Drowsiness Detection Using IoT and Facial Expression

R. N. Ashlin Deepa, DontiReddy Sai Rakesh Reddy, K. Milind, Y. Vijayalata, and Kamishetty Rahul

Abstract In India, approximately 500,000 people are losing lives due to road accidents every year. With the rapid urbanization and development of big cities and towns, the graph of accidents is steadily increasing. Accidents due to driving after consuming alcohol and falling asleep behind the wheel have a share of about 8%. We have come up with a prototype to provide a solution to these crucial problems. This phenomenal rise in road accidents in cities is a matter of great concern and alarm to all of us. Drivers being drunk, sleeping, skipping signals, wrong route driving, and whatnot are the reasons for these frequent accidents. These recurring accidents have caused the citizens to fear driving around. They feel very insecure and vulnerable when stepping into their vehicles to travel in and around the city. So, we have designed a solution to detect drowsiness while driving. We are using image processing with the help of a camera to extract facial landmarks of the eye and image processing techniques that draw out the facial landmarks for detecting whether the driver is drowsy or awake. Additionally, we have planted an Arduino board with an MQ3 sensor to detect alcohol from the drivers' breath to check drivers' condition.

Keywords ATmega328 processor · MQ3 alcohol sensor · Arduino board · Facial recognition · Alcohol detection · Computer vision (CV) · Image processing · Facial landmark detection (FLD) · Drivers breath

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1 Introduction

Road accidents are one of every mother's worst fears, as well as the nightmares of every human on the road. Accidents that occur when a motorist is under the influence of alcohol or falls asleep behind the wheel account for around 10% of all accidents, affecting numerous families. According to the Ministry of Road Transport and Highway, there were 4552 accidents recorded in India each year, resulting in the deaths of thousands of people due to inattentive driving (road accidents in India 2016). Approximately, 20% of people have acknowledged falling asleep while driving, with 40% saying they had done it at least once throughout their driving careers. Research shows, in India, 40% of highway crashes or near-crashes occur due to drowsy driving. However, more than 50% of all deadly highway crashes which involve more than two cars are alcohol-related. Based on National Highway Safety Administration report (NHTSA's) [1] 2.2–2.6% of accidents happened every year because of drowsy drivers during 2005–2009. According to [2–5], alcohol consumption increases the severity of traffic accidents and direct medical health costs. This can be the reason that causes the road accident.

The research and studies done in the past were eclectic but could not solve the issue with the influence of alcohol. Implementing these innovative ways to keep a check on people using various means of transport can prevent road accidents by a great deal and ensure public safety. It symbolizes our initiative, which aims to make human driving safer and accident-free. There are a variety of sleepiness detection systems that measure driver tiredness levels while driving and alert them if they are not paying attention to the road. Facial expressions like yawning, eye closing, and head motions may all be used to infer how weary someone is in terms of behaviour-based methods, some related investigations [6] have been presented to determine the fatigue as a percentage of eyelid closure (PERCLOS) by detecting the eyelid closure frequency. As an unconscious behaviour caused by fatigue, yawning is also used for visual fatigue detection. References [7–9] achieve good results in fatigue testing using yawning facial video, which verifies the feasibility of fatigue detection through facial expressions. Computer vision techniques based on artificial neural networks (ANNs) have been successfully (and still being) applied to many road safety problems (e.g. traffic safety analysis of toll plazas and identifying behavioural changes among drivers [10]). The biological condition of the driver and the automotive behaviour are researched utilizing behavioural, vehicular, and physiological parameter-based techniques to determine driver tiredness. Some investigations have demonstrated that heart rate variability (HRV) is related to fatigue. HRV is used to measure the change features of heart rate [11] (Fig. 1).

While face recognition technology is rapidly evolving, we cannot still combine alcohol detection and facial identification. Our technology seeks to reduce the number of road accidents caused by intoxicated drivers soon. It can be used in any vehicle and is undetectable to criminals. This initiative intends to ensure the safety of those who are seated within a vehicle.

