An Enhanced Novel Iot-Based Car Accident Detection and Alert System

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The excessive use of vehicles for our day-to-day tasks in this revolutionized era has become a necessity, making our lives convenient and technology-dependent. This rise in the use of vehicles has led to a greater number of road accidents that have affected the lives of humans dramatically resulting in an increased fatality rate. According to the World Health Organization (WHO), about 50 million people are injured due to road accidents every year. This is mainly due to the unavailability of timely emergency health services. This study is presented to address this critical issue by leveraging the unmatched capabilities of the Internet of Things (IoT). A novel IoT-based car accident detection and alerting system considering various car parameters simultaneously for more precise results is proposed which is designed in two stages. First, the accident that has occurred is detected via sensors considering the key vehicle parameters like speed, pressure, acceleration, and gravitation force. Second, upon detecting an accident an emergency alert containing all relevant information regarding the driver, vehicle as well as the exact location of the accident calculated through a GPS module along with its severity is sent to the nearby hospital, police, and driver's emergency contacts using the GSM module. The proposed approach is employed on a toy car to show its significance and outperforms the existing systems in terms of accuracy 98% and responsiveness.

Keywords: IoT, car accident detection, accident alert system, GSM, GPS, Arduino UNO, sensors

Introduction:

Our daily lives depend heavily on transportation, and its development has made many of our activities easier. Accidents are also increasing sharply as a result of the ongoing rise in car usage. According to the World Health Organization (WHO), each year, 1.3 million people lose their lives in traffic accidents, and millions more are injured or disabled [1]. According to the Association for Safe International Road Travel (ASIRT), road accidents are currently the eighth most common cause of death (up from ninth in its 2015 report). Unless significant changes are made, ASIRT predicts that road accidents might soon become the fifth most common cause of death. Road traffic accidents have a substantial financial cost in addition to the harm they inflict on society. According to ASIRT, road accidents account for one to two percent of each nation's yearly budget (Road Crash Statistics, 2019). The biggest causes of accidents include insufficient sleep, driving under the influence of alcohol, and an inadequate distance between two vehicles [2].

Even in sophisticated countries with effective road safety measures, the number of road traffic deaths has increased recently on a global scale [3]. Nonetheless, low- and middle-income nations continue to bear the greatest proportion of traffic-related deaths and injuries [4]. For instance, such incidents claim the lives of 15 individuals on average every day in Pakistan. According to data from the Pakistan Bureau of Statistics, 4036 people have died in 9582 incidents, implying that there is typically more than one fatality for every two traffic accidents ("Traffic Accidents (Annual) Pakistan Bureau of Statistics", 2019) as shown in figure 1. Given the high death rate, it is especially critical that both industrialized and, more crucially, emerging nations increase road safety. Intelligent traffic management systems are being developed with the increasing growth in the advanced technology of the Internet of Things IoT [5].

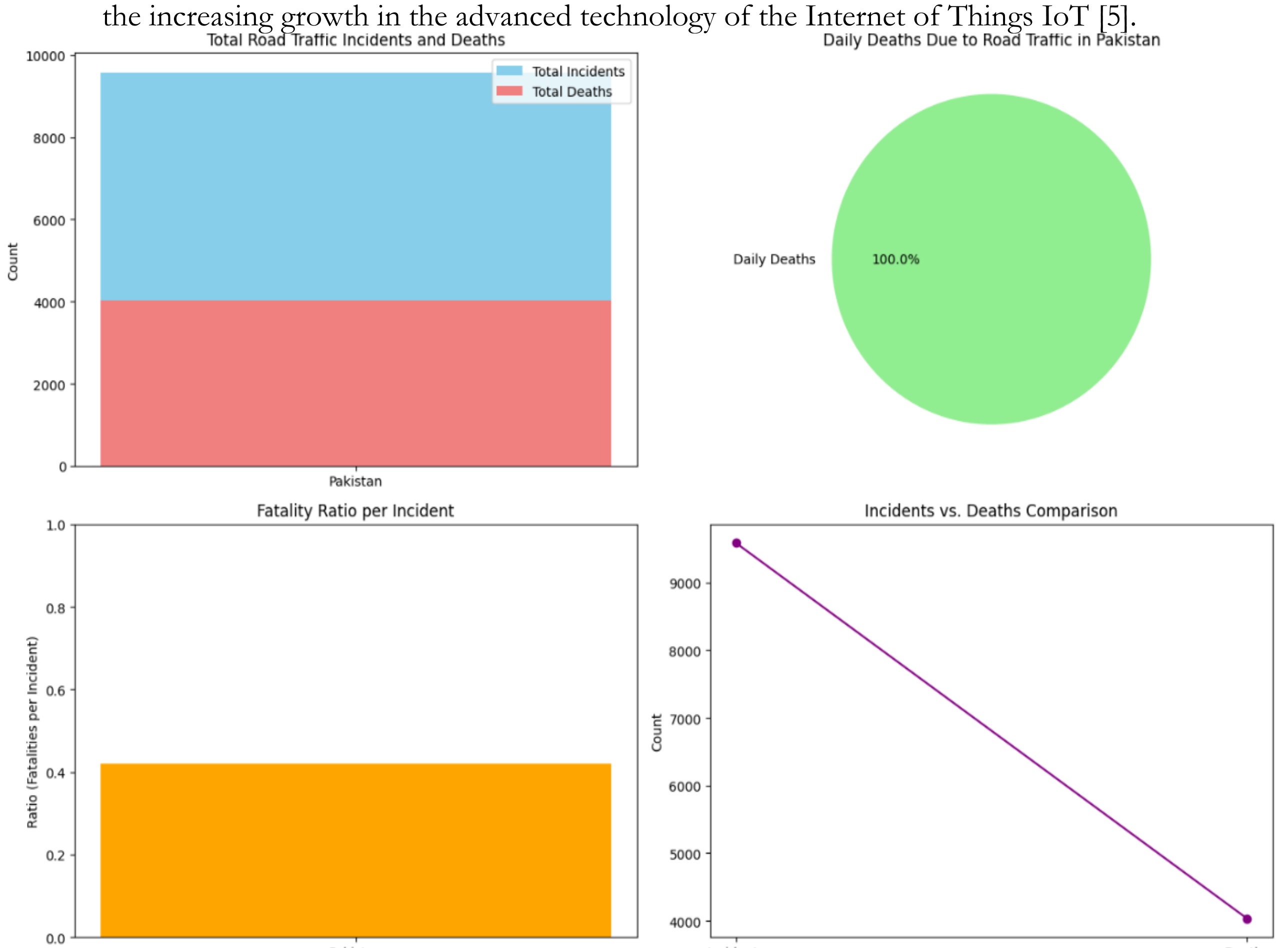

Figure 1: Impact of traffic accidents and their statistical data in Pakistan.

The phrase "Internet of Things" (IoT) describes the exchange of information between objects and people. Technology is advancing at an exponential rate in today's society. Compared to earlier times, broadband Internet is now more affordable and accessible. As of 2018, 36% of the world's population uses smartphones, and technology costs are declining. Global smartphone usage is expected to increase from 2.1 billion in 2016 to over 2.5 billion in 2019 (The Statistics Portal, 2018). IoT is the subject of research, and because of its potential advantages across a range of domains, industries are making significant investments [6]. A beneficial atmosphere for IoT is being created by all of these factors. IoT is providing its benefits in every field and different industries are leveraging its advanced abilities for monitoring and controlling for fulfilling their requirements.

One of the main causes of the person's death at the scene of the accident was the absence of first aid supplies. It can occasionally be challenging to determine the precise location of accidents, and a delay in discovering the location of an accident results in more fatalities from traffic accidents. The majority of accidents happen on highways, and other cars that are driving by the scene of the accident fail to notify the police and medical facilities. Since this issue requires an instant resolution, intelligent accident detection technology has been developed to follow the accident site and notify the police and hospital without the need for human intervention [7]. With the transmission of data from the sensors to the cloud to be stored, where it can be accessible for recognition and action, IoT is expected to have a significant impact on the safety and security industry [8].

Applications for global navigation satellite systems, like the Global Location System (GPS), are growing in number, particularly for vehicle navigation and location. A lot of cars that are supplied nowadays include GPS units that track their whereabouts and transmit the data to cloud servers [9]. Modern cars also have other sensors that continuously gather and store data for use in smart transport management or accident detection [10]. High sampling rates make it difficult to store and analyze this data because they are motivated by the need for greater accuracy and algorithmic effectiveness [5].

A communication link that makes use of the Global System for Mobile Communication (GSM) network model and GSM base station controller enables information transfer between the terminal of the vehicle and the monitoring center [11]. By transmitting messages to the GSM device, which notifies it of the location of the vehicle, tracking is completed. The global system for mobile communication is a mechanism used to send messages via SIM. A Global Package Radio Signal GPRS/GSM modem with integrated power supply and communication ports makes up a GSM module. American Telephone (AT) commands are necessary for the GSM module to function [12]. The GSM is triggered to send messages to the emergency contacts via the microcontroller once the sensor's logical function surpasses the higher limit [13].

Various sensors were used, including temperature, vibration, gas, humidity, fingerprint, and infrared sensors. A device known as a gas sensor is used to detect gas levels or air pollutants [14]. An efficient pertinent distinction that may be computed as an output voltage is produced when the material resistance of the sensor changes in response to the gas concentration. A machine, system, or device's vibration level and frequency are measured using a vibration sensor. These measures can be used to anticipate breakdowns as well as identify asset imbalances and other issues. Engine coolant temperatures are measured via temperature sensors [15]. To prevent continuous battery ventilation and needless energy use, humidity sensors keep an eye on the battery's internal air humidity. The signals from this sensor are sent to the Engine Control Unit (ECU). The sensor's data is then used to modify the fuel-air mixture and the timing of the ignition. Fingerprint scanners are used to recognize and validate a user's fingerprint. It is reliable and safe to utilize fingerprint readers and scanners for security authentication [13].

Black box systems are typically employed in airplanes to gather data for accident investigations [16]. Our suggested strategy for on-road automobiles employs the same black-box technological methodology. Important information is locally stored and retrieved from all the data via the Internet of Things, including the driver's alcohol intake, vibrations, and engine temperature. Information related to accidents is necessary to manage the cause of an accident or the criminal [17][18][19][20]. This type of information is usually obtained by investigators through hearsay or by interviewing bystanders who happen to be in the area when the accident occurs for information. Black boxes have been deployed in many cars in recent years to identify the components that caused a collision [13].

In this article, we have presented a novel ADRS that makes the use of several car parameters for the more accurate detection of an accident to reduce the false alarm rate which has not been used collectively in other approaches so far in our knowledge. Moreover, our approach can also aid in preventing the escape of a felon from the scene as its location will be kept until the accident has been recognized and dealt with by the emergency services. The proposed ADRS will also help investigate the real cause of the accident through the use of the Black-box module deployed in the proposed framework.

Objectives:

The primary objectives of our study are:

1. **Design an Enhanced IoT-Based Accident Detection and Alert System**

- Developing a system that precisely detects vehicle accidents utilizing multiple IoT sensors, such as accelerometer, pressure sensor, and vibration sensor.
- Decreasing false alarms by incorporating diverse vehicle parameters for accurate accident detection.

2. **Ensure Real-Time Emergency Alert and Response Mechanism**

- Implementing an automated alert system that notifies the nearby hospitals, police stations, and the driver's emergency contacts with necessary accident details.
- Providing accurate location of the accident tracked using GPS and ensuring message delivery through GSM communication.

3. **Classify Accident Severity for Effective Emergency Response**

- Categorizing accidents into severity levels (minor, moderate, severe) to aid the emergency services rank their response.
- Enabling a buzzer-based driver recognition system to reduce unimportant alerts for minor accidents.

4. **Store and Utilize Accident Data for Investigation**

- Incorporating a black box system to record and store accident-related information for investigation purposes to know the real cause of the accident.
- Storing the information in the cloud for easy fetching and future reference.

5. **Improve Road Safety and Decrease Fatalities**

- Providing a system that certifies timely medical assistance, decreases the risk of fatalities due to lagging responses.
- Aiding law enforcement in locating hit-and-run cases by continuously sending the vehicle's location until emergency services intervene.

6. **Validate System Performance and Accuracy**

- Testing the proposed system deploying a prototype (toy car model) to evaluate its accuracy and responsiveness.
- Comparing the system's performance with existing approaches like CNN, SVM, and RNN to showcase its supremacy.

Novelty Statement:

A novel IoT-based car accident detection and alerting system considering various car parameters simultaneously for more precise results is proposed which is designed in two stages.

The first stage is the accident detection and the second stage is the accident alerting or notification stage.

Literature Review: In [21] suggested an intelligent accident detection and rescue system that uses artificial intelligence (AI) and the Internet of Things (IoTs) to simulate the cognitive processes of the human mind. The accident is detected by an Internet of Things kit, which then gathers and transmits to the cloud all accident-related data, including position, pressure, speed, gravitational force, etc. When an accident is identified in the cloud, the rescue module is activated and the output of the IoT module is validated using a deep learning (DL) model. All nearby emergency services, including the hospital, police station, mechanics, etc., are alerted as soon as the DL module detects an accident. The false detection rate is reduced by using dynamic weights in ensemble transfer learning. Owing to the dataset's unavailability, several videos on the Internet are used to create a customized dataset. With training, validation, and test accuracy of 98%, respectively, the experiment findings demonstrate that InceptionResnetV2 performs better than ResNet. The suggested method is tested on a toy car to gauge its effectiveness in the real world. In [5] proposed a method that seeks to leverage smartphones' sophisticated features to create an affordable, deployable solution for improved transportation systems in older automobiles. In this regard, a specially designed Android application is created to collect data on location, sound, pressure, speed, and gravitational force. One element that is used to enhance the detection of accidents is speed. It results from glaringly different environmental factors (such as noise and deceleration rate) that occur in low-speed crashes as opposed to high-speed collisions. To recognize traffic accidents, the data that is collected is further processed. Additionally, a navigation system is designed to inform the closest hospital about the incident. With simulations and comparison with an actual data set of traffic incidents obtained from the Road Safety Open Repository, the suggested method is verified and exhibits encouraging accuracy findings.

In [22] presented an article that describes the development of an intelligent accident detection system to identify traffic accidents. Location tracking and alerting systems that use GPS location to identify accidents instantly are both components of intelligent accident detection. As a result of an accident, the sensor which is connected to the car is triggered. The Global System for Mobile Communication (GSM) will be used to send phone calls and notification messages to the local police station, hospital, and family members.

In [23] proposed a method that explains the viability of outfitting a car with sensors that can identify collisions and notify emergency services right away. Someone must actively seek assistance after an automobile collision, such as by dialing 911 for emergency services. The police, ambulance, friends, and family are not automatically notified. An automated notification and reaction to the scenario can be generated using the Internet of Things (IoT). The person who has a subscription to that car will receive a warning message after an accelerometer and GPS sensor send a signal to the cloud automatically. The GPS position and the accident's severity will be indicated by the signal. The ambulance will rapidly arrive at the scene by using the GPS coordinates.

The structure and functionality of an advanced monitoring and alarm system for automotive vehicle parameters are covered in the method presented by [13]. A microcontroller that continuously monitors automobile vehicle parameters maintains the data logs including vehicle parameter data in the cloud and on a protected digital memory card. The system actively checks for any unexpected vehicle accident detection in addition to periodically recording the vehicle parameters data of the car. When a collision occurs, the sensor may let people swiftly and legally assess the situation and notify the emergency services of the scene. Whenever an anomalous system event occurs, the information will be updated by the system. A car's black box collects driving data before, during, and following an accident. Speed, acceleration, braking, steering, and airbag activation are among the information collected. In addition to improving road conditions to lower fatality rates, the automotive black box technology can help with vehicle safety, improve collision victim care, and support insurance companies with vehicle crash investigations. Experimental results show that the suggested strategy outperforms RFID, SVM, CNN, and RNN methods in terms of accuracy by 29.3103%, 22.70%, 18.103%, and 11.26%. In [24] presented a project, the MEMS sensor detects when a car collides with another vehicle and transmits the data, which is subsequently analyzed by Arduino. Through the GSM Module, the Arduino transmits an alert message, including the position, to a police control room or a rescue team. Therefore, the police can utilize the GPS Module to locate the location as soon as they receive the information. The required actions will then be conducted after the location has been verified. When an accident happens, the initiative notifies the family members and emergency agencies so they can get aid right away.

In [25] proposed an Internet of Things-based system for classifying and detecting accidents. The technology identifies and categorizes vehicle accidents according to their degree of severity and notifies emergency services providers of the pertinent details. A microcontroller, GPS, and a collection of sensors make up the system, which measures several physical characteristics associated with vehicle motion. To find the most accurate classifier for the system, various machine learning classifier types were also compared in their performance within the built system. The Gaussian Mixture Model (GMM), Classification and Regression Trees (CART), Naive-Bayes Tree (NB), and Decision Tree (DT) are the classifiers. The system's deployment demonstrated the superior precision and recall of the GMM and CART models. It was also demonstrated that the g-force value and fire occurrence are the primary determinants of accident severity.

The literature highlights diverse accident detection and alerting approaches, each with its strengths and limitations. Some studies deploy smartphone-based applications for accident detection and alerting, such as the approach in [5], which is dependent on mobile sensors but is limited to detecting accidents occurring at low speeds. Other approaches, like those in [21] and [23], utilize IoT-based systems with sensors and GPS for real-time accident detection, but they often go without multi-sensor integration, leading to false alarms. Furthermore, methods employing deep learning models, such as those in [21], increase accuracy but need huge computational power and large datasets for training. Some approaches integrate GSM-based alert systems [22], while others support black-box technology for investigation after an accident [13]. However, many of these systems either focus merely on detection or alerting but do not extensively integrate numerous parameters to boost accuracy. Contrary to this, the proposed IoT-based accident detection and reporting system (ADRS) merges numerous vehicle parameters considering speed, pressure, acceleration, vibration, and driver authentication to enhance accident detection accuracy. The system also includes a severity classification mechanism to reduce false alerts and certifies continuous tracking of the location until emergency services intercede. Additionally, the integration of a black box module aids in investigation, making the proposed system more robust and reliable in comparison to existing methods. The experimental results prove its increased accuracy (98%) over conventional methods like RFID (62%), SVM (68%), CNN (72%), and RNN (76%), showcasing the significance of this study in boosting road safety and emergency response efficiency.

Table 1: Literature review for "Accident Detection and Alerting systems" already existing

Published Year	Author name	Methodology	Results	Limitations & Future Work
2022 [21]	Nikhlesh et al.,	Cognitive agent-based collision detection smart accident alert and rescue system. IoT kit for accident detection and	99.3% training and 94.4 test accuracy for ResNet50.	No limitations were mentioned, including the security, and driver alert

		DL module for activation of rescue module.	Accuracy overall is 98%.	system in the future.
2019 [5]	Fizzah et al.,	Android application for data collection for accident detection. Navigation system used for reporting accidents.	Increased accuracy than real dataset of accidents obtained from Road Safety Open Repository.	Only Detects accidents occurring at low speed. F.W. (Including mobile edge computing to reduce latency and enhance security and privacy.)
2021 [22]	Rafik et al.,	An Intelligent accident detection system. Location sent via GPS after accident detection and alerts (phone calls & messages) sent to emergency services via GSM)	Effective accident detection and alerting. Prevents false alerts.	No limitation mentioned, F.W (Can be used to prevent vehicle thefts)
2018 [23]	Arif et al.,	A vehicle equipped with an accident detection and alert system. Signals from the accelerometer and GPS are sent to the cloud for accident detection and from there alert is sent to emergency services.	Effective accident detection and alerting.	Did not use A-GPS technology for location tracking in bad weather conditions. F.W (interconnected vehicles, interconnected mobile units for best route selection and avoiding road congestion)
2021 [24]	Karthik et al.,	MEMS sensors are used for accident detection, location tracking via GPS, and message alerts sent via GSM to emergency services.	Effective accident detection and alerting.	No limitation and F.W. mentioned.
2023 [13]	Josephins hermila et al.,	Vehicle parameters are collected via sensors for accident detection and alerts are sent via GSM. Black box stores accident info. For investigative purposes.	Compared with RFID 29.3%, SVM 22.7%, CNN 18.1% and RNN 11.2% proposed system shows more accuracy.	No limitation mentioned, F.W (focus on self-driving vehicles to improve road security and avoid accidents in real-time)

The Proposed Methodology:

In this article, we have presented a novel ADRS (accident detection and reporting system) which will not only identify the occurrence of an accident but will also give out emergency alerts to the emergency personnel i.e. nearby hospitals, police stations, and the emergency contacts of the Vehicle owner. Our proposed approach is based on two main phases. In the first phase which is the Accident Identification phase the accident will be detected with the help of various IoT sensors and in the second phase which will be the notification phase or the rescue alert phase, an emergency alert will be sent to the emergency services for immediate medical assistance. This alert will contain all the relevant details of the driver, vehicle, and the exact location as well as the severity of the accident. The signal flow diagram of the proposed ADRS is shown in Figure 2.

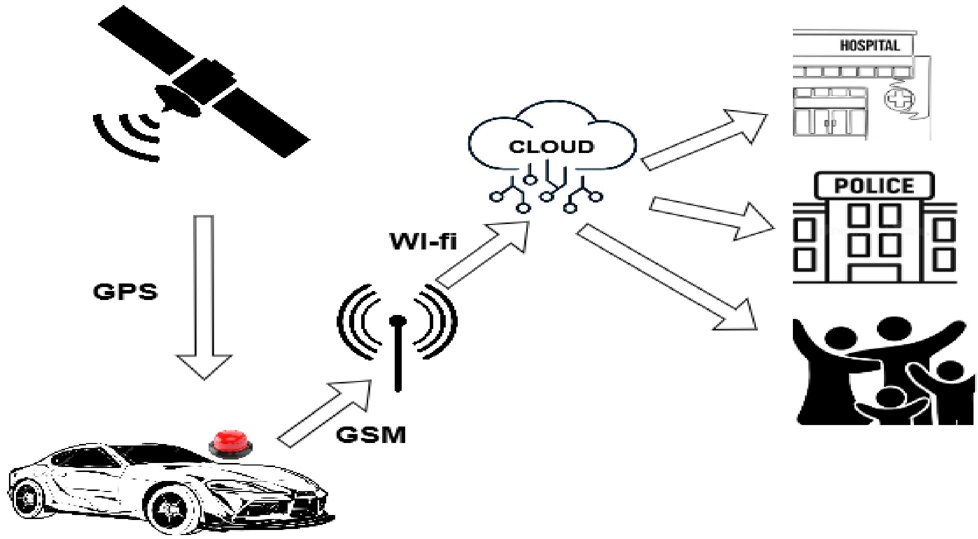

Figure 2: Signal Flow diagram / Working of Proposed ADRS

(Figure 2 explained) The signal flow diagram shows how the system works in transmitting the alert signal and how the information is being transferred among the different parts of the system. After an accident is detected, the location of the accident is tracked via GPS and then this location along with all the necessary details of the accident i.e. the vehicle's and driver's information is transmitted in an accident alert or notification via the GSM module to all the emergency services including the hospitals and the police stations as well as the emergency contacts of the driver for prompt intervention to deal with the situation at hand. The methodology flow diagram of the proposed approach is shown in Figure 3.

Phase 1: Accident detection phase:

In this phase, an accident is detected based on the data or the vehicle parameters that are sensed or gathered by the different sensors used in the system. All this information is saved in a micro SD card as well as is also being sent to the cloud for the emergency services to take action using this data. The accelerometer, pressure sensor, and other sensors send a signal to the microcontroller in case of an accident. The microcontroller then checks the severity of the accident (level 1 being the least severe up to level 3 being the most) and activates the buzzer which emits a continuous beep sound for some time (30s) and waits for the driver to set it off if not a serious situation has occurred.

Phase 2: Emergency alert phase/ Notification phase:

If the alarm is not set off manually then an emergency alert or message to the nearby hospitals, police, and the emergency contacts of the driver via the GSM module. This alert contains severity as well as the exact location of the accident which is calculated by the GPS module and the relevant details of the driver, and vehicle. An SOS message and the location detected by the GPS is also displayed on the LCD. All of the accident-related information is recorded and saved by the black box and SD card for investigation purposes so the police to know the exact cause of the accident and is sent to the cloud. It is to be noted that the location of the vehicle is not shared until an accident has occurred and also the microcontroller looks for a "clear" variable in the cloud database which is set by the server after an accident is recognized by the police and the emergency personnel have dealt with the situation after this microcontroller gets rid of its local variable and then waits for the next impact. This can help in preventing the escape of a felon from the scene as its location will be kept until a clear variable is received. Table 2 shown below, gives the details of the various components that are used in the proposed ADRS system.

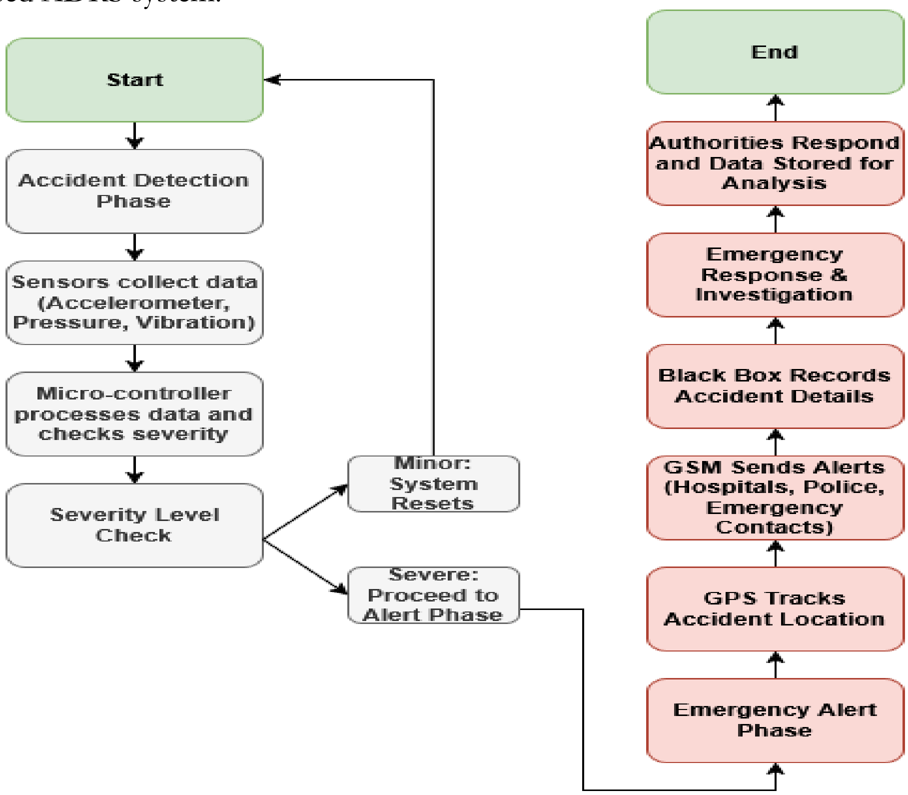

Figure 3: Methodology Flow Diagram of the Proposed ADRS

Table 2: Main components used in the proposed ADRS along with their descriptions & specifications.

S. No	Components Used	Description	Specification
1	Arduino UNO	It is used to check the severity of the accident (It is cheap and can connect various sensors simultaneously so we are using it due to these advantages).	The boards are programmed using the Arduino programming language (APL). Uses the ATmega328P datasheet.
2	Pressure sensor	To detect pressure, if it is > 350 Pa an accident flag will be raised.	When an automobile collides, its pressure is detected by a pressure sensor. The purpose of the pressure sensor is to improve system accuracy and lower the possibility of incorrect accident reporting and identification.

3	Accelerometer	To measure the gravitational force its threshold value is 4G. If > an accident flag will be raised. Value under 1 if deceleration is in case of sudden break.	The sensor's open loop acceleration measuring architecture consists of a signal conditioning circuit and a polysilicon micro-machined surface. Analog voltage signals that change in direct proportion to acceleration are regarded as output signals. Both static acceleration (gravity) and dynamic acceleration (motion, vibration) are measured in tilt-sensing applications.
4	Vibration sensor	Is used to sense vibration (0 no vibration 1 vibration).	A SW-420 module, which is used to detect vibrations and is based on an LM393 comparator. There is an on-board potentiometer for adjusting the threshold. When no vibration is detected, the sensor outputs 0 (Logic Low), and when vibration is detected, it outputs 1 (Logic High).
5	Buzzer	It will give a continuous beep sound in case of an accident	An electromechanical device is sometimes known as a piezoelectric device. A compact, inexpensive, and tiny two-pin structure, when in alert mode, it continuously beeps. The buzzer's operational voltage ranges from 4 to 9 V DC.
6	Gas sensor	To check the presence of gases like co, methane, and alcohol if a driver is drunk or smoking.	Grove-Gas Sensor (MQ-2) detects and measures gases like carbon monoxide, propane, hydrogen, liquefied petroleum gas, alcohol, and even methane.
7	Temperature sensor	To check the temperature inside the engine.	To measure the engine's temperature, which in a typical condition is between 195 and 220°.
8	Noise sensor	To check the noise generated, the threshold value 140dB.	To identify background noise. To increase accuracy and lower the likelihood of false positives, a noise sensor is employed.
9	Fingerprint sensor	For driver authentication.	To authenticate the driver.
10	Pulse sensor	For checking the drive's pulse rate.	The driver's pulse rate parameter is tracked using a pulse sensor.
11	Power supply	For a constant supply of power.	The voltage regulator is from the widely used 7805 series. This integrated circuit regulator is one of several fixed linear voltage regulators used to control these kinds of fluctuations (IC).
12	GPS	To track the exact location of the accident will also be used to calculate speed.	The GPS receiver receives the signal data and uses it to determine the user's exact location [26]. Calculates some other parameters, including speed, journey mileage, bearing, distance to destination, tack, and the times of sunrise and sunset.
13	GSM	To send accident alerts in case of an accident.	A computer and a GSM-GPRS network are connected by the GSM/GPRS module.

			GSM is a mobile communication system that notifies our phones via SMS.
14	Black box & SD Card	Facing the driver to capture and store accident-related info for investigation of the real cause of the accident	The camera module is positioned such that it faces the driver. A Micro-SD card module is specifically used for data logging. Arduino can generate and save files on SD cards by utilizing the SD library.
15	LCD	To display an SOS message and the location detected by the GPS.	The LCD (a basic module that prefers LEDs with seven and multiple segments) employs a 5 x 7-pixel matrix to display each character, and it can display up to 16 characters per line on 2 lines in a 16*2 variant. Command and Data are the two registers that make up this LCD.

Databases being used in the Cloud:

- Driver Database (all info of driver name, address, and emergency contacts)
- Vehicle Database (all info related to the vehicle its no, name type, owner ID)
- Hospital Database (all info related to nearby hospitals)
- Police station Database (all info related to nearby police stations)

The proposed ADRS components' structure integrated within the layered architecture of the IoT is shown in Figure 4. The sensors used in the proposed system are used for the collection of the various car parameters aiding in accident detection and they constitute the edge technology layer, the microcontroller used processes this data for detecting the accident and checking its severity. This is the middleware layer. This data is then sent to the cloud (internet layer) for storage and from there, accident alerts containing the exact location of the accident tracked through GPS are sent to the emergency services via GSM. This is the application layer.

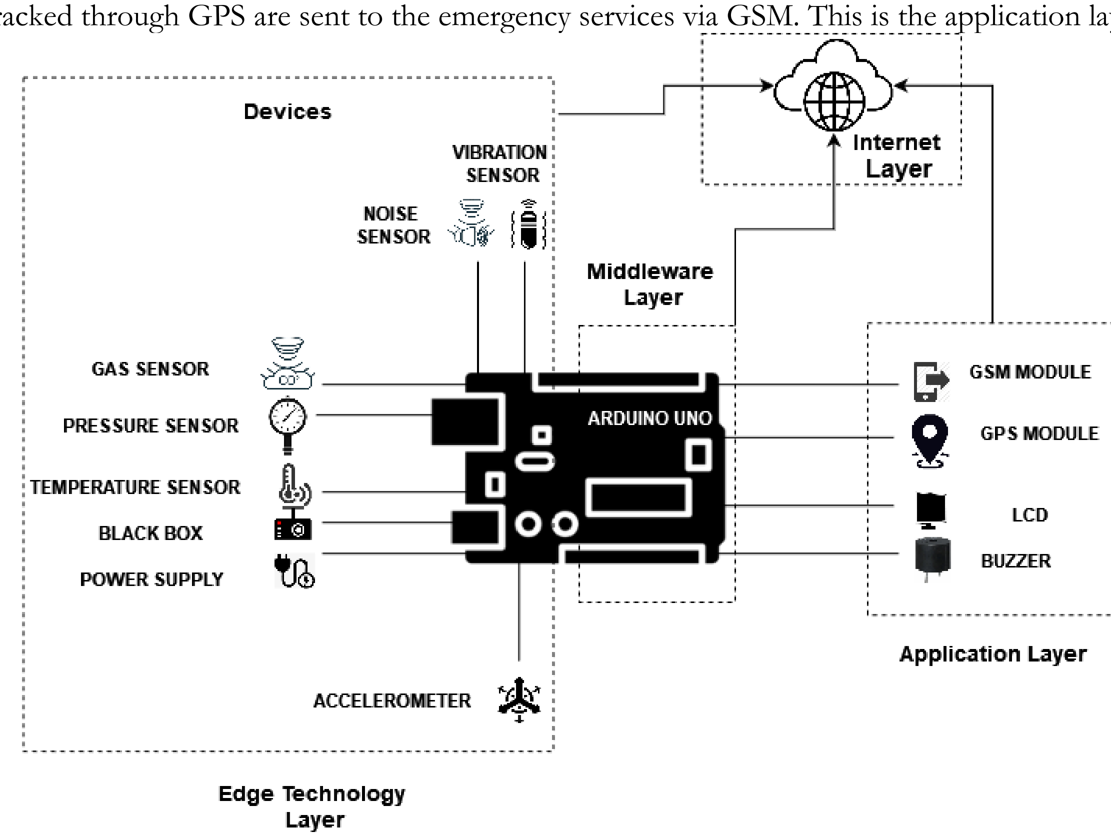

Figure 4: Proposed System Components' structure with IoT layer architecture

The pseudo-code for the proposed ADRS algorithm is given in Figure 5(a) (b) and(c).

```
# ----------------------- INITIALIZATION -----------------------
def initialize_system():
    activate_sensors()  # Accelerometer, Pressure Sensor, etc.
    initialize_microcontroller()
    initialize_storage()  # SD Card & Black Box
    initialize_cloud_communication()
    initialize_buzzer()
    initialize_gsm_module()
    initialize_gps_module()
    initialize_lcd_display()

# ----------------------- DATA COLLECTION -----------------------
def collect_sensor_data():
    accel_data = read_accelerometer()
    pressure_data = read_pressure_sensor()
    return accel_data, pressure_data

# ----------------------- ACCIDENT DETECTION -----------------------
def check_severity(accel_data, pressure_data):
    if accel_data > threshold_high or pressure_data > threshold_high:
        return 3  # Severe Accident
    elif accel_data > threshold_medium or pressure_data > threshold_medium:
        return 2  # Moderate Accident
    elif accel_data > threshold_low or pressure_data > threshold_low:
        return 1  # Minor Accident
    else:
        return 0  # No Accident Detected

# ----------------------- ALERT DRIVER (BUZZER) -----------------------
def trigger_buzzer(severity):
    if severity >= 2:  # Alert if Level 2 or Level 3 accident detected
        activate_buzzer()
        if wait_for_driver_response():  # If driver turns it off, assume minor incident
            log_event("Accident detected but driver responded. No alert sent.")
            return False
    return True  # No response means serious accident, proceed to emergency alert
```

(a)

```
# ---------------------- RECORD DATA ----------------------
def record_accident_data(severity, location, driver_details, vehicle_details):
    data = {
        "severity": severity,
        "location": location,
        "driver": driver_details,
        "vehicle": vehicle_details,
        "timestamp": get_timestamp()
    }
    save_to_sd_card(data)
    save_to_black_box(data)  # For police investigation

# ---------------------- EMERGENCY ALERT ----------------------
def send_emergency_alert(severity, location, driver_details, vehicle_details):
    alert_message = f"Accident Detected! Severity: {severity}, Location: {location}, Driver: {driver_details}, Vehicle: {vehicle_details}"
    send_sms_to_hospitals(alert_message)
    send_sms_to_police(alert_message)
    send_sms_to_emergency_contacts(alert_message)
    display_sos_message_on_lcd(location)

# ---------------------- MONITOR CLEAR STATUS ----------------------
def check_clear_status():
    return fetch_clear_status_from_cloud()  # Cloud variable check

def handle_clear_status():
    while not check_clear_status():  # Keep sending location until police clear the accident
        location = get_gps_location()
        send_emergency_alert(severity, location, driver_details, vehicle_details)
        print("Sending location... Waiting for police clearance...")
    reset_local_accident_data()
    print("Accident cleared. System reset.")
```

(b)

```python
# ---------------------- MAIN FUNCTION ----------------------
def accident_detection_and_alerting():
    initialize_system()

    while True:
        accel_data, pressure_data = collect_sensor_data()
        severity = check_severity(accel_data, pressure_data)

        if severity > 0:
            if trigger_buzzer(severity):  # If buzzer is not turned off, send alerts
                location = get_gps_location()
                send_emergency_alert(severity, location, driver_details, vehicle_details)
                record_accident_data(severity, location, driver_details, vehicle_details)
                handle_clear_status()  # Monitor until police clear the scene

        reset_sensors()  # Prepare for next accident detection

# ---------------------- RUN THE SYSTEM ----------------------
driver_details = {
    "name": "John Doe",
    "license": "ABC12345",
    "contact": "+1234567890"
}
vehicle_details = {
    "make": "Toyota",
    "model": "Corolla",
    "year": "2020",
    "license_plate": "XYZ789"
}

# Start accident detection and alerting process
accident_detection_and_alerting()
```

(c)

Figure 5 (a) (b) (c): Pseudo code for the proposed ADRS algorithm

(Formatted) Algorithm for Accident Detection Phase:

The algorithm for the first phase of the proposed ADPRS which is the accident Detection Phase is given below:

1.	def collect_sensor_data(): # Collect sensor data
2.	accel_data = read_accelerometer()
3.	pressure_data = read_pressure_sensor()
4.	return accel_data, pressure_data
5.	def check_severity(accel_data, pressure_data): # Determine the severity level based on sensor data
6.	if accel_data > threshold_high or pressure_data > threshold_high:
7	return 3 # Severe (Level 3)
8.	elif accel_data > threshold_medium or pressure_data > threshold_medium:
9.	return 2 # Moderate (Level 2)
10.	elif accel_data > threshold_low or pressure_data > threshold_low:
11.	return 1 # Minor (Level 1)
12.	else:
13.	return 0 # No accident detected

14.	def trigger_buzzer(severity): # Trigger the buzzer based on severity
15.	if severity >= 2: # Level 2 and above
16.	activate_buzzer()
17	wait_for_driver_response()

First, the data from the sensors will be collected, after that the severity of the accident is measured based on the collected data and comparing it with the defined threshold values of the sensors. If the accident is detected the buzzer will be triggered (triggering defined for severity level 2 and above) and wait for the driver's response.

Algorithm for Emergency alert phase/ Notification phase:

The algorithm for the first phase of the proposed ADPRS which is the accident Detection Phase is given below:

1	def send_emergency_alert(severity, location, driver_details, vehicle_details): # Function to send emergency alert via GSM
2	alert_message = f'Accident Detected! Severity: {severity}, Location:
3	{location}, Driver: {driver_details}, Vehicle: {vehicle_details}"
4	send_sms_to_hospitals(alert_message)
5	send_sms_to_police(alert_message)
6	send_sms_to_emergency_contacts(alert_message)
7	severity_level = 3 # Example severity level # Trigger the emergency alert phase
8	emergency_alert_phase(severity_level, driver_details, vehicle_details)

In case an accident is detected, an alert will be sent containing the exact location of the accident as well as all the relevant details of the vehicle, driver, and severity of the accident to emergency services. This alert will be sent in the form of sms, via the GSM module as mentioned in the emergency alert function. In the "trigger the emergency alert phase" part mentioned, in the algorithm the driver and the vehicle details will be mentioned according to the databases in the cloud and fetched from the cloud databases.

The proposed system's flow diagram is shown in Figure 6 below, which shows the details of how the system works.

Results:

The proposed system is employed on a toy car for its validation and is deployed in the VS Code using Python language. It is shown in Figure 7 (a) & (b) and the simulation results of the system are given in Table 3. When the values of the sensors exceed their threshold values an accident is detected and the alert message shown in the table is sent to the emergency services. In the proposed ADRS various sensors that monitor the vehicle's parameters as well as the driver's related factors i.e. the authentication of the driver as well as the pulse monitoring of the driver, contribute to the process of accident detection when the values are shifted from the threshold. All the necessary information is being recorded by the Black Box and is also being sent to the cloud for future investigation. In case of an accident has been identified the exact location of the accident, as well as the severity of the accident is sent via the GPS, and an emergency alert is sent via the GSM to the emergency services as well as family members for dealing with the situation appropriately. The experimental results show that the system is quite efficient in its performance.

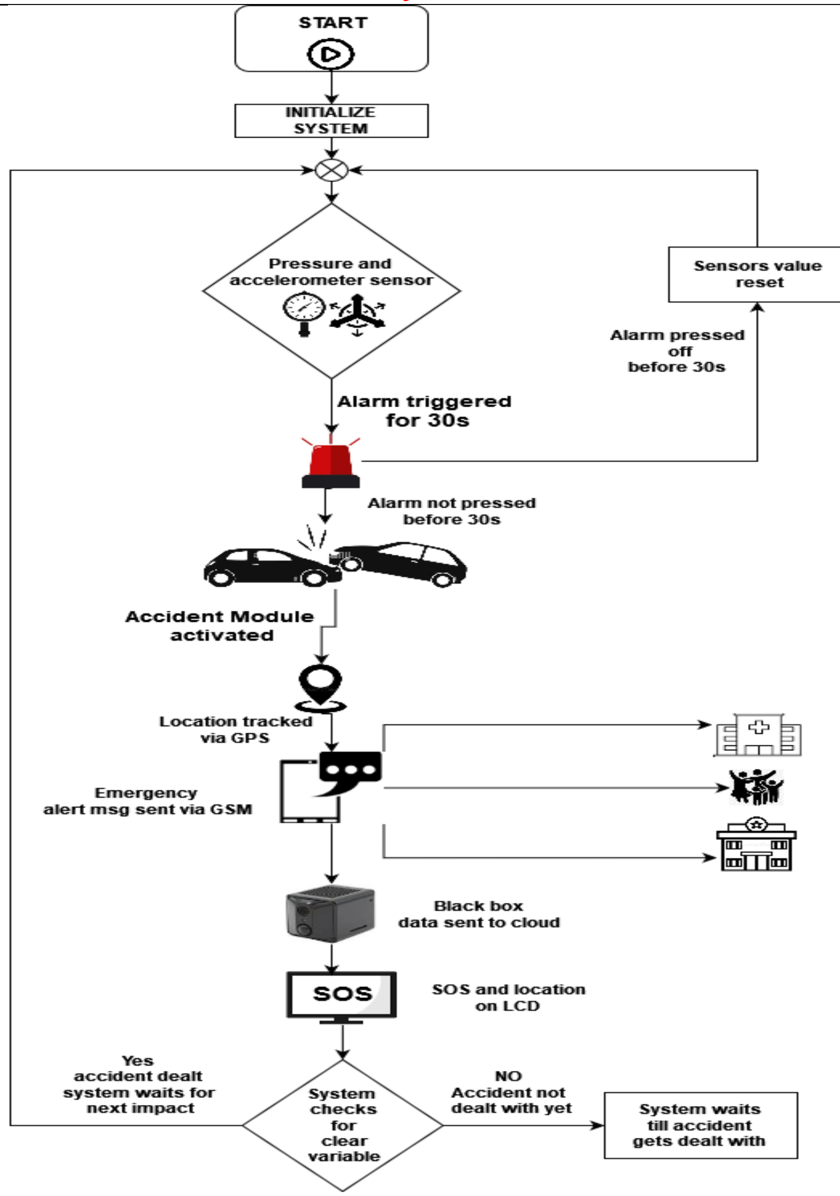

Figure 6: Flow Diagram of proposed ADRS

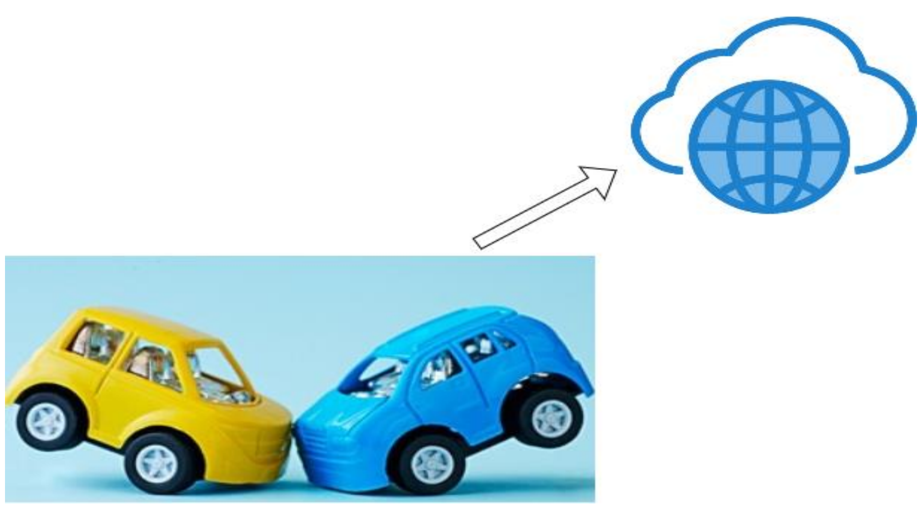

Figure 7 (a): 2 Toys cars equipped with sensors for accident detection sending accident information to the cloud upon colliding or encountering an accident

Figure 7 (b): From the cloud, the accident alert with all the relevant details of the accident is sent to the nearby hospital website interface for the immediate rescue operation

Table 3 An accident of severity level 2 was detected and an emergency alert was sent to emergency services.

Sensor	Threshold value	Value detected	Alert Sent
Pressure (pa)	350 pa	360 pa	Accident Alert! Location: Main Street, Sector 12, City Center, Severity Level: 2, Vehicle: Toyota Corolla, License Plate: ABC-1234, Driver: John Doe, Contact: +1234567890
Accelerometer (G)	4G	4.5 G	Accident Alert! Location: Main Street, Sector 12, City Center, Severity Level: 2, Vehicle: Toyota Corolla, License Plate: ABC-1234, Driver: John Doe, Contact: +1234567890
Noise (DB)	140 db	150 db	Accident Alert! Location: Main Street, Sector 12, City Center, Severity Level: 2, Vehicle: Toyota Corolla, License Plate: ABC-1234, Driver: John Doe, Contact: +1234567890

We have compared our proposed ADRS with other approaches like CNN, SVM, RNN, and RFID to show its significance. The proposed system outperforms these approaches in terms of performance metrics like accuracy, precision, recall, and specificity. The main reason behind better accuracy is considering various vehicle and driver parameters that aid simultaneously in detecting an accident. The comparison graph of the evaluation metrics of our proposed ADRS with existing techniques is shown in Figure 8.

Table 4: Performance comparison table of proposed ADRS with existing techniques

Method	Accuracy	Precision	Recall	Dataset Used	Testing Environment	Specificity
RFID	62%	52%	50%	From Kaggle	Collab	48%
SVM	68%	57%	55%	From Kaggle	Collab	53%
CNN	72%	61%	58%	From Kaggle	Collab	56%
RNN	76%	66%	62%	From Kaggle	Collab	60%
Proposed ADRS	98%	88%	86%	System tested on sensors' values	VS Code	84%

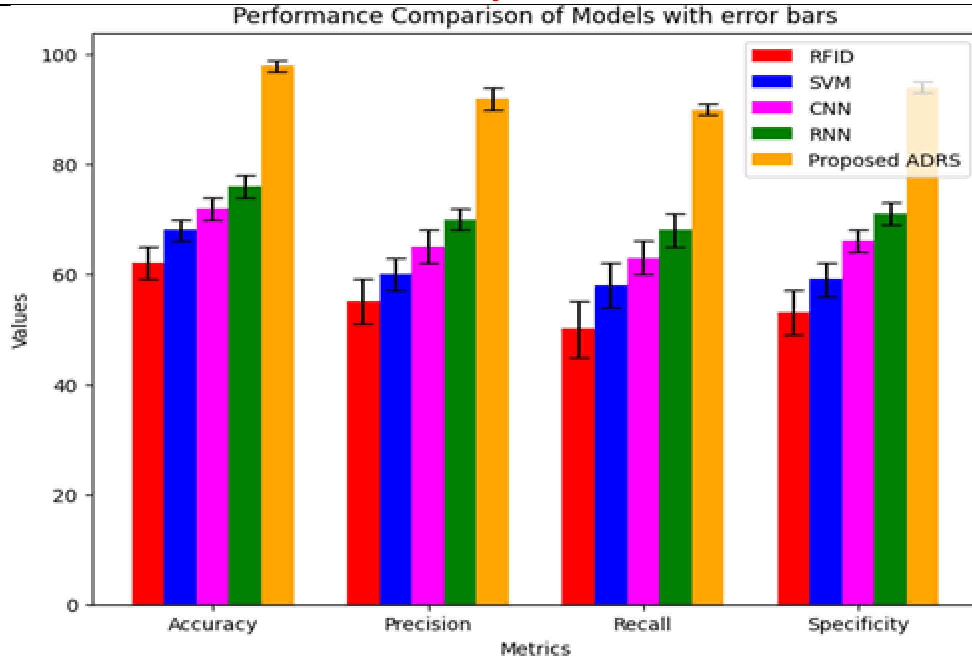

Figure 8 Comparison of performance of the Proposed ADRS with existing techniques

The details of all the evaluation metrics of the proposed ADRS and the existing techniques are shown in Table 4. The proposed ADRS outperforms with an accuracy of 98%.

Conclusion:

In this study, we have proposed a novel IoT-based ADRS that will not only detect an accident but will also raise alerts for dealing it with on time and efficiently to reduce lives lost. The function of a vehicle monitoring system makes it possible to better manage and control traffic, which raises profits. Better scheduling or route planning allows us to handle larger loads in less time. Whether used for personal or professional purposes, vehicle tracking guarantees safety and security as well as communication, performance, and productivity monitoring. As a result, this ADRS will become increasingly important in our daily lives in the years to come. The main objective of this accident detection and alerting system is to reduce the number of fatalities from unavoidable accidents. To increase the likelihood of survival, a medical team is dispatched to the scene of an accident that the system detects. In the future, we will include security aspects in the proposed system and we will also make use of the interconnected mobile units employed in ITSs. When a unit detects an accident, the Intelligent Transport System's networked mobile units can alert one another. This could alert the driver of an accident nearby by interacting with the car's computer. Vehicles can share road conditions and traffic congestion to create a database of current load circumstances, from which the optimal route to destinations is calculated.

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