International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 2 (2018) pp. 1219-1226

An Improved Algorithm for Drowsiness Detection for Non-Intrusive Driving

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Abstract

To address issues related to unsafe driving leading to road accidents, a car-integrated system which observes the driver's behavior based on varied stimuli is discussed in this paper. Sensor parameters are used for detecting head movement, steering grasping and driving under influence of alcohol. A system, which identifies driver drowsiness by assessing any one, two or all three parameters viz., head movement, alcohol influence and steering grasping is proposed as part of this work. When one, two or all these conditions prevail, it is deduced that the driver is in a state of drowsiness. A simulated environment was setup for the testing and the results have been compared to normal driving scenarios. Analysis results demonstrate that, driver drowsiness can be detected by the proposed system. A range of sensors are used to read and send data to the processing unit and a proposed algorithm would analyze and detect the drowsiness of the driver.

Keywords: Driver drowsiness, Steering grasping, Head movement, Driving under alcoholic influence, Sensors, Arduino, Drowsiness Detection.

INTRODUCTION

The relation between driver drowsiness and road accidents is fairly well established. The probability of road accidents increases when the concentration of alcohol in blood is beyond 0.08g/100ml [1]. The objective to design a driver drowsiness detection system is to increase road and driver safety. Government has set laws as a precautionary measure to prevent driving under alcoholic influence. Many a times, a driver who is under the influence of alcohol, is not able to take evasive action prior to a collision. To prevent such accidents lot of attention is given to the field of road safety research.

This paper focuses on designing a system for the detection of alcohol influence, head movement and steering grasping of a driver to validate the functionality of detecting driver drowsiness within the vehicle. With an array of sensors (Load Cell, Alcohol Sensor and Accelerometer), the data can be acquired pertaining to the movement of the head, the force used to grasp the steering wheel and density of alcohol in the breath of the driver. Recognition of driver drowsiness by a proposed algorithm is discussed in this paper.

The work also discusses the Proof-of-Concept implementation of the proposed algorithm using Arduino programming language which is a set of functions merged with C & C++ functions. Inside the test environment, it logs the data based on vehicular traffic. With real world driving conditions, the validation of the expected functionality of the sensors is carried out.

The work related to this paper has been illustrated in "Existing System". While "Implementation" contains the implementation of the proposed system.

The paper highlights various symptoms of drowsiness while driving i.e. alcoholic influence, irregular head movement and steering grasping. An overview of the sensor units used for the testing of the platform are given in "Implementation". Various hardware components are presented, such as static point load cell which facilitates the detection of steering grasping. The load cell is used to measure the force with which the steering wheel is grasped at the most relevant points while driving. In order to detect irregular head movement, a three-axis accelerometer is used. A breathalyzer is used to estimate the content of alcohol in the blood by measuring the amount in the breath. The installed system combines data from the various sensors and the processing is done by the proposed algorithm.

The paper illustrates the role played by various sensors in the drowsiness detection system. "Methodology" discusses the results of various tests and observations.

RELATED WORK

A lot of attention is being paid towards monitoring the behavior of drivers, to avoid road accidents. Various studies have considered the use of driving simulators and real environment containing multiple sensors, as stated by S. Olariu [2].

Former studies have provided an insight into various sensing parameters, namely video cameras facing the driver, microphones, and sensors to capture biometric signals.

Y. Qian et al., [3] had set up a simulated environment which predicted the distractions based on lip and eyelid movements. With the help of a camera, various relevant features including position of the head, eyelid movement and performance in driving was analyzed for crucial cognitive distraction.

L.M. Bergasa et al., [4] had evaluated the driver's gaze angle, head rotation and position of the car within a lane to determine distraction. A model of a neural network was proposed which predicted the behavior based on the position of the feet on the pedals of the vehicle. In a simulator, the vehicle speed and lateral position was studied to analyze reaction time to indicate the level of attention. Various strategies with the help of global motion and color helped in tracking eyes, lip corners and box framing the face. The method failed if the driver wore glasses, had a conversation or gets obstructed due to hand movement.

J. Sun et al., [5] had developed a system for detecting drowsiness and the discussed system collected information ranging from speed, lateral position, yawing angle and angle of the steering wheel. With the help of neural network and combination of various indicators, it predicted whether the driver was drowsy or not. Henceforth, an appropriate alert signal was issued.

A. Rakotonirainy et al., [6] had developed a non-contact platform where it checked for drowsiness by checking whether the eyes were open or shut by making use of a camera. It captured the face and processed the image to check for the interval of the eyes being closed.

G. Singh et al., [7] had installed force sensors on the acceleration pedal which collected data to analyze driver fatigue.

M.S. Devi et al., [8] had developed a system where cameras were placed in front of the driver to detect the number of times the driver's eyelids shut while driving. If the eyelids were shut in 5 consecutive frames, then it was inferred that the driver had fallen asleep and a warning signal was issued.

H. Singh et al., [9] had developed a system that detected sudden acceleration and retardation, which was plotted on a graph to detect driver fatigue. The driver was warned by an alarm and seat belt vibration.

EXISTING SYSTEM

The system contains a water-cluster-detecting breath sensor which detects electric currents of positively and negatively charged water clusters in the breath [10]. An alcohol sensor is coupled with the water-cluster-detecting sensor. Both the breath and alcohol sensor works simultaneously. A driving simulator is developed to analyze the breathing pattern of the driver while the test subject is recognizing moving objects on the display. A driver's seat, steering wheel, dashboard and a liquid crystal display was a part of the simulator.

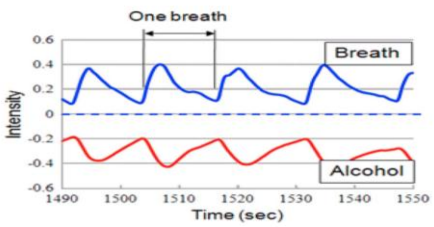

Figure 1: Breath and alcohol peaks for breath-alcohol content of 0.165 mg/L. [10]

Figure 1 [10] shows that it takes up to ten seconds to capture one breath.

The system fails to detect if the driver is not within ten centimeters of the sensor [10]. The problem with the existing system lies in the fact that it will not be able to detect the alcohol content in the driver's breath if the driver is in his/her driving position. A situation also arises where the driver may not want to exhale into the sensor. No provision has been made in the existing system to eliminate this problem.

IMPLEMENTATION

Load Cell

A load cell is synonymous to 'force', 'weigh' or 'weight'. The load acting upon the sensor is converted into measurable analogue or digital output. The force applied is directly proportional to the output. The load acting on it is converted into electrical signals. The beam is bonded with the structure which indicates the force applied on it. To attain maximum sensitivity four strain gauges are used. Out of the four strain gauges, two strain gauges are used as tension and two in compression. The electrical resistance is altered when the electrical resistance of the strain in the load cell is affected.

Table 1: Data acquired from load cell sensor and it's corresponding behavior

Loosely Gripped	Inconsistent	Steering Not Grasped	Steering Grasped Properly
2.91	-5.95	-3.88	15.38
5.10	-4.12	-4.00	13.59
3.5	1.23	-3.98	11.64
1.83	-4.8	-3.95	15.13
1.9	-3.12	-4.01	16.35
-1.72	8.09	-4.02	21.92
2.38	-4.46	-4.03	23.96
3.49	1.07	-4.08	15.97
7.7	11.25	-4.05	18.61
1.71	14.52	-4.06	15.51
-1.76	-8.73	-4.01	17.42
1.98	0.46	-4.01	15.62
1.45	18.81	-3.99	20.13
1.68	1.92	-4.04	21.24

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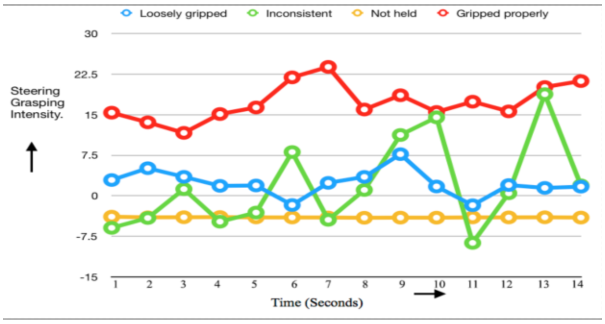

Figure 2: Driver steering grasping averaged over subjects.

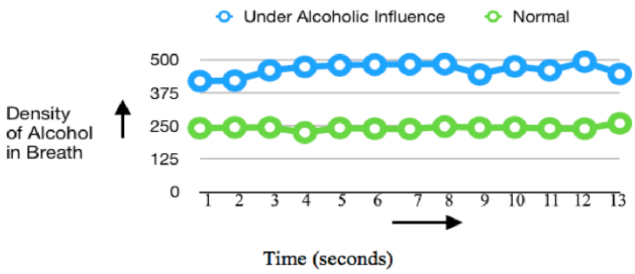

Figure 3: Alcoholic influence averaged over subjects.

Figure 2 shows the various ranges, when the load cell is working as an individual unit by using sensor values represented in Table 1. The steering grasping behavior is classified into: (i) Loosely Grasped (ii) Inconsistent (iii) Not Held (iv) Properly Grasped. The sensor sends the data to the processing unit. Figure 2 shows that each behavioral pattern falls within a distinct range of values. The proposed algorithm can detect the particular classification of behavior exhibited by the driver.

Breathalyzer

The breathalyzer estimates the amount of alcohol content in the blood. Measurement of the content of alcohol in the blood can be done, by testing the blood sample of the driver. However, this requires a laboratory environment. Another alternative is to use a sensor which detects the amount of alcohol contained in the breath, and this in turn can be used to measure the alcohol content in the blood.

Ethanol is detected whenever human breath is exhaled into the sensor. The oxidation of ethanol produces acetic acid and water. People who drink alcohol will release some gases. If ethanol is contained in the gas then it will be oxidized by chromium trioxide.

Table 2: Data acquired from alcohol sensor and it's corresponding behavior

Driver Under Alcoholic Influence	Driver Not Under Alcoholic Influence
419	241
421	244
459	244
473	224
479	242
481	239
482	238
483	247
444	243
475	244
459	240
492	239
446	259

Figure 3 shows the various ranges of the sensor based on the density of the alcohol in the breath by using sensor values represented in Table 2. When the driver is under alcoholic influence, the sensor sends a value above 375 to the processing unit. If the driver is under alcoholic influence, then the sensor sends a value ranging from 200 to 250 to the processing unit. These distinct ranges are identified through the proposed algorithm and the values are analyzed to determine whether the driver is intoxicated or not.

Three-Axis Accelerometer

The three-axis analogue accelerometer reads the X, Y and Z acceleration as analogue voltages. It can find out the angle at which the sensor is tilting with respect to the earth's gravity. The direction and velocity of the head movement can be determined by reading the intensity of the dynamic acceleration. With the help of the two properties, the detection of movement of the head is done.

Irregular head movement is a symptom of drowsiness that under which a human head fails to remain in a normal position. The head tends to fall on either side resulting in multiple head jerks.

The accelerometer is able to detect the force, angle and direction at real-time and if the head goes beyond the threshold, the algorithm is able to recognize that the position of the head is not in a normal position which is not suitable for driving. The repeated detection of sudden force and tilting indicate that the driver is drowsy and is not fit for driving.

The X and Y axes are able to detect the tilting of the head. In the case of turning the head to left or right, the algorithm will not sense it as tilting. The turning of the head to left and right in the case of driving, is not considered as a symptom of drowsiness.

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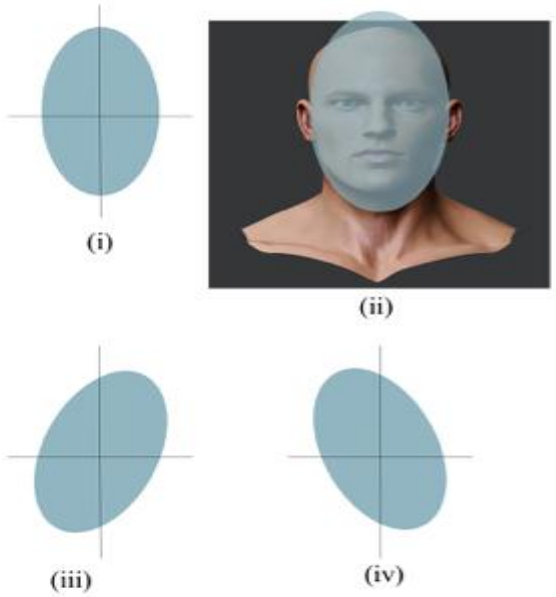

Figure 4: Symbolizing left and right head tilting.

Figure 4 shows that an elliptical symbol is masked on a real human face to symbolize the shape and volume of a human head ((i) and (ii) in Figure 4). The mean position of the head is shown in (i) and right and left tilting is shown in (iii) and (iv) respectively. This procedure is followed to analyze the head movement mechanism of the system.

Table 3: Data acquired from load cell and it's corresponding behavior

Head Movement	Looking Left	Looking Right	Forward Tilting	Left Tilting	Right Tilting
334.5	343	348	360	323.5	362.5
334.5	342.5	351.5	360.5	324	363
335	344	349.5	362.5	323.5	361.5
333	342.5	351	362	319.5	363
335	342.5	352.5	361	325.5	364.5
335.5	340	353	362	325	363
335	341.5	353	361.5	322	341
335.5	340.5	354	363.5	320.5	362
335.5	345.5	354	370.5	323	362.5
336.5	339.5	354	370.5	328.5	363.5
335	341.5	353.5	365	329	366
333	340.5	354.5	368	325.5	362.5
333	340	353	369	328	363.5

The results of the accelerometer working as an individual unit is illustrated in Figure 5 by using sensor values represented in Table 3, where in it represents the different types of head movement while driving.

When the driver's driving pattern is not influenced by alcohol content in the body, then the head movement is not considered as drowsiness.

According to Figure 4 the stance of looking forward and driving has a sensor value, averaging to 335 for both the x-axis and y-axis. In the case of looking left, the sensor value averages to 338 for the x-axis and to 343 for the y-axis. Similarly, in the case of looking right the sensor averages to the value of 340 for the x-axis and 365 for the y-axis. These parameters are not detected as drowsiness by the algorithm.

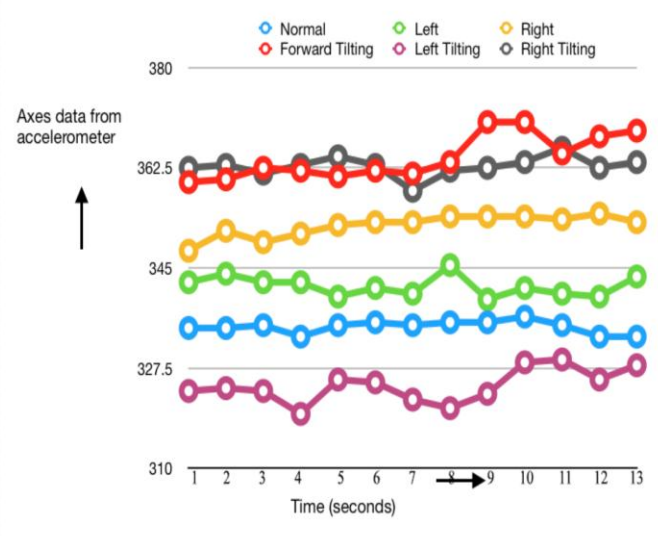

Figure 5: Head movement averaged across subjects.

The tilting and jerking of the head is considered to be symptoms of drowsiness and it represents an unfit expression of the driver's health. Figure 5 shows the forward tilting of the head averages to the value 338 for the x-axis and 380 for the y- axis. The right tilting of the head averages to the value of 380 for the x-axis and 338 for the y-axis. According to Figure 5, the forward and right tilting falls in the same region, since, the average reading of the x-axis of the forward head tilting phenomenon averages the y-axis values of the right head tilting and vice versa. In the case of left tilting it averages to the value of 285 for the x-axis and 345 for the y-axis. The algorithm can detect both normal behavior and drowsiness as the sensor values sent to the processing units fall under distinct ranges.

METHODOLOGY

The system flowchart (Figure 6) shows that an array of sensor are present (Accelerometer, Alcohol Sensor and Load Cell) which simultaneously send data to the processing unit. The data is further analysed by the algorithm which makes decides whether the driver is drowsee or not. If the driver is found to possess drowsiness then an alert is provided within the car.

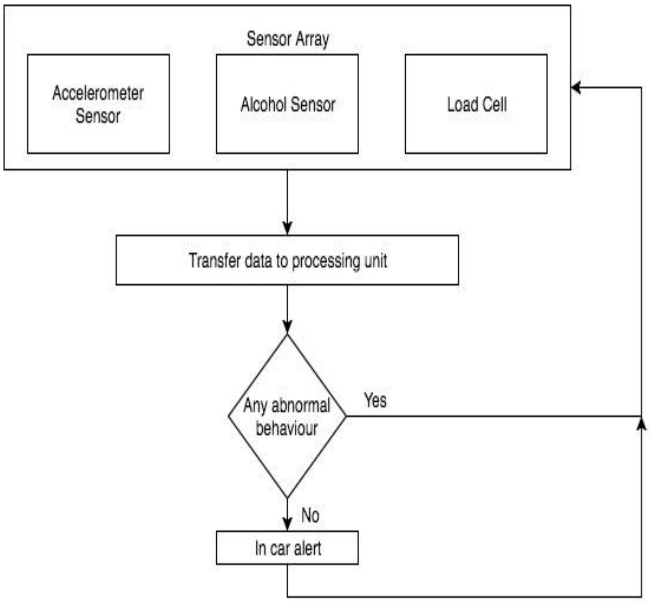

Figure 6: Flowchart of proposed system for driver behavior detection system mechanism.

The experiment was done with drivers with a valid license within a simulated environment. All the subjects were trained and many test sessions were provided to make them acquainted with the system.

The alcohol sensor was placed on the steering wheel, which is naturally the closest object to the driver's face. This was considered as the best position while trial sessions were made. It is also easy to install it in the region where the horn of the car is fitted.

The sensor confirms the amount of alcohol contained in the breath of the driver which can directly be converted to the amount of blood alcohol content (Table 4.).

According to Figure 3, the reading from the sensor is below 300 which indicates that there is no alcohol in the breath. Highly concentrated alcoholic breath would provide a sensor reading of ~375 and above.

Table 4: Corresponding blood alcohol concentration units for breath alcohol concentration units

Particulars	Value for Alcohol Concentration in Breath	Values for Alcohol Concentration in Blood
Micrograms of alcohol per one litre of breath (µg/L) vs Grams of Alcohol Per One Hundred Millilitres of Blood (%BAC)	350	.070
Micrograms of alcohol per one hundred millilitres of breath (µg/100ml) vs Grams of alcohol per one litre of blood (g/1L)	35	70
Milligrams of alcohol per one litre of breath (mg/L) vs Grams of alcohol per one litre of blood (g/L)	0.35	0.70
Grams of Alcohol per two hundred and ten litres of breath (g/200L) vs Grams of alcohol per one kilogram of blood (g/kg)	0.73	0.66

The key characteristic of driving is the grasping of the steering wheel. The usual way of operating a steering wheel is by turning the wheel using hand movements. Drowsiness of the driver can be detected by measuring the force using which the steering wheel is grasped by the person at wheel. The selection of the sensor position is done by analyzing the various designs of the steering wheel available and the best position to be held i.e. at either ends of the horizontal spoke.

Most steering wheels are designed in such a way that, drivers hold on either sides of the wheel with both hands. The various designs contain a horizontal spoke, where the horn is fitted. This design naturally enables the drivers to hold the steering wheel at either end. Figure 7 illustrates the design of steering wheels and holding positions.

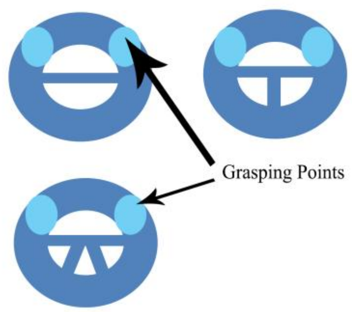

Figure 7: Symbolic representation of grasping points on steering wheel.

The grasping points shown in Figure 7 are the positions that are naturally held by the driver. Load cells are fitted in grasping points (Figure 7) to detect the force at which it is grasped. Holding the steering loose may cause the car to go out of control. Having a valid license indicates that the driver possesses the knowledge of grasping the steering properly i.e. the firmness that is needed. If the steering wheel is grasped loosely i.e. not adequately firm, then the load cell indicates that the load put on the steering wheel is not enough to drive. Whenever the driver grasps the steering wheel with the adequate firmness, the load cell's value will cross the threshold and this is read by the proposed algorithm. The load cell sends a value which is negative but not below -2, when the steering is not held by the driver.

According to the proposed algorithm, the approach requires an accelerometer for analyzing the head movement.

The X & Y axes of the sensor determines whether there is any abnormal tilting of the head. This also results in having multiple head jerks due to tilting of the head which is a symptom of drowsiness. Real life scenarios suggest that it is not possible to keep the head at a perfect right angle i.e. at a

90-degree angle to the floor of the car throughout the drive.

Proposed Algorithm:

Step 1: Provide power to the system and validate the proper working of the sensors (Load cell, Breathalyzer, Three-axis Accelerometer).

Step 2: If Breathalyzer reading > 320

OR

If Load Cell reading > 8

OR

If Accelerometer X >300 && X<380 && Y>300 && Y<380

Then

Alert the driver with appropriate symptom detected.

Step 3: Go to Step 2

RESULTS

The processing unit collects data from each sensor simultaneously. The proposed algorithm is capable of detecting three different parameters i.e. head movement, driving under alcoholic influence and steering grasping. If the driver possesses only one of the above symptoms, then the algorithm is able to detect it. If it is a combination of any two out of the three parameters, then also the algorithm is able to detect it. The condition of all the three symptoms of drowsiness being possessed by the driver is detected by the proposed algorithm.

Figure 8 shows the result when the driver is under alcoholic influence and having irregular head movement and jerking. In "Implementation" it is illustrated that the breathalyzer sending a value more than 320 indicates that the driver is under alcoholic influence. As represented in Figure 7, the alcohol sensor data is combined with the load cell data. It shows consistent irregularity in the head movement where the value sent to the processing unit is a low of 250 and achieves a high of 400 within ~4 seconds. It is also seen that the alcohol sensor reads a consistent high value of almost 900 combined with the accelerometer which is detected by the proposed algorithm.

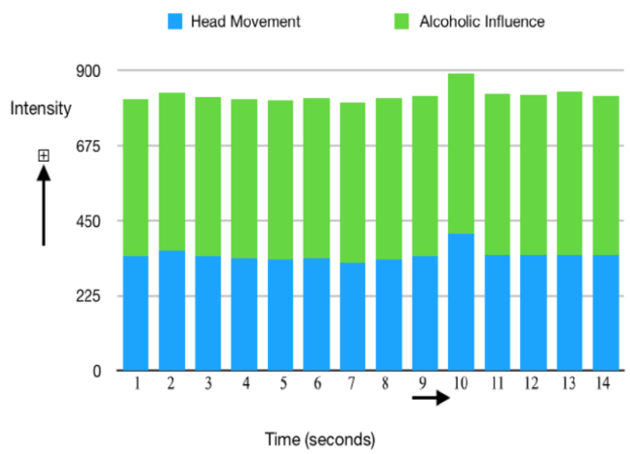

Figure 8: Head movement and alcoholic influence intensity at regular time intervals.

