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A Review on Accident Detection and Monitoring System

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***Abstract*— Accidents occurring on the roads have been identified as one of the major causes of injuries and fatalities across the globe due to the lack of immediate accident detection systems and the delayed response of the emergency services. Recent advances in Internet of Things (IoT), wireless communication, and embedded systems have led to the development of advanced accident detection and monitoring systems to automatically detect accidents occurring on the roads. Accidents occurring on the roads can be detected through various technologies such as accelerometers, vibration sensors, GPS modules, and communication devices. These systems greatly reduce the time taken for responding to accidents occurring on the roads and thereby improve the efficiency of the accident response mechanism. The current review paper aims to present an overview of various accident detection and monitoring systems presented in various studies. The paper also aims to present the advantages and limitations of the accident detection systems and their future scope of work.**

Keywords—IoT; Vehicle Accident Detection; Arduino; Alcohol Detection; Accelerometer Sensor

I. INTRODUCTION

The rapid development of infrastructure related to transportation and the increased number of vehicles on the road have improved the connectivity of people in modern society. However, the rapid development of infrastructure related to transportation and the increased number of vehicles on the road have also caused a sharp increase in the number of accidents on the road across the globe. In addition, there has been a sharp increase in the number of injuries and loss of life due to accidents on the road. Based on the studies conducted on the safety of the global transportation system, it has been identified that the delayed reporting of accidents is one of the major reasons for the sharp increase in mortality rates during accidents on the road. In addition, the conventional safety features of vehicles are not capable of automatically detecting accidents and communicating the situation to the relevant parties immediately. In addition, the conventional safety features of vehicles are designed to reduce the impact of accidents and collisions. Hence, there is a need for the development of intelligent accident detection and monitoring systems to resolve the issue of delayed reporting of accidents on the road and ensure the safety and security of people driving on the road [1].

The development of embedded systems and Internet of Things technologies has, in recent times, offered opportunities for the development of various intelligent accident detection and monitoring systems for vehicles on the road. The conventional sensor-based accident detection and monitoring systems make use of accelerometers, vibration sensors, gyroscopes, and GPS for monitoring the parameters of vehicles and detecting abnormal situations or conditions related to accidents on the road. The accelerometers and vibration sensors are used for detecting abnormal situations or conditions, such as accidents and collisions, on the road by sensing the abnormal impact faced by vehicles during accidents and collisions on the road. Once the abnormal situation is detected by the accelerometers and vibration sensors of the vehicle, the system may be designed to transmit the alerts to relevant parties immediately, thus improving safety and security for people driving on the road [2].

Research has been conducted on various studies related to the integration of IoT technologies with vehicle monitoring systems for accident detection and communication. IoT technologies make use of wireless communication technologies, including GSM, Wi-Fi, and Bluetooth, for communication and data transfer. These systems are useful for enabling vehicles on the road to operate as intelligent nodes on the road. IoT-based accident detection systems are effective and may be used for automatically communicating accidents to relevant authorities. These systems are useful for locating victims during accidents on the road, thus improving rescue operations [3].

Another important research area in accident monitoring systems is the development of data recording systems for vehicles, similar to the ones used in airplanes referred to as the black box. The use of such systems is important in the recording of various operations of vehicles, such as speed, acceleration, braking patterns, and environmental conditions before and after accidents. This type of data is important in analyzing accidents and developing future safe vehicle designs. The use of accident monitoring systems with a black box approach and IoT communication systems is important in facilitating the recording of data with the aim of understanding accident causes and developing future transportation strategies [4].

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Automated accident response systems have also been proposed for the purpose of enhancing emergency communication in case of accidents that happen on the road. These types of accident response systems use a combination of sensor technologies and automated messaging services for the purpose of sending messages to emergency responders and hospitals when an accident happens on the road. Using a GPS module and different types of wireless communication technologies, it is possible to send accurate information when an accident happens on the road. This reduces the need for human witnesses for the purpose of reporting accidents that happen on the road, and it is possible to send accurate information immediately for enhancing the survival chances of accident victims [5].

Other research has also focused on accident prevention systems that are capable of detecting accident conditions before they happen on the road. These types of accident prevention systems have shown the potential for enhancing road safety by utilizing a distributed sensing infrastructure and intelligent monitoring systems for the purpose of detecting unsafe driving habits, road conditions, and vehicle malfunctions that may cause accidents on the road. These accident prevention and detection systems are capable of detecting potential accident conditions and sending alerts to drivers before the accident happens on the road [6].

