ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24NOV581

Comprehensive Systems Review for Accident Detection, Prevention, and Real-Time Alerting Mechanisms

[1]Khelan Vaishnav; [2] Rudra Joshi; [3]Parul.H. Panchal
[1]Department of Electronics Engineering,
Birla Vishwakarma Mahavidyalaya, VVnagar, Anand, Gujarat, India

Abstract:- The growth of technology and infrastructure at a rapid pace has made our lives easier. The increased frequency of road accidents and possible traffic dangers brought about by newer technologies has resulted in a significant loss of life and property due to inadequate emergency facilities and preventive measures. The greatest hazard to human life is traffic accidents. High speeds combined with intoxication are the main causes of many accidents. Vehicle safety and accident prevention and detection systems are important because they reduce the number of accidents and the time it takes for an accident to be recognized, allowing rescue personnel to attend to injured victims more quickly. This article presents the MCU-designed Vehicle Tracking and Accident Detection system along with several accident avoidance strategies.A prototype of an accident prevention & detection system using a vibration sensor as the detector and an ultrasonic sensor, or IR sensor, is to detect a signal in case of a near collision or a distance between two vehicles to prevent an accident. Even after this, if an accident occurs, they send a signal to the connected microcontroller via the vibration sensor. When the signal is received, the controller activates the relay, causing the airbag to deploy and the brakes to automatically lock. Meanwhile, a message is sent to the nearest help center, so ambulance service and other aid can come in the quickest time feasible.A black box gathers driving information before, during, and after a crash about the vehicle in which it is installed. The data collected by the black box includes speed, braking, acceleration, steering, and airbag deployment. The help can be provided in areas like vehicle safety, collision victim care, insurance corporations, vehicle crash investigations, and improving road conditions through the automotive black box system, which can reduce death rates to a significant level. The main aim of this paper is to include the overview and basics of certain techniques utilized to prevent, detect accidents, and alert the nearby help centers for the fastest aid in case of an accident.

Keywords:- *MCU, Vehicle Tracking, Microcontroller, Accelerometer Sensor, GSM & GPS Module, Vibration Sensor, Ultrasonic Sensor, IR Sensor. Black Box.*

I. INTRODUCTION

In today's society, the usage of cars is rapidly increasing. Such increasing car use has increased traffic, resulting in a spike in road accidents. This results in the loss of property and human life owing to the lack of quick safety facilities. Accidents cannot be completely avoided, but their consequences can be mitigated. The various systems have been proposed which attempts to minimize accidents as much as possible, but if one does occur, the system offers emergency services to victims in the shortest amount of time feasible. A very effective smartphone-based accident detection and notification system that will track the accident using sensors that have been placed. Data is processed through a microcontroller unit, and then using a Smartphone app GPS, GSM Modules, it will send an alert to the nearest emergency services and the victim's family in case of an accident. If an accident is on the verge of occurrence, then the sensors (Ultrasonic, IR) process the data and send it to the PIC microcontroller and alert the driver.

The entire setup is mounted in the car. An ultrasonic sensor is installed at various positions on the car, and a vibration sensor is used. Ultrasonic and infrared sensors detect distance and inform the driver if an impediment or vehicle is nearby. Vibration Sensors monitor the vibration at the location where it is installed. The signal is then compared to the standard values, which further confers the accident of the car, unnecessary shock or vibration caused by equipment. The tilt of the car with regard to the earth's axis can be determined by the level of acceleration measured by the accelerometer, which shows that the car is overturning at high speeds. GPS Module is used to determine the location of the vehicle.GSM is utilized to transmit the exact location of a vehicle to precoded/stored numbers. The message will include longitude and latitude information. These results allow us to pinpoint the location of the accident as well as the accident itself. The GSM modem uses a sim card to facilitate two-way communication. Such a module functions similarly to a standard phone.

People's lives are endangered due to a lack of adequate emergency facilities in our country. [1] introduces an automatic alert mechanism for vehicles that provides critical information to the medical team in a short period of time following an accident. This technology detects accidents and delivers an alert message to rescue responders in substantially

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24NOV581

less time, potentially saving people's lives.

If you are traveling at a safe speed on a moderately congested roadway. It hasn't been snowing for long, but the pavement is already covered with snow and getting hazardous. Suddenly, another driver indicates to join your lane and does a quick turn. To prevent colliding with the approaching car, you must engage your brakes. The hard braking totally locks the wheels at high speed, causing you to spin around. These kinds of situations have the potential to be quite deadly. ABS Braking System is a car security feature that can help prevent this type of incident. Accidents, even if they cannot be avoided, technology like the Internet of Things can reduce them with the correct safety measures. Some studies discuss the impact of meteorological conditions on the number of accidents, based on earlier publications.

Certain equipment commonly used in this type of system are listed below:

A. Vibration Sensor

A vibration sensor is a crucial instrument for condition monitoring and predictive maintenance in a variety of industries. It detects and monitors oscillations or vibrations caused by equipment, buildings, or natural events, allowing for the early detection of problems or inefficiencies. A vibration sensor's primary role is to transform mechanical motion into an electrical signal that can be examined to detect the vibration's frequency, amplitude, and intensity.

➢ *Types of Vibration Sensors*

- **Accelerometers**: These sensors are among the most widely used for vibration measurement. They measure the acceleration forces caused by vibration or movement and can capture high-frequency vibrations. Accelerometers are commonly found in industrial applications, machinery monitoring, and even in mobile devices.
- **Piezoelectric Sensors**: These sensors operate on the piezoelectric effect, where certain materials generate an electric charge in response to applied mechanical stress. Piezoelectric vibration sensors are highly sensitive and are suitable for detecting subtle vibrations, making them ideal for precision industries like aerospace or medical device manufacturing.
- **Velocity Sensors**: Velocity sensors measure the velocity of an object's movement due to vibration. They are particularly useful in applications where vibration frequency is lower, and their output is proportional to the speed of the moving parts being monitored.
- **Displacement Sensors**: These sensors measure the actual displacement or movement between two points due to vibration. Displacement sensors are suitable for monitoring slow-speed machines or large structures like bridges and buildings to detect shifts in alignment or structural integrity.