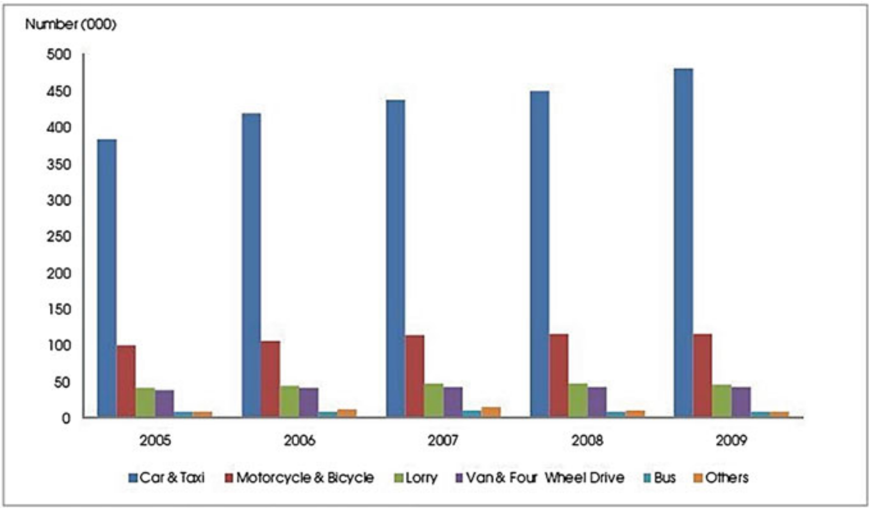

Fig. 1 Road accidents of various types of vehicles in Malaysia from the year 2005–2009

2 Related Work

In the United States, 2.5% of incidents were recorded in 2009. Throughout these five years, the number of accidents decreased slightly. But, the ratio of accidents caused by drowsiness tends to be stable from 2.3 to 2.7% [1]. Different AI procedures like PERCLOS calculation, HAAR-based course classifier, and OpenCV are used to decide the driver's condition including driver languor recognition [12]. In 2017, [13] used descriptive and binary logit model to identify the factors affecting the occurrence and severity of rear-end crash. They found that the likelihood of being involved in fatal rear-end crashes in rural roads is 2.889 times higher than in urban roads, and 1.923 times with speeding behaviour of drivers. However, the probability to be involved in rear-ends crash injuries increases in factors such as: tailgating; Abu Dhabi licensed drivers; driving experience between 0 and 4 years; and passenger car type. Also, it was found that the severity of rear-end crashes is less on relatively wider roads (road with four lanes or more). In instances where alcohol may be present, it is critical to evaluate the user's mental condition. To solve this, a hardware system that is based on infrared light, following the face detection step, the facial components that are more important and considered as the most effective for drowsiness, are extracted and tracked in video sequence frames [14]. Immediate detection of sleepiness during driving is important [15]. The system is capable of distinguishing between a standard eye blink and a drowsiness-related eye blink. It can work in low-light situations and even while the driver is wearing spectacles. This method was successful in distinguishing the normal eye blink from drowsiness-related eye blink, but it couldn't provide a solution when the user was observed wearing a pair of glasses. Iris recognition is one of the methods used to assess the user's state of mind. Iris recognition technology is continuously growing over the years and could resolve drunken driving accidents worldwide. Lately, with a single camera view, the system now uses OpenCV and Raspberry Pi modules. Image processing methods determine the eye state. This study solely considers the condition of the eyes and ignores the frequency with which people yawn [16]. It is crucial to discover a strategy to assist the user's safety as the priority. The eye closure is detected using HAAR-based cascade classifier and an alcohol gas sensor that functions as a Breathalyser [17]. The downside to Haar cascades is that they tend to be prone to false-positive detections, require parameter tuning when being applied for inference/detection, and, in general, are not as accurate as the more modern algorithms we have today. A sleepy driver's driving pattern may differ from that of a regular driver. Driver sleepiness may be predicted by monitoring a few metrics such as lane departure, steering movement, abrupt changes in acceleration, gas pedal, and brake pedal [18].

