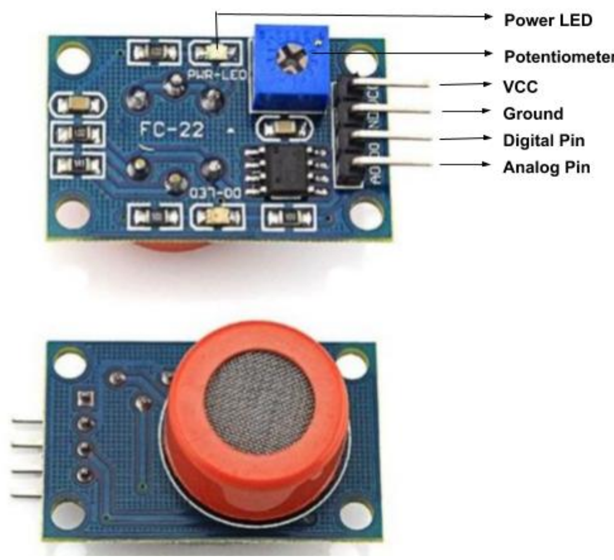

Fig. 3. MQ-3 alcohol gas sensor.

the sensors is fed to RPi to analyze and a message with the sobriety state of the driver is displayed on the LCD, depicted in figure 4. The other output devices of the system are LED lights, a speaker or a buzzer.

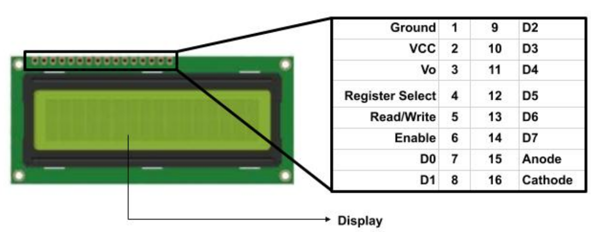

Fig. 4. LCD screen.

If the driver is found drunk, the microprocessor keeps the relay, depicted in figure 5, off and power is not supplied to turn on the ignition system of the vehicle. If the driver is sober, the relay is turned on and the driver is able to start the vehicle.

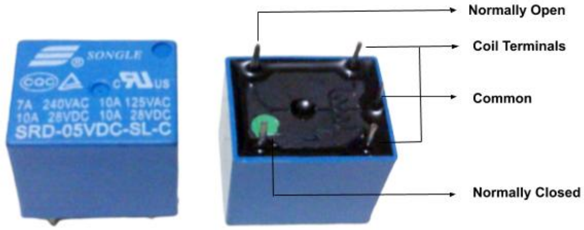

Fig. 5. Relay.

The system uses a 5-MP camera, depicted in figure 6. Since probability of drowsiness is higher during night time, it is essential to have night vision enabled in the camera. Hence, infrared lights are used to capture a video at any light intensity. The video feed from the camera is sent to the microprocessor to detect the signs of drowsiness such as micro-sleep and yawns. The video feed is analyzed at the rate of one frame every two seconds. If the microprocessor observes micro-sleep for 3 consequent frames or 5 consecutive yawns, an alarm is raised using the vehicle's sound system or a buzzer.

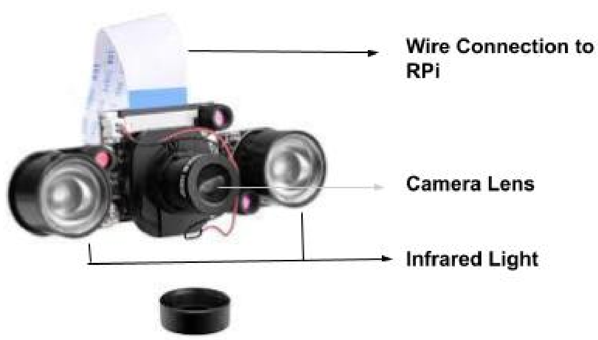

Fig. 6. IR-enabled camera for night vision.

