IoT-Based Road Accident Rescue System Implementation for Smart City Applications

Harshit Srivastava
Dept. of ECE, NIT Rourkela
Odisha, India
harshit_srivastava@nitrkl.ac.in

Goutam Kumar Sahoo
Dept. of ECE, NIT Rourkela
Odisha, India
goutamkr_sahoo@nitrkl.ac.in

D. D. Senanayake
Dept. of ECE, NIT Rourkela
Odisha, India
119ec0210@nitrkl.ac.in

B. A. U. Maduwantha
Dept. of ME, NIT Rourkela
Odisha, India
119me0350@nitrkl.ac.in

M. G. C. Samudrini
Dept. of ECE, NIT Rourkela
Odisha, India
119ec0192@nitrkl.ac.in

A. I. Nanayakkara
Dept. of ECE, NIT Rourkela
Odisha, India
119ec0194@nitrkl.ac.in

Santos Kumar Das
Dept. of ECE, NIT Rourkela
Odisha, India
dassk@nitrkl.ac.in

Poonam Singh
Dept. of ECE, NIT Rourkela
Odisha, India
psingh@nitrkl.ac.in

***Abstract*—Road accidents are one of the biggest problems in the world, in which many precious lives have been lost. This work proposes a road vehicle accident detection system with location alerts to rescue accident victims. The main hardware modules include the MPU9250, a 9 degree-of-freedom (9-DoF) micro electro mechanical system (MEMS) based inertial measurement unit (IMU), Arduino nano with ESP8266 microcontroller and GPS. The IMU's three axis accelerometer, gyroscope and magnetometer data are programmed to determine the orientation and position of the vehicle. A Wi-Fi-based communication is established using ESP8266 to send data received from sensor units to Google Firebase cloud servers in real-time. The performance of the developed device has been evaluated using a laboratory setup and also in real-time driving scenarios. The developed sensor module performs well on accident detection and emergency alert generation, which can be used in vehicles to save many lives in the event of an accident through its automatic alert service.**

***Keywords*—Road Accident, Inertial Measurement Unit (IMU), Smart city, Internet of Things (IoT), Road Safety.**

I. Introduction

Road traffic accidents result in significant economic damages for both individuals and their families as well as for entire countries. Governments may incur costs as a result of car accidents, including those for necessary medical care, rehabilitation support, and property damage. According to the WHO, road traffic accidents cost the majority of nations 3% of their gross domestic product [1]. Not only this but also a major problem is that the responsible authorities can't detect when and where the accident has happened and this latency will lead to a delay in the help victims need. This system has developed a solution that can be applied in the actual world to all of the aforementioned difficulties, all of which can be solved automatically. It has automatic accident detection and, when an accident involves the vehicle, also introduces automated accident alerting. The suggested system will immediately transmit an alert to a registered database with the necessary information, such as speed and location, after it detects an accident involving a specific vehicle. In this case, we have combined already-existing technology into the creation of this solution. Lack of prompt medical attention for accident victims at the scene accounts for half of the death rate. We can learn the precise location of an accident vehicle using the Global Positioning System (GPS) device's location tracking features. This is a special use of the technology that tackles significant shortcomings in accident reporting and detection. Impact sensors and GPS provide a quick, impartial, and maybe acceptable way to discover and report accidents in a society that is growing increasingly motorised. Additionally, since this is not a very expensive form of accident detection and reporting, the majority of people will be able to utilise it in their cars.

On our roadways, there are several kinds of motor traffic. These include cars, motorcycles, buses, vans, and trucks. All of these vehicle categories have been in collisions at some point. The following categories apply to motor vehicle collisions:-

- Vehicle collisions, in which two or more automobiles are involved.
- Rollovers, or overturning.
- Collisions with stationary objects, such as rocks, solid concrete, buildings, and trees, are all examples.
- Knocking against pedestrians and animals.

Crash sensors can detect impacts of varying magnitudes that occur in every collision [2], [3]. Road Accidents are one of the leading causes of death, disability, and hospitalization of people worldwide in general and Indian particular. The problem is considerably more concerning for low- and middle-income countries because, despite the fact that these nations have about 60% of the world's vehicles, they account for 93% of all traffic fatalities worldwide. India accounts for at least one in ten of the global traffic fatalities. Given that India has one of the greatest road networks in the world, the issue of road safety is even more crucial. The issue has been made worse by the unheard-of rate of motorization and the expanding urbanisation brought on by a rapid rate of economic expansion [4].

