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ACCIDENT DETECTION AND REPORTING SYSTEMS IN IOT-ENABLED VEHICLES: TRENDS, TECHNOLOGIES, AND CHALLENGES

Vivek Sharma[1]

[1] System Analyst, MITS Deemed University
viveks@mitsgwalior.in

Abstract: There has been an increase in the usage of accident detection and response systems to improve road safety and reduce the number of fatalities brought on by traffic accidents. This article examines the use of Internet of Things (IoT) technology for real-time accident detection and categorization, as well as emergency communications in a vehicle environment. Continuous monitoring of vehicle dynamics is facilitated by a multi-sensor system, which includes accelerometers, a Global Positioning System (GPS), pressure sensors, and microphones. Data obtained is processed by microcontrollers and smartphones, and machine learning methods are employed to categorize the severity of an accident. When the detection has been made, alerts are sent to the emergency services through Global System for Mobile Communications (GSM) or 5G networks. The system also uses the Open-Source Computer Vision Library (OpenCV) in detecting visual accidents in surveillance videos and predictive analytics to predict the possibility of an accident using past and real-time data. Edge computing and cloud services are covered along with communication technologies to ensure effective data processing and a response with minimal delays. The paper also identifies existing barriers, such as sensor accuracy, false alarms, connectivity, and data privacy. Additionally, new trends that include the hybrid reasoning models, federated learning, and blockchain embedding are also suggested to improve the system's robustness. This study give a detailed picture of the realization, opportunities, and future of IoT-enabled accident detection systems in intelligent transportation and the safety of people.

Keywords: IoT, Accident Detection, Real-time Monitoring, Emergency, Smart Transportation, Deep Learning, Intelligent Safety Infrastructure, Smart Helmet, 5G-enabled IoT.

1 INTRODUCTION

The high rate of growth in the population of the world has experienced a phenomenal growth of the need of vehicles and this has caused a lot of traffic jams and road carnage [1]. Road crashes which are defined as crashes involving vehicles, objects or people are now ranked as one of the top causes of injury-related deaths throughout the world. In such cases, early delivery of emergency services is very critical in determining the survival rate of the victims of the accident [2]. There is also the issue of delayed medical help, which is normally attributed to traffic jams or an unstable communication system, which plays a key role in causing death, even when the injuries sustained are not life-threatening.

In order to counter this, Accident Detection and Reporting Systems (ADRS) based on Internet of Things (IoT) and Artificial Intelligence (AI) have come up as useful tools. These systems aim to reduce human intervention in accident reporting by automatically identifying and notifying emergency services, such as hospitals and police stations [3]. Most literature has proposed a diversified set of methodologies, which include smartphone crash detection, GPS/GSM tracking, vehicular ad hoc networks (VANETs), and machine learning (ML)-based methodologies.

The recent developments in IoT have revolutionized the transportation ecosystem. New cars are becoming telematics-enabled and fitted with sensors supported by the IoT that retrieves real-time information on speed, use of airbags, vehicle type, and driver habits [4]. Such information sent to cloud servers not only helps in the real time detection of accidents but also helps in analyzing the accident after it has occurred to come up with prevention strategies. There are also adaptive traffic lights, smart parking sensors and automatic tolling, which are considered to be smart transportation systems and they add to the road safety and traffic efficiency.

The ADRS framework proposed has two-phase system, namely, (i) accident detection on the basis of IoT sensors and deep learning (DL) models; and (ii) auto rescue procedure, whereby other hospitals, police, and emergency teams in the area are alerted [5]. The hardware architecture have such components as Raspberry Pi, ESP8266, GPS modules, cameras, GSM modules, force sensors, and alarm controllers, all of which be used in concert to record, send, and process data about car crashes.