But, adding too many parameters to monitor often introduces new problems. The prime causes of driver sleepiness include sleep deprivation, constant work for long hours, the use of sedative medications, working at odd hours, and untreated sleep problems [19]. A normal individual driving a car will have a predictable driving pattern; nevertheless, if he strays from his lane or any other vehicle-based metric, an unwanted alarm may be sent. The vehicle-based metric has only been employed by a few researchers since it may lead to more false positives [20]. The early detection of sleepiness is critical to avoid accidents and the loss of precious lives. Although considerable research has been done on detecting driver sleepiness, the majority of it falls into three categories: vehicle-based measurements, physiological-based measures, and behavioural-based measures [21]. Du et al. [22] proposed a multimodal fusion recurrent neural network (MFRNN) framework. They used RGB-D cameras and infrared video to extract the driver's eye-opening degree, mouth opening degree, and heart rate information, and at the same time, extracted time information related to each fatigue feature to improve the performance of driver fatigue detection. The MQ3 alcohol sensor was utilized to detect the presence of alcohol in human breath [23]. This paper proposes a method for detecting the drowsy state based on the time-series analysis of the angular velocity of the steering wheel. Thus, according to the literature, using an alcohol sensor attached to an Arduino board proposed system detects driver's drowsiness. It uses a camera and image processing algorithms to extract the facial landmarks of the eye and eye aspect ratio to determine if the driver is drowsy or awake. A framework was proposed using a convolutional neural network (CNN) to effectively extract the deep representation of eye and mouth-related fatigue features from the face area detected in each video frame, based on the factorized bilinear feature fusion model, we performed a nonlinear fusion of the deep feature representations of the eyes and mouth [24]. In Fig. 2 we can see various driver drowsiness detection methods use currently.

The system which is proposed in this paper covers cases where driver can be drunk but cannot be detected in the alcohol sensor, this is where the drowsiness detection algorithm comes to work which keeps a check on the driver whether he is falling asleep behind the wheel. Further, in the paper, we have given detailed flow of the system developed along with analysis and experimental results.

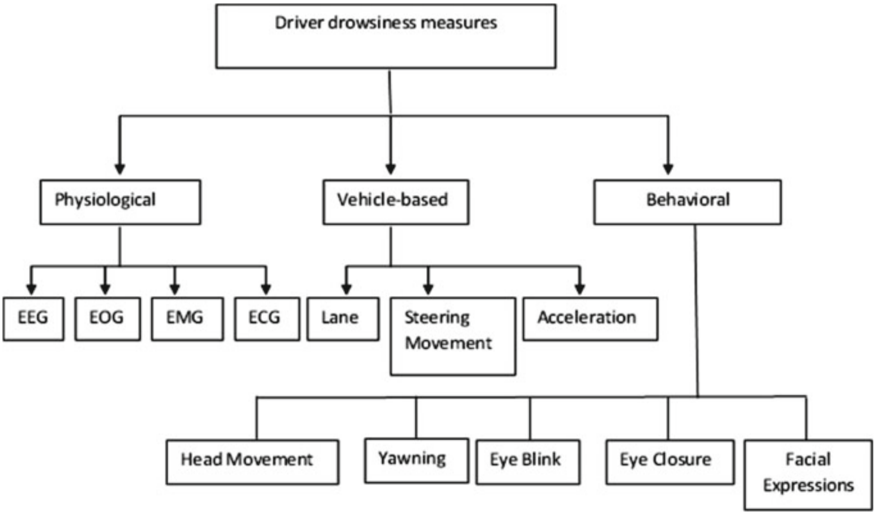

Fig. 2 Existing systems on driver drowsiness measures

3 Methodology

Detecting drowsiness of drivers is still ongoing research to reduce the number of such miss-happenings and accidents. This research work discusses advancements of using an alcohol detector, a device that detects a change in the alcoholic gas content of the surrounding air. These devices are also known as breath analysers because they analyse the alcohol level in the breath. When the analyser detects the presence of alcohol in the car, the engine is instantly locked. We introduced face detection algorithms and the Internet of Things (IoT), two highly advanced and now extensively used technologies, into our project to address this latter issue. Identifying the user's state of mind and taking immediate action is a complex task. There are various methods and techniques to assess the state of mind of the user.

We have taken up this project to minimize accidents percentage. Any vehicle out there can use this system and is hidden from suspects. It also ensures the safety of those who are seated within a vehicle. This paper aims to summarize the development of the system and gather the latest methods so it can become a base for researchers in future. When compared with the traditional procedure, this method provides a series of advantages [25]. This paper proposes a comprehensive and complete study of ongoing works identified with it additionally presents. Here, we use OpenCV and Dlib library to enhance detailed feature extraction of the eyes, the mouth, and positions of the head to estimate the driver's level of drowsiness.