Fig. 1 presents a million cities between 2015 and 2020 showed a slightly dropping trend in the percent share of accidents and injuries. In 2020 the Covid-19 pandemic's spread

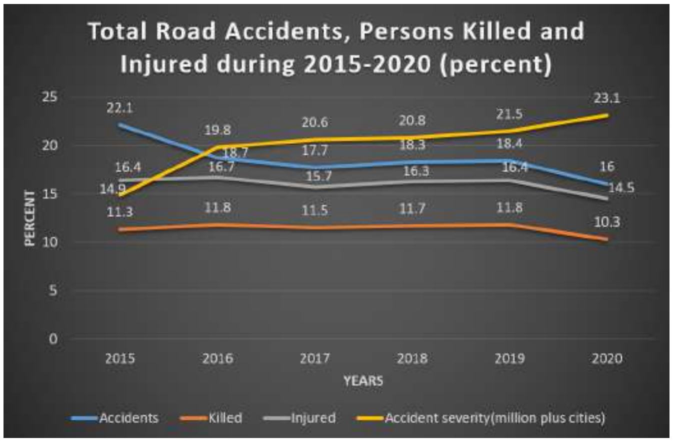

Fig. 1: Share of million-plus cities statistics on road accidents.

and the ensuing restrictions on movement, notably during lockdown, greatly decreased the overall number of traffic accidents and fatalities in the country. However, the number of fatalities in cities with a population of more than a million remained largely consistent, showing a slight drop in 2020. From 2015 to 2020, the accident severity has shown an upward tendency in the cities with a population of more than a million, rising from 14.9 percent in 2015 to 23.1 percent in 2020. The police and/or other agencies receive information on traffic accidents through a variety of ways, including direct reporting to the police station, phone calls from unreliable sources, casual discovery by officers on patrol, etc. This delay will prevent victims from receiving the aid they require. Here, we have used the MPU 9250 sensor, arduino nano, ESP8266, GPS module TTL UART – external antenna, Global Positioning System (GPS) and internet, programming, and Firebase Realtime Database which is a cloud-hosted NoSQL database as the technology involved for the development of the above-mentioned system. The further discovery of the comprehensive accident data on Firebase can yield significant information and knowledge that can be put to good use in reducing the steadily rising number of motor vehicle accidents on our roads. For instance, black spots can be easily identified, making it easier to mark such spots on the roads. The classification of vehicle kinds and classes that are more likely to be involved in collisions can also be aided by analysis.

The following is how the paper is set up: The proposed system and methodology is included in Section II. The experimental studies and result discussion are presented in Section III and conclusions of this article are presented in Section IV.

II. Proposed System and Methodology

A. Motivation

Accidents are happening every day despite many efforts made by various agencies. Also, during the post-accident process, many lives could have been saved if the accident victims were rescued in time and hospitalized. An efficient method of accident detection and timely reporting of accidents is essential to save many lives from danger [5]–[7]. Various automated accident detection systems have been developed, some systems are offline, and some systems are real-time Internet of Things (IoT) systems [8]–[10]. A work by Li *et al.* [11] proposed a system for detecting accidents using accelerometers, airbag sensors and GPS with GSM-based information. However, the non-availability of airbag sensors in most cars imposes limitations. Also, smartphone based crash systems are expensive and prone to false alarms [12]. While IMU sensors are based on MEMS technology, offer high update rates, are cheap, and mostly contain accelerometers, gyroscopes, and magnetometers for all three axes. It provides ample information about sudden acceleration, angular and heading change [13]. In real-time testing, noise is often embedded with the signal during the data acquisition process [14]. It would be a difficult task to detect the error, and thus it is necessary to remove the noise to detect errors in signal acquisition.

B. Work implementation methodology

1) Methodology: The methodology considered to achieve the system design is shown in Fig. 2. System hardware, software and system evaluation follows the normal process of job implementation work. The hardware components used are MEMS 9-axis IMU sensor (MPU9250), a GPS module with external antenna TTL UART, arduino Nano, ESP8266: a Wi-Fi enabled microcontroller and DC power supply. The Arduino IDE was used to program the microcontrollers. A Firebase cloud platform is used for user friendly mobile or web application creation. The performance of the system is evaluated based on a threshold-based algorithm.