The block diagram of the architecture of the system is depicted in figure 7. The 12V input from vehicle's battery is converted into 5V using a voltage regulator and is fed to RPi, which in turn powers all other devices. The two parts of the system are, sobriety and fatigue check. In the sobriety check, MQ-3 and BMP-280, comprising a movable mouthpiece, feed data into RPi. RPi processes this data and outputs the result on the LCD screen, alerts the driver and passengers and controls the ignition system of the vehicle through a relay. In the fatigue check, camera sends a live video feed to RPi, where it uses an ML algorithm to infer the alert or drowsy state of driver throughout the journey.

A. Sobriety Check

The components of the system for sobriety check are alcohol gas sensor MQ-3, air pressure sensor BMP-280, analog to digital converter (ADC) ADS-1115, RPi microprocessor, LCD screen, speaker or buzzer, LED lights and a 5V relay. The flow diagram of sobriety check is given in figure 8.

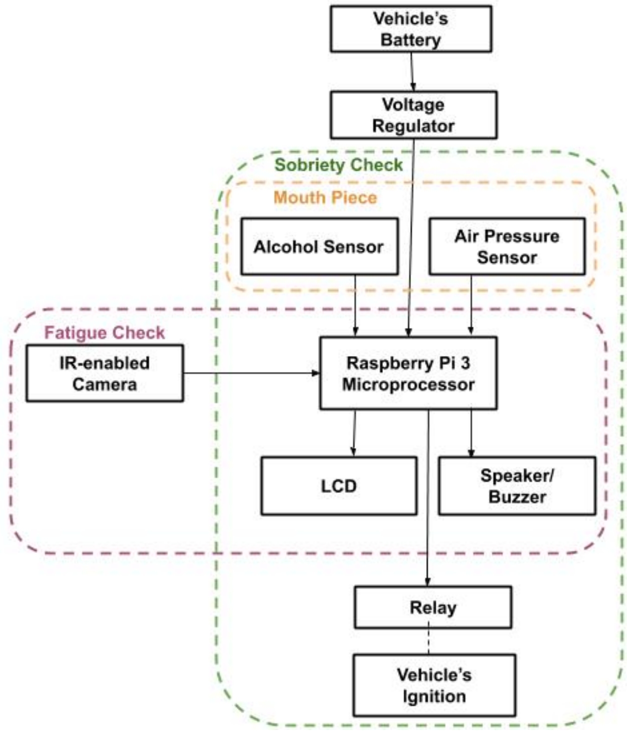

Fig. 7. Architecture for sobriety and drowsiness check.

- **Connecting sensors and ADC:** MQ-3 is a low-cost semi-conductor sensor with high-sensitivity to alcohol gases from concentration of 0.005mg/100ml to 50mg/100ml. It has tin oxide as the resistive material, which gives higher conductivity as the concentration of alcohol gases increases [21]. MQ-3 is an analog sensor, hence, we use 16-bit ADC to convert the analog values to digital values. BMP-280 is a small absolute barometric air pressure sensor, based on Piezo-resistive pressure sensing element, used for pressure and temperature measurement. It has built-in ADC [22].
- **Calibration of sensors:** As the device is powered on and button is triggered, both MQ-3 and BMP-280 are calibrated for 30 seconds, by aggregating the ambient values of pressure and alcohol concentration. While performing the calibration, sudden deviations in sensor's data which may be due to erroneous working are ignored. Thereafter, driver is prompted to blow air into the mouth piece. The values obtained by the sensors are processed by RPi.
- **Check alcohol content on a blow:** BMP-280 perceives a sudden change in pressure and temperature values when blown into. Prolonged increase in the these values i.e. for 6 consecutive seconds registers a blow. Hence, BMP-280 ensures the person blows sufficiently hard which requires him to use his lungs to provide a legit breath for the test. If intensity of blow crosses a certain threshold, the