B. Global System for Mobile Communication (GSM) Module.

The Global System for Mobile Communication (GSM) module is a widely used communication technology in a variety of applications, most notably mobile communication. It is based on the GSM standard, which was created by the European Telecommunications Standards Institute (ETSI) to provide protocols for second-generation (2G) digital cellular networks. GSM modules allow devices to transmit and receive messages, voice calls, and data over the GSM network, making them essential components in many embedded systems, including mobile phones, IoT devices, and telemetry applications.

A GSM module is a hardware component that enables devices to communicate with a GSM network. It includes a SIM card slot for network authentication, and it can handle various functionalities, including:

- **Voice Communication**: The primary function of GSM technology is to transmit and receive voice calls over mobile networks. GSM modules can be embedded into devices to support this feature, allowing them to function as mobile communication terminals.
- **SMS Messaging**: GSM modules are widely used for short message service (SMS) capabilities. SMS is an essential function for many embedded systems, enabling the transmission of text messages between devices, including remote monitoring systems, alert systems, and personal communication devices.
- **Data Transmission**: While GSM primarily operates as a voice and text communication system, GSM modules can also handle data transmission, albeit at lower speeds compared to modern standards like 4G and 5G. GPRS (General Packet Radio Service) is often integrated with GSM for this purpose, allowing devices to connect to the internet or exchange small packets of data, such as sensor readings or device statuses.
- **Network Authentication**: GSM modules include a slot for a Subscriber Identity Module (SIM) card, which allows them to authenticate with a mobile network. The SIM card stores the International Mobile Subscriber Identity (IMSI), which is used to identify the device on the network and grant it access to services.

C. Global Positioning System Module

A Global location System (GPS) module is a specialized hardware device that uses signals from the GPS satellite constellation to provide exact location, navigation, and time. It acts as a bridge between GPS satellites and a host device (such as a mobile phone, car system, or IoT device) by processing location data and relaying it in useful formats.These satellites continuously send signals containing their precise time and position. GPS receivers on the ground collect signals from many satellites to compute their precise location via a technique known as trilateration.

Volume 9, Issue 11, November – 2024 International Journal of Innovative Science and Research Technology
ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24NOV581

➢ *Trilateration*

For determining the location, a GPS receiver must compute the distance between at least four satellites. This is accomplished by measuring the time required for the satellite's signal to reach the receiver. Because GPS signals move at the speed of light, the time difference between when the signal was delivered and received enables the receiver to determine the distance to the satellite. Once the distances between numerous satellites are established, the receiver can determine its position in three dimensions (latitude, longitude, and altitude).

D. Microcontroller Unit.

It processes the data that it gets from impact sensors and will make a decision whether the accident has occurred or not on the basis of threshold values provided initially to it. It will get the location coordinates through the GPS module, and it will in turn send the location coordinates to the app installed in the smartphone by making use of the Bluetooth module. It will also be capable of communicating through the SATCOM module in case the phone gets damaged during an accident and will send all the information to the SATCOM module for the reporting procedure. The MSP430 of Texas Instruments will be the best-suited option for the system because it has a large amount of buffer space, enhanced program flash memory, and low power consumption.

E. Ultrasonic Sensor

An ultrasonic sensor is a type of transducer that detects distance by producing ultrasonic sound waves and then interpreting the time it takes for the reflected waves (echo) to return to the sensor. These sensors are commonly employed in a variety of applications, including precision non-contact distance measuring, object detection, and ranging.

➢ *An Ultrasonic Sensor is Made up of the Following Key Components:*

- **Transducer**: The core component that converts electrical energy into ultrasonic sound waves and vice versa. The transducer can act as both a transmitter (emitting sound waves) and a receiver (detecting the reflected waves).
- **Control Circuit**: This component manages the timing of the transmission and reception of signals. It processes the time delay between sending the sound wave and receiving the echo to calculate the distance to the object.
- **Amplifier**: To enhance weak signals that return as echoes, many sensors include an amplifier that boosts the returning signal strength for better detection and accuracy.
- **Microcontroller Interface**: Ultrasonic sensors often provide an interface, such as UART or I2C, to connect to a microcontroller or processor, enabling integration with larger systems for automation, decision-making, or data logging.

➢ *Ultrasonic Sensors Come in Various Types Based on their Mode of Operation:*

- **Proximity Sensors**: These sensors detect the presence of an object within a certain range without necessarily measuring the exact distance. They are commonly used for collision avoidance systems in vehicles and robotics.
- **Ranging Sensors**: These sensors provide precise distance measurements by calculating the time taken for the sound waves to travel to an object and back. They are used in applications that require accurate positioning, such as industrial automation and robotics.
- **Dual Transducer Sensors**: Some ultrasonic sensors are equipped with two transducers—one dedicated to transmitting and the other to receiving—allowing for faster and more accurate measurements.

➢ *Block Diagram of Accident Prevention and Detection System:*

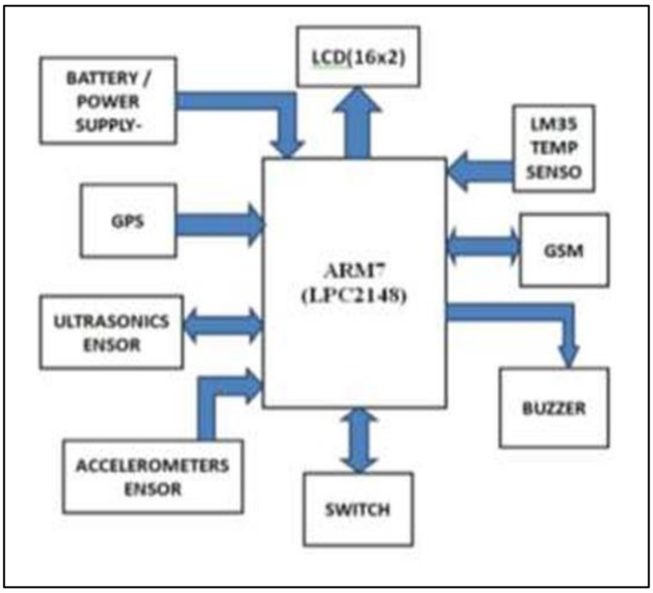

Fig 1: Overview

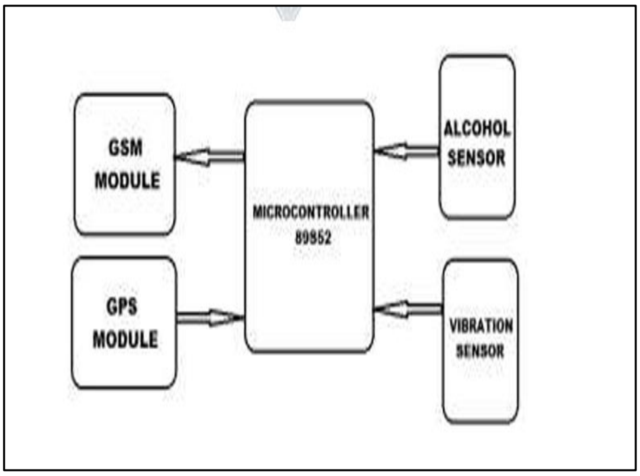

Fig 2: Overview

➢ *Figure 1 Overview*

The block diagram of Figure 1 shows us the use of ultrasonic sensors, vibration sensors (accelerometer sensors), Temperature Sensors, GSM, and GPS modules, along with other peripherals like buzzer switches, and LCD module connected to MCU(microcontroller units). The combination of all this makes an accident prevention as well as detection system. We can also deploy an alcohol sensor, which was

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24NOV581

suggested in [19], [20], to enhance our system performance and application.

➢ *Figure 2 Overview*

The block diagram of Figure 2 shows us the use of basic components like GPS, GSM modules, vibration sensors, and alcohol sensors connected to an MCU (microcontroller unit). This system is very basic and can efficiently detect an accident but cannot prevent the accident very efficiently compared to the system in Figure 1.

➢ *The Above Figures are Taken from the [1] and [2].*

- *Core System Components*

✓ **Vibration sensors, accelerometers, and MEMS sensors** detect impact collisions and unexpected motions(Turning of a car upside down).
✓ **The GPS module** tracks the vehicle's location by detecting its geographical coordinates and providing the exact position.
✓ **GSM Module**: It enables communication with the user or any pre-stored number by sending messages/alerts to it.
✓ **The microcontroller unit (MCU)** is the system's main unit, which processes sensor input data and controls the process of detection and alerting.
✓ **Proximity sensors** such as Ultrasonic sensors, IR sensors in the system are used to detect surrounding cars and barriers and alerts the driver if an obstacle is near. This plays a crucial part in accident prevention systems.
✓ **Alcohol Sensor** monitors the driver's intoxication level to avoid drunk driving. This is done by detecting the intoxication of a driver during the exhalation.

- *Switches/Buttons:*

A provision provided in the system that is manually activated by the user to disable an alarm in a non-critical circumstance. under a certain period of time.

➢ *Technical Aspects and Integration of System Components*

- *Accident Detection using Sensors*

✓ **Vibration Sensors**: These are piezoelectric sensors that detect vibration or shock when a vehicle hits an object, such as a collision. The vibration sensor detects abrupt movements or changes in the vehicle's status and transmits a signal to the microcontroller (MCU). **Accelerometers and MEMS sensors** monitor the rate at which the vehicle's velocity or direction changes. If the accelerometer detects fast deceleration (meaning an accident or rollover), it sends the information to the MCU for further processing.
✓ **Interaction with GPS**: A vibration sensor or accelerometer is triggered when a collision is detected, the Microcontroller Unit quickly gets the vehicle's location(GPS coordinates) by the GPS module. These coordinates show the precise location of the occurrence.
✓ **Signal Transmission via GSM**: When an accident is detected, the Microcontroller Unit activates the GSM module, which sends an alert message, including geographical coordinates of the location where accident is occured, to emergency contacts or service centers which is stored in the GSM module.

- *The Accident Prevention System*

✓ **Proximity Sensors and Driver Alerts:** Proximity sensors i.e(Ultrasonic Sensors, IR Sensor) continuously measures the distance between the vehicle and adjacent objects or cars. If a prospective collision is detected (i.e. detection of an item within a crucial range), the system through a MCU processes the Sensor Data and alerts the driver and, if necessary starts autonomous braking.
✓ **Autonomous Braking**: If the driver does not respond to the proximity warning within a particular time, Autonomous braking starts which reduces the vehicle's speed and brings it to a complete rest to avoid an accident.
✓ **Driver Alert System:** Apart from autonomous braking, the driver receives audio and visual alerts directing them to reduce the vehicle's speed or take appropriate action.

II. LITERATURE REVIEW

➢ *Some of the Important Literatures which have been Studied are Discussed Below:*

- The suggested GPS And GSM Based Accident Alarm System in [7] attempts to locate the vehicle accident site by delivering a message through a system installed within the car that includes GPS and GSM modules as well as a vibration sensor. In addition to GPS and GSM, assembly programming is employed to improve accuracy. In this project, when an accident occurs, the vibration sensor detects the signal and sends it to the MCU. The MCU delivers the alert message to an approved cellphone number via GSM. An alternate system is like pressing a switch, to halt the flow of delivering the message in the event of no casualties.
- Presented Automatic Vehicle Accident Detection System Based on ARM & GPS in [9] which includes a vibration sensor or a MEMS sensor, detects the vehicle's collision. The GPS module recorded the position of the automobile collision and delivered a message with the assistance of a GSM modem that included the coordinate values. Another feature is offered, which might be quite useful at critical moments. If a person need aid due to medical reasons, such as exhibiting signs of a heart attack, unconsciousness, etc., all that has to be done is to press a single switch given in the system.
- The suggested method in [2] improves vehicle monitoring and accident detection capabilities. Here, the MCU is employed to detect the occurrence of the accident using the vibration sensor. The GPS module is used to locate the car and map the coordinates of the detected accident, while the GSM module is used to relay the position collected by the supplied module to the customers' emergency contacts [2]. At the same time, a database is kept for customers who have this accident detection system installed in their vehicles. The database collects unique client IDs, necessary personal information,

possible accident detection sites in the form of coordinates, and so forth.This system provides an accurate, low-power, cost-effective, and efficient accident detection and tracking solution.

- The suggested method in [5] identifies the location of the accident and provides associated information. The study is underway to track the whereabouts of the vehicle even in dark, awkward places with no network for receiving signals. In this system, GPS is employed for vehicle tracking, which records the location of the car. Messages are delivered via GSM, and the ARM controller records the mobile number in the EEPROM and transmits them when an accident is detected. As a result of this project's execution, we will be able to determine the position of the car involved in the accident and offer first assistance as soon as feasible. Accelerometers can detect dangerous driving, and they are even used in Car Alarm Systems. This project is beneficial in detecting accidents accurately by employing both vibration sensors and Micro electro Mechanical system (MEMS) or accelerometer.
- The proposed seatbelt enforcement system in [6] is a crucial step toward increasing seatbelt compliance and overall vehicle safety. The device successfully prevents the driver from operating the car without wearing a seatbelt by using both an alert and an ignition interlock. This strategy has the potential to significantly reduce injuries and fatalities from traffic accidents, making it an important contribution to the field of automobile safety technology.When comparing this system with other seatbelt enforcement mechanisms described in the literature, the use of an ignition lock provides a more robust method of enforcing compliance than traditional seatbelt warning systems, which often rely only on visual or audible cues. For instance, earlier systems typically use an indicator light and a brief chime to alert the driver, but these systems can easily be bypassed. In contrast, the ignition lock ensures that the driver must wear the seatbelt in order to operate the vehicle, thereby ensuring active compliance
- The vehicle accident-avoidance system developed in [7] is a significant development in automobile safety. By combining proximity sensors, driver alerts, and autonomous braking, the system can detect and respond to possible accidents before they happen. Its capacity to monitor surrounding cars within a predetermined radius and take remedial action in crucial situations makes it an effective tool for decreasing traffic accidents and boosting driver safety. As technology advances, such systems are expected to become standard features in future automobiles, paving the path for safer roads and fewer traffic deaths.
- Compared to other systems stated in the literature, the vehicle accident-avoidance system proposed in [7] has similarities to existing collision avoidance systems (CAS) and adaptive cruise control (ACC). However, what sets the suggested system apart is its fixed detection radius and dynamic response based on the severity of the problem. Traditional collision avoidance systems depend heavily on forward-facing sensors and are primarily intended to avoid frontal collisions. In contrast, the system in [7] scans the vehicle's whole surroundings and may respond to cars approaching from any of the sides.
- The suggested system in [10] uses GPS and GSM modules to detect accidents, inform nearby medical clinics, and send messages to registered cell phones with accident data. The location can be provided by GPS Module, which records the vehicle's position and covers the geographical coordinates of the region. A vibration sensor detects an accident by sensing a change in frequency or vibrations of the vehicle and engine. It functions as a main module in the system.

➢ *The Research Work Done in [11] Gives us Certain Information Regarding Recent Studies, Overview of Some of them is Given Below:*

- The concept of **Vehicular Ad-hoc Networks (VANETs)** has been utilized to enhance road safety by enabling vehicles to function as nodes within a network. According to sources [13], [14], and [15], when an accident occurs, alert messages are disseminated through a **Radio Frequency (RF) module**, facilitating rapid communication between vehicles and potentially improving response times during emergencies. Various **preventive techniques** aimed at accident avoidance and life preservation have also been discussed in the literature. For instance, the system proposed in [16] emphasizes the safety of two-wheeled vehicles by monitoring the driver's alertness, specifically detecting drowsiness to mitigate the risk of accidents. In a different approach, the technique described in [17] employs an **accelerometer sensor** to monitor vehicle speed, issuing alerts when the speed falls below a predefined threshold, which may indicate a potential accident scenario. Moreover, additional systems highlighted in sources [20] and [21] focus on preventing driving under the influence of alcohol. These systems utilize **alcohol sensors** installed on the steering wheel to assess the driver’s intoxication level. If alcohol is detected in the driver's breath—measured through the alcohol content in exhaled oxygen—the system prohibits the vehicle from being operated, thereby enhancing road safety by reducing the likelihood of alcohol-related accidents. Collectively, these studies underscore the importance of integrating advanced technologies and sensors to develop effective preventive measures aimed at reducing accidents and safeguarding lives on the road.
- Study and research done in [19] proposes an IoT-based accident severity prediction system employing three machine learning methods: Random Forest, LightGBM, and XGBoost. The machine learning approach uses meteorological variables to forecast the severity of vehicle crashes.

➢ *The Following are this Work Areas Principal Contributions and Outcomes:*

- Completing an in-depth review of the relevant research on car accidents, which may be divided into three areas: driver actions and characteristics, accident prediction, and accident detection.
- Creating a traffic accident severity model based on many meteorological factors.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24NOV581

- Three machine learning (ML) techniques are suggested to simulate the severity of accidents: Random Forest, LightGBM, and XGBoost.

➢ *Limitations and Difficulties of Current Systems:*

The existing accident detection and prevention methods outlined above provide several daily challenges:

- Network Dependency: Most structures rely on GSM networks for spoken communication, which are unavailable in distant or inaccessible places, resulting in critical communication problems.
- Inaccurate Alarms: Systems that depend on vibration and accelerometers are prone to false alarms, particularly when there is an occurrence of small accidents or sudden motions, which results in ineffective emergency responses.
- User Dependency: Many systems need user involvement and an immediate switch, which is impossible in cases of serious injury when the motive power is unable to function.
- Data privacy: When integrated with centralized databases, technologies that stores private information or utilizes real-time tracking which causes new issues about data security and privacy.
- Infrastructure Challenges: Implementing complex systems, like VANETs, on a large scale seems to be difficult because of the high infrastructure costs and standards that are required across cars.
- Sensor malfunctions: The whole performance of these systems is heavily dependent on the sensors, and the system's efficiency may be reduced if no method exists to detect sensor errors.

Despite developments in accident detection, prevention, and response systems, real-world deployment remains difficult because of such as network reliance, false alarms, and user interaction. Future research should be done in the area that focuses on strengthening the resilience of these systems by including alternate communication methods (e.g., satellite-based communication), improving sensor accuracy, and minimizing human dependence to ensure wider adoption and reliability.

III. OBSERVATIONS AND RESULTS

Certain Observations and Results were obtained by papers mentioned in References out of which some are presented here.

➢ *The Results of [4] are Listed Below:-*

- *Hardware Results:*

✓ Hardware Circuitry (Figure 1)
✓ Text messages received from the GSM module (Figure 2),
✓ Google Maps link, when browsed (Figure 3)

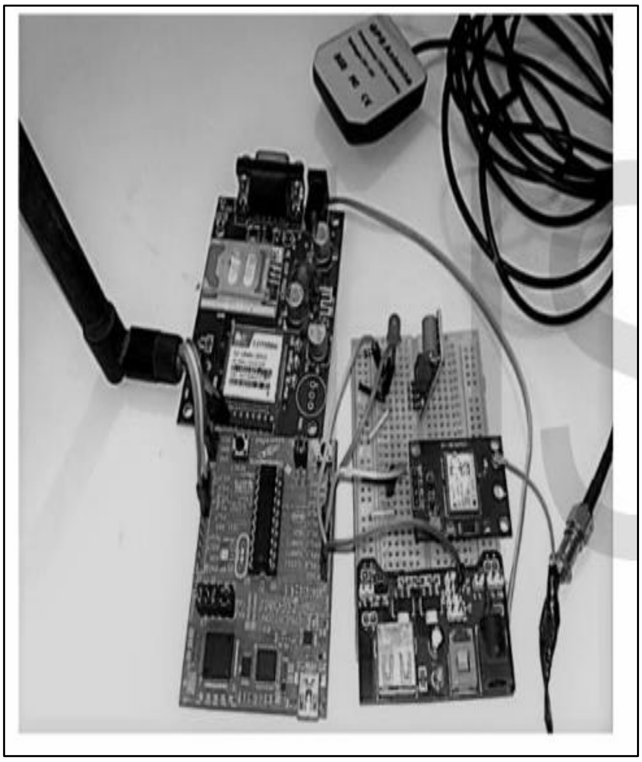

Fig 3: This is Physical Appearance of the Circuit Diagram

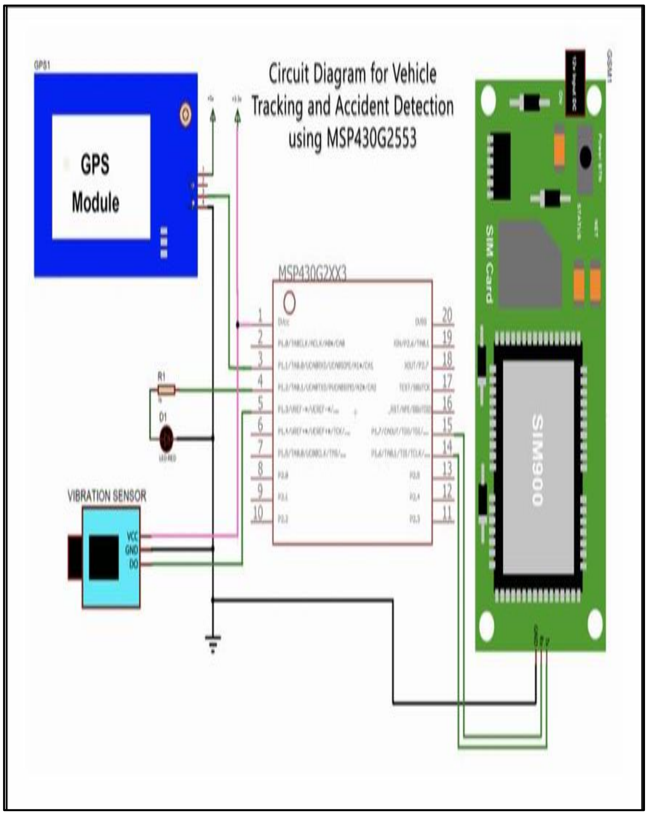

Fig 4: This Figure is a Circuit Diagram of the system (Hardware Circuitry)

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24NOV581

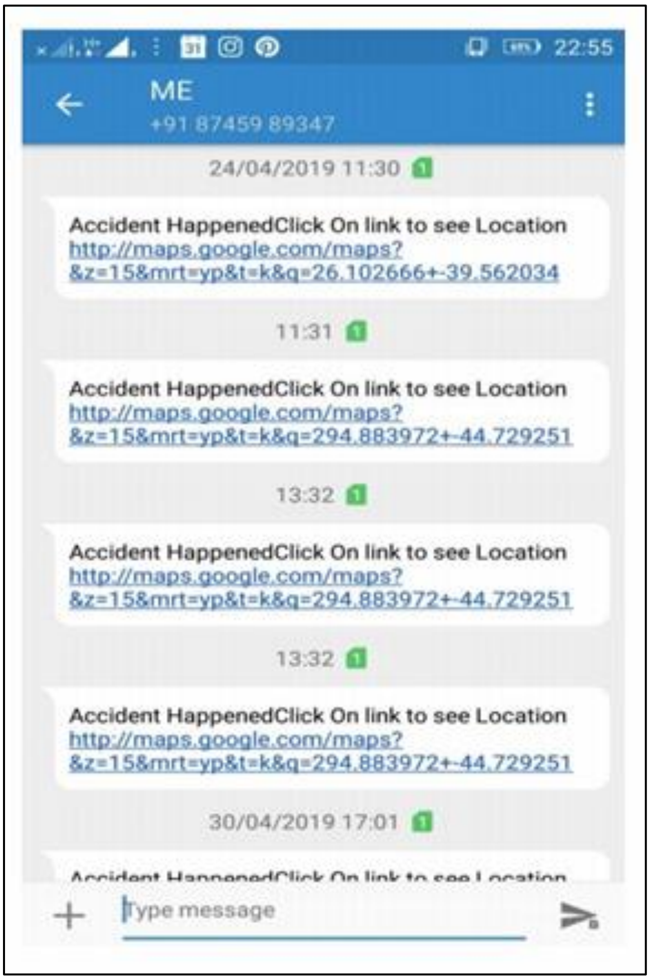

Fig 5: This Figure Two Shows the Text Messages Received from the GSM Module while Experimenting the System

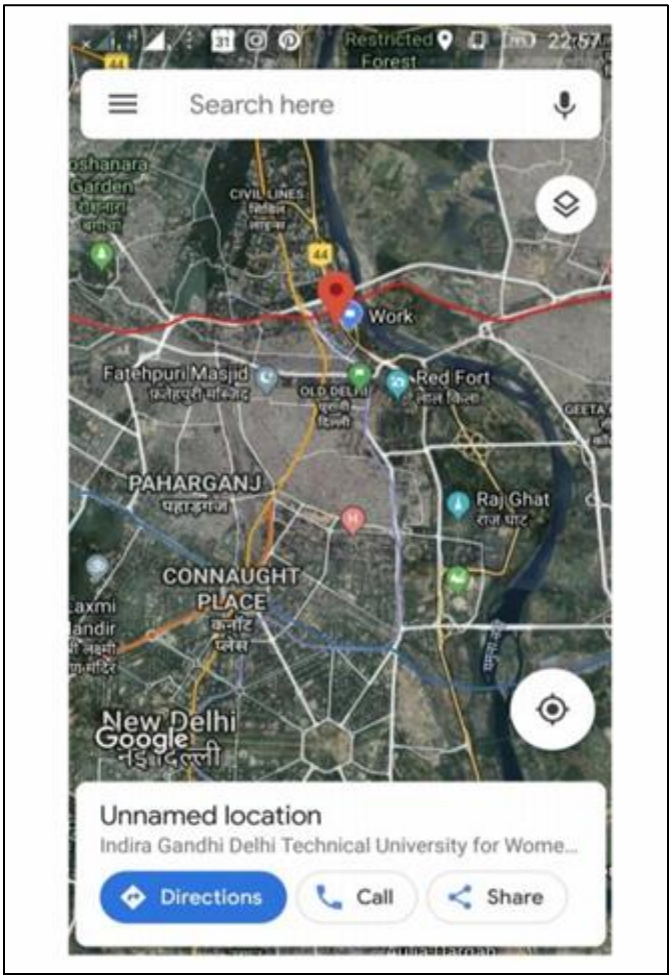

Fig 6: This Figure Shows the Google Maps link, when Browsed from Received Messages from GSM.

➢ *MySQL(Software) Results*

Table 1: Customers with their Data

mysql> select * from customers ;

custID	Name	Contact	Address	CarIns	BloodGrp
2101	Durgesh Singh	9987238619	20/8, Block A, Saraswati Vihar	Yes	AB-
2102	Aditi Singh	9937226710	D/78, Sector-8, Dwarka	Yes	O+
2103	Niharika Sharma	8798225510	A8, Shaanti Apartments, Janakpuri	No	O+
2104	Nidhi Chatterji	9310100456	43, Kaveri Hostel, IGDTUW, KAshmere Gate	Yes	O+
2105	Kishan Lal	9310456112	22/25, Rajouri Garden (Near Pillar 420)	Yes	B-
2106	Saraswatichandra	9876543210	20/C, DDA SFS Flats, Pirampura	N/A	B+
2107	Atul Grover	7890123456	209C, Pushpanjali Apartments, Sector - 19, Noida	No	A-
2108	Kanan Rawat	9281758401	1091, CPS Apartments, Sector 9, Pocket 1, Rohini	Yes	O+

Table I shows the customers and their details who get the accident detection system installed in their vehicles.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24NOV581

Table 2: Accident_Detect W.R.T. Customers IDs

MySQL 8.0 Command Line Client

mysql> select * from customers ;

custID	Name	Contact	Address	CarIns	BloodGrp
2101	Durgesh Singh	9987238619	20/8, Block A, Saraswati Vihar	Yes	AB-
2102	Aditi Singh	9937226710	D/78, Sector-8, Dwarka	Yes	O+
2103	Niharika Sharma	8798225510	A8, Shaanti Apartments, Janakpuri	No	O+
2104	Nidhi Chatterji	9310100456	43, Kaveri Hostel, IGDTUW, KAshmere Gate	Yes	O+
2105	Kishan Lal	9310456112	22/25, Rajouri Garden (Near Pillar 420)	Yes	B-
2106	Saraswatichandra	9876543210	20/C, DDA SFS Flats, Pirampura	N/A	B+
2107	Atul Grover	7890123456	209C, Pushpanjali Apartments, Sector - 19, Noida	No	A-
2108	Kanan Rawat	9281758401	1091, CPS Apartments, Sector 9, Pocket 1, Rohini	Yes	O+

8 rows in set (0.00 sec)

mysql> select * from accident_detect;

accID	c_ID	Contact	Latitude	Longitude	DateTime	Emergency_Contact_and_Name
1001	2105	9310456112	28.665300	77.232399	2019-04-24 11:30:36	986543201 (Amit Singh)
1002	2105	9310456112	28.665300	77.232399	2019-04-24 11:31:13	986543201 (Amit Singh)
1003	2105	9310456112	28.665300	77.232399	2019-04-24 13:32:56	986543201 (Amit Singh)
1004	2104	9310100456	28.699078	77.138710	2019-04-24 13:32:56	789540123 (Dhrishti Gupta)
1005	2105	9310456112	28.665300	77.232399	2019-04-30 17:01:22	986543201 (Amit Singh)
1006	2105	9310456112	28.621918	77.087868	2019-04-30 21:48:21	986543201 (Amit Singh)
1007	2106	9876543210	28.664785	77.232216	2019-05-01 11:49:13	8978675645 (Akshra Raj)

7 rows in set (0.00 sec)

mysql>

Table II shows details of the victim.

➢ *Results Of System Proposed in [3] Yields Results which Gives Position of Vehicles Table Below Illustrates the Results*

Table 3: Messages Received during the Experiment

Attempt No	Vehicle Position	Registration Details
1	32^{0}55'47.7865''N,74^{0}65'11''87E	XXXX
2	42^{0}25'44.8845''N,77^{0}75'31''97E	XXXX
3	32^{0}55'26.3842''N,56^{0}33'11''87E	XXXX
4	32^{0}65'57.2866''N,77^{0}85'11''87E	XXXX

➢ *Results of Study Works in [21] are Listed Below:*

Table 4: Models' Performance

Classifier	Accuracy	Precision	Recall	F1-Score	Log loss	ROC AUC	Calibration Loss
XGBoost	0.698	0.697	0.698	0.697	0.713	0.861	0.008
LightGBM	0.705	0.705	0.705	0.705	0.699	0.866	0.008
Random Forest	0.655	0.658	0.655	0.656	0.840	0.825	0.081

Above Table illustrates model performance. In this case, since the LightGBM algorithm has a better performance in terms of accuracy, precision, recall, and F1-score, it can be concluded that it is a better fit for the problem at hand.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24NOV581

	Predicted			
Actual	2	3	4	
2	6763	1268	1311	9342
3	1121	6598	1470	9189
4	1521	1721	6044	9286
	9405	9587	8825	27817

Fig 7: XGBoost Confusion Matrix

	Predicted			
Actual	2	3	4	
2	6813	1300	1229	9342
3	1088	6631	1470	9189
4	1465	1649	6172	9286
	9366	9580	8871	27817

Fig 8: Light GBM Confusion

	Predicted			
Actual	2	3	4	
2	6100	1257	1985	9342
3	1143	5916	2130	9189
4	1452	1630	6204	9286
	8695	8803	10319	27817

Fig 9: RF Confusion Matrix

The confused matrix for three distinct models—Random Forest, LightGBM, and XGBoost—is shown in Figures 7, 8 and 9. The matrix's y-axis shows all the anticipated occurrences, while the x-axis indicates the actual occurrences that were accurately detected. The true values for each accurate forecast of an occurrence are shown on the diagonal line of the matrix. The Confusion Matrix shows that the three algorithms' performances are essentially comparable, with LightGBM outperforming the others in the classification of class number 2. While Random Forest outperformed LightGBM and XGBoost in the class number four classification, it fared worse in class number three. Overall, we can say that LightGBM performed better since it showed better results in terms of accuracy, precision, recall, and F1- score.

Along with their receiver operating characteristic (ROC) curves and Calibration curves that are illustrated in Figures 10, 11, and 12.

The following figures:- Figure 10, Figure 11 and Figure 12 shows the ROC curves for 3 classes.

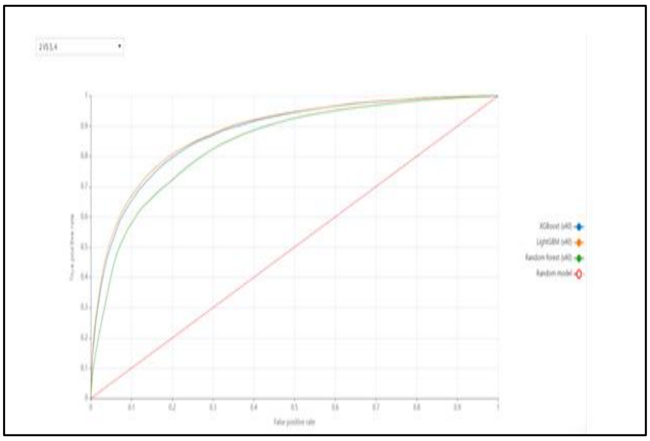

Fig 10: ROC Curve 2 VS 3,4

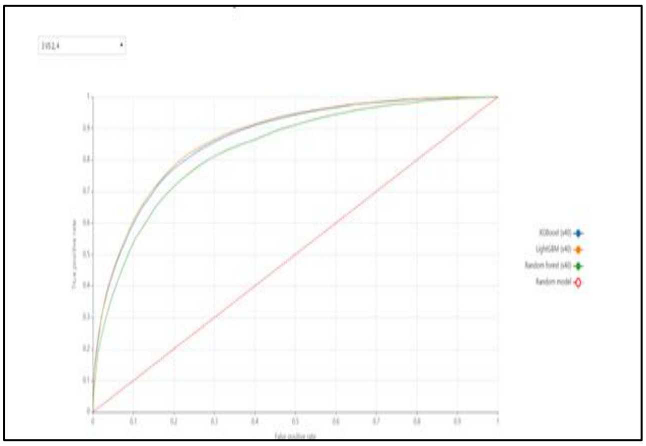

Fig 11: ROC Curve 3 vs 2,4

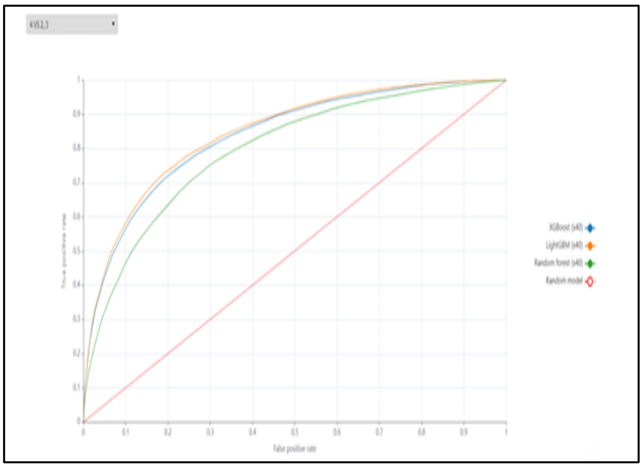

Fig 12: ROC Curve 4 VS 2,3

Three Classification Models' ROC Curves: A Model is Less Accurate the Closer it gets to the Diagonal Line. Thus, in this case, LIGHTGBM is More Accurate