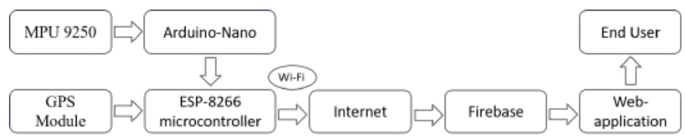

Fig. 2: Proposed process of work implementation

In the system design phase, an algorithmic flow chart was designed for the software code as shown in Fig. 3. Based on the flowchart the actual coding of the software was Implemented in programming languages. The coding part was done for ESP8266 and Arduino Nano. Proper execution of the previous steps ensured smooth and easy implementation of this phase. In the testing phase the complete coding part was verified. In the deployment step, the verified code was uploaded to the board (implementation on the breadboard), and it was tested by moving the entire circuit. This information will be given to the fire base. In the final stage proper execution of all the preceding steps ensured a working system as per the requirements provided and most importantly also ensured satisfactory utilization.

2) Implementation Overview: This section outlines the software, procedures, personnel, and information that were immediately committed to the successful implementation of a GPS-based motor vehicle accident detection and reporting solution. The following software products were used during the implementation process.

- Arduino IDE: An open-source electronics platform called Arduino is built on simple hardware and software. This software was used to program the ESP8266 and Arduino Nano in this project.

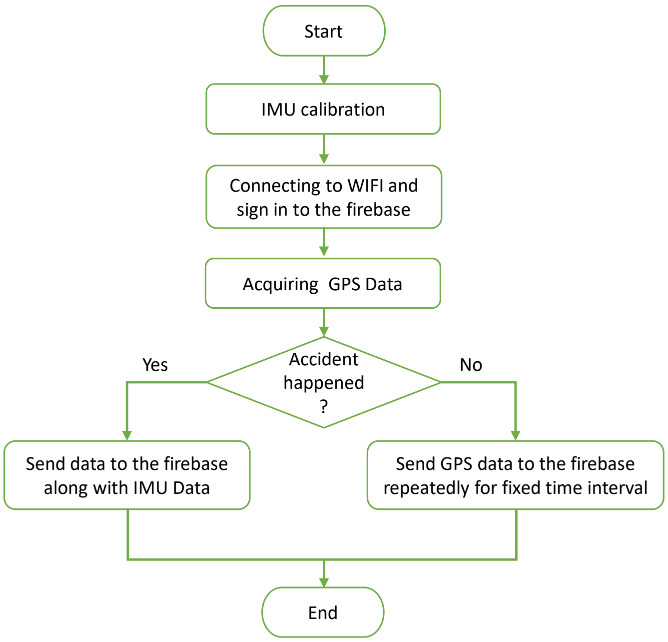

Fig. 3: Algorithm steps for implementation

- Firebase: Google has created a platform called Firebase for building mobile and web applications. In this project, Firebase received information about the accident's position, location (latitude and longitude), and speed. The GPS module and MPU9250 sensor were used to collect those data. The firmware of the ESP8266 Wi-Fi module was used to send such data.

The following hardware, gadgets and tools were used for implementation process.

- ESP8266: A family of systems on chip microcontrollers that have integrated Wi-Fi and dual-mode Bluetooth and are inexpensive and low-power.
- Ardunio Nano:The Nano is a small, complete, and breadboard-friendly board based on the ATmega328 (Arduino Nano). It has more or less the same functionality as the Arduino Uno but in a different package. It lacks only a DC power jack and works with a Mini-B USB cable instead of a standard one.
- MPU9250: A system in a package (SiP) that combines two chips: the MPU-6500, which contains a 3-axis gyroscope, a 3-axis accelerometer, and an onboard digital motion processor (DMP) that processes complex motion fusion algorithms.
- GPS Module: A good GPS TTL UART module with external antenna option provides 3.3V - 5V DC.
- Breadboard: Sometimes called a plug block, this is used to build temporary circuits. This is useful to designers as it allows components to be removed and replaced easily.
- Jumper wire: This is an electrical wire that connects remote electric circuits used for printed circuit boards.