In addition to this, with the advancement of artificial intelligence and machine learning technologies, the existing accident detection systems have demonstrated greater intelligence compared to the traditional accident detection systems. The intelligent accident detection systems incorporate AI models that have the capability to analyze accident conditions by analyzing the sensor data, driver behavior patterns, and environmental conditions. In addition to this, machine learning models have the capability to analyze large amounts of information collected through sensors and vehicular networks to improve the accuracy of accident detection systems. The intelligent accident detection systems have the capability to identify regular vehicle movement and abnormal vehicle movement due to accidents. This helps to improve the overall accuracy of accident detection systems [7].

The public safety communication systems have also been integrated with IoT frameworks to improve emergency responses during accidents. The safety communication systems incorporate IoT technologies that have the capability to integrate various devices and sensors with communication systems to ensure continuous monitoring and instant generation of alerts during emergency situations. The IoT-based safety communication systems have the capability to disseminate accident-related information to a large number of stakeholders. The safety communication systems improve the safety of emergency response operations during critical situations on the road [8].

Apart from the implementation of accident detection systems using various types of sensors, visual monitoring, and reporting-based accident detection systems have also been proposed for the improvement of the accuracy level in the detection of accidents. In computer vision-based accident detection systems, cameras are utilized for capturing the visual scenes on the road, analyzing the conditions on the road, and detecting accidents. This system can be helpful in providing detailed information in the event of accidents, where visual information can be sent to the monitoring centers. The implementation of such systems might be difficult due to the need for high computational and communication resources, which might not be feasible in the development of low-cost embedded systems [9].

Artificial intelligence-based accident detection systems have also been proposed for smart city environments. In a smart city environment, different vehicles operate in collaboration with one another to improve the safety of the roads. In such systems, cloud computing platforms have been proposed to analyze the data gathered from the vehicles and devices installed for monitoring the conditions of the roads to detect accidents and predict the occurrence of accidents. Such intelligent transportation systems have been proposed to improve the safety of the roads by providing the facilities of predictive accident analysis. However, the implementation of such systems might not be possible in the context of developing real-time embedded systems in vehicles due to the requirement of high-scale infrastructure support and cloud connectivity, which might not be possible in such systems [8], [10].

Vehicular communication technologies such as vehicle-to-everything communication and vehicular fog computing architectures are also contributing to the improvement of the capabilities of accident detection and monitoring systems. In this regard, vehicles are able to communicate with other vehicles and systems to improve accident awareness. In addition, the vehicle-to-everything communication framework also enables vehicles to communicate and share information related to accidents and road hazards. However, the implementation of such technologies requires effective communication infrastructure and network management systems [11], [12].

Further, there have also been various research activities carried out on the development of long-range communication systems such as LoRa technology-based vehicular monitoring systems and safety systems such as wearable safety systems for accident detection. The LoRa technology-based systems have been effectively utilized for long-range communication with low power consumption. This makes the system more suitable for accident monitoring systems. In addition, safety systems such as smart helmets have also been proposed for monitoring various environmental conditions, the health of the driver, and accident detection. Even though the proposed systems have been effectively utilized for accident monitoring and safety, the existing accident monitoring systems have been found to have various challenges in terms of the complexity of the system, the cost efficiency of the system, the communication capabilities of the system, and the integration of various sensing technologies with the embedded systems [13],[14].

In view of the various challenges identified in the existing accident detection and monitoring systems, it is essential to develop more efficient accident monitoring systems that can integrate various sensing, communication, and alerting technologies with a single embedded system. The objective of

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the present review article is to analyze the existing accident detection and monitoring technologies, identify the various research gaps in the existing accident monitoring systems, and present various sensor-based, IoT-enabled, and intelligent monitoring systems for accident monitoring and safety. In addition, the importance of the integration of various driver monitoring systems, accident detection systems, and emergency communication systems with a single safety system is also discussed in the present article.

