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SMART ROAD ACCIDENT DETECTION, LOCALIZATION AND SERIOUSNESS PREDICTION USING DEEP LEARNING AND IOT

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ABSTRACT

This paper proposes a smart road accident detection, localization, and severity prediction system using deep learning and IoT to enhance emergency response and minimize fatalities. The system integrates IoT sensors, including accelerometers, GPS, and cameras, to detect accidents in real time. Accident-related data, such as impact force, speed, and location, is transmitted to the cloud, where deep learning models analyze the severity of the incident. A convolutional neural network (CNN) classifies accident images, while Long Short-Term Memory (LSTM) networks process temporal data to improve accuracy. The system utilizes GPS for precise localization and cloud-based alert mechanisms to notify emergency services instantly. By combining IoT and AI-driven analysis, this approach reduces false alarms, ensures faster emergency response, and enhances road safety. Experimental validation on real-world accident datasets demonstrates high accuracy in detection and severity classification. This innovative solution contributes to smart city infrastructure by integrating advanced accident prediction and response mechanisms, ultimately saving lives and improving traffic management.

Keywords: *AI; intelligent transportation systems (ITS); cognitive science; deep learning; IoT; ResNet; InceptionResnetV2; accident detection; sensors*

1. INTRODUCTION

Road accidents are a major global concern, causing millions of fatalities and injuries annually. According to the World Health Organization (WHO), over 1.4 million people die in road accidents each year, with many deaths resulting from delayed medical intervention. The key challenges in accident management include real-time detection, accurate localization, and severity estimation to optimize emergency response. Conventional methods rely on eyewitness reports or vehicle-based alert systems, which often suffer from inefficiency, inaccuracy, and high response times. There is a pressing need for an automated, intelligent system that can detect accidents, determine their location, and predict their severity with high precision.

This paper aims to develop an advanced accident detection system that combines IoT sensors with deep learning models for improved accuracy. The proposed system detects accidents in real-time, determines their exact location using GPS, and predicts accident severity based on sensor data and image/video analysis. By integrating IoT and AI, the system ensures a faster and more reliable emergency response, reducing fatalities and improving road safety.

The key objectives of this paper are:

i. Real-Time Accident Detection: Utilizing IoT sensors and deep learning models to accurately detect road accidents and minimize false alarms.
ii. Accurate Localization: Implementing GPS and cloud-based tracking to pinpoint the exact location of an accident for a faster emergency response.
iii. Severity Prediction: Using CNNs and Long Short-Term Memory (LSTM) networks to classify accident severity, ensuring appropriate emergency service allocation.
iv. Efficient Emergency Alert System: Developing a cloud-based notification mechanism that automatically informs emergency responders, hospitals, and law enforcement.
v. Experimental Validation: Evaluating the system’s performance using real-world accident datasets to demonstrate its effectiveness in reducing response times and saving lives.

2. LITERATURE SURVEY

Several accident detection and alert systems have been developed using IoT, computer vision, and machine learning. IoT-based systems utilize sensors such as accelerometers and GPS to detect sudden vehicle impacts and transmit alerts. However, these methods often generate false positives due to abrupt braking or road bumps. Deep learning models, such as Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs), have been used to analyze accident images and videos for more accurate classification. Some studies integrate IoT and AI, but they lack comprehensive severity prediction and precise localization techniques.

Pathik et al. (2022) [1] proposed an IoT and AI-enabled accident detection system using sensors and deep learning models like ResNet and InceptionResNetV2. The system achieved 98% accuracy.

Vijaylaxmi et al. (2021) [2] introduced an IoT-based alert system that used GPS and GSM modules to notify emergency contacts.

Patil et al. (2023) [3] developed an AI and IoT-based road accident detection system using accelerometers and GPS modules. The system reported accidents via ThingSpeak.

3. METHODOLOGY

The proposed system uses a combination of the Internet of Things and deep learning to develop an integrated accident detection and reporting system (ADRS), to overcome existing shortcomings in the ADRS.