The need to minimize false positives caused by sudden braking, potholes, or loud noises is one of the key issues of ADRS. Thus, the introduction of strong algorithms founded on acoustic and acceleration data with different priorities given to their reliability and contextual trends has been proposed [6]. Also these systems allow authorities to transmit accident-prone areas through the analysis of spatial and temporal accidents and this results in specific infrastructure being made and traffic being enforced. The use of ADRS systems enabled by the IoT industry is an essential part of improving road safety due to the ability to shorten response times, save lives, and prevent accidents on a proactive level [7]. As these systems continue to evolve, integrating AI and big data analytics, they promise a future of smarter, safer, and more responsive transportation networks.

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1.1 Structure of the Paper

The structure of this paper is organized as follows: Section I provides the introduction, outlining the motivation and background of IoT-based accident detection systems. Section 2 discusses IoT-enabled accident detection system. Section 3 highlights recent trends in accident detection techniques. Section 4 delivers a comprehensive literature review comparing existing and proposed solutions. Finally Section 5, the paper concludes with insights and future directions.

2 IOT-ENABLED ACCIDENT DETECTION SYSTEMS

The automobile utilizes a number of sensors to collect data on accidents. A classification model is used to classify the data according to severity degree after it has been processed by a microcontroller. The microcontroller sends out an emergency alarm in case of an accident via a GSM transmitter. To utilize the system, it doesn't need a fancy car or smartphone [8]. The Seeeduino, GPS Module, XBee WiFi Module, and XBee Shield make up the system. In order to transmit the data to the smartphone, the sensor drone stays connected to it via Bluetooth. The smartphone manages the majority of the processing device.

2.1 Devices and Sensors

These include sensors and data-gathering and data-transmitting devices, which are the IoES's physical components. Robots, drones, smart helmets, and wearables are a few examples of gadgets. Biometric devices that gauge oxygen levels and blood pressure, and heart rate are examples of sensors, as are environmental sensors that track temperature, humidity, and air quality [9]. These devices and sensors can be used to detect and monitor emergency situations, provide situational awareness, and collect data in real time.

The system is designed to identify accidents by utilizing several sensors included in smartphones, such as the accelerometer, GPS, pressure, and microphone acquisition. Make a mobile app that constantly checks the sensors and sends the readings to a cloud service for processing. A threshold analysis determines an accident. This article's main contribution is that it developed a system that notifies the nearest hospitals and ambulances of an accident in the event that it is detected.

2.2 Detection

To detect the accidents using OpenCV, the CCTV videos be entered into the system and processed with the help of OpenCV libraries (Figure 1). The video would be divided into separate frames, and each frame would be considered regarding any traces of an accident like a sudden change of motion or some unusual activity [10]. The OpenCV algorithms would thereafter be applied to detect and analyze certain features of the frames including vehicles, pedestrians, road signs and so on. Should an accident be discovered, the system would identify where the accident is located with the help of the OpenCV libraries. The rescue systems would then be informed about this location via an application.

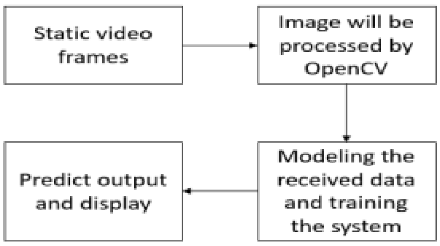

Figure 1: Detection using OpenCV

2.3 Prediction

The system also uses the data collected and stored in past accidents (Figure 2), in addition to the use of up-to-the-minute data, including meteorological, traffic, and road conditions for the purpose of accident prediction. The information can be subsequently utilized to give a warning or alert to the law enforcement agencies and members of the area or to regulate the flow of traffic or otherwise reduce the chances of an accident. It is also possible that the system uses the historical information to train the model used in predicting future accidents with high accuracy.