The ATmega328 processor in the Arduino can perform more tasks than traditional microcontrollers. We are utilizing an MQ3 alcohol sensor to detect the presence of alcohol in human breath. Alerting the driver if he's too drunk can help prevent damage of all sorts. The face recognition algorithm works quite effectively

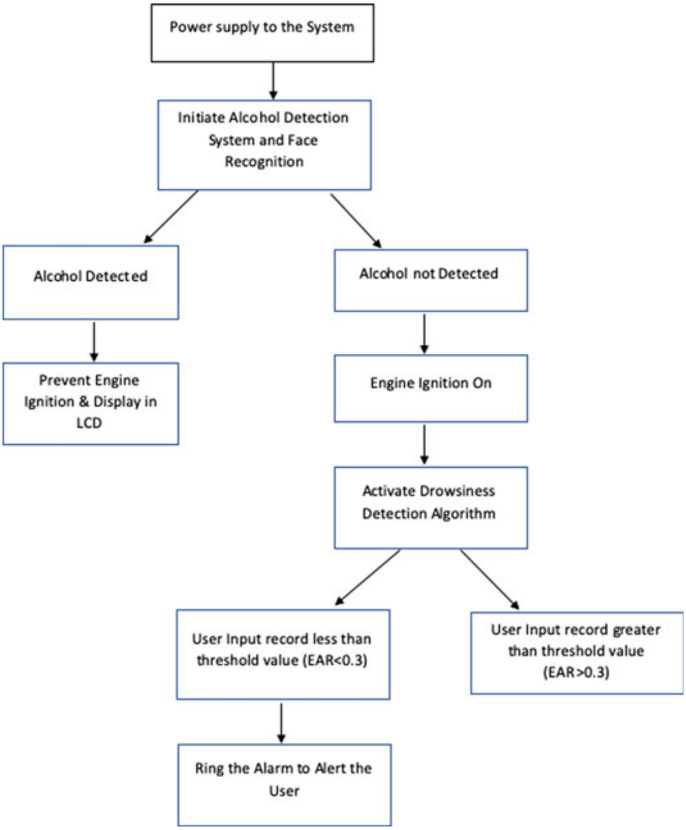

Fig. 3 Architecture of proposed methodology

in checking whether the driver is falling asleep, cautioning him to ensure safety to the fullest. Currently, there are no effective systems used in vehicles to tackle such kind of problem. However, this developed system can make a massive difference in saving lives and looking after their safety. The flow of the proposed methodology is given in Fig. 3 and the methodology is given in Algorithm 1.

3.1 Algorithm 1

Step 1: Load the alcohol detection algorithm integrated with the Arduino board along with the MQ3 sensor.

Step 2: Take readings from the user which are taken in by the MQ3 sensor and converted into analogue values.

Step 3: Compare the analogue values generated and processed by the controller with the threshold values set.

Step 4: If the input record is seen to be greater than the threshold, go to step 6.

Step 5: If the input record is seen to be less than the threshold value set, halt the alcohol detection algorithm and go to step 7.

Step 6: The engine ignition is system is locked since the input record of the user is greater than the threshold value set.

The driver drowsiness detection algorithm follows as:

Step 7: Activate the driver drowsiness detection algorithm.

Step 8: OpenCV library is activated for image processing, facial landmarks extraction is done continuously for a window of 48 frames.

Step 9: The eye aspect ratio threshold of 0.3 is set and compared with the user's records.

Step 10: NumPy extracts the eye-coordinates of user and therefore eye aspect ratio of the user's input record is calculated.

Step 11: The eye aspect ratio is compared with threshold and the counter for sounding the alarm is incremented.

Step 12: Alarm is activated when the user's eye aspect ratio is found to be less than 0.3 ($EAR < 0.3$) and repeat from step 7.

Step 13: Go to step 7 if the eye aspect ratio of the user is found to be greater than the threshold.

Step 14: Repeat this until the user is found to be drowsy and the engine ignition is locked.