II. Review of Previous Work

Several research studies have been carried out on the development of real-time accident detection systems using Internet of Things technology along with embedded microcontroller devices. In such cases, accelerometers, vibration sensors, and gyroscopes are generally used for detecting unusual variations in the dynamics of the vehicle, indicating accident or rollover conditions. In such cases, the data obtained from the sensors, based on the unusual movement of the vehicle, is sent to remote locations using wireless communication modules embedded in the system. Such Internet of Things-based monitoring systems for accident conditions help in the development of automatic accident reporting systems, where the location of the accident is obtained efficiently, thereby saving the time taken for rescue operations [1], [2].

Several research studies have been carried out on the development of automatic accident rescue systems using sensing devices along with wireless communication modules for the transmission of emergency messages. In such cases, the data obtained from the sensors, indicating unusual movements of the vehicle, is sent to remote locations using embedded microcontroller devices, where it is converted into alert messages along with the coordinates obtained from the GPS module, indicating the location of the vehicle. Such automatic accident response systems have been developed, indicating the possibility of efficient communication during accident conditions [3], [5]. Table 1 shows the review in tabular form.

Table 1 Review of Previous Work

Ref No	Technique	Advantages	Remarks
[1]	IoT-based vehicle monitoring system	Real-time accident detection and remote monitoring	Requires stable wireless communication
[2]	Embedded accident detection using sensors	Low cost implementation and automatic alert generation	Accuracy depends on sensor calibration
[3]	IoT-based accident rescue system	Rapid emergency notification and GPS tracking	Network dependency may affect response
[4]	Vehicle black box monitoring system	Continuous recording of vehicle parameters	Primarily useful for post-accident analysis
[5]	Automated accident response system	Immediate alert transmission to emergency services	Requires reliable communication network
[6]	Accident prevention with roadside sensing	Early detection of hazardous driving conditions	Infrastructure deployment required
[7]	AI-based vehicle safety monitoring	Intelligent detection and predictive analysis	Higher computational complexity
[8]	IoT-based public safety alert system	Multi-device emergency communication	Integration complexity in large networks
[9]	Visual accident detection system	Enhanced situational awareness using image analysis	High computational requirements
[10]	AI-enabled emergency response framework	Improved analytical capability for accident detection	Cloud processing dependency
[11]	Deep learning accident detection model	High detection accuracy in complex scenarios	Requires large training datasets
[12]	V2X communication-based accident awareness	Real-time vehicle-to-vehicle communication	Requires advanced infrastructure
[13]	Vehicular fog computing monitoring system	Low latency distributed processing	System architecture complexity
[14]	LoRa-based vehicular monitoring network	Long-range communication with low power	Limited data transmission rate
[15]	Smart safety helmet monitoring system	Driver health and environmental monitoring	Mainly applicable to specific vehicle domains

Another type of accident monitoring systems is related to the data recording and analysis mechanism of vehicles. These types of accident monitoring systems are related to the recording of the operational data of vehicles before and after collision accidents. These types of accident monitoring systems are similar to the black box recording systems of airplanes. In this system, the data recording mechanism is performed by collecting data from vehicles during accidents. The analysis of the data recorded by this system can be used to analyze the causes of accidents by analyzing the patterns of behavior leading to accidents. The integration of IoT communication systems with data recording systems can improve the efficiency of accident investigation and improve the methodologies of analyzing vehicle safety [4], [6].

A. Recent advances in intelligent transportation systems:

The recent advances in intelligent transportation systems are related to the integration of intelligent accident detection systems based on artificial intelligence concepts. The machine learning concepts are related to the application of data analysis algorithms for analyzing the data recorded from vehicles. The machine learning models can identify the normal and abnormal conditions of vehicles during accidents by analyzing the patterns of motion of vehicles and environmental conditions. The machine learning models can also be used for intelligent accident analysis by identifying the conditions of driving leading to accidents. Although intelligent systems can be used to improve the reliability of accident detection systems, a large

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number of computational resources are required for processing data [7]-[10].

Apart from the in-built accident detection systems, advanced vehicular communication systems have been proposed to enhance road safety through the integration of various systems in the transportation sector. Vehicle-to-everything communication and vehicular fog computing have been proposed to enable communication among vehicles. The proposed systems have the potential to enhance the communication of accident-related information and other forms of information to enhance general awareness. In addition, long-range communication systems and safety monitoring systems have been proposed to enhance accident monitoring systems. However, regardless of the advantages of the proposed systems, the need to address the various challenges in the development of the systems cannot be ignored. Infrastructure dependency and communication reliability are among the most crucial factors to be considered in the development of accident monitoring systems.