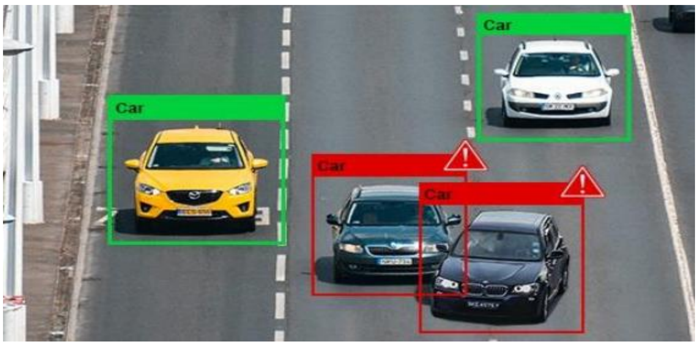

Figure 2: Accident Frame

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2.4 Communication Technologies

Accident detection lowers the number of fatalities from traffic accidents by preventing regrettable events that cause damage or harm. The fundamental elements utilized in the accident detection phase are depicted in Figure 3. These elements aid in determining when an accident has occurred. To ascertain if an accident has occurred, the detection phase makes use of the smartphone's GPS, accelerometer, microphone, and pressure sensor data. Additional information on the elements utilized in the accident detection phase is provided below.

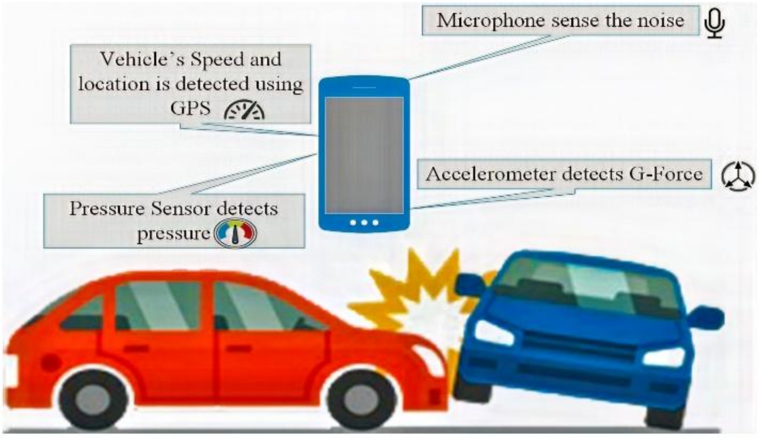

Figure 3: The Basics Component used in This Technology

It has been suggested that the technique might be split into two halves, based on an affordable 5G and IoT-based reporting and accident detection system: accident identification and accident reporting. A smartphone's pressure, accelerometer, microphone, and global positioning system (GPS) can all work together to identify an accident. The data from the sensors is collected and sent to the edge cloud for processing using a smartphone application [11]. Accident causes are identified by threshold analysis. The family, police station, and closest hospital are alerted when an accident is discovered.

2.5 Processing and Computing Layers

These sensors use a network to send the object-specific data they have collected to a system for processing and analysis. Decision-making units receive this processed data and decide which automatic actions to initiate. It should be noted, nevertheless, that sensors do not have unlimited storage or processing capacity, which might cause problems, especially with dependability and security. Some of these problems have been addressed with the use of cloud computing [12]. Figure 4 shows the average a few examples of IoT applications are [13].