The proposed method of the project includes both image processing and alcohol detection systems. The image processing project uses Python programming language. Since many image processing tools, functions, and libraries may be modified to create a robust environment, the programming language Python is being employed. There is no data collected for these projects. Both of our projects are developed in a real-time environment. For the drowsiness detection project, we are taking in the live video stream as our data. Since it is paramount to alert the driver at that very moment, we are using image processing techniques for live feed and not some pre-stored datasets. The same scenario applies to alcohol detection. The MQ3 sensor planted with Arduino board detects alcohol from the drivers' breath. Algorithms and approaches are used for proper implementation and functioning, and they are detailed below.

3.2 Drowsiness Detection

The drowsiness detection algorithm extracts the user's facial landmarks with precision to alert the user when he closes his eyes for longer than usual. We used various top-notch modules and functionalities in the implementation of our drowsiness detection algorithm. They are

- OpenCV is an open-source vision and machine learning applications library. This algorithm is applied to recognize objects identified, human activities classified in photographs, and camera motion tracked.
- To make working with OpenCV simple, we would need the imutils kit, my computer view sequence, and the image processing functions.
- SciPy: The SciPy kit is needed in an eye aspect ratio measurement to calculate the Euclidean gap between facial landmarks.
- The thread class ensures that our script will continue to execute even if the warning noises are played on a different thread from the main thread.
- We need the play-sound library to play our WAV/MP3 alarm.

We would need the Dlib library to detect and locate visual landmarks.

3.3 Alcohol Detection

In order to detect the alcohol levels of the operator, the MQ3 (alcohol) sensor is installed on the control unit. Analogue values are generated by the sensors and processed online by the controller. IoT updates sensor data to the server constantly. If the value of the alcohol sensor is at the limit, the gadget prevents accidents by stopping the automobile ignition system and keeps the intake data in the user's record. The control air is continuously checked in the cloud and updated with the assistance of the MQ3 (alcohol sensor). The mechanism interrupts the ignition system if the alcohol measurements surpass the threshold value. This is done by preventing the supply of fuel to the ignition system. The Arduino Uno is used for the entire system. Arduino Uno is responsible for the MQ3 module, LCD display. The interface of all modules is programmed in order to work the whole of the module. The panel may be connected to the personal computer, and the microcontroller programming can be done for the sensor to operate and to breathe. Reading is shown on the LCD board interfacing with the Arduino Uno board. Once the sensor detects, the information is transferred to the automotive ignition system that does not start the engine.

The MQ3 (alcohol) sensor is mounted on the driver's steering to detect the driver's alcohol level. The sensors produce analogue values and are interpreted by the controller via the internet. The sensor data is continuously updated with IoT to the server. When the alcohol sensor values reach the threshold, the device avoids accidents by halting the car ignition system and stores the alcohol intake values into the vehicle user's log. With the aid of the MQ3 (alcohol sensor) the air exhaled by the controller is constantly monitored in the cloud and updated by the IoT. If detection of alcohol exceeds the threshold value, the system interrupts the ignition system. This is done by preventing the supply of fuel to the ignition system.

4 Analysis

The test is critical because it finds defects/bugs that assure software quality before sending the client. It makes the programme easier to use and more dependable. Software testing guarantees that software is reliable and efficient. When testing any product or project we need to check it on various bases and use all the possible test cases. To determine if a product is robust enough to function in several conditions, it must be tested that the system stands out in all situations and environments. According to previously reported approaches, there are very few public datasets currently available for comprehensive performance evaluations of different approaches for driver drowsiness detection, particularly those with driver attention information from real-world driving scenarios [26] (Fig. 4).

The above graph depicts eye aspect ratios of the user input records over a time period window frame. The frequency of the eye aspect ratio values is plotted against the actual values taken from the user. The pulse in the graph is observed to be constant over a period of time when the values of the user readings are found to be less than the threshold. Peak is observed at the median of the graph when the values of the eye aspect ratio cross the threshold of 0.3. The yellow region depicts the time frame in which the user is assumed to be drowsy due to the input recordings. The red region depicts the peak confirming the user's drowsiness state (Fig. 5).