3) Testing: Here all the hardware parts were checked one by one. First, the microcontroller ESP8266 and Arduino Nano were checked. Then, the MPU9250 was checked by sending data to the serial monitor of Arduino Nano and then using the GPS module with the ESP8266. In this work, GPS and MPU9250 data will be sent to Firebase by making accounts of Firebase. This is achieved by adding libraries and some coding parts to the Arduino code. The hardware components are assembled with the required details. The entire circuit is tested with an IoT environment on a breadboard to observe laboratory-based work performance. In-house testing process of data acquisition, data transfer to cloud database, decision making and reporting on accidents are done. The details of the test results will be discussed in the following sections.

III. Experimental Studies and Results Discussion

This section provides experimental evaluation of the system and results discussion. After the implementation and testing part, the prototype was evaluated for the purpose of determining whether the developed system was giving the expected results. The expression for absolute linear acceleration (ALA) is defined as

$$ALA = \sqrt{(Accx^2 + Accy^2 + Accz^2)} \tag{1}$$

Where, Accx = acceleration in X direction, Accy = acceleration in Y direction and Accz = acceleration in Z direction.

A. Assumptions and laboratory setup for system evaluation

- We have reduced the ALA limit from 3.5 to 1.5 for testing purposes.
- If the user chooses to stop auto monitoring through the app, we assume that the driver is safe, and the device will not send any accident-related information to the cloud.
- We assume that this device is intended to be used on a normal vehicle such as Maruti 800.
- The user must have a stable internet connection.
- Must have a reliable GPS connection.
- The device must be mounted on a flat surface relative to the vehicle.

The experimental setup for laboraty based model testing can be seen from the Fig. 4. The hardware components are assembled in breadboard to develop the complete circuit. The DC power to the circuit can be given from external power bank or from car battery supply. The hardware module implementation of GPS, MPU9250, ESP8266 and Arduino Nano is shown in Fig. 5.

MPU9250 processing is implemented in Arduino nano board and GPS & cloud Firebase is processed in the ESP8266 board. Optimizing the code until expected results come. The hardware connection circuit board is developed to test in real time with vehicle and fine tuning threshold values for required operations. The process of data acquisition and cloud base data storage can be seen from the Fig. 6.

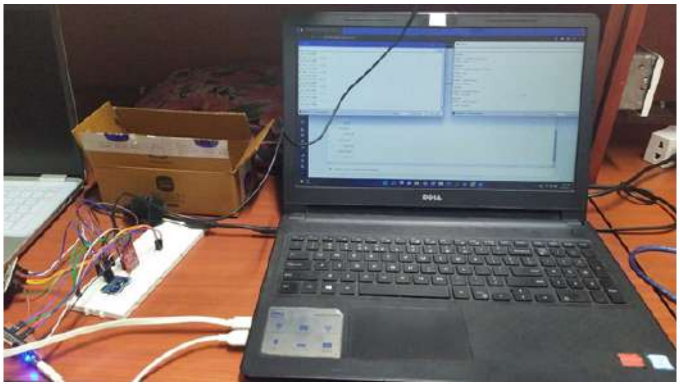

Fig. 4: Experimental study setup in laboratory implementation

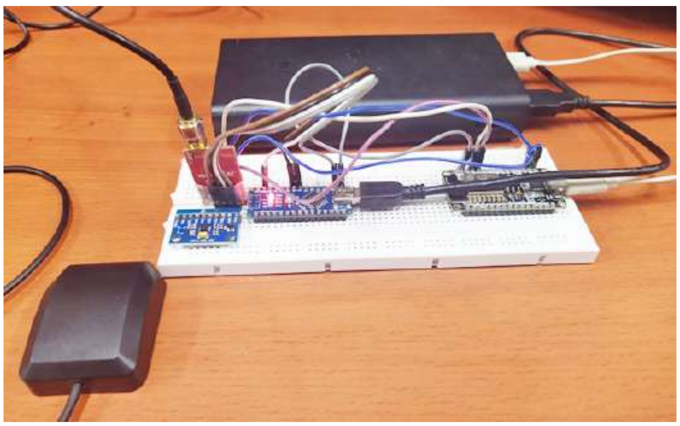

Fig. 5: The breadboard circuit implementation.

