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Driver Assistance System using Raspberry Pi and Haar Cascade Classifiers

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***Abstract*—Around 43% of road accidents are due to drowsiness of a driver, says a study by the Central Road Research Institute (CRRI). Another leading cause for road accidents is drunken driving. Any amount of alcohol can impact a person's driving ability and slows their response time. On an average 8 people die every day because of driving under the influence of alcohol. In case of an accident to reduce the fatalities and get quick emergency response a vehicle crash detection mechanism is necessary. Road accidents claim nearly three lives every minute, so it is of utmost importance to develop a cost-efficient driver assistance system for automobiles. This will help us to monitor the driver's physiological behaviors which will affect the stability of the vehicle and avoid accidents. To implement this, a variety of software algorithms, input and output extraction hardware tools have been employed in a collaborative way. The system developed consists of three interconnected modules namely, driver drowsiness detection using Haar cascade classifier and OpenCV, followed by alcohol content detection using MQ3 sensor and lastly the accident/crash detection using Piezoelectric sensor. To detect the onset of fatigue or loss of vigilance of the driver, within the close vicinity of the driver multiple sensors are embedded on this prototype.**

Keywords—Integrated system, Drowsiness, Image Processing, Haar Cascade Classifier, OpenCV, Alcohol detection, MQ3 sensor, Raspberry Pi, Piezoelectric sensor .

I. INTRODUCTION

Vehicle crash often lead to internal as well as external injury, damage to property, disability and sometimes even death. Each year, 1.35 million people are killed in an accident around the world. Near about 3,700 people are killed every day globally, in accidents. Traffic collisions have become a major concern for the government, and it even compromises the welfare of the people. The seventh leading cause of death all over the world is road accidents. It has caused death globally for citizens of all age groups especially people between 5-30 years of age were involved in about 60% of the accidents. It is estimated that from 2015–2030, treatment for small and severe crash injuries will cost the economy of the world about approximately $2.6 trillion dollars (in 2017 USD). That's nearly around 0.28% of the yearly tax on global GDP.

A driver might not even know when he or she is fatigued because signs of fatigue are hard to identify. Fatigue or Drowsiness can be described as the physical state of extreme tiredness and lack of energy. They show symptoms like yawning, shaking head, frequent eye-closure etc. A driver at this state will tend to lose their vigilance over the steering of the vehicle. In the 4 or 5 seconds at highway speed, the vehicle will travel the length of a football field. The effect of alcohol can affect the motor skills of the driver. As a result, the coordination skills and ability to handle the likelihood of an accident is compromised. Most of the crashes happens when the blood alcohol content (BAC) level of the driver is of at least 0.08%. Individuals between the age group of 21-24 are the most affected in alcohol related accidents. It is obligatory to develop and design a system that has the competence to both detect and monitor the drunken or drowsy driver and inform the designated users of the current situation. Even under undesirable circumstances such as dim lighting, thermal and vibratory shocks, damp humidity the system needs to be robust and effective.

The prototype consists of three main modules, starting with drowsiness detection phase relied on the concepts of object detection framework. This concept is applied by subjecting both eyes and face to localization and tracking at the same time. The second module being alcohol content detection mechanism whose underlying principle is the concepts of electrochemistry. The principle of breath analyser used by the traffic police is used here. The detection in the gas sensor is done by oxidizing or reducing the ethanol gas molecule which are absorbed by the built-in electrode in its close proximity. The voltage is generated to Raspberry Pi board as a result of an electrochemical reaction. The last module being the vehicle crash detection mechanism depends on the piezoelectricity completely. In this scenario when an automobile undergoes an accident, the vibrations and shocks (mechanical energy) produced are converted into direct current electrical energy by the piezoelectric sensor. When the required voltage is generated the Raspberry Pi gets the message.

The end phase system chosen is Internet of things (IoT). Now that all the inputs have been extracted to perform the analysis of alertness deficiency, we design a fast and durable output end system. The IoT system has the facility to inform the designated users about the prevailing situation via android app through messages and mail without any discrepancies.

II. Related Works

In the precursor techniques, data used for driver monitoring systems were analog and physiological in nature just like the ECG (Electrocardiogram), EEG (Electroencephalogram), Galvanic skin response, blink amplitude, body temperature, Heartbeat rate and many more [1][2]. For enhancement of the system, they were utilized in a collaborative manner. To ensure accuracy the above-mentioned signals were utilized in a collective way. The main issue with these systems was that they used a lot of wires and complex hardware connections. Aside from the physiological analog signals, PERCLOS [4] was one metric which was widely utilized in facial recognition and eye-tracking.

TABLE I. Review of Peer Research Works

Authors	Proposed method
Anuva Chowdhury et al.,2018	Data used for driver monitoring systems were analog and physiological in nature just like the ECG,EEG,EOG,Galvanic skin response, blink amplitude, body temperature[1]
Huang et al., 2019	Holo Lens-based face detection, enabling supplementation and superposition of real and virtual information. Used multiple cameras to record facial expressions.[6]
Zaldivar et al., 2011	OBD interface was used to detect vehicular or automobile collision. The prototype made use of OBD-II devices and smartphones, where the automobile or vehicular crash was detected using this OBD (On-board diagnostics) .[11]
P. Viola and M. Jones, 2001	Object detection frameworks which perform multiple convolutions and segmentations to classify the objects based on the trained datasets. The OpenCV and Haar cascade algorithm are collaboratively used to perform the process of object classification.[7]
Sakairi 2012	Alcohol content detection is performed using water-cluster detecting.WCD breadth sensors were employed which is coupled with alcohol sensor to detect electric current from alcohol.[12]
Javed Ahmed et al, 2015	Non-intrusive computer vision system developed to concentrate the eyes of driver and check the drowsiness using image processing techniques [4]

The Haar cascade algorithm has been used collaboratively for our classifier used in this prototype. To detect drowsiness some techniques used LEDs and multiple cameras to record the facial expressions [6]. But these methods faced a lot of setbacks when the cameras were subjected to variable lighting and running backgrounds. Finally, the eye openness evaluation was calculated by techniques like the Spectral regression embedding (SR). Here we get know about the model of the eye shape by applying SR on the segmented eye image [7]. The former methods for alcohol content detection were primarily based on the analysis of driver behavior like continuous closing of eyes, Lane maintenance, Speeding, insobriety due to drinks and much more. Water-Cluster detection (WCD) breadth sensors [8] where also used for some prototypes. The extraction part handling the mechanism of vehicle crash detection also had seen many techniques along the ages. Some of them even constituted of digital devices like android phones and sensors. One such prototype made use of OBD-II devices and smartphones [9], where the automobile or vehicular crash was detected using this OBD (On-board diagnostics)

III. Proposed System

The proposed system consists of three modules as shown in Fig.1 namely drowsiness detection, alcohol detection, crash detection.

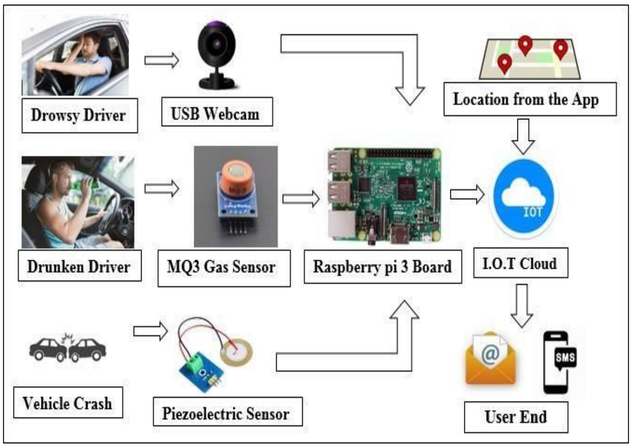

Fig. 1 Architecture of the Proposed System

A. Drowsiness Detection Mechanism

The webcam is utilized to obtain the video feed which records the driver's face continuously. The video is loaded into program in grayscale mode for better performance and sampling is performed to get the discrete frames where we have applied Viola Jones algorithm to perform eye detection and tracking [7].

The algorithm has four phases:

1. Selection of Haar Features
2. Creation of Integral Images
3. Adaboost Training
4. Cascading Classifiers

The initial step for localization of eyes is the detection of human face which is performed by the Haar features. They are widely used in object detection frameworks. Haar features are sequences of rescaled square shape functions which are similar to convolution kernels in the Convolution Neural Networks. It consists of two classes namely edge features and line features proposed by Viola Jones algorithm. Edge features are able to detect edges effectively like the lips, eyebrows etc. While line features are able to detect lines like the nose bridge where there is a sudden change in intensities of pixels. The Haar Cascade algorithm applies the above-mentioned features on the discrete images to calculate the pixel intensities as shown in Fig 2.

$$\Delta = (\text{Sum of Black pixel intensities}) - (\text{Sum of white pixel intensities}) = \left(\frac{1}{n}\right) * \sum I(x) \qquad (1)$$

Where I(x) – Pixel intensities

n – Number of black or white pixels

The intensities of the pixels are separated as dark and light regions and are summed up and then subtracted against each other to determine the delta which forms the integral image. The integral images are used for accelerating the feature evaluation. Adaboost boosting algorithm is used to improve the efficiency of the neural networks [7]. It is utilized to form strong and weak classifiers to create a cascade classifier which discards images which are not classified as faces and improves the accuracy. It selects the best features out of several thousand features and trains the classifiers to use them. The weak classifiers are threshold functions based on the features *fj*.

$$H(X) = SGN\,(\Sigma AJHJ(X)) \qquad (2)$$

$$hj(x) = \begin{cases} -Sj & \text{if } fj < \theta j \\ +Sj & \text{if } fj > \theta j \end{cases} \qquad (3)$$

H(x) – Strong classifier
hj(x) – Weak classifier
αj – Weights to boost the performance of the weak classifiers
Sj – Polarity (either -1 or 1)
θj – Threshold value based on features

The final stage is to cascade the classifiers. The features are clustered into different stages of classifiers and applied one-by-one. If a window goes beyond the stage one, apply the stage two of features, if not reject it. Window which goes beyond all stages is the face zone. In this way we can reduce of the number of features being applied on a single window. The face and eyes are now continuously monitored after the process of recognition. The system continues to track the eyes while they are open. If the eyes get closed, the classifier no longer detects the target, and it starts the counter. If the counter value becomes greater than or equal to the threshold value which is set by the user to determine drowsiness, data is sent to the Raspberry Pi[10]. The data is immediately recognized at the Raspberry Pi3 minicomputer and location available in the phone of the driver to be taken by the Raspberry Pi is sent to the owner of the Vehicle as both SMS and an E-Mail. The Data is initially being fetched from the Driver's phone and it is uploaded to the Firebase for processing it.

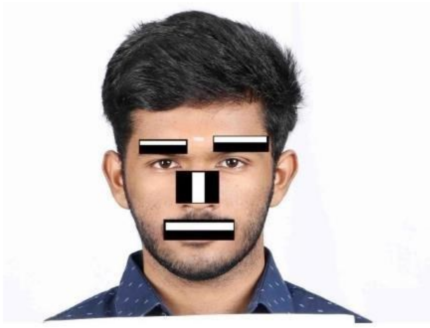
Fig. 2 Illustration of Line and Edge Features

B. Alcohol Content Detection

MQ gas sensors are widely used nowadays which takes less than 0.5 seconds and high sensitivity to detect liquor content. In this project, we have implemented MQ3 gas sensors, as it recognizes ethanol gas molecules at concentrations from 0.05mg/L to 10mg/L. The sensor operates on temperature between -10°C and 70°C, works on 5V DC and draws around 800mW.It is employed in the breath analyzers used by the traffic policemen.

The sensor is made up of primarily Aluminum oxide and Tin Dioxide. When clean air passes through the sensor, Sn02 attracts the oxygen molecules and potential barrier is formed below the surface of Tin dioxide particles due to the formation of electron depletion layer. When alcohol is detected, oxygen density is reduced which results in the lowering of potential barrier. The conductivity of Tin Dioxide increases with respect to the concentration of alcohol which results in the current flow [9] and generates the potential difference. This analog voltage generated is converted into digital data using an ADC and is received at the Raspberry pi and status as 'Drunken' is sent to the user via email.

Steps involved:

- Diffusion of alcohol molecules through the oxide membrane
- Electrochemical oxidation or reduction takes place
- Voltage is generated through the external circuit
- Status is sent to the user via email

C. Vehicle Crash Detection

The last input extraction module after the Alcohol content detection and the Drowsiness Detection Mechanism is the Vehicular crash detection mechanism. We have used the piezoelectric sensor also known as the vibration sensor to implement this module. The piezoelectric sensor essentially uses the piezoelectric effect by converting physical variation in pressure, strain, force or acceleration into an electrical current.

Steps involved:

- Detect collision as a form of Vibration
- Measure magnitude of Vibration (ms2 or N) is taken from the sensor
- The measure is checked for a threshold to differentiate accidents from usual bumps
- An Analog signal is created as per the pressure produced
- ADC and Data sent to Raspberry pi

The piezoelectric or vibration sensor is an electrical combination of a voltage source and a filter network consisting of capacitances and inductances. The voltage produced is directly proportional to the applied mechanical force. The pressure is usually applied transversely or longitudinally or along with the piezoelectric sensor. These pressure or strains cause the occurrence of electric dipole moments in the solids due to the force applied on the piezoelectric material like quartz etc. The amount of charge displaced depends directly on the piezoelectric coefficient and the dimensions of the sensor. The amount of charge can be calculated mathematically using:

$$Q_x = d_x * F_y * \left(\frac{b}{a}\right) \tag{5}$$

$$I(t) = {dQ_x}/{dt} \tag{6}$$

Q_x – Amount of charge displaced in the x-axis

d_{xy} –Piezoelectric coefficient

F_y –Force applied on the neutral y-axis

a,b –Dimensions of the sensor

I(t) –Current generated during the process

IV. EXPERIMENTAL SETUP

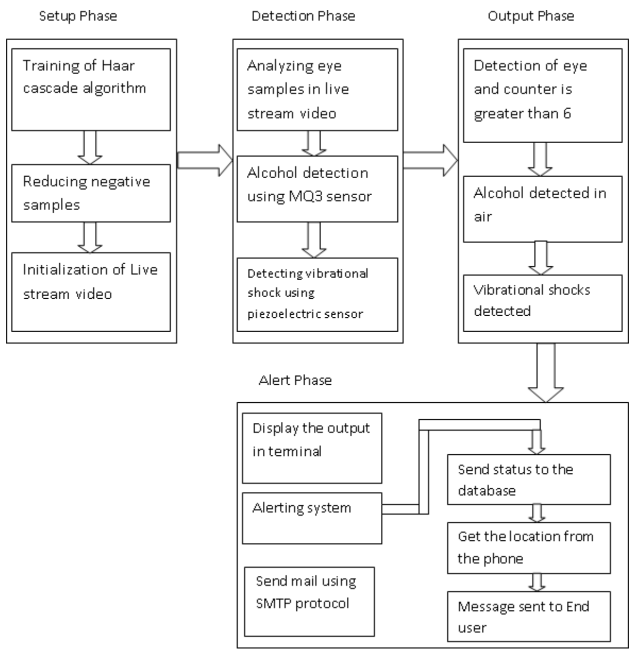

Fig 3. Four Phases of the System

The four phases of the system are shown in figure 3. The First phase is the setup phase used for training the classifiers for drowsiness detection. Next is the detection phase where input is received from all the three modules and the physiological state of the driver is closely monitored. The next phase is the output phase which is used to analyze the results from the detection phase using Raspberry pi and the information is sent to the alert phase. The final phase is the alert phase where the designated user is alerted using IoT devices.

A. Setup Phase

The first phase of the project is used to train Haar cascade classifiers with data sets which consist of classes that are created using eye and facial samples. The eye samples are cropped out of faces for better accuracy. The data set is stored in the Raspberry pi which is also called a minicomputer. With help of the modules, the OpenCV automatically applies bounding boxes and automatically resizes the images as shown in Fig5. Initially, the images are captured using a USB webcam which is connected to the Raspberry Pi minicomputer in one of its USB ports. The HAAR cascade classifier is applied to this live streaming video to analyze the physiological state of the driver. The sensor used in this prototype does not require any initial training.

B. Detection Phase

The second phase is the Detection phase and its primary focus is to monitor target objects like face and alcohol content in the car. The bounding boxes are used to localize the eyes so that the eyes are closely monitored. In the Alcohol detection mechanism, an MQ3 sensor is used to analyze the ethanol content in the air. Adsorption takes place when alcohol molecules come in contact with the MQ3 sensor. Alcohol molecules are nothing but ethanol particles (C_2H_5OH). The gas sensor is placed straight to the driver's face so that efficient sensing of Alcohol molecules. The magnitude of the force threshold is set by the user in order to distinguish the vehicle crash force magnitude from the rest.

C. Output Phase

The important phase of the prototype is the output phase where the facial elements are closely monitored. Buzzers are activated to alert the passengers and driver if the eye is closed for more than 6 seconds. Buzzers go high if the excess alcohol content is present in air or vibration shock greater than the threshold is detected by the sensor. These data are sent to the raspberry pi which is the main component of this prototype. The output for each scenario is stored as algorithms in Raspberry pi. The DC motor stops immediately after the buzzers go high indicating that the vehicle has stopped.

D. Alert Phase

The final phase is the alerting phase in which the end-user is alerted using IoT components. The Buzzer is an internal caution device whereas these Short Message Service (SMS) and Global Positioning System (GPS) location tracking come under cloud computing and are external in this case. SMTP (Simple Mail Transfer Protocol) is used to send an email to the end-user with the type of event that occurred as shown in Fig 7. The Data is initially being fetched from the Driver's phone and it is uploaded to the Firebase for processing. The type of alert system can be chosen by the user like whether a mail has to be sent or an SMS is sent or an entry is to be made on the app of the user. The result is projected along with the latitudinal and longitudinal coordinates of the vehicle as shown in Fig 8. Also, the app is logged in previously by the driver, so that the agencies/owner can distinguish between their drivers.

V. Results and Discussion

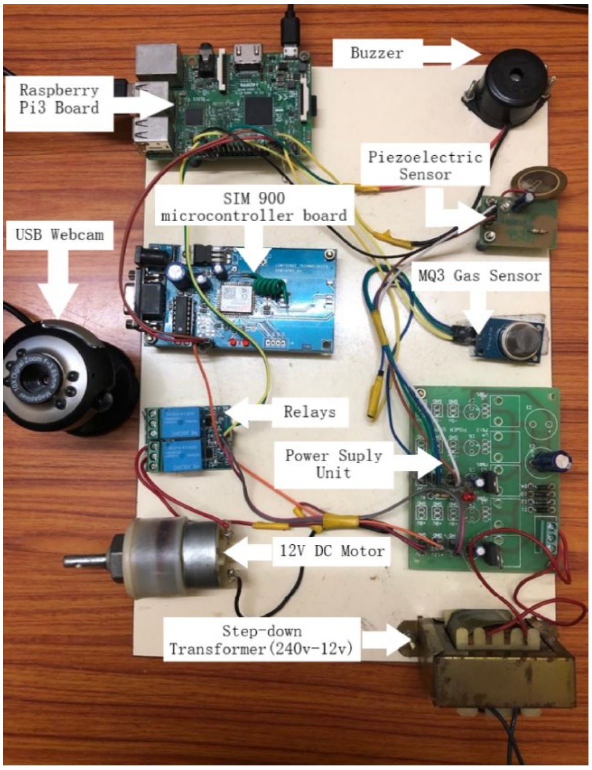

Fig 4. Hardware Setup

The hardware setup of the proposed work is shown in figure 4. As the system executes, the popup appears so that the driver can adjust his seating position to face the camera. In a drowsiness detection mechanism, the bounding boxes localize the eyes and start to monitor them as shown in figure 5.

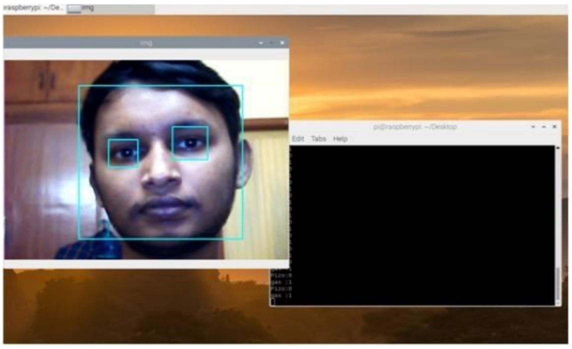

Fig. 5 Eye Closure Detection

The eye is localised instantly after starting the prototype. After the eye is detected, the USB camera continuously monitors the facial interactions of the driver. A counter is initialized if the eye is closed.

TABLE II. PERFORMANCE ANALYSIS

Parameters	Time Duration
Time to recognise eyes	2 seconds
Time to detect Sleepiness of driver	4 seconds (Variable)
Time to detect Vehicle crash	1 second
Time to detect Alcohol content	1 second
Time to send Message	3 seconds

Performance Metric is assessed using different real time scenarios the results of which are shown in Table 2. If the count in the counter is more than 6 seconds, then the driver is considered sleepy and data is sent to Raspberrypi. The minicomputer stores this information. From there notification about the scenario is sent to designated drivers, passengers and users through SMS and mail.

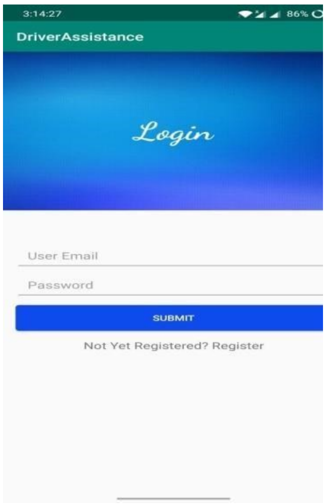

Fig. 6. Login Screen

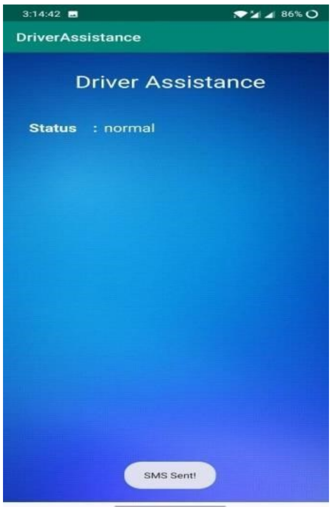

Fig. 7 Driver Status in App

End users can view the information regarding the driver's physiological state and location coordinates during the alert phase. A database in Firebase stores the information regarding the location of the vehicle when an accident occurs. The android application is used to extract the location of the driver which is secured using User Id and Password as shown in Fig 6. The android application is created in Android Studio and it is installed in Driver's mobile to monitor him as shown in Fig 7.

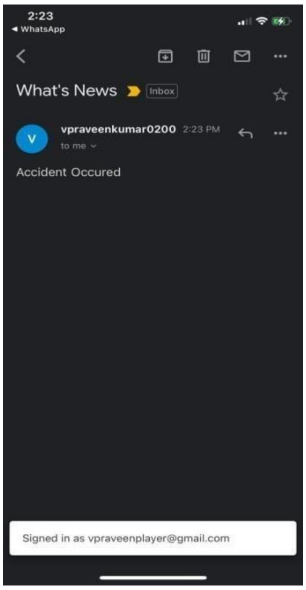

Fig. 8 Email Alert

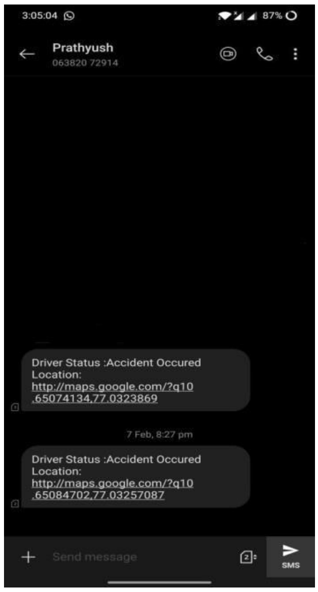

Fig. 9 SMS Alert

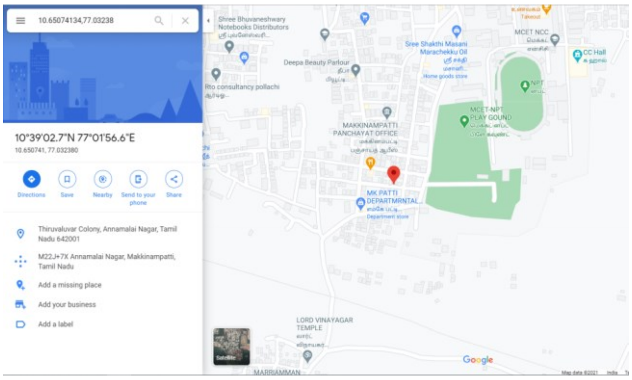

Fig.10 Location Identification in App

The accuracy of the Location is perfect as the app uses the GPS used in the mobile. Sample of one scenario is shown in figure 10. The Locations embedded in the message can be directly viewed in Google maps by clicking the link in SMS received.

The features of the proposed work are list below.

1. We have implemented an integrated model with multiple sensors and varied functions.
2. This helped us achieve a desirable outcome. This is

a cost-efficient model built using optimal and need-only basis components.

3. This provides the best available features. In this system, to achieve immediate communication, the alert message is sent within a few seconds.
4. A basic internet connection is required for the prototype to run in the vehicle.
5. As the location is sent to the owner, quick recovery in times of crisis and casualties can be reduced in case of accidents

VI. Conclusion

In this paper, we have given detailed information on how we have designed and implemented the driver assistance system using several hardware components and software algorithms with compatibility and cost-efficiency. The main motive of this work is to ensure the safety and security of drivers and passengers travelling in the vehicle. There are lots of researches related to this line of work, but our work validates and extracts input from multiple sensors and is digitally processed and delivered instantaneously to the end-user. The alert delivery schemes used in the system are compact and fit for daily use. These were possible only because of the underlying foundation of the IoT. The components used in this prototype are cost efficient and can be used in challenging conditions. The utilization of a much-advanced futuristic technology also adds novelty to our project which many researchers missed using in the past.

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