3.1. IoT Module for Accident Detection

- The designed hardware device contains sensors and actuators to detect an accident and its intensity. A force sensor is used to identify the accident which is mounted on the vehicle chassis.
- The force sensor is connected to the ATMEGA328 microcontroller to detect accidents and raise the alarm system. If the speed and force’s values exceed a predefined threshold, an accident has occur.
- When the accident is detected, it will first activate the alarm for 30 s. If there is no accident or the accident is average or negligible, the driver can reset the force sensor and alarm controller by simply pressing a button. NodeMCU will send the nearby mechanics’ information to the registered mobile that can be used to

resolve any technical issue in the vehicle.

- If the button is not pressed before 30 s, it will send a legal accident signal to the ESP8266 module. The ESP8266 module will activate the camera and send video, photos, GPS data, and other items to the Master Controller Raspberry Pi. The GPS data are also sent to the LCD display to show GPS information captured by the GPS.
- Once the accident is detected, longitude and latitude details are sent to the cloud and the rescue module. The rescue module is responsible for sending the accident details to all emergency services. All the information of the vehicle owner, relatives, and mechanics can be retrieved from the database.
- However, we need to find the nearest hospital and police station. To find the nearby hospital and police station, we are using the Haversine formula, which determines the shortest path between two points when they are on Earth.

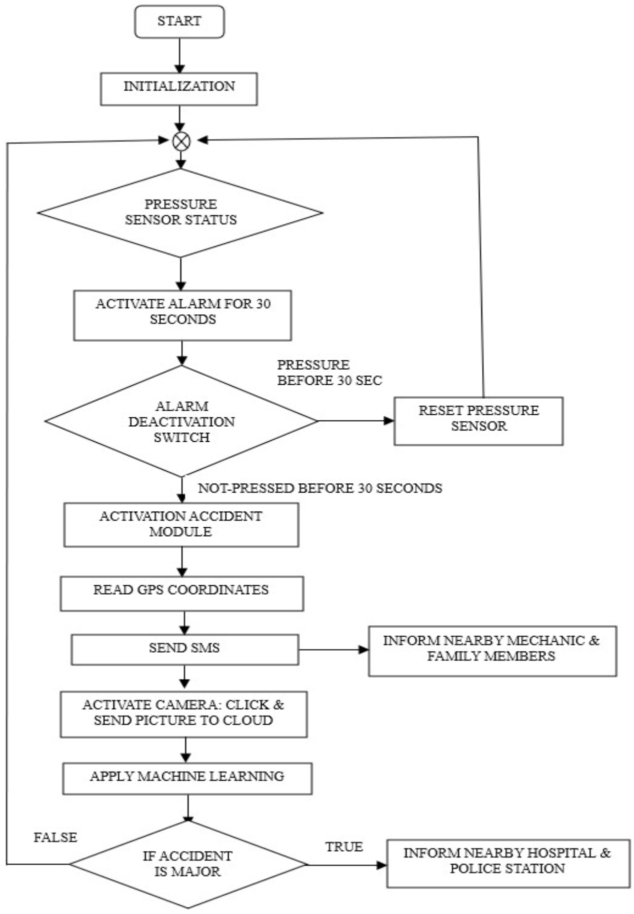

Fig 1: Flow diagram of the proposed system

3.2. Deep Learning Module for Seriousness prediction

- The main goal of this module is to cut down on the number of false alarms.
- One of the main causes of road accidents is the speed of vehicles on the road. Most of the existing ADRS mainly identify an accident based on the speed sensor. If the vehicle's speed is changed suddenly and exceeds the predefined threshold, then the system detects an accident. So, the false detection rate of these systems can be high, because in various circumstances, the vehicle's speed can be changed, such as a speed

breaker, an obstacle on the road, a technical problem of the vehicle, etc.

- The proposed ADRS uses the deep learning technique to minimize this misidentification rate, which takes the input video from the dashboard's camera.
- Once the device has detected the accident, NodeMCU will activate the camera and give the activation signal to Raspberry Pi. The camera will take some images, record the 30 s video, and upload it to the cloud for analysis.
- In the cloud, a pre-trained ResNet and InceptionResnetV2 model is trained to identify current situations as accidents or not accidents. First, the input video is converted into the frames and passes to the model. This module will help us to minimize false accident deletion and improve the accuracy of the model.

4. DESIGN AND IMPLEMENTATION

4.1 System Overview

The proposed system integrates IoT sensors, GPS, and deep learning models to detect accidents in real time, accurately localize the crash site, and predict accident severity. The architecture consists of three primary modules:

i. Accident Detection Module – Identifies accidents using IoT sensors.
ii. Localization Module – Determines the precise location of the accident using GPS.
iii. Severity Prediction Module – Uses deep learning models to classify accident severity.
iv. Emergency Notification System – Alerts emergency services and contacts.

4.2 System Architecture

The system comprises two major components:

4.2.1 IoT-Based Hardware Setup

The hardware module is installed in vehicles and is responsible for detecting accidents. It consists of:

i. Accelerometer & Gyroscope – Detects sudden motion changes.
ii. Vibration Sensor – Measures the impact force during a collision.
iii. GPS Module – Captures real-time location data of the accident.
iv. Raspberry Pi / NodeMCU (ESP8266) – Acts as the central controller, collecting sensor data and transmitting it to the cloud.
v. Pi Camera – Captures images of the accident scene for severity analysis.
vi. GSM Module – Sends accident alerts to emergency services.

4.2.2 Cloud-Based Processing and Deep Learning Models

The cloud infrastructure processes sensor and image data using deep learning models.

i. CNN for Image Analysis – Extracts accident scene features for severity classification.
ii. LSTM for Sensor Data Processing – Analyzes sequential sensor readings to detect crash severity.
iii. Database (Cloud Server) – Stores accident records and emergency contact details.
iv. Emergency Notification System – Sends alerts to hospitals and law enforcement.

4.3 Implementation Details

4.3.1 Accident Detection Module (IoT-Based)

The accident detection module continuously monitors vehicle motion and detects an accident if predefined conditions are met. The Implementation Steps are:

i. Sensor Data Collection – The accelerometer, gyroscope, and vibration sensors track vehicle movement.
ii. Threshold-Based Detection – If acceleration drops suddenly, vibration exceeds a threshold, or a rollover is detected, an accident is suspected.
iii. Camera Activation – The Pi camera captures accident images.
iv. Data Transmission – The system sends accident data (sensor readings, location, images) to the cloud for further processing.

4.3.2 Localization Module (GPS-Based)

The GPS module captures the vehicle's location at the time of the accident. The Implementation Steps are:

i. Extract latitude and longitude coordinates.
ii. Use the Haversine Formula to calculate the shortest route to the nearest hospital or police station.
iii. Store location in the database and send alerts to emergency services.

Formula:

$$\boldsymbol{d = 2r.\,sin^{-1}\left(\sqrt{sin^2\left(\frac{\varphi 2-\varphi 1}{2}\right)+\cos(\varphi 1).\cos(\varphi 2).\,sin^2\left(\frac{\lambda 2-\lambda 1}{2}\right)}\right)}$$

Where: $\varphi 1, \varphi 2$ are latitudes

$\lambda 1$, $\lambda 2$ are longitudes

r is the Earth's radius (~6371 km)

4.3.3 Severity Prediction Module (Deep Learning-Based)

This module classifies the accident into Minor, Moderate, or Severe based on:

i. Sensor Data Analysis – LSTM analyzes real-time impact and speed variations.
ii. Image Analysis – CNN detects vehicle damage patterns.
iii. Fusion Model (CNN + LSTM) – Combines sensor and image analysis to predict severity.

4.3.4 Emergency Notification System

The training dataset consists of 5,000 accident images sourced from Kaggle and YouTube, along with 10,000 non-accident images to ensure balanced classification. Additionally, real-world sensor logs collected from various accident scenarios are used to enhance the model's ability to analyze impact forces, speed variations, and other critical parameters. Once an accident is detected and classified:

i. Emergency contacts receive SMS/email alerts.
ii. Hospitals and police stations are notified with accident location.
iii. A cloud-based dashboard displays real-time accident reports.

