Smart vehicle management by using sensors and an IoT based black box

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ABSTRACT

As the number of transports on the road increases every day, so does the number of accidents. Reckless driving and consuming alcohol are two of the leading causes of accidents. Apart from these issues, the safety of humans and vehicles is also critical. A thorough investigation is required to minimize the accident rate and improve human safety, particularly if an incident occurs. The purpose of this study is to develop a few sensor-based black box system that will help us reduce traffic accidents by continuously providing precise guidance to the driver. At the same time, the evidence will be uploaded to its server for further evaluation. This system also includes a way of detecting drowsiness in the driver. Finally, using global positioning system (GPS) and global system for mobile communications (GSM), the relevant authorities will get information on the vehicle's condition and whereabouts. For security purposes, a panic button is introduced here to get emergency help from the security personnel by detecting the victim’s area.

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1. INTRODUCTION

Autonomous vehicles are the most emphasized invention in the automobile industry. Due to simplicity, such as sustainable mobility and less complexity, autonomous vehicles play a major role in the world. The worldwide transport network is continuing to evolve, and new automobiles are being introduced to the road on a daily basis to make life easier. As a result, traffic accidents are increasing. According to the National Highway Traffic Safety Administration, 94% of accidents are caused by drivers who make poor choices on the road [1]. Drowsy driving, poor vision, racing, getting drunk, and other factors all have a part in severe traffic accidents. According to one study [2], drowsy driving is responsible for about 6000 traffic incidents each year. Another statistic [3], says that sleepy driving causes 100,000 fatalities each year. 36300 crashes occur in the USA each year, with lower vision issues accounting for roughly 17% of all crashes [4]. In Bangladesh, a media article [5], states that 60 persons die in every 10,000 road accidents because of poor vision. Alcohol-related incidents accounted for more than 25% of all road accidents in 2019, while exceeding the speed limit accounted for roughly 26% [6], [7]. Another research [8], found that in 2019, 47% of passengers in automobiles were not wearing seat belts, resulting in 22,215 fatalities. After the collision, an analysis is needed to define the exact damage and a feasible solution to prevent a repeat of the accident. Moreover, additional research is necessary to solve the police case. Due to a lack of adequate real-time evidence, the judgment process might become distorted. Along with the vehicle, human safety is also critical.

Many drivers and passengers have reported experiencing robbery when traveling. A few days ago, a doctor from Bangladesh, was robbed and tortured for 8 hours on a bus [9]. A person carrying his company's money in a car was stopped at a checkpoint by fake cops, who robbed the money and the vehicle [10].

Based on the above-mentioned circumstances, we propose an internet of things (IoT)-based black box for automobiles in this research. The IoT is a popular study in modern science, especially in the field of monitoring systems [11]-[15]. This black box contains a variety of sensors and cameras. The major purpose is to gather data while driving and preserve it for later examination. We developed a system to detect all-sided data in order to identify any vehicle or objects and give the driver a safe driving path. Our prototype will begin buzzing after it has identified the current state of both eyes and the driver's degree of alcohol consumption while driving. In dangerous circumstances, this black box is capable of transmitting a rescue signal to the nearby police stations, allowing for immediate assistance. The following are the primary features of the paper:

- A smart vehicle algorithmic approach has been presented by this system.
- This system detects surrounding objects, amount of alcohol, and driver drowsiness by using sensors.
- This prototype can identify location zones, sub-zones and send a rescue signal to police or volunteers.
- This technology recommended using a camera to collect real-time video footage.
- This system produced a prototype that transmits an SMS to officials through GSM in case of an accident.