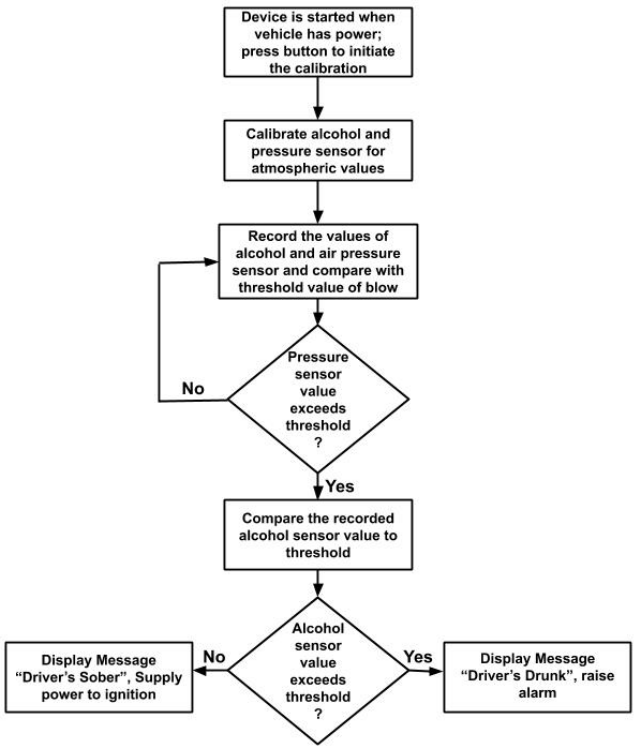

Fig. 8. Flow diagram for sobriety check.

blow is considered valid. The time-period of 6 seconds was chosen empirically. The device stores the data for BMP-280 and MQ-3 simultaneously; hence, MQ-3 data during the 6 seconds of a proper blow is used to calculate the alcohol content in the driver's breath. MQ-3 sensor gives us values in voltage which are converted to parts per million (PPM) and mg per 100ml of blood.

- **Perception of MQ-3 output:** The permissible limit of alcohol content in a driver's body in India is 30mg per 100ml of blood per 300 PPM [25]. Therefore, we have defined 3 levels of sobriety, namely, sober, mildly drunk, drunk for breath alcohol levels below 10mg per 100ml of blood, between 10mg per 100ml and 30mg per 100ml of blood and above 30mg per 100ml of blood respectively. When a driver is sober, it is indicated by a green LED and mild drunkenness is indicated by a yellow LED; in both the cases, power is supplied to ignition and driver can drive the vehicle. However, if a driver is drunk, it is indicated by an alarm and glowing of red LED; consequently, power is not supplied to ignition, refraining the driver from driving.

B. Fatigue Check

The components of the system for a fatigue check are IR-enabled camera, RPi microprocessor, LCD screen and a speaker or a buzzer and use of ML algorithms to identify the signs of drowsiness in a driver's behavior. The flow diagram of fatigue check is given in figure 9.

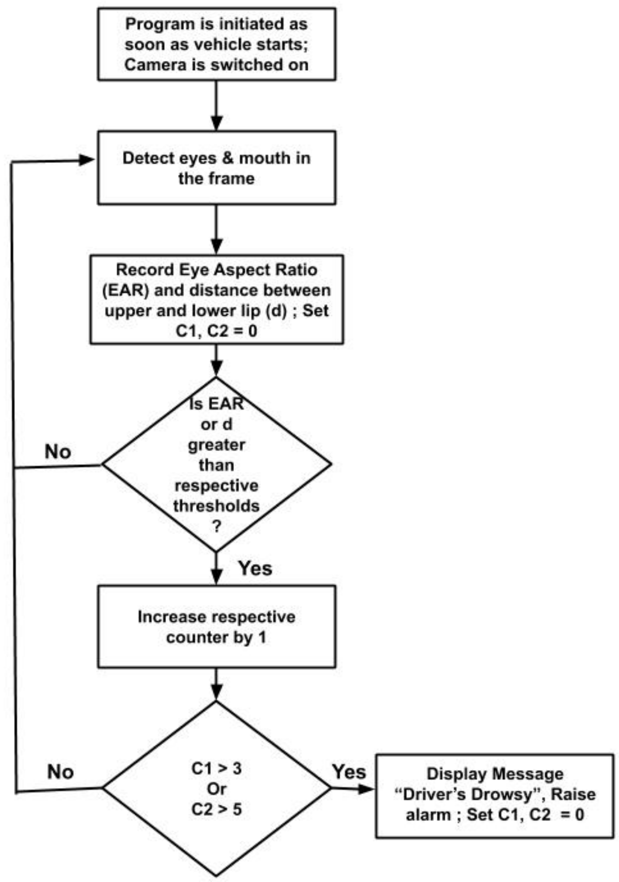

Fig. 9. Flow diagram for fatigue check.

