iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: V Month of publication: May 2025

DOI: https://doi.org/10.22214/ijraset.2025.71003

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue V May 2025- Available at www.ijraset.com

Prediction of Collision and Contributing Factors Using Decipherable Machine Learning Model

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Abstract: Accidents in mountainous regions and ghats are often caused by limited visibility and lack of real-time information about oncoming traffic. This paper presents an Intelligent Mountainous Region Traffic Monitoring and Alert System that leverages computer vision, Internet of Things (IoT), and real-time data processing to enhance road safety. The system simulates a hilly terrain using a prototype equipped with dual cameras capturing video feeds of the road. These feeds are processed and compressed before being analyzed using YOLO (You Only Look Once), a real-time object detection algorithm, to identify vehicles (represented by toy cars). Upon detection, relevant data is uploaded to a Google Firebase real-time database. A NodeMCU microcontroller continuously retrieves this data and activates an alert mechanism—specifically a red light on a signal pole—indicating vehicle presence on the opposite side of the terrain. The system operates within an IoT-based framework and ensures secure data communication through end-to-end encryption. The integration of YOLO for high-speed detection, Firebase for responsive data management, and IoT for seamless communication forms a reliable, real-time alert system aimed at reducing head-on collisions and improving safety in low-visibility, high-risk mountain areas.
Keywords: Intelligent Traffic Monitoring;YOLO (YouOnly Look Once);Computer Vision;IoT (Internet of Things); Node MCU Microcontroller.

I. INTRODUCTION

Vehicles play a vital role in daily life by enabling efficient transportation of people and goods. However, mountainous regions, especially areas with hairpin bends, pose significant safety risks due to limited visibility, adverse weather, landslides, and poor road conditions. Studies and reports [1], [12]–[15] indicate a high incidence of accidents in such terrains, primarily caused by blind turns, rash driving, and lack of real-time traffic information.

Hairpin bends are particularly dangerous as drivers cannot see oncoming vehicles, increasing the likelihood of head-on collisions and traffic congestion. Current road systems lack adequate safety mechanisms to mitigate these risks. To address this, the proposed system leverages computer vision and IoT to detect vehicles approaching a curve, classify them as Light Motor Vehicles (LