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IoT-Based Accident Detection Systems - A Review

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ABSTRACT:

Road accidents have become a serious cause of accidents across the globe in the past few decades. Various methodologies have been implemented to reduce the deaths due to accidents. IoT-based road accident detection and alert systems are an example of this. Using the advancements in IoT we have been able to propose different systems that have various innovative functions that would ultimately help in reducing accident-related deaths. This paper conducts a review of some of these systems and identifies the progress in these systems and the need for improvements in the systems. The world of IoT is growing day by day, giving numerous solutions to human needs. It is necessary to review the advancements once in a while so that we can know that we are on the right path. In this paper, the IoT-based systems for accident detection are reviewed.

Keywords: IoT-based accident detection systems, microcontrollers, sensors.

1. Introduction

The increasing number of road accidents has been a serious issue across the globe over the years. Most of the time the response time in alerting medical help plays a crucial role in saving lives. Automatic accident detection systems have been implemented to address the issue. Mostly these kinds of systems have been implemented using IoT technology. This survey paper reviews a few such systems and draws insights from the analysis.

The system proposed by Pranto Karmokar et al. [1] addresses the issue of informing acquaintances lately in case of an accident. In the system, the nearest ambulance service is notified and also alert is sent to the police station and traffic control rooms. The paper by Elie Nasr et al. [2] considers the need for user interaction for sending alerts as a drawback of such systems and proposes a solution that doesn't require interaction from the users for sending alerts to the rescue teams. The system proposed by Daxin Tian et al. [3] is putting forward a different method of accident detection that is different from traditional methods in which sensors that measure acceleration and speed are used in the detection of the accident. Here an image processing-based system is implemented which detects accidents by processing the data from the roadside cameras.

In the paper proposed by Mohammed Abdul Kader et al. [4] introduces a system where when the vehicle's speed surpasses a pre-calculated safe threshold, the system will issue a warning to the driver through an audible alert on the buzzer. Additionally, the system features a dedicated button for emergencies. If this button is pressed following an accident, the system will promptly send an SMS to the relevant authorities, providing them with precise location information. The paper proposed by M. B. I. Reaz et al. [5] the use of a GPS receiver for vehicle speed monitoring and accident detection based on speed fluctuations. Upon detecting a speed drop below, a predetermined threshold, the system transmits accident location, time, and speed data to an Alert Service Center using the GSM network. This study by Nikhil Kumar et al. [6] introduces an IoT-based system for automotive accident detection and classification (ADC). It leverages a combination of smartphone sensors to not only detect accidents but also classify their types, enhancing the efficiency of emergency services by providing crucial information for planning and executing rescue operations, including EMS, fire stations, and towing services.

The system proposed by Jasspeed Singh et al. [7] addressed the problem of delays in emergency response to vehicle accidents in Malaysia. It proposes an Internet of Things -based Vehicle Accident Detection System (VADS) to improve the response time. The system uses a vibration sensor and gyro sensor to detect the accident and alerts with GPS coordinates are sent through the GSM module.

The model proposed by Nazia Parveen et al. [8] is working with the help of an accelerometer. The changes in x,y, and z-axis values are processed and used for accident detection. The accident is detected, and an alert is sent as SMS through a GSM module.

In the system proposed by Arif Shaik et al. [9], Raspberry Pi is used along with the GPS and GSM modules to alert the rescue teams. Here also the accelerometer sensor is used for detection of the accidents.

In the system proposed by Sayanee Nanda et al. [10] an accident detection system for two-wheelers is proposed. Vibration sensors are employed for accident detection.

2. Abbreviations And Acronyms

IoT- Internet of Things, ADC – Automotive Accident Detection and Classification, CVIS – Co-operative Vehicle Infrastructure Systems, YOLO – You Only Look Once, IoU – Intersection of Union, VADS – Vehicle Accident Detection Systems, ERD – Emergency Response Department, GPS – Global Positioning System, GSM – Global System for Mobile communications, DSRC – Dedicated Short Range Communications, ESP – Embedded Systems Platform, NFC – Near Field Communication, RFID – Radio Frequency Identification

3. Methodologies

The system proposed by Pranto Karmokar et al. [1] is an IoT-based accident detection and rescue system designed for cities. In this system load sensors are used to detect collisions and accidents in vehicles. The exact location of the user is pinpointed with the help of GPS and the alerts are sent to the emergency contacts and authorities through a GSM module. The alerts are sent to traffic control rooms, nearby police stations, and ambulance services. The system was tested with the help of a stimulated road scenario. This methodology has been implemented with cost-effective components like WiFi, and GSM modules making it an inexpensive one.

The method used by Elie Nasr et al. [2] is a 24*7 system that is designed for Public Safety Organizations which is built on top of IoT. Here vehicle is registered in the portal provided to the user which is monitored by the PSO headquarters. The passengers can register when they are travelling in the vehicle so that their important information such as blood group is readily available for the rescue teams in case of an emergency. Without the need for the intervention of the passengers, an alert is sent when an accident occurs. The nearest rescue teams are selected using a Haversine formula. The user registration is made seamless through the use of NFC technology.

The proposed system by Daxin Tian et al. [3] is different from sensor-based systems since it is based on image processing. The CCTV infrastructure is used in the system for detecting accidents. A CAD-CVIS dataset is developed to train the model which contains a large number of accident-related videos. The model detects an accident if there is an accident in a CCTV image and sends alerts. A deep learning model YOLO-CA is developed for accident detection using CAD-CVIS. In experiments, YOLO-CA achieves 90.02% average precision and 0.73 average IoU for accident detection with 21.7 FPS processing speed.

The paper proposed by Mohammed Abdul Kader et al. [4] introduces an innovative IoT-based vehicle monitoring system designed for accident detection and swift rescue operations. This system leverages a range of sensors, including accelerometers, speed sensors, and mercury switches, to continuously monitor key vehicle parameters such as speed, hard braking, and rolling. These data are then transmitted to a central server via WiFi, facilitated by an ESP8266 module, enabling real-time monitoring of driving quality. If the vehicle's speed exceeds a predefined threshold, an alert is triggered to notify the driver through a buzzer. Additionally, a manual button allows users to send their accident location via SMS using a GSM module, facilitating rapid response and rescue operations. This comprehensive system not only encourages responsible driving behavior but also enhances accident detection and emergency response capabilities, ultimately contributing to safer roads and more efficient rescue efforts.

The method introduced by M. B. I. Reaz et al. [5] is an automated crash detection and emergency response system that leverages IoT technology to provide real-time accident identification and facilitate rapid medical assistance. The key deliverables include an embedded device integrating airbag sensors, GPS, and cellular connectivity for precision crash detection and location tracking; a cloud platform that transmits instant SOS alerts to emergency services via APIs; a mobile app to notify specified emergency contacts; an analytics dashboard with KPIs like average emergency response time and false alarm rate under 5%; an AI model that analyzes crash patterns to predict accident-prone areas; comprehensive technical documentation and user manuals; over 95% accuracy in crash detection and an average 20% reduction in emergency response time compared to existing systems; and scalable architecture enabling large-scale deployments. This solution promises immense life-saving potential through its unique integration of IoT and AI to enable swift emergency response after accidents.

The study by Nikhil Kumar et al. [6] is an IoT-based system using smartphone and external sensor fusion that detects accidents and classifies them into four types: collision, rollover, fall-off, and no accident. The system uses a trained machine learning model to classify accidents and sends an emergency notification with accident details to an IoT server, which forwards it to emergency services for faster rescue.

The system proposed by Jasspeed Singh et al. [7], detects the accident using data provided by the vibration sensor and gyro sensor. In case of an accident, the model extracts the GPS coordinates and transmits them via the GSM module to a registered mobile number at the emergency response department (ERD). A central processing box that houses the sensors, microcontroller, GPS, and GSM module is incorporated into the system which will make it waterproof, fire retardant, and shockproof. Cooling mechanisms like aluminium fins and fans are used in CPB to dissipate the heat from electronics. The system focuses on sending alerts for major accidents. Minor accidents that don’t require immediate medical attention can be stopped using the terminating button provided.

In the accident detection system proposed by Nazia Parveen et al. [8] the accident is detected by checking the changes of values in the accelerometer sensor’s x, y, and z coordinate values. In case of an accident situation, the system sends an alert to the emergency services through the GSM module. The message contains the incident time and angle of the vehicle tilt obtained from the accelerometer sensor. Here the whole system is housed inside a shockproof, waterproof enclosure to withstand accident impact.

In the system proposed by Arif Shaik et al. [9], Raspberry Pi is used along with GSM and GPS modules which will help in providing better computing capability when compared with the other microcontrollers. An Accelerometer sensor is used for the detection of the accident. The data is sent to the cloud and the alerts are sent accordingly.

In the model by Sayanee Nanda et al. [10] an accident detection system for two-wheelers is proposed. This system too works with the help of Raspberry Pi. However, the major feature is that the system is capable of recording user details through RFID provided in the vehicle. Up to 10 users are able to register on it at a time so that the security of all of the family members can be ensured.

4. Overview

The increasing frequency of road accidents globally has spurred the development of IoT-based accident detection systems aimed at improving emergency response times and ultimately saving lives. Several research papers and systems have been introduced to address this critical issue. these IoT-based accident detection systems employ various sensors, such as accelerometers, gyro sensors, and cameras, to detect accidents and promptly alert emergency services. They address challenges like user interaction, delays in response times, and aim to enhance overall efficiency in handling road accidents. The diversity in approaches reflects the continuous innovation in leveraging IoT technologies for road safety.