➢ *Applications:*

- Stolen Vehicle Recovery: Vehicle tracking systems, using RF or GPS technology, are vital for recovering stolen automobiles. These monitoring modules may be installed in both personal and commercial cars, allowing law enforcement organizations to monitor and locate vehicles in real time. For example, the LoJack device is especially designed to help police track down stolen automobiles by embedding a secret transmitter into the vehicle. This transmitter transmits tracking signals that law enforcement may follow, considerably increasing the likelihood of finding stolen automobiles quickly.
- Effective Fleet Management: Vehicle tracking technology enables real-time monitoring of all vehicle locations. Businesses may improve their operational efficiency by knowing the exact locations of their drivers, ensuring that client demands are handled as quickly as possible. This is especially useful for delivery services and multi-vehicle businesses, when prompt service is essential. Businesses may optimize routes, minimize fuel consumption, and enhance overall service quality by effectively tracking and dispatching drivers using just a cell phone and an internet connection.
- Asset Tracking: Businesses use tracking systems to monitor their precious assets in real-time. Organizations may use advanced tracking technology to see where their assets are on a map and receive real-time reports on their operating condition. This functionality is critical for companies that rely on high-value goods, since it allows them to successfully manage their inventory while preventing loss or theft.
- Transit Tracking: Vehicle tracking systems are also useful for monitoring freight transportation between locations. This technology allows customers to ensure that their assets or cargo do not halt or depart from their intended itineraries. This not only enhances item security, but also allows for better logistical planning and timely delivery, both of which are critical for preserving customer satisfaction throughout supply chain operations.

To summarize, vehicle tracking systems have several applications that improve security, efficiency, and management in a variety of industries, including law enforcement, fleet management, asset monitoring, and logistics. These technologies are becoming increasingly important in today's networked and fast-paced world, helping to improve safety and operational effectiveness.

➢ *Future Enhancements*

- Satellite-Based Communication: Future systems may include satellite communication to address the limitations of GSM networks in remote locations.
- AI-Based Detection: By Utilizing Machine Learning Algorithms, More and Better identification of accidents can be done by distinguishing between minor and severe occurrences by analyzing sensor data patterns.
- Smart City Integration: Working with smart city infrastructure allows for real-time traffic monitoring, predictive analytics, and quicker emergency response.

IV. CONCLUSION

The Vehicle Accident Prevention, Detection, and Alert System described in this paper employs a combination of GPS tracking and GSM alert-based algorithms implemented on a Microcontroller Unit (MCU), PIC Microcontroller, Arduino, and a variety of sensors, including Ultrasonic and Infrared Sensors. The method described in [6] includes theft prevention features by sending users warnings allowing them to activate a fuel cutoff if necessary. Furthermore, this device can detect speed bumps and defined zones, increasing overall driving awareness. A seatbelt reminder is an important safety element; if the driver is not strapped up, a buzzer will sound an alert, and the car will remain immobilized until the seatbelt is correctly tightened.

Furthermore, the technology described in [7] seeks to prevent accidents by recognizing surrounding cars. When all nearby lanes are full, it will automatically stop the car or reroute it to a safer lane. This feature is especially useful for tired drivers, since the technology assists in line-following by analyzing inputs from ultrasonic and infrared sensors, thereby lowering accident rates.

The automobile accident detection system demonstrated in [5] uses an automated way to collect geographic data and deliver SMS notifications in the event of an accident. The results show that this method improves sensitivity and accuracy, making it more user-friendly and dependable. Furthermore, the suggested technique has considerable benefits for the automobile sector because of its cheap development costs. Using commonly accessible devices like as Bluetooth and GPS, this approach is not only cost-effective, but also low in power consumption, ensuring that vehicle performance is not compromised. The **Texas Instruments Low Power MCU** is particularly notable for its ability to monitor and identify automobiles while keeping them affordable.

Furthermore, the work in [4] emphasizes the benefits of low-power modes, which enable the study of various MCU sleep states until an interrupt event requires device reactivation. The **SQL Server Management System** provides an accessible platform for relational database management, allowing for rapid prototyping and low-cost applications.

In conclusion, the suggested methods for vehicle monitoring and accident, avoidance and detection provide a novel way to improving road safety. The solutions investigated in numerous research prioritize both accident detection and prevention, using sensors such as accelerometers, shock sensors, pressure sensors, and ultrasonic sensors to achieve these objectives.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24NOV581

Various strategies are discussed in various papers mentioned in references, which focuses not only on accident detection but also on its prevention. These systems must also include measures for detecting tiredness, driving while inebriated, regulating speed, and maintaining safe distances from objects. While the incorporation of such technology may incur costs, the benefits in terms of safety and accident reduction are significant. However, dependence on hardware and software technology poses weaknesses, since sensors can be destroyed during accidents, potentially resulting in inaccurate readings and consequences. Future frameworks must be established to construct accident prevention and detection systems that are less reliant on individual hardware or software components.

Finally, the results of the study cited in [19] demonstrate the efficacy of the suggested approach for forecasting the severity of vehicle collisions. The LightGBM model outperformed other machine learning models in terms of prediction accuracy, precision, recall, F1 scores, and area under the ROC curve. This underscores the need of new technology to solve the growing problem of traffic accidents, which are the top cause of death globally. Continued research and testing are required to maximize these findings and assure consistent, trustworthy outcomes in future trials.

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