2. LITERATURE REVIEW

The light detection and ranging (LiDAR) sensing technology uses a data point clustering algorithm to identify objects in a driver assistance system [16]. Another study [17], suggests a technique in which dedicated short range communications (DSRC) roadside units can detect disconnected vehicles and transmit the signal to neighboring automobiles. Another study [18], unveiled a collection of technologies, even in the presence of numerous barriers, that allow their algorithm to precisely extract the road borders. Following a high-resolution database, LiDAR point cloud and red, green, blue (RGB) imaging technologies are combined to recognize every object and generate a 3D rectangle box [19]. One research [20], has explored an algorithmic approach for identifying the driver's facial expression. The authors further stated that their method will carry out an operation for finding a safe parking space, allowing their autonomous vehicle to travel there on its own. In one paper [21], the combination of drowsiness, alcohol, and overload detection sensors is recommended to diminish the accident rate. This technology uses the eye blinking ratio to determine whether or not to slow down the vehicle. In a separate investigation [22], facial landmark points were used to identify the person's eye flickering rate. An application to develop human-computer interaction for determining the degree of tiredness was suggested by researchers in [23]. In that situation, they estimate the movements of the head, both eyes, and yawning without the aid of any worn accessories. The authors of [24], used a microcontroller and an alcohol-detection sensor to determine whether alcohol was present in the vehicle. Additionally, a global system for mobile communications (GSM) module is included to alert the vehicle's owner of the driver's intoxication. In a study [25], radio frequency identification (RFID) and alcohol detection sensors are described. The publication claims that the speed of the vehicle will be restricted if the amount of alcohol consumption is above the limit and that the automatic toll will be collected after the vehicle passes through a toll plaza. Liu *et al.* [26], suggests a technique through which blind spots are detected both during the day and at night using various sensors, radars, and frequencies. In the event that it notices any unusual movement within the targeted zone, this method can simultaneously transmit a warning signal to the driver. Kim *et al.* [27], creates a projection map to alert the driver if the motion vectors identify any blind spots. Marigowda *et al.* [28], employed RFID and user architecture to create a secure transportation system. Their system allows the host server to instantaneously evaluate all of the driver's and vehicle's paperwork. Li and Zhuang [29], claimed to use an RFID-based smart toll collecting system that does not require the driver to brake in order to pay the toll.

3. METHOD

In Figure 1, with the assistance of Raspberry Pi, the system's principal microcontroller, the architecture is working properly. A bunch of sensors such as LiDAR, alcohol, and speed detectors are also utilized to improve the accuracy of the functions. The RFID module and camera are also part of the system, with the camera observing seat belt status and eye blinking ratio.

The autonomous vehicle section includes all of the sensors. The driver assistance system includes a display monitor in front of the driver that displays the results obtained from the sensors. The essential measurements and warning messages will be shown on the screen. A buzzing alarm is also installed in the vehicle's dashboard to alert the driver if drowsiness is detected. Concerning authorities can get the real-time data and scenarios from the firebase.

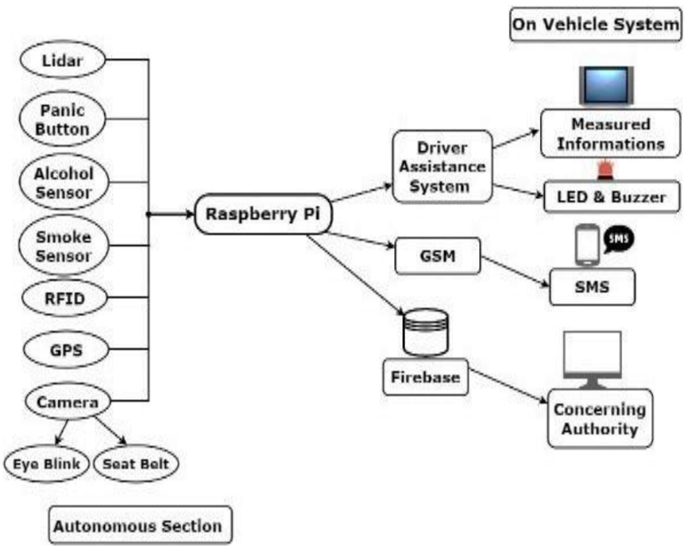


Figure 1. The architecture of the proposed system

3.1. LiDAR

A LiDAR sensor is used here to compute the distance from any sided vehicle by collecting all side information. The laser pulses are thrown to all sides by LiDAR, which then receives the reflected pulses. The calculation procedure then begins by calculating the total pulses and time for the reflected laser beams. The results from the LiDAR are then collected by Raspberry Pi. After receiving the data, LiDAR creates a 3D point cloud to get a more specific visualization of any targeted obstacle. The point cloud's Bird's-eye view provides a sketch that includes the object's height and width. The density of the object, as well as the updated map, will be displayed on the driver's screen [19]. Following the map, the driver will be aware of other nearest vehicles. Figure 2 depicts the entire situation. In this system, LiDAR identifies the vehicle in front of it and, according to its principles, makes a sketch of it to alert the driver. This sketch is generated using the object's measured height and width. This is how the LiDAR operates in this proposed system.

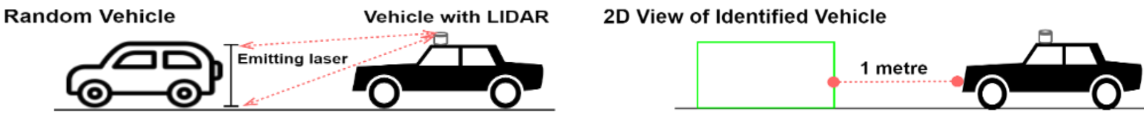


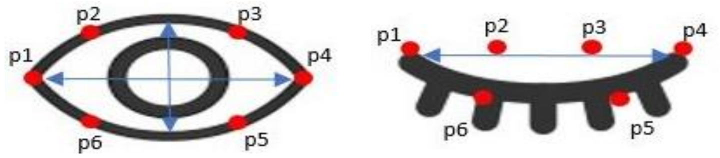
Figure 2. Working procedure of LiDAR in this system

3.2. Drowsiness detection

Sixty-eight facial landmark points (FLP) is the most accurate method for detecting the driver's drowsiness. Pre-trained 68 FLP capture data from the eyes, mouth, and nose. By utilizing those parameters, it can recognize any facial expressions and the rate of eye blinking in both normal and sleepy situations. The eye aspect ratio (EAR) is calculated by using a total of 12 points, with 6 points for each eye as. A camera mounted on the dashboard takes footage of the driver's eye condition, and the 68 FLP evaluates the ratio according to its functioning mechanism.

$$\text{EAR} = \frac{||p2 - p6|| + ||p3 - p5||}{2\,||p1 - p4||}$$

Figure 3 shows six points on each eye, numbered p1 to p6. The prototype starts calculation to identify the EAR after scanning these spots for both eyes. In Figure 3(a) the system recognizes the eyes as open if the measured ratio exceeds the threshold (0.25). In Figure 3(b) the system considers the eye status closed if the ratio is less than 0.25. The prototype uses the average value of a few ratios over a period of time to obtain more accurate results [20]. If the average value remains below the threshold, the system sends a signal to the alarm to begin buzzing and alerting the driver. At the same time, a text SMS will be sent to the associated phone number. This is a continual procedure that looks for signs of tiredness in the driver's eyes and any unusual facial expressions.



(a) (b)

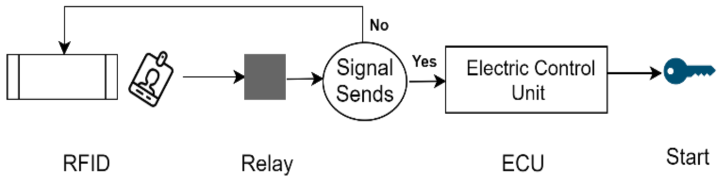
Figure 3. EAR points (a) open condition and (b) close condition

3.3. Alcohol and smoking sensor

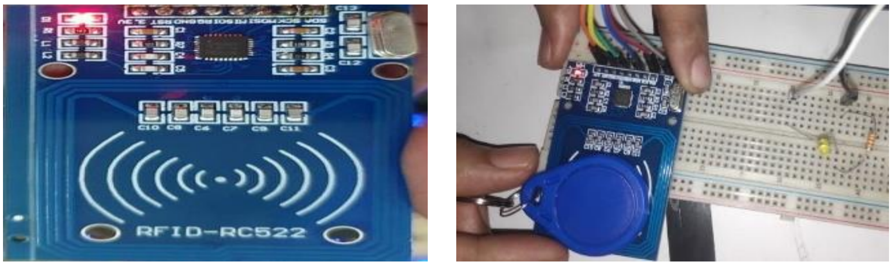
For detecting alcohol consumption, a sensor named MQ3 is used here. This sensor can detect the presence of alcohol in a person's breath as well as in the nearby surroundings. This sensor is capable of detecting concentrations ranging from 25 to 500 parts per million (ppm). If the amount of alcohol consumption is higher, the sensor initiates a procedure in which the LED blinks rapidly. The more the consumption, the more blinking there will be. The MQ2 sensor is used in this system to detect the level of smoke or any combustible gas created inside the vehicle. MQ2 can detect any volume between 200 and 10,000 ppm. This sensor's sensitivity increases if it detects any gas or smoke in close surroundings. For both circumstances, a text SMS will be sent to the appropriate authority.

3.4. Radio frequency identification

In this project, a RFID-based locker system is used to improve the vehicle's security system. Figure 4 shows the implementation and working process of RFID. The important pieces of information about the vehicle (registration, insurance) as well as the information about the owner and driver (name, address, driving license) must be included in this RFID card. A driver should have to punch his card into the RFID reader before starting the engine. The relay will deliver a positive signal to the electric control unit (ECU) if all of the data matches the pre-defined information. The ECU will only allow the driver to start the car after receiving a positive signal from the relay. Otherwise, the driver will not be able to start the engine. Before starting the engine, the entire operation will take no more than 4-5 seconds. Figure 4(a) displays the working procedure, whereas Figures 4(b) and 4(c) depict the RFID hardware implementation.



(a)



(b) (c)

Figure 4. Implementation of RFID (a) flow diagram of RFID, (b) RFID module, and (c) hardware setup

Furthermore, while parking in a restricted area or a shopping center, the driver's and owner's names and phone numbers, as well as the vehicle's number, must be written down. Scanning the RFID’s QR code and collecting that information digitally may save a lot of time. When an unfamiliar vehicle enters any major government buildings or in hilly areas, this procedure might be performed.

3.5. Tracking system

The "Panic button" is integrated into this system to ensure human safety. The primary goal of this button is to catch the attention of any law enforcement agency during a life-threatening situation. The prototype collects GPS data when the button is pushed. The system has several pre-defined "zones" and "sub-zones". A zone is defined as a specific region, and the roads or blocks inside that zone are called sub-zones. The main advantage of selecting a zone is to get immediate assistance from anybody. Because robbery is a rapid activity that takes place in a short period of time. As a result, the victim needs immediate assistance. If a person is attacked in one location, but assistance arrives from 20 kilometers away, it will not be a feasible option. To avoid this situation, the concept of selecting a zone and subzone appeared to send an emergency rescue attempt to the victim. For the highway cases, per kilometer is considered a sub-zone. The GPS data for a running vehicle will be updated every 30 seconds to provide the specific location.

In the algorithm, there are some pre-defined emergency numbers for police stations, checkpoints, and voluntary organizations. The prototype sends an emergency signal to the nearby police checkpoints as well as the volunteers after pressing the button. In case of the unavailability of the nearest check post, the system immediately transmits all relevant data to the national emergency number for further action.

Figure 5 shows how the vehicle tracking system will work. In Figure 5(a), a "zone" is considered as a particular region while Figure 5(b) indicates a block that is regarded as a "sub-zone". One car (victim) became trapped in a risky scenario and used the panic button to get assistance. After receiving a signal from the vehicle, one police car approaches the victim to provide security. In Addition, according to the victim's GPS, one volunteer from the voluntary organization is heading to the location to offer support to the victim. This is how it works with the panic button. This prototype utilizes google map to collect the coordinates to generate a bounding box. Each of the four corners of this box has four sets of latitude and longitude, each with a maximum and minimum point. The victim’s vehicle also bears one location coordinate. All locations within this range can easily be recognized by following the inequalities listed (1) and (2) [30].

$$Minimum\ latitude\ \leq\ vehicle's\ latitude\ \leq\ maximum\ latitude \tag{1}$$

$$Minimum\ longitude\ \leq\ vehicle's\ longitude\ \leq\ maximum\ longitude \tag{2}$$

If the vehicle's latitude and longitude endpoints are equal or inside the bounding box, the vehicle is generally considered to be within that sub-zone by this prototype. Figure 5(c) presents the coordinate points for the bounding box, as well as the victim's location. The victim's latitude and longitude must be between the highest and lowest latitude and longitude, according to inequalities (1) and (2). The victim's latitude and longitude are 23°48'51.4"N and 90°25'39.3"E, respectively. As a result, this latitude and longitude are inside the maximum and minimum points. By using this approach, the sub-zone computation is done.

If the prototype fails to identify all four sets of latitude and longitude, another formula known as the "Haversine formula" will be used. Two sets of latitude and longitude are required to use this formula. Among them, the victim's vehicle will continually transmit one set. So, this formula will work if the prototype can locate at least one set from the map. The formula is employed in this system to obtain the accurate coordinate value. This formula can be used to calculate the great circle distance between two spots [30], [31]. For given two points on a sphere:

$$\mathrm{haversin}\left(\frac{d}{r}\right) = \mathrm{haversin}\ (\alpha 2 - \alpha 1) + \cos\ (\alpha 1).\cos\ (\alpha 2).\mathrm{haversin}\ (\beta 2 - \beta 1) \tag{3}$$

here,

$$d/r\ =\ central\ angle\ (radius) \tag{4}$$

in this formula,

$$haversin = Haversine\ function\ [\mathrm{haversin}(\theta) =\ \sin^2\left(\frac{\theta}{2}\right) = \frac{1-\cos(\theta)}{2}] \tag{5}$$

in (4), by applying inverse haversine,

$$d = r.\,haversin^{-1}(h) = 2r.\arcsin(\sqrt{h})$$
$$d = 2r.\arcsin(\sqrt{haversin\,(\alpha 2-\alpha 1)+\cos\,(\alpha 1).\cos\,(\alpha 2).\,haversin\,(\beta 2-\beta 1)}\,) \quad (6)$$
$$d == 2r.\arcsin(\sqrt{\sin^2\left(\frac{\Delta\alpha}{2}\right)+\cos\,(\alpha 1).\cos\,(\alpha 2).\sin^2\left(\frac{\Delta\beta}{2}\right)}\,)$$

(a)

(b)

(c)

Figure 5. Tracking system in an area (a) zone, (b) sub-zone, and (c) coordinate points of the bounding box

The prototype can calculate the distance using this formula. If the measured distance is within 2 kilometers, the prototype will send out a rapid response signal within 2 kilometers on each side of the car. If the distance is greater, the prototype will choose the next subzone to send the rescue signal to the pre-set phone numbers. Figure 6 depicts the flow diagram of this process. The Raspberry Pi stores all of the information. Following that, various pieces of data are uploaded to the Firebase server for further processing. For many IoT-based applications, Firebase is an efficient server for preserving real-time data [32], [33]. This server saves all of the data associated with the vehicle's registration numbers. All of the variables and scenarios are kept in JavaScript object notation (JSON) format in firebase. These data can be obtained in CSV format if required. Any data may be checked at any moment to assess the state of the vehicle. This file also contains real-time data, allowing for a proper inquiry following an accident.

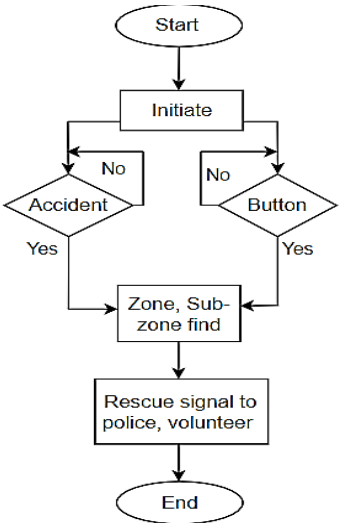


Figure 6. Flow diagram of tracking system

3.6. System prototype

The simulated design before building the system and the corresponding prototype are shown in Figure 7. Figure 7(a) depicts a three-dimensional image of our suggested model, comprising LiDAR, display, buzzer, and camera. The other one, 7(b), is a front view of our car. Figures 7(c) and 7(d) depict the hardware model and the vehicle in motion, with the driver seated in his seat. This prototype vehicle is considered for a single person and a few loads.