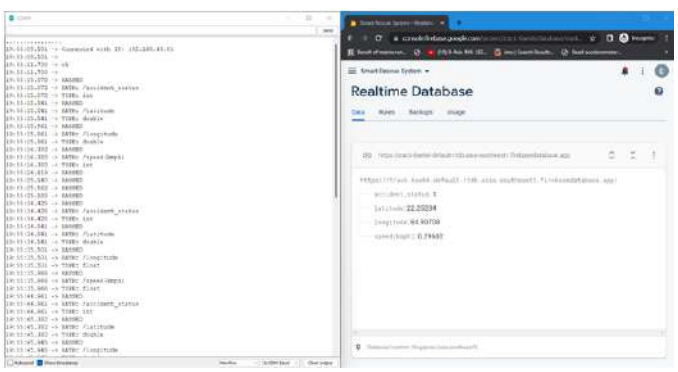

Fig. 6: A screenshot of the data acquisition and storage process.

B. Real-time experimental result analysis

In normal driving scenario the ALA threshold was set to 3.5g as the real world ALA threshold should be between 3.5g to 5g to detect fatal accidents. In uneven road condition the ALA threshold was set knowingly to 2g for testing purposes. we customize the ALA threshold value to know that how many times ALA value go beyond 2g during our testing. Our setup was able to identify it.In a real-world scenario, the ALA threshold was set to a maximum value of 5g to detect any abnormal event, which occurs when it crosses the 5g level, regardless of vehicle or road conditions. As accident is an unpredictable event and it occurs some times but in our testing for safety purpose we verified the IMU sensor impact for various normal test cases under control environment with safe drive. Various real time test cases are conducted in a real road environment with controlled non-accident scenario. Fig. 7 shows the hardware made for in-vehicle use in real-world testing.

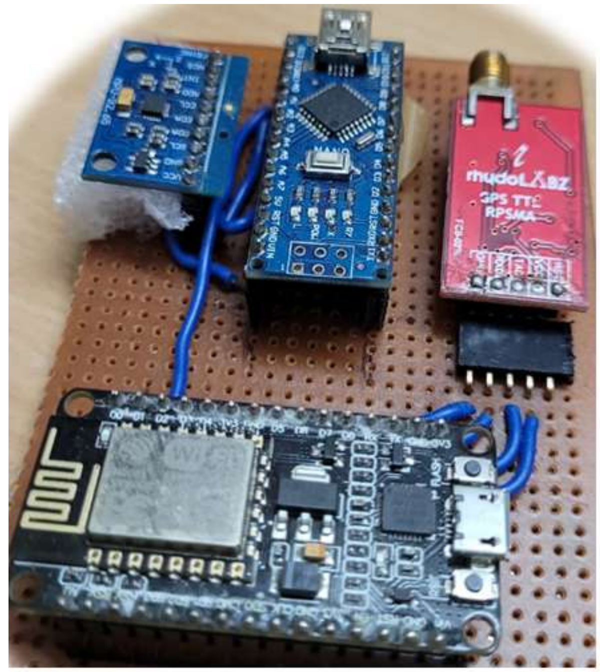

Fig. 7: Designed hardware module for in-vehicle testing.

While testing our device, we used the Timestamp Camera Application version 1.212. That app displays a watermark of time with millisecond accuracy, a GPS coordinates, a location address, a location with a map, the vehicle's speed, heading, and altitude on top of the video in real-time. It made it much easier for us to document the road conditions and obstacles we encountered during the test drive. A screen-shot of the Time-stamp Camera App based result is shown in Fig. 8.

Fig. 8: Road scenario with time-stamp application result.

C. Comparison with existing works

The proposed system will offer much more features than what is provided by state-of-the-art systems. Table I gives the comparative studies with existing systems.