- **Connecting camera to RPi:** The camera is connected to RPi using a camera cable and is positioned facing the driver such that in well-lit environment, camera is able to capture a clear image of the driver's face, in low-light intensities infrared lights illuminate the camera image and doesn't pose distraction to the driver.
- **Facial Landmark Detection:** Fatigue check is initiated when the ignition has started. Hence, in the stream of frames, the device tries to identify faces. On finding a face, facial landmark detection is used to extract eyes and mouth. The 68 facial landmark coordinates from dlib facial landmark predictor are given in figure 10 [23].
- **Micro-sleep Detection:** With the help of dlib facial landmark predictor, eyes are detected in the image. Thereafter, we monitor the eye aspect ratio (EAR). In reference to figure 10, EAR for left eye is calculated as:

$$EAR = \frac{|| P_{38} - P_{42} || + || P_{39} - P_{41} ||}{2 \; || P_{40} - P_{37} ||} \tag{1}$$

where P_n is the facial landmark point at number 'n' in figure 10. EAR for an open eye is larger than EAR for a closed eye. Hence, a sudden drop in EAR for 3 consecutive frames or 6 seconds is assumed to be a micro-sleep. The threshold for change in EAR was empirically

Fig. 10. Facial Landmarks [23].

found to be 0.18 in our system. The change in EAR in different light intensities is given in figure 11 and 12.

Fig. 11. Alert vs drowsy driver in well-lit area.

Fig. 12. Alert vs drowsy driver in dark area.

- **Yawn Detection:** Likewise, with the help of dlib facial landmark predictor, mouth is detected in the image. Thereafter, we monitor the distance 'd' between upper and bottom lip. In reference to figure 10, 'd' is calculated as the absolute distance between mid of upper lip 'u' and mid of bottom lip 'b', given by:

$$u = \frac{P_{50} + P_{51} + P_{52} + P_{53} + P_{54}}{5} \quad (2)$$

$$b = \frac{P_{56} + P_{57} + P_{58} + P_{59} + P_{60}}{5} \quad (3)$$

where P_n is the facial landmark point at number 'n' in figure 10.

$$d = \mid u - b \mid \quad (4)$$

'd' for a yawn is much larger than 'd' when a person is quiet or talking. Hence, a sudden large increase in 'd' for 2 consecutive frames is counted as a yawn. The threshold for change in 'd' was empirically found to be 25 in our device. The yawn counts in different light intensities is given in figure 13 and 14.

Fig. 13. Yawn count in well-lit area.

Fig. 14. Yawn count in dark area.

- **Alert the driver:** The system monitors one frame every 2 seconds. If the driver's eyes is closed in 3 consecutive frames i.e. for 6 seconds and/or the driver has yawned 5 times in the journey, an alarm is raised and the device prompts the driver to take a break.

IV. Results

The proposed system for sobriety check and fatigue check is developed with the motive of reducing the human-error related accidents. Hence, they are tested in real-time environments or closest simulations possible. The sobriety and fatigue check systems were tested separately.

A. Sobriety Check System Testing

The MQ-3 in the device was tested for different concentrations of 99% pure isopropyl alcohol ranging from 1mg per 100mL of water to 40mg per 100mL of water. The average of absolute error of five device readings from the concentration of alcohol are given in table I.

The results revealed that MQ-3 based sobriety check system can work efficiently to discourage drivers from driving under the influence of alcohol. It should be noted that to perceive the effect of alcohol based hygiene products and medicines, we also tested after an alcohol based mouthwash. However, the high thresholds for pressure and temperature requires a hard blow where the breath comes from stomach, instead of mouth. For a drunk person, the MQ-3 values kept on increasing throughout the blow, however, for mouthwash, MQ-3 values

TABLE I
ABSOLUTE ERROR IN READINGS OF SOBRIETY CHECK SYSTEM

Concentration of Alcohol	Absolute Error in Device Reading
1mg/100mL	0.2mg/100mL
5mg/100mL	0.7mg/100mL
10mg/100mL	2.2mg/100mL
20mg/100mL	1.8mg/100mL
30mg/100mL	4mg/100mL
40mg/100mL	3.7mg/100mL

were slightly high at start of blow but did not increase in consecutive seconds. Hence, the device worked efficiently.