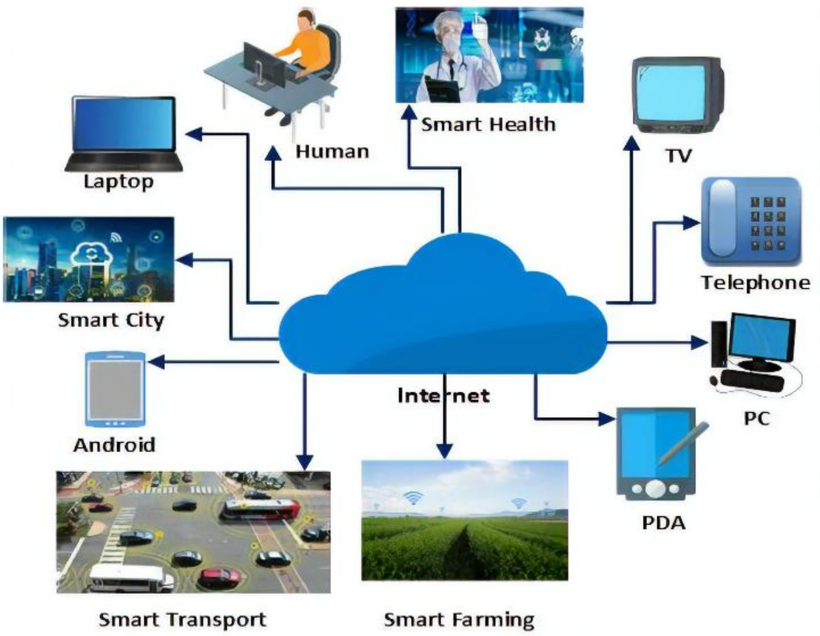

Figure 4: Processing and Computing Layers

- **IoT in Healthcare:** The Internet of Things (IoT) has several uses in the healthcare industry, including better patient care and real-time monitoring. It enables constant vital sign monitoring, particularly in hospital settings, including blood

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pressure, heart rate, and glucose levels. IoT also supports medical cold storage by tracking the condition and expiry of medicines and vaccines [14]. For elderly or disabled individuals, fall detection systems can trigger timely assistance. In dentistry, smart toothbrushes connected via Bluetooth can analyze brushing habits. Additionally, wearable devices like smartwatches help monitor physical activity, including step count and heart rate, promoting overall wellness.

- **IoT in Smart Environment:** Real-time monitoring of climate conditions, water and air quality, and natural disaster risks. It supports early detection of floods, landslides, and forest fires by tracking environmental changes [15]. IoT can also be used in controlling pollution and protecting wildlife by using tracking of animals and a monitoring system of emissions by vehicles and industries using GPS.
- **Role of IoT in Industries:** The application of IoT is crucial in industrial safety and efficiency because it uses real-time monitoring of toxic gases, water, oil, and oxygen levels in storage facilities. It assists predictive maintenance, fleet control, and temperature control to avoid the failure of equipment and the safety of the workers [16]. The IoT is also useful in ozone detection during food production or processing, monitoring indoor air quality, and improving rescue operations through the correct localization of workers trapped in relation to disasters such as explosions or landslide.
- **IoT In Agriculture:** Smart monitoring and control systems arising out of IoT in agriculture make agriculture more productive and sustainable. It allows controlling the climate of the greenhouse, tracking the animals, and detecting the quality of air to ensure the optimal climate. The pH, moisture, and salinity levels also be monitored in the field and soil with the help of sensors; the use of water be optimized to eliminate wasting. IoT can also be used in pest control, disease detection through the use of RFID tags and the ability to make long distance decisions so that the farmers can respond timely and efficiently to the demands of the agriculture practices.
- **IoT in the Automotive Industry:** IoT enhances vehicle safety, efficiency, and user experience through advanced monitoring and automation. Onboard diagnostics help with real-time vehicle maintenance, fault detection, and safety checks like seat belt usage and drowsiness alerts. IoT enables vehicle tracking, collision and fire detection, and automated toll and fine payments via RFID [17]. Connected cars offer infotainment features, while geo-fencing, speed monitoring, and driving behavior analysis improve driving control. Additionally, biometric systems provide secure driver authentication and anti-theft protection, making vehicles smarter and more secure.

2.6 The Need for Accident Detection Systems

These technologies are obviously necessary given the profound effects that traffic accidents may have on both people and society at large [18]. These technologies have the potential to decrease reaction times, improve overall traffic safety and decrease the harm that crashes due to individuals and society. The following are some major advantages of accident detection systems:

- **Improved Response Times:** Accident detection systems can facilitate the prompt notification of emergency services, enabling quicker reaction times and perhaps saving lives.
- **Reduced Risk of Secondary Accidents:** It can put other drivers on the road in danger when an accident happens. An further accident is more likely to occur if emergency services are not promptly contacted. Systems that use sensors and other technologies to identify collisions can lower the likelihood of follow-up collisions and protect drivers.
- **Enhanced Road Safety:** The technology can assist to increase overall road safety by promptly notifying emergency services and identifying places that may require upgrades in infrastructure or road design.
- **Cost Savings:** Accident-related costs can be high and include missed pay, hospital bills, and auto repairs. Through prompt accident detection and reaction time reduction, these innovations can mitigate the impact of mishaps on individuals and the broader community.