TABLE I: Comparative studies on IoT-based system for accident detection

Reference	Advantages	Limitations
Sarker *et al.* [15]	• Developed an intelligent accident detection, location tracking and notification system using GPS and GSM. • provides a low-cost portable system for accident detection and location tracking.	• The use of ultrasonic sensor imposes limitations as it operates for short distances. Sometimes it predicts the collision wrong.
Nasr *et al.* [16]	• A smart and reliable IoT system with shock sensors detects road accidents and notifies immediately with their geographic coordinates. • It provides basic medical information to rescue teams, identifies precise accident locations and facilitates the routing process.	• A minimum of three alarms must be sent to confirm an accident. If one is sent, it is considered a fault alarm. • The load on the server is not considered as the number of transactions is limited by the number of crashes during a period of time.
White *et al.* [12]	• Shows how smartphone sensors and their processing capabilities can be used to address the challenges of detecting traffic accidents without direct interaction with the vehicle's onboard sensors. • Reduced software maintenance complexity through smartphone application upgrade mechanism.	• The destruction of the smartphone can prevent the distribution of accident information. • The proposed system consumes a significant amount of battery power. • Low speed traffic can cause WreckWatch to deactivate.
Navidi *et al.* [17]	• Provides GPS/INS-based navigation algorithms, calibration of navigational sensors, and a de-noshing method for vehicle accidents.	• Accident detection using GPS/INS sensors and providing emergency information using internet along with latitude and longitude of the accident location.
S. Soma [18]	• The developed system sends short messages to WhatsApp of a mobile number via Wi-Fi over the Internet in case of a crash. • It monitors vehicle speed, detects vehicle location, sends alert messages to mobile phones for remote information and provides for changing mobile numbers at any time.	• System development is expensive and data transfer is not secure. • It requires a strong internet network connection.
Chaudhari*et al.* [19]	• Provides a threshold-based crash detection mechanism for measuring vibration followed by automatic alerts using GPS and GSM. • In case of false alerts, the vehicle occupant can stop emergency assistance requests by pressing a button.	• System development uses motion sensor module and GSM/GPRS module. However, real-time performance requires faster processing.
Lakshmy*et al.* [20]	• Developed an accident prevention mechanism through automatic engine locking and abnormal vibration detection followed by alcohol detection. • Deep-learning-based accident prediction using the accident scene image captured by the vehicle's front-facing camera. • Information sharing to the nearest emergency center using GPS and GSM module.	• System development uses multiple hardware devices, however, fast processing is required for real-time performance. • Keras is the neural network API used here with TensorFlow as the back-end which requires high-end processors.
Proposed	• Development of an IoT-based in-vehicle embedded system for accident detection for reduction in accident fatality rate. • A low-cost Wi-Fi-based communication system implementation using IMU sensors, Arduino Nano, ESP8266 microcontroller, and GPS to perform processing and location tracking. • The ESP8266 is used as a dedicated device that sends the data received from the sensor units to the Google Firebase cloud server, therefore reducing latency. • The performance of the developed device was also evaluated in a laboratory setup and in real-time driving scenarios. • It can be used in vehicles to save many lives in the event of an accident.	• A crash detection signal needs to be transmitted via the Internet to a cloud server application. Internet connectivity issues can affect performance.

IV. Conclusions and Future works

This study has designed and created an IoT-based automotive test-bed environment that automatically detects collision and roll-over and notifies the appropriate organizations right away. But in here, we are testing accidents causing above 3.5g force, roll over, and free fall. Also this device won't detect small accidents such as scratches, shattering, etc. and it only supports a WIFI bandwidth of 2.4GHz. To get the most accurate results this device should place away from strong magnets such as speakers and all other electromagnetic interference. Not only that but also the GPS antenna should place where we can get a strong signal and the supply power must be within the given rating. The relevant authorities can readily obtain the precise location by using this prior information, can help in saving many lives in this process. Additionally, by using the data in the database and the stored data in the cloud, they can identify important information such as the locations and times where many accidents occur, etc. in future, which may enable the relevant authorities to make policies and put them into practice effective measures to lower the number of injuries and fatalities brought on by traffic accidents.

References

[1] W. H. O. D. of Violence, I. Prevention, W. H. O. Violence, I. Prevention, and W. H. Organization, *Global status report on road safety: time for action*. World Health Organization, 2009.

[2] M. S. Shaheed and K. Gkritza, "A latent class analysis of single-vehicle motorcycle crash severity outcomes," *Analytic Methods in Accident Research*, vol. 2, pp. 30–38, 2014.

[3] S. Komarizadehasl, B. Mobaraki, J. A. Lozano-Galant, and J. Turmo, "Evaluation of low-cost angular measuring sensors," in *Proc. Int. Conf. Recent Trends in Geotech. Geo-Environmental Eng. and Edu.(RTCEE/RTGEE)*, 2020, pp. 23–25.