B. Fatigue Testing

The training of ML algorithms usually require high computational power, however, since we were using a pre-trained model the computational requirements were low. Moreover, reducing the frames per second rate gives the microprocessor sufficient time to process the data, which also reduces the lag. Hence, a frame per 2 seconds was chosen empirically to reach a good trade-off between accuracy and speed. The proposed fatigue detection system was tested with real-time video-feed of 3 different people for 1 minute each in different lighting. The details of each person is given in table II.

TABLE II
DETAILS OF PEOPLE TESTING THE FATIGUE DETECTION SYSTEM

Person	Age	Gender
Person1	28	Male
Person2	40	Female
Person3	53	Male

Each person tested the system for different number of micro-sleeps and yawns, denoted by $n(M)$ and $n(Y)$, in different lighting conditions, given in the table III and IV. The detection rate (d_r), also called true-positive rate or sensitivity, is defined as number of micro-sleep or yawn instances detected of the total instances.

TABLE III
RESULTS FOR FATIGUE TESTING IN A WELL-LIT ROOM.

Person	n(M)	Detected n(M)	n(Y)	Detected n(Y)
Person1	5	4	3	3
Person2	4	2	5	4
Person3	5	4	4	3
Total	14	10	12	10
d_r	0.71		0.83	

The results of this testing were three-fold. First, the fatigue check system performed fairly well on real-time testing environment. Second, the results in low-light intensity were better. This was because the IR illuminated the camera feed well, making the edges of facial features prominent, as seen in figure 11 to 14. Third, yawn detection performed slightly better than micro-sleep detection.

Overall, results signify the potential usability of this device in safeguarding human lives on the roads.

TABLE IV
RESULTS FOR FATIGUE TESTING IN A DARK ROOM.

Person	n(M)	Detected n(M)	n(Y)	Detected n(Y)
Person1	6	4	4	3
Person2	4	3	5	5
Person3	5	5	4	3
Total	15	12	13	11
d_r	0.80		0.85	

V. CONCLUSION AND DISCUSSION

Several advancements in IoT and ML technologies have made it feasible to develop smart devices that can assist humans and add to the quality of our lives. The goal of our work was to develop a device that ensures a driver, responsible for the safety of his, the passengers' and the passers' by lives, is sober and attentive. Several tests of the device in simulated and real environments conclusively proved that the system is well-equipped to prevent drivers from committing DUI offenses and alert a drowsy driver. We wish to tap into the potential of our work as a practical security feature for current and new automobiles. Hence, this work is one-step forward to make driving safer for Indian population.

However, this work has its limitations and we envision to aggrandize the capability and usability of our device in several ways. Firstly, our work is limited to detecting alcohol only, we would like to extend our device to account for other intoxicants as well. Secondly, we would like to experiment with other ways of detecting alcohol content in a driver's body. We would like to see how other sensors such as MQ-135, TGS-822 work for the same use case. Fuel cell based technology is costlier as compared to semiconductor based sensors, we will be interested in understanding the cost-accuracy trade off here. Some advancements have been made in non-invasive forms of alcohol detection using transdermal sensors or IR-spectroscopy, which can be analyzed. Third and more importantly, we would like to increase the functionality of our device, using a gyroscope accelerometer module to perceive the driving pattern of drivers. Fourthly, we would like to use ultrasonic sensors to perceive the traffic around the vehicle, to slow-down or park the vehicle for a rash or inattentive driving pattern. Moreover, our camera enabled device, with the help of ML, can monitor the driver for other unhealthy driving practices such as receiving phone calls, not wearing seat-belts, smoking etc. Lastly, we can use a GPS-GSM module to send a message to a stakeholder for frequent driving offenses. Overall, we hope to develop a wholesome system that safeguards any and all human lives on roads by discouraging the unhealthy driving behaviors.

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