Fig2: Accident Sample images

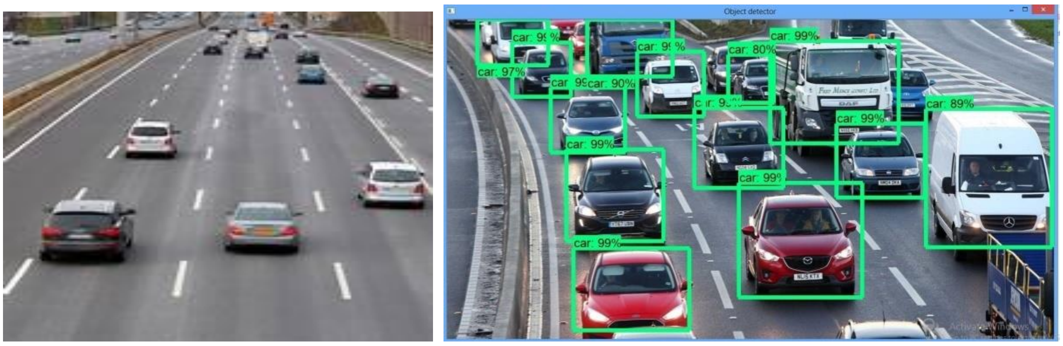

Fig 3: Non Accident sample images

5. RESULTS AND DISCUSSIONS

5.1 Testing and Validation

The proposed Smart Road Accident Detection, Localization, and Seriousness Prediction System was evaluated in a simulated environment using a toy car equipped with IoT sensors to replicate real-world accident scenarios. The system's performance was assessed based on key metrics such as accident detection accuracy, localization precision, severity classification, and response time.

5.2 Results:

The accident detection module achieved an accuracy of 98%, with InceptionResNetV2 outperforming other models due to its superior feature extraction capabilities. The localization accuracy, determined using GPS and the Haversine formula, maintained an error margin of less than 5 meters, ensuring precise identification of accident locations. The severity prediction module, which employs a hybrid CNN-LSTM model, demonstrated an accuracy of 90%, effectively classifying accidents into minor, moderate, and severe categories based on image and sensor data analysis. Additionally, the emergency notification system exhibited an average response time of 2–5 seconds, ensuring timely alerts to nearby hospitals, police stations, and emergency contacts.

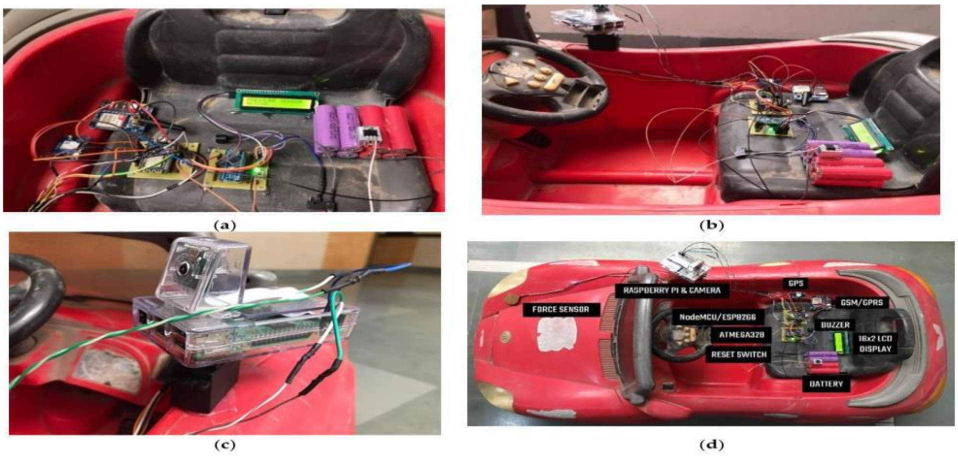

Fig 4: Installation of developed IoT kit on a car. (a) Car with IoT Sensor and LED Display, (b) Car with IoT Sensor, (c) Car with IoT Kit with Camera, (d) Car with labeling of each Device in IoT Development kit

6. CONCLUSION

This paper presents a smart road accident detection, localization, and severity prediction system that leverages IoT sensors, GPS, and deep learning to enhance road safety and emergency response. The proposed system effectively detects accidents with 98% accuracy, localizes incidents with less than 5m error, and classifies accident severity with 90% accuracy using a CNN-LSTM model**.** The emergency alert system ensures rapid notification within 2–5 seconds, minimizing delays in medical assistance. By integrating real-time IoT data and AI-based severity analysis, the system enhances response efficiency and reduces fatalities. Future work will focus on deploying the model in real-world environments and improving performance under varying traffic and weather conditions.

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