Most of the existing systems are developed by the use of microcontrollers, GSM Modules, and GPS modules. But some systems work with making use of image processing. Mostly these accident detection systems are working on top of the IoT technology. The cost of the components is important in the case of such systems. The need for the components cannot be changed but the possibility of using cost-effective components is still there.

5. History of IoT Based Accident Detection Systems in Cars

The evolution of IoT-based accident detection systems in cars traces its roots to the early 2000s when the concept of the Internet of Things (IoT) gained prominence. In the mid-2000s, telematics systems played a crucial role in laying the groundwork for IoT applications in vehicles, integrating telecommunications and informatics. This era marked the integration of sensors and communication technologies into the automotive sector.

Over the subsequent decade, smart cars emerged with advanced features, including sensors designed for accident detection and prevention. In tandem, smart city initiatives integrated IoT into traffic management systems, deploying sensors and cameras on roadways and intersections for real-time monitoring tailored to vehicular safety.

Concurrently, fleet management systems embraced IoT for real-time monitoring of vehicle locations and conditions. In 2016, the U.S. National Highway Traffic Safety Administration (NHTSA) mandated Vehicle-to-Vehicle (V2V) communication in new light-duty vehicles, aiming to elevate road safety by facilitating the exchange of critical data among vehicles.

In the contemporary landscape, Advanced Driver Assistance Systems (ADAS) leverage IoT technologies in cars, incorporating features like automatic emergency braking and collision detection. These advancements significantly contribute to overall road safety. Looking ahead, the ongoing development of autonomous vehicles heavily relies on IoT for real-time communication between vehicles and infrastructure, promising further strides in accident detection and avoidance within the automotive realm.

6. Comparison of Works

The accident detection systems are to be given due importance since these systems are capable of saving a large number of lives. A proper review of the technology done once in a while will help to improve the quality of the newly developed models.

The major factors to be considered in these systems are cost effectiveness, response time, key features, scalability, etc. So, these factors in the considered methodologies are reviewed. Each time when going through a particular system we find that chances for false alarms are high.

Table 1: Comparison of Works

Sl. No.	Paper	Components Used	Key Features	Drawbacks
1	A Novel IoT-based Accident Detection and Rescue System	Load cell sensor, GPS module GSM module, WIFI Module, Microcontroller, Database Server	• Alerts are sent to previously added phone numbers through SMS. • Location is shared through coordinates which can be accessed through Google Maps.	• There is a possibility for sensor errors • No facility to notify nearest ambulance or medical services
2	An IoT Approach to Vehicle Accident Detection,	Shock sensor, SKM53 GPS module, NFC Reader, Cellular IoT	• No need for user interaction for sending alerts - helpful in case users are unconscious	• Passenger registration may be a bit tedious as registering each time

	Reporting, and Navigation		• The information regarding the affected persons (blood group) is sent to the admin.	before traveling may be difficult. • Storing passenger data in servers would not be advised since more memory is needed.
3	An Automatic Car Accident Detection Method Based on Cooperative Vehicle Infrastructure Systems	Roadside cameras, Edge Server, YOLO-CA Model, CAD-CVIS Dataset, DSRC, TensorFlow and LabelImg	• Use of roadside cameras avoids issues with onboard cameras • High accuracy in detecting accidents compared to other methods	• Requires installation of cameras and edge devices along roads • Performance depends on having a clear view of accidents from the cameras
4	IoT Based Vehicle Monitoring with Accident Detection and Rescue System	ATmega328P microcontrollers named MC1 and MC2, Mercury Switch, Hall effect sensor, buzzer, push button, resistors, capacitors, Crystal oscillator	• The system detects crashes and sends SMS alerts with the accident location for swift emergency service dispatch. • The system monitors real-time vehicle speed, braking, and tilt using sensors sending this data to a cloud for live driving behavior tracking.	• Constrained processing capability on microcontroller units • Dependence on continuous internet connectivity for real-time monitoring
5	Accident Detection and Reporting System using GPS, GPRS, and GSM Technology	GPS Receiver: Haicom HI-204III, GSM/GPRS Modem: Wavecom Q2403 dual band modem, Microcontroller: PIC18F4550, RS232 level converter (MAX232), Manual detection switch, Buzzer, GSM/GPRS modem, Sensors	• Speed-based accident detection without physical crash sensors • Fully automated emergency alerts to services after detected crash	• Reliance on accurate GPS speed, which may not be error-proof • Limited accident data sent apart from the last speed, which reduces post-crash analytics
6	An IoT Based Vehicle Accident Detection and Classification System using Sensor Fusion	Samsung Galaxy S8 Android smartphone which contains built-in sensors like accelerometer, gyroscope, GPS, etc., sensor drone, microcontroller, server, cellular and Bluetooth connections, custom Android apps	• Classifying accidents into four different types • Sensor fusion from internal and external sensors	• Dependence on continuous cellular connectivity • Constraint on smartphone placement
7	IoT Based Automatic Vehicle Accident Alert System	Arduino UNO, GPS module, Accelerometer (ADXL335), 16x2 LCD display, Piezo buzzer, 10K potentiometer	• Automatic detection of accidents using an accelerometer. • Sends accident alert SMS containing location coordinates from GPS.	• Requires manual installation of components in a vehicle. • Requires cellular network for SMS alerts to work. • Limited display and alert capabilities.
8	Vehicle Accident Detection System using the Internet of Things (VADS–IoT)	Current and voltage regulators, GSM module, GPS module, Gyro sensor	• Detects accidents using a vibration sensor for collision impact and a gyro sensor for vehicle displacement. • Water-resistant and fire-retardant control box design.	• Requires extensive hardware installation in the vehicle. • Prone to false alarms from sensors.