TEST CASE 5.A: After running the image processing drowsiness detection algorithm, the algorithm extracts the facial landmarks and monitors the user's live stream

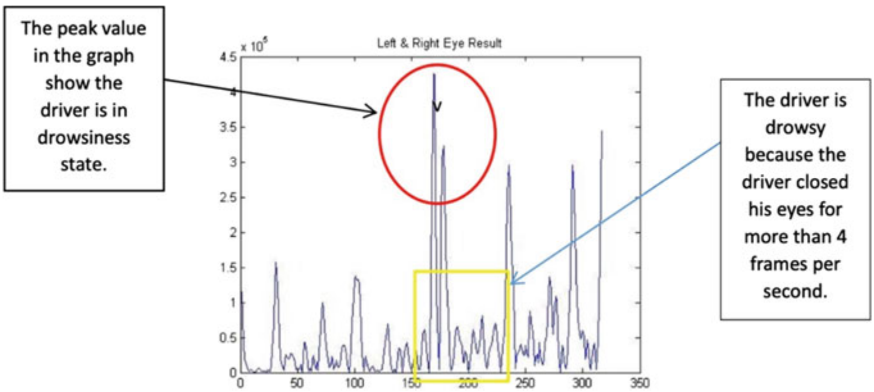

Fig. 4 Drowsiness and alcohol detection peak values

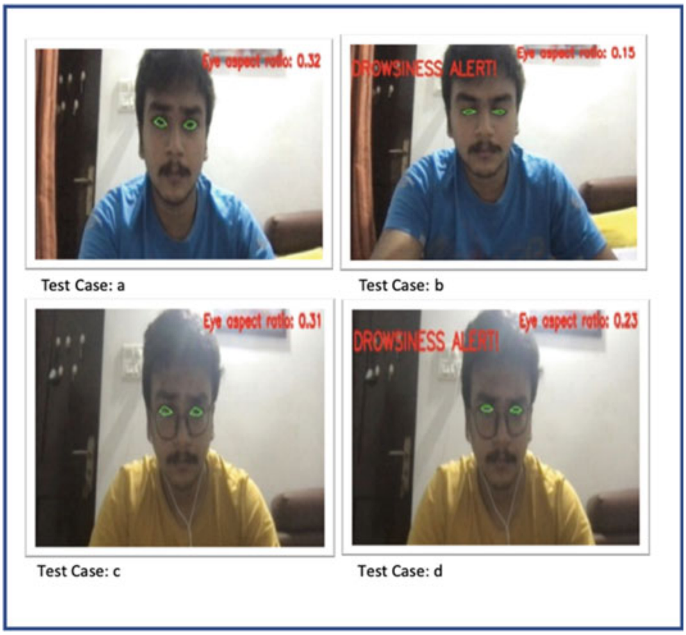

Fig. 5 Model test cases

for contiguous frames of 42. The average aspect ratio in this case, where the user keeps his eyes open for a certain number of frames is 0.3. Since the result of the drowsiness detection algorithm is seen to be greater than the threshold, No Drowsiness Alert was detected eye aspect ratio greater than 0.3(i.e. 0.32 > 0.3). This indication ensures a safe journey without alerting the alarm to halt the driver's journey.

TEST CASE 5.B: After running the image processing drowsiness detection algorithm, the algorithm extracts the facial landmarks and monitors the user's live stream for contiguous frames of 42. The average aspect ratio in this case, where the user keeps his eyes open for a certain number of frames is 0.3. Since the result of the drowsiness detection algorithm is seen to be less than the threshold the value is taken to be critical. Drowsiness Alert, the alarm is triggered which would help the driver get hold of the situation. This is when the eye aspect ratio was found less than 0.3 (i.e. 0.23 < 0.3).

To test our model further to its extremes, we used a pair of glasses to assess the performance of the model. Which resulted in:

TEST CASE 5.C: After running the image processing drowsiness detection algorithm, the algorithm extracts the facial landmarks and monitors the user's live stream for contiguous frames of 42. The average aspect ratio in this case, where the user keeps his eyes open for a certain number of frames is 0.3. Since the result of the drowsiness detection algorithm is seen to be less than the threshold the value is taken to be critical. Drowsiness Alert, the alarm is triggered which would help the driver get hold of the situation. This is when the eye aspect ratio was found less than 0.3 (i.e. 0.31 > 0.3).