III. Accident Monitoring Systems

Accident monitoring systems have been identified as a critical component of intelligent transportation systems, focusing on road safety and reducing the response time of emergency services. Accident monitoring systems have been designed to continuously monitor the condition of vehicles and environmental conditions using sensors and communication modules, identifying abnormal conditions such as sudden accidents, rollover of vehicles, or hazardous driving conditions. Embedded systems, wireless communication systems, and cloud computing technologies have enabled the development of accident monitoring systems that are capable of identifying accidents and immediately communicating with emergency services. Fig. 1 shows the distribution of various technologies used in accident detection systems such as sensor-based technology, IoT-based technology, AI-based technology, computer vision-based technology, and V2X-based technology.

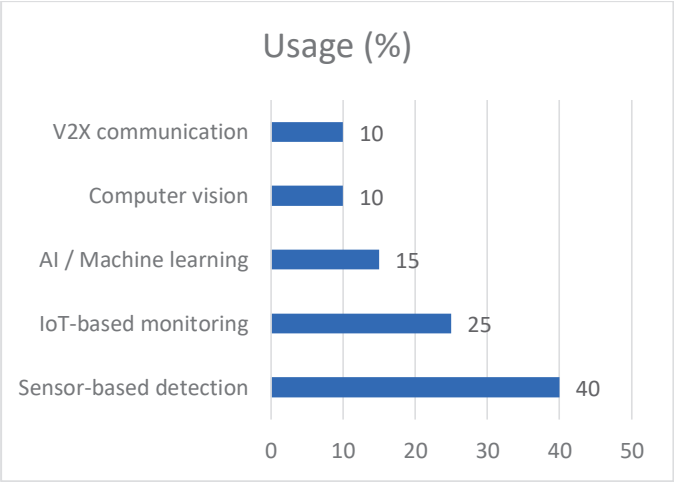

Fig. 1 Accident Detection Technologies Used in Research

The main purpose of accident monitoring systems is to ensure that accidents are immediately detected and communicated immediately. Accident monitoring systems have been identified as one of the most critical technologies used for accident detection purposes, utilizing sensor detection technologies. Accelerometers, vibration sensors, gyroscopes, and pressure sensors are some of the most widely used sensors for accident detection purposes, focusing on sudden changes in vehicle dynamics during accidents. These sensors are used to convert vehicle movement into electrical signals that are analyzed by embedded systems to determine whether an accident has occurred or not. Accident detection systems are triggered when the signals from the sensors are above the threshold value, allowing for automatic communication with emergency services without the need for drivers or witnesses during accidents. Fig. 2 shows the hardware used in accident monitoring systems such as accelerometers, GPS modules, communication modules, microcontrollers, and vision sensors.

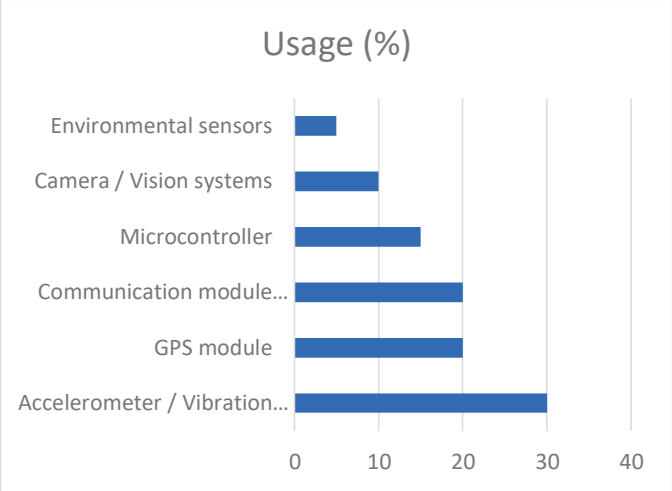

Fig. 2 Common hardware components used in accident monitoring systems

The second significant feature of the accident monitoring systems is the location tracking and communication feature. In the context of accident monitoring systems, the GPS system is generally connected with the accident detection system, which helps in the tracking of the location of the accidents. After the accident is detected by the accident detection system, the details of the location of the accident site and the accident status are sent to the emergency centers by means of wireless communication systems such as GSM, Wi-Fi, Bluetooth, or IoT communication technology. This minimizes the time gap between the occurrence of the accident and the response to the accident. This is highly beneficial in saving the lives of the accident victims.