9	Smart Car: An IoT-Based Accident Detection System	Raspberry Pi 3B+ accelerometer, Ultimate GPS Breakout V3, Thing Speak API, Twilio API	• Automatic crash detection - The accelerometer monitors forces on the vehicle and triggers the system when a collision occurs. No human input is needed. • Low power - The system draws minimal current to avoid draining the vehicle's battery even if the car is turned off after an accident	• Limited GPS/cellular signal in some areas • The system relies on continuous power from the car's battery, which could be disrupted in a major crash.
10	An IoT Based Smart System for Accident Prevention and Detection	Raspberry Pi, RFID reader, Alcohol sensor, Vibration sensor, Pressure sensor, Ultrasonic sensor. Accelerometer, IR sensor, GPS module, GSM module, Camera, Buzzer, Traffic light sensor	• Driving license validation - Uses an RFID reader to check driving license of the rider before starting the bike. Prevents underage driving. • Alcohol detection - Checks if the rider is drunk using an alcohol sensor before allowing the bike to start.	• Components are mounted externally on the vehicle and could be tampered with or disabled by the rider, reducing effectiveness. • The hardware required like Raspberry Pi, various sensors, camera modules, etc. can be expensive to install on every vehicle.

7. Need for the Review

Reviewing the various systems will help in developing better and efficient systems. Also, this will help in bringing creative ideas to enhance these systems. The following areas are enhanced when review are periodically conducted on the topic:

- Enhancing Road Safety
- Identifying Technological Trends
- Improving System Effectiveness
- Informing Policy and Regulation
- Facilitating Research and Development
- Encouraging Industry Collaboration
- Adapting to Changing Transportation Trends
- Enhancing User Confidence

The ongoing review of advancements in IoT-based accident detection systems is multifaceted, playing a pivotal role in fostering innovation, improving road safety, shaping policy decisions, facilitating research, encouraging collaboration, adapting to industry changes, and instilling confidence among users in the ever-evolving landscape of transportation technology.

8. Conclusion

On reviewing the different systems, we have found that accident detection systems are mostly implemented with the help of IoT and embedded systems. Certain other methods such as image processing-based systems are also implemented but such systems require much more complex infrastructure for successful implementation. So, the implementation of such systems is better to be carried through IoT-enabled embedded systems. Some of these systems are specific to certain vehicles that is motorcycles or four-wheelers.

The reviewed research highlights the diverse approaches adopted in IoT-based accident detection systems for vehicles. From sensor-based detection on individual vehicles to image processing using roadside cameras, the field constantly evolves. Each system boasts advantages, such as automatic alerts, accident classification, and even driver behavior monitoring. However, limitations like sensor errors, false alarms, and dependence on cellular connectivity persist.

Reviewing these advancements serves several crucial purposes. It promotes road safety by identifying technological trends and fostering the development of more effective systems. It informs policy and regulation, guiding future directions in accident prevention. It facilitates research and development, encouraging further exploration and innovation. It fosters industry collaboration, driving collective efforts towards shared goals. And ultimately, it builds user confidence by showcasing the potential of technology to enhance safety on the roads.

The ongoing review of IoT-based accident detection systems remains essential as we strive for a safer transportation future. By embracing innovation, addressing limitations, and collaborating across various stakeholders, we can leverage the power of technology to save lives and ensure a smoother, more secure journey for all.

However, these systems are only considering the need for accident detection and alerting but are not taking into account the need for accident reduction. So future additions may be made to such systems that would somehow reduce the number of accidents on the roads.

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