3 TRENDS IN ACCIDENT DETECTION TECHNIQUES

An IoT-based system and an intelligent security architecture are suggested for instant accident detection. To protect the driver's privacy, this system needs the utmost security and privacy. The design and evaluation of the artefacts were also conducted using the design science research approach. Developing a secure and effective IoT system to detect and report moving collisions in real time [19]. Additionally, the message is encrypted using Elliptic Curve Integrated Encryption and then sent via GSM using Message Queuing Telemetry Transport.

3.1 Hybrid Approaches

The challenges of rational thought in assisted living technology-enabled settings underscored the importance of using hybrid reasoning techniques to handle the overlapping, concurrent, and contradictory goals and interests of several residents [20]. It emphasizes how important smart monitoring and reaction are to the effectiveness and security of smart home automation.

3.2 Predictive Analytics for Accident Prevention

The emphasis on a situation in which condition checking and trend tracking are not immediately supported by the data. In particular, there is no information on typical or hazardous parameter values or references in the data gathered from IoT sensors. In order to overcome this difficulty, offer a broad framework for dealing with such circumstances [21][22][23]. The goal of trend monitoring is to identify deteriorations that surpass critical values by routinely collecting and analyzing data. The process of condition checking involves taking regular measurements using precise indicators while the component is in use in order to determine its present state. Figure 5 illustrate the Predictive Analytics for accident prevention.

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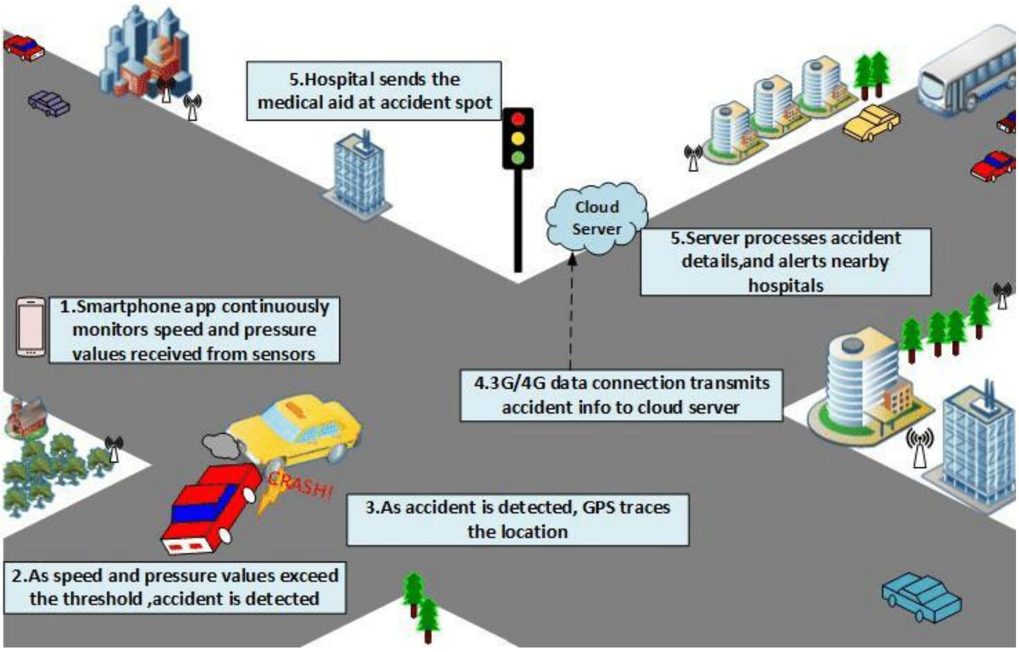

Figure 5: Predictive Analytics

3.3 5G-enabled real-time communications

In 5G-enabled IoT systems, AI can improve data processing, optimize network management, and improve decision-making processes. Additionally, edge computing's close proximity to IoT devices can improve real-time processing and reduce latency, which is especially advantageous for applications that need to analyze and respond to data instantly [24]. The trend in this system creates real-time communication in Figure 6.