[4] ROAD ACCIDENTS IN INDIA 2020 lR., *ROAD ACCIDENTS IN INDIA 2020.* [Online]. Available:~https://morth.nic.in.

[5] G. K. Sahoo, S. A. Patro, P. K. Pradhan, S. K. Das, and P. Singh, "An IoT-based intimation and path tracing of a vehicle involved in road traffic crashes," in *Proc. IEEE-HYDCON*, 2020, pp. 1–5.

[6] G. K. Sahoo, P. K. Pradhan, S. K. Das, and P. Singh, "A user specific APDS for smart city applications," in *Research in Intelligent and Computing in Engineering*. Springer, 2021, pp. 267–277.

[7] K. Parasana, G. K. Sahoo, S. K. Das, and P. Singh, “A health perspective smartphone application for the safety of road accident victims,” in *2021 Advanced Communication Technologies and Signal Processing (ACTS)*. IEEE, 2021, pp. 1–6.

[8] N. Kumar, D. Acharya, and D. Lohani, “An IoT-based vehicle accident detection and classification system using sensor fusion,” *IEEE Internet of Things Journal*, vol. 8, no. 2, pp. 869–880, 2020.

[9] N. Pathik, R. K. Gupta, Y. Sahu, A. Sharma, M. Masud, and M. Baz, “AI enabled accident detection and alert system using IoT and deep learning for smart cities,” *Sustainability*, vol. 14, no. 13, p. 7701, 2022.

[10] E. Fantin Irudaya Raj and M. Appadurai, “Internet of things-based smart transportation system for smart cities,” in *Intelligent Systems for Social Good*. Springer, 2022, pp. 39–50.

[11] C.-z. Li, R.-f. Hu, and H.-w. Ye, “Method of freeway incident detection using wireless positioning,” in *Proc. IEEE International Conference on Automation and Logistics*, 2008, pp. 2801–2804.

[12] J. White, C. Thompson, H. Turner, B. Dougherty, and D. C. Schmidt, “Wreckwatch: Automatic traffic accident detection and notification with smartphones,” *Mobile Networks and Applications*, vol. 16, no. 3, pp. 285–303, 2011.

[13] M. S. Amin, M. B. I. Reaz, S. S. Nasir, and M. A. S. Bhuiyan, “Low cost gps/imu integrated accident detection and location system,” *Indian J. Sci. Technol*, vol. 9, no. 10, pp. 1–9, 2016.

[14] B. B. Pradhan, S. Ari, G. K. Sahoo, D. K. Jena, S. K. Patra, and R. Appavuraj, “Wavelet transform based error detection in signal acquired from artillery unit,” in *Proc. IEEE 1st Int. Conf. Condition Assessment Techn. Electrical Syst. (CATCON)*, 2013, pp. 243–248.

[15] S. Sarker, M. S. Rahman, and M. N. Sakib, “An approach towards intelligent accident detection, location tracking and notification system,” in *Proc. IEEE Int. Conf. Telecommun. Photonics (ICTP)*, 2019, pp. 1–4.

[16] E. Nasr, E. Kfoury, and D. Khoury, “An iot approach to vehicle accident detection, reporting, and navigation,” in *Proc. IEEE Int. Multidisciplinary Conf. Eng. Technol. (IMCET)*, 2016, pp. 231–236.

[17] N. Navidi *et al.*, “Collision vehicle detection system based on gps/ins integration,” *Journal of Computer and Communications*, vol. 5, no. 2, pp. 48–70, 2017.

[18] S. Soma, “Iot based vehicle accident detection and tracking system using gps modem,” *International Journal of Innovative Science and Research Technology*, 2017.

[19] A. Chaudhari, H. Agrawal, S. Poddar, K. Talele, and M. Bansode, “Smart accident detection and alert system,” in *Proc. IEEE India Council Int. Subsec. Conf. (INDISCON)*, 2021, pp. 1–4.

[20] S. Lakshmy, R. Gopan, M. Meenakshi, V. Adithya, and M. R. Elizabeth, “Vehicle accident detection and prevention using iot and deep learning,” in *Proc. IEEE Int. Conf. Signal Process., Informatics, Commun. Energy Syst. (SPICES)*, vol. 1, 2022, pp. 22–27.