Fig. 3 shows the performance metrics of accident monitoring systems such as the efficiency of accident detection, reduction of emergency response time, reliability of alerts sent, and efficiency of monitoring. The development of IoT technology has greatly enhanced the functionality of the accident monitoring system. In the context of IoT technology, the accident monitoring system has enabled the vehicles to

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function as intelligent devices, which send the details of the accidents to the remote servers or cloud platforms. This helps in the monitoring of the accidents, and the accident management system can be implemented for the monitoring of the accidents occurring between the vehicles. This is highly beneficial in the context of smart transportation systems.

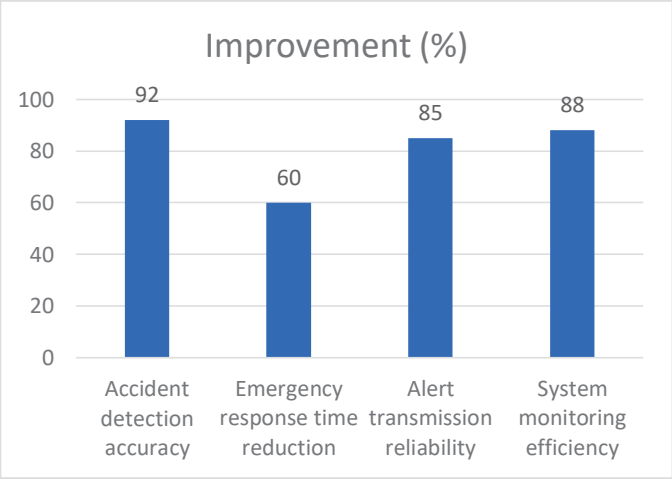

Fig. 3 performance metrics in modern accident monitoring systems

The concepts of artificial intelligence and machine learning have also been implemented in the accident monitoring systems for the purpose of enhancing the reliability of the accident detection systems. In the context of machine learning, it has been observed that the machine learning algorithms are able to analyze the patterns of accidents and differentiate between the accidents and the normal conditions of the vehicles. This is highly beneficial in enhancing the reliability of the accident monitoring systems by analyzing complex patterns of accidents. This is highly beneficial in the context of smart cities, as the accident monitoring systems need to analyze complex patterns of accidents.

Despite the major successes achieved in the development of accident monitoring technologies, there are some challenges associated with the development of effective accident monitoring systems. These include the reliability of the communication system and sensors, which is considered a challenge in the development of effective accident monitoring systems. Additionally, the high computation and infrastructure requirements are also considered potential challenges in the development of effective accident monitoring systems. As such, research is being conducted to ensure the development of effective accident monitoring systems that are cost-effective and energy-efficient for integration into various vehicles.

IV. Conclusion

The review has provided a detailed analysis of the accident detection and monitoring systems that have been developed by using sensors, embedded systems, and intelligent communication systems. There are several intelligent systems that have been proposed by using vibration sensors, accelerometers, GPS, and IoT communication systems for accident detection and sending emergency messages with the help of location information. The intelligent system can reduce the delay in accident reporting and improve the efficiency of accident monitoring operations. In addition, the integration of wireless communication modules and IoT communication systems can improve the efficiency of accident monitoring systems with the help of remote monitoring operations. Moreover, the integration of intelligent systems can improve the efficiency of accident detection systems by analyzing complex driving patterns. The analysis of existing studies has revealed that the intelligent accident monitoring system can have a significant impact on improving road safety and reducing the number of fatalities caused by delayed accident reporting.

In addition to that, the research in accident detection and monitoring systems for the future could also be focused on developing intelligent monitoring systems that incorporate various types of monitoring technologies and various types of analysis of the data collected through these systems. The inclusion of artificial intelligence and deep learning technologies could also improve the accuracy of accident prediction and detection by analyzing large amounts of vehicular data collected through various sensors and infrastructures installed on the road. The inclusion of various types of vehicle-to-everything communication technologies could also improve the safety of the vehicles by allowing them to communicate with other vehicles and infrastructures installed on the road to share accident-related information. In addition to that, the inclusion of low-power communication technologies such as LoRa and 5G could also improve the communication of vehicles in accident scenarios in remote areas. The development of lightweight embedded platforms with improved energy efficiency could also improve the deployment of accident monitoring systems in modern transportation systems.

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