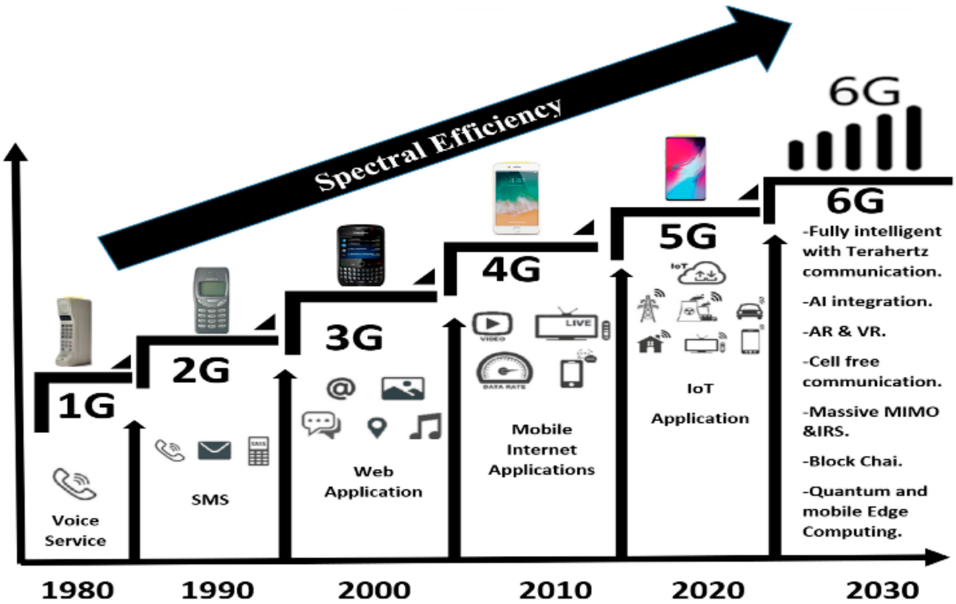

Figure 6: Trends in Evolution

3.4 Challenges of Accident Detection

There are still issues in this sector, such as data volume, vehicle collaboration, and privacy, which may be addressed in a variety of ways, including federated learning. Although traffic management has made use of edge computing, monitoring of traffic violations has received less attention [25]. In a similar vein, fog computing has been applied to traffic control, although not much attention has been paid to monitoring infractions. The proposed edge and fog computing systems are mainly concerned with speed and traffic signal monitoring and do not include passenger counts or seatbelt status checks.

- **Sensor Reliability and Data Accuracy:** Accurate accident detection heavily relies on the quality and reliability of sensors such as accelerometers, gyroscopes, GPS, and cameras. The occurrence of environmental conditions such as rough roads, potholes, or sudden braking can serve to reproduce accident conditions resulting in false positive results. Further performance degradation can be achieved due to sensor failure, inaccurate calibration or misalignment.

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- **False Positives and Missed Detection:** The most crucial issue is to differentiate between real collisions and non-critical driving incidents. Aggressive driving actions, hard braking or minor collision can be misinterpreted as severe collision by the systems. On the other hand, under-sensitive systems can also miss out identifying actual accidents, particularly concerning low-impact or non-front crashes.
- **Network Connectivity and Latency:** Systems built on the principles of the IoT frequently rely on reliable cellular or satellite networks to send an alarm about a crash. Emergency notifications can be delayed or blocked in a rural area or other isolated places due to lack of network coverage. The latency of networks can adversely affect the transmission of any data in real-time that is essential to responding to a crisis in time.
- **Data Security and Privacy Concerns:** Accident detection systems record private data, including a vehicle's location, speed, and driving habits. The protection against data breaches and cyberattacks requires ensuring that the communication and storage is secured. In addition, data privacy regulations (e.g., GDPR) should be observed when disclosing any information connected to the accident to a third party.
- **Integration and Interoperability Issues:** The systems to detect accidents should be able to fit well with vehicle onboard systems, smartphones, clouds and emergency teams. Lack of standardization in communication protocols and hardware interfaces often leads to compatibility issues between different vendors or vehicle models.

4 LITERATURE REVIEW

This literature review explores recent advancements in IoT-based accident detection and response systems. It highlights the shift from manual and GSM-based methods to intelligent solutions, wearable sensors, and real-time communication technologies. The review compares existing approaches, identifies trends, and outlines challenges, providing a foundation for developing more efficient and automated safety systems in transportation.

T et al. (2025) present research focus on developing IoT-based Train Accident Detection and Loco Pilot Health Monitoring System based on the YOLOv5 model with real-time object detection and wearable IoT sensors for day-to-day health monitoring by Cameras and sensors. Materials and Methods: This Research is based upon two groups. Group 1: Existing method for accident detection and loco-pilot health monitoring relies mainly on Mask R-CNN monitoring systems and manual reporting systems. Group 2 The proposed IoT-based train accident detection system and loco-pilot health monitoring using the YOLOv5 model provide a more advanced automated solution [26].

M.E et al. (2025) A device using an ESP32-CAM, GPS, and several sensors to report in real time on fire, vibrations, and locations, it takes a picture, sends data to the cloud through an ESP32 microcontroller, and calls for help. In an accident, the device sends automatic SMS alerts to the configured contact numbers of the emergency event and details of the location. With its modular and energy-saving design, the VBBS is suited for instant-responsive monitoring and quick rescue operations with positive implications on road safety and responses [27].

Sharma et al. (2024) emergency services are not readily available and are deficient in delivering prompt care and first aid, which may result in a few minutes' difference in death. Therefore, it is necessary to create a system that addresses each of these issues, and SOS is capable of overcoming the delay time brought by directly informing the family members of the victim with the help of an app, so that they can take immediate action and help their family members in that situation [28].

Manga et al. (2024) Driver carelessness and speeding are the most frequent causes of auto accidents, while there are numerous other potential contributing variables. Furthermore, a lack of awareness seems to make it challenging to get to the accident site in time. IoT technology's rise can assist in resolving this issue by reducing the number of accidents. The explanation of a clever system that warns drivers regulates vehicle speed, and notifies others appropriately in the case of an accident. This gadget continually monitors the distance between any obstructions and approaching cars using a distance sensor [29].

Patil et al. (2023) issue of traffic accident rates is one of the most significant problems facing health and social policy in nations throughout the continents today. In this article, the authors address the number of fatalities and injuries resulting from traffic accidents in various Indian states. The many elements that lead to road accidents have also been clarified by us. The several techniques for spotting car wrecks or accidents that numerous studies have reported are covered in this book [30].

Radhamani et al. (2023) Driving around bends and curves is risky. A potential remedy for Hairpin Bend Roads has been suggested in this paper: an IoT-based accident prevention system. In addition to installing traffic warning lights that notify drivers of both automobiles approaching the bend of the impending vehicle on the other side of the bend, the planned project seeks to decrease accidents, particularly at U-curve and hairpin bends. An ultrasonic sensor included in the proposed gadget instantly alert any car approaches the hairpin curve when it happens [31].

Ram et al. (2022) failure to adhere to safety rules or the delayed reporting of accidents are the primary causes of these incidents. Wearing a suggested smart helmet allows the rider to avoid accidents and even tell whether they're drunk. The prototype's infrared sensor, accelerometer, and breath analyzer are used to detect this. A coded interface receives data from the accelerometer, which monitors the rider's abrupt tilt. The breathalyser will sound an alert if the rider's blood alcohol content (BAC) exceeds the permitted level [32].

A et al. (2022) frequency of road accidents has risen, leading to a substantial loss of life and property, mostly as a consequence of insufficient emergency services. It is made worse by elements such as a rise in traffic, reckless driving, bad roads, and extreme

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weather. In 2021, the World Health Organization (WHO) estimated that almost 1.3 million people lost their lives in car accidents annually. After an accident, the delay in providing emergency medical care is the main factor that increases the death rate. Utilizing the Internet of Things (IoT), this study developed a solution to deal with this issue [33].