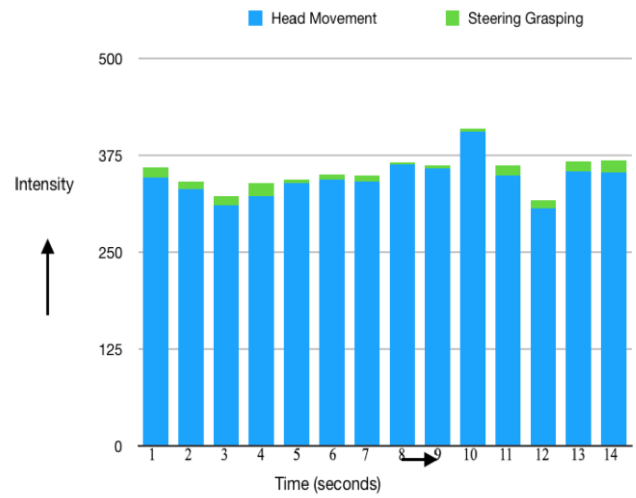

Figure 9: Head movement and steering grasping intensity at regular time intervals.

Figure 9 shows the result of inconsistent grasping of the steering wheel and having irregular head movement and jerking. By taking values from the load cell and accelerometer, the result is represented in Figure 9, which shows the irregular head movement. The value of the axes ranges from ~300 to ~400, the proposed algorithm detects it as drowsiness. If the steering wheel is grasped properly, the sensor should return a consistent value. In Figure 9, the region which represents the steering grasping intensity shows that the grasping force is inconsistent. Within 2 to 3 seconds it is seen that there is little or no grasping of the steering wheel. The proposed algorithm detects that there is no proper grasping of the steering wheel and irregular head movement is prevailing, which indicates the presence of drowsiness.

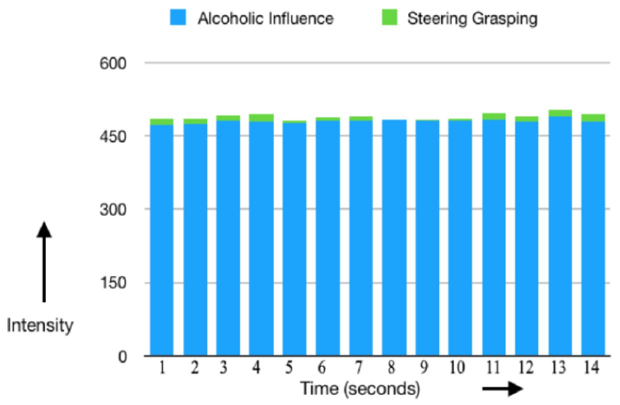

Figure 10: Alcoholic influence and steering grasping intensity at regular time intervals.

As illustrated in “Implementation”, a value of more than 320 units displayed by an alcoholic sensor, shows that the driver is under the influence of alcohol. Similarly, in Figure 10, the data from the alcohol sensor is consistently above 450. This data combined with the load cell’s data for steering grasping indicates that the steering is grasped inconsistently, since, the region indicating it in Figure 10, shows that the sensor reads a value which is lesser than the threshold that is. 8 sensor value in time frames: 2,3,5,6,7,8,9,10,12.

Figure 11 shows the data processed by the proposed algorithm when the driver is not drowsy.

Comparing Figure 12 with Figure 11, the former shows the data when the proposed algorithm detects that driver is drowsy. The proposed algorithm detects all three parameters: (i) irregular head movement, (ii) alcoholic influence (iii) steering grasping. In Figure 11, the region indicating head movement shows that the proposed algorithm detects it as irregular head movement. Consecutive time frames in Figure 12 show the jerking caused due to head movement. The alcohol level in Figure 11 is consistently high with a reading of 300 and above, which indicates that the breath of the driver contains alcohol. The steering grasping intensity in Figure 12 shows that the steering wheel is not properly grasped during the time frames: 1,2,8 and 12. As depicted in the graph the other time frames: 3,4,9,11,14 which indicate a grasp which does not cross the threshold in the proposed algorithm.

The proposed system does not require the driver to get close to the alcohol sensor as it is required in the existing system. The driver can maintain his regular driving posture and the algorithm can detect the alcohol content in the breath.

The existing system takes a longer time frame of approximately 10 seconds to detect one breath exhaled by the driver [10] whereas the proposed system takes approximately 1 second. The proposed system also detects head movement and steering grasping to detect drowsiness. Table 5 shows that the proposed system is able achieve higher accuracy to detect driver drowsiness compared to the existing system. A more accurate detection of drowsiness due to alcohol is achieved since, the proposed system also detects symptoms related to drowsiness like head movement and steering grasping.

Table 5: Corresponding parameters and time taken by the existing system and the proposed system for drowsiness detection

Parameter	**Time Taken by Existing System**	**Time Taken by Proposed System**	**Detected by Existing System**	**Detected by Proposed System**
Driver Under Alcoholic Influence	~10 Seconds	~1 Second	Yes	Yes
Head Movement	NA	~1 Second	No	Yes
Intensity of Steering Grasping	NA	~1 Second	No	Yes

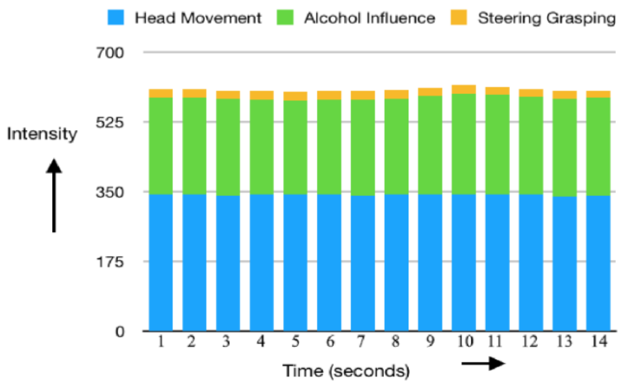

Figure 11: Normal behavior of the driver at periodic time interval.

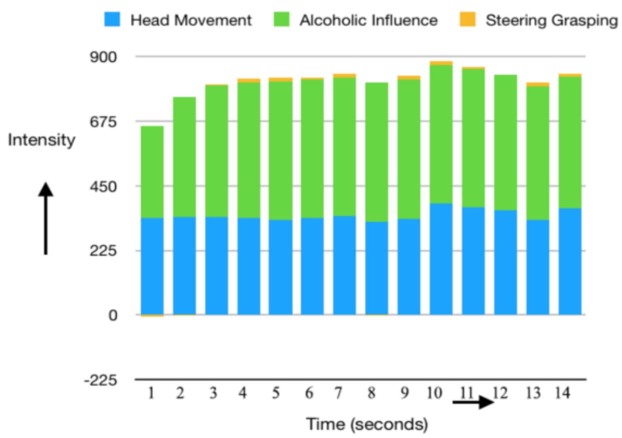

Figure 12: Abnormal behavior of the driver at periodic time interval.

CONCLUSION

Despite the rigorous implementation of traffic rules in the past few decades, there is a steady increase in the number of accidents due to drunk driving. This work focuses on the behavioral patterns of the driver and proposes a cost effective drowsiness detection system. This system integrates into a vehicle and detects driver drowsiness by using three sensors viz. Accelerometer, Breathalyzer and Load Cell. The proposed algorithm successfully detects the drowsy and unfit condition of the driver.

The functionality of the system can be further enhanced by enabling the feature of live tracking. Necessary updates will be made to align the present system with Internet of Things (IoT), which will facilitate the ease of having a live location tracking feature. The system henceforth can actively share the particular unfit condition of the driver with designated emergency contacts.

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