(a) (b) (c) (d)

Figure 7. Prototype of (a) full proposed model, (b) front view, (c) hardware model, and (d) running condition

3.7. System evaluation

Figure 8 shows the outputs of the various warning features of the system through the display screen. Figure 8(a) depicts how LiDAR identifies an item near the smart car and presents warning information on the monitor. The car exceeded the limit, as shown in Figure 8(b). Figure 8(c) identifies the eye's condition as sleepy when the EAR is less than 0.25. As a result, the motorist receives an SMS warning. If alcohol is discovered in the vehicle, the system will provide the information indicated in Figure 8(d). The suggested model's performance and implementation consequences are shown below.

(a) (b) (c) (d)

Figure 8. Display screen (a) object detected, (b) over speeding, (c) drowsiness detected, and (d) alcohol detected

Figure 9 shows the output from the RFID and camera modules. Two sets of notification text are shown in Figures 9(a) and 9(b), which illustrate the RFID state. Figures 9(c) and 9(d) displays the state of a driver's eyes for detecting tiredness. In Figure 9(c), the EAR is 0.18, which is below the 0.25 criterion. As a result, the suggested prototype considered the situation as the eyes were closed. Figure 9(d) shows that the EAR is 0.36 and classed as an open eye condition. Figure 10 shows some warning information from the GSM module, where 10 (a) shows drowsy driving and 10 (b) shows over speed driving notification.

(a) (b)

(c) (d)

Figure 9. RFID (a) not matched (b) matched, Eyes (c) closed (EAR=0.18), and (d) opened (EAR = 0.36)

(a) (b)

Figure 10. Warning information (a) drowsiness detected and (b) over-speed condition

4. COMPARISON BETWEEN EXISTING AND PROPOSED SYSTEM

Each project has some unique qualities. Those qualities increase the project's profitability and productivity. Among the many contrasts between the existing and suggested models, these are a few of the main fundamentals. To highlight the differences, a few sets of comparisons between today's technology and our suggested approach is included in Table 1.

Table 1. Comparison between existing and proposed system

Features	Proposed systems	Existing systems
Storage of Information	Firebase	SD Card [34], [38], [45]
Working microcontroller	Raspberry Pi	PIC16F877A microcontroller [35], Arduino UNO [41], Arduino Mega 2560 [42]
Drowsiness detector	EAR through 68 landmark points	Eye blink sensor [37], [43]
Object detection	LIDAR	Ultrasonic ranging module HC-SR04 [38], proximity sensor [44]
Security of the Vehicle	RFID key	Blynk mobile application [39]
Seat belt detection	Camera	Seat belt sensor [40]
Speed check	In-vehicle display and text via GSM	Flashing light [36]
Information about Danger	Panic button signal by creating zone and sub-zone	Piezoelectric sensor [43]
Sending information	Using GSM through Firebase server	Bluetooth module [43]
Alcohol/smoking check	MQ3 sensor, MQ2 sensor	Gas sensor [44]

5. NOVELTY

One of the key considerations of this prototype is to capture all information and then store it for later study to reduce the rate of accidents. The firebase server is a better way of storing data rather than the secure digital (SD) card even without the internet. Another important aspect of this system is that it sends the rescue signal to the nearest police station. When the panic button is pressed or an accident occurs, the system will detect the location. Another addition is identifying the driver's drowsiness using 68 FLP, which is a standard way of assessing the mouth and eye aspect ratios. In the case of an occurrence, the authorities can get the information from the server.

6. CONCLUSION

Image processing can be used in the system to obtain precise readings. Many artificial intelligence (AI) based technologies, such as machine learning (ML) and computer vision (CV), may be employed in this prototype to determine the precise facial expression of the driver. Safe parking assistance and an automated speed reduction method can be introduced in this black box device. Although the rate of accidents will not be lowered immediately, this technique may assist to minimize it. To keep track of these records, a committee of experts could be formed, with the goal of determining the true cause of any accident and proposing a better way to prevent it. As a result, we may predict a community with fewer accidents in the future.

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