Table 1 presents a typological overview of significant research studies on IoT-based accident detection devices, highlighting methodology, problems being addressed, and constraints.

Table 1: Summary of Literature Review on IoT-Based Accident Detection and Reporting Systems

Author (Year)	Key Findings	Methods/Approach	Challenges Addressed	Limitations / Gaps
T et al. (2025)	Developed IoT-based train accident detection and loco pilot health monitoring system using YOLOv5.	YOLOv5 model with real-time object detection, wearable IoT sensors, and camera monitoring.	Inefficiencies in existing manual and Mask R-CNN-based monitoring systems.	Dependence on real-time data quality; potential latency in detection.
M.E et al. (2025)	Designed ESP32-based modular device for real-time accident alerts and safety monitoring.	ESP32-CAM with GPS, vibration, fire sensors, cloud sync, SMS alerts.	Lack of real-time communication and automated response during emergencies.	Limited to predefined events (fire, vibration); SMS alert reliability depends on network availability.
Sharma et al. (2024)	SOS app to notify family during emergencies to reduce delay in rescue.	Mobile app-based SOS alert system for real-time emergency response.	Delay in emergency services and lack of instant communication to family members.	Relies on user action to trigger SOS; app adoption required.
Manga et al. (2024)	IoT system to reduce automobile accidents due to speed and negligence.	Obstacle detection using distance sensors; alerts to driver and nearby vehicles.	Accidents from over speeding and unawareness of surrounding vehicles.	Primarily preventive; may not work well in low visibility or harsh weather conditions.
Patil et al. (2023a)	Reviewed traffic accident trends and detection methods in India.	Analysis of factors contributing to road accidents and survey of detection technologies.	Rising traffic fatalities; need for better accident detection mechanisms.	Lacks implementation or proposed system; mainly statistical overview.
Radhamani et al. (2023)	Proposed IoT-based prevention system for accidents at hairpin bends.	Ultrasonic sensor-based vehicle detection and traffic warning signals.	Road curve dangers and collision risks in hairpin bends.	Limited to specific terrains; effectiveness may reduce in foggy or noisy signal environments.
Ram et al. (2022)	Smart helmet detects accidents and rider intoxication via alcohol level.	IR sensor, accelerometer, and breath-analyzer integrated into helmet.	Unreported accidents and drunk driving detection.	Wearability and user compliance; false positives in alcohol detection.
A et al. (2022)	Developed IoT-based emergency response system to reduce road accident fatalities.	IoT-integrated sensors and alert systems to minimize emergency response time.	Delays in emergency medical response post-accident.	Infrastructure dependency; adoption in rural areas may be limited.

5 CONCLUSION AND FUTURE WORK

Through the integration of IoT, accident detection systems are revolutionizing road safety by facilitating emergency reporting and real-time monitoring. These systems employ classifiers and threshold analysis to identify accidents using sensors like GPS, accelerometers, microphones, and pressure sensors installed in cars and cellphones. Enhanced communication technologies like 5G, GSM, and cloud/edge computing ensure timely data transmission and emergency response. Computer vision with OpenCV, predictive analytics using historical and real-time data, and hybrid reasoning models further strengthen the system to proactively detect and predict accidents. Beyond transportation, IoT applications in healthcare, smart spaces, agriculture, and industry showcase cross-domain benefits aimed at safety and efficiency. However, challenges such as sensor inaccuracies, false positives, connectivity issues, data privacy, and lack of interoperability must be addressed. Future research should enhance sensor fusion to reduce false positives and improve detection under varied conditions. Integrating federated learning and privacy-preserving AI can ensure data security and regulatory compliance. AI-based predictive analytics considering dynamic factors like weather, traffic, and driver behavior are vital to accident prevention. Establishing collaborative frameworks that connect smart infrastructure, vehicles, and emergency services is essential for building an intelligent, scalable, and reliable IoT-driven accident detection and prevention ecosystem.

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