TEST CASE 5.D: After running the image processing drowsiness detection algorithm, the algorithm extracts the facial landmarks and monitors the user's live stream for contiguous frames of 42. The average aspect ratio in this case, where the user keeps his eyes open for a certain number of frames is 0.3. Since the result of the drowsiness detection algorithm is seen to be less than the threshold the value is taken to be critical. Drowsiness Alert, the alarm is triggered which would help the driver get hold of the situation. This is when the eye aspect ratio was found less than 0.3 (i.e. 0.19 < 0.3).

TEST CASE 3.A: We have tested the threshold values of the alcohol detection model by giving manual user inputs. When no alert alcohol consumption, when the input is less than threshold value, i.e. (215 < 500).

TEST CASE 3.B: We have tested the threshold values of the alcohol detection model by giving manual user inputs. When alert alcohol consumption, when the input is more than the threshold value, i.e. (560 > 500).

In our research, we used two-way analysis as shown in Table 1. Our first phase includes the information gathered by the model when the driver is facing the camera. The data from the first stage is used in the second phase, which comprises a thorough examination of the data using machine learning classifiers to determine whether the proposed approach is helpful. Naive Bayes, support vector machine, and random forest were the classifiers used in the empirical analysis. We evaluated the results obtained using performance measures to evaluate the classifiers' performance.

Table 2 depicts the values of the accuracy, precision, recall, TPR, FPR, classifier, and F-Measure against the various classifiers that we have used. We have collected a dataset of 750 images comprising of the images of various users who have been tested against the drowsiness detection algorithm in distinct circumstances. The dataset consists of the predictions made by the algorithm. The validity of the algorithm is compared with the actual conditions. These images are run through some of the best classifiers such as SVM, random forest, and Naive Bayes algorithm. SVM proves to have an accuracy of 80% when tested with a fresh set of images. The Naive Bayes algorithm considers a wide variety of possibilities choosing the best set of combinations. It proved to be 80% accurate similar to the SVM classifier. We have

Table 1 Results of user input records

Test case	Threshold value	User input record	Result (displayed message)
3.a	500	250	"Have a safe journey"—Engine ignition system on
3.b	500	560	"Alcohol level high, shouldn't drive!"—Engine ignition system locked

Table 2 Evaluation of classifier's performance

S. No.	Classifier	TPR	FPR	Accuracy	Precision	Recall	*F*-measure
1	SVM [13]	80	20.4	80	80.1	80	79.9
2	Random forest (proposed method)	84	16.1	84	84	84	84
3	Naive Bayes [27]	80	20.7	80	80.7	80	79.8

used the random forest algorithm as it proves to be the best among the classifiers used, having an accuracy of 84%.

From the above statistics, we can enumerate that the random forest classifier gives the best classification results with an accuracy of 84%.

5 Conclusion

An alternative perspective is utilizing a camera to determine the driver's drowsiness using the driver's facial areas. Based on the findings of image analysis, the driver is categorized as sleepy or not. Image data analysis methods are advantageous and properly represent raw data. The technology was also tested while in motion under various lighting conditions. A quantitative and a qualitative result backed up the proposed plan. Since the focus of our study is on facial recognition and alcohol detection, the entire system is in charge of preventing accidents. Our system acts more effectively in these cases. The model could be developed even more by supporting authorities in the event of an emergency. We have devised a very successful way of constructing an intelligent system for alcohol detection in automobiles with Arduino at its heart. One of the perks of this sensor is that its range is about 2 m, so it is possible to install it in secret. The system as a whole also has the advantage of being lightweight and dependable. The long-term purpose of the model is to reduce the number of alcohol-related and drowsiness-related accidents. Integrated measures such as combining physiological and behavioural-based or vehicle-based and behavioural-based can provide more accuracy than individual measures. Since this research is also dependent on road conditions, light effect, and traffic situation, further trial findings for other nations are necessary. This study is quite helpful in projecting accidents to the greatest extent possible. Prediction of accidents can assist people who are looking to stay safe and secure. So, they may arrange the necessary protocols accordingly once they know the possibility in future. Automobile organizations can benefit since they are aware of the trend and need in security and guarantee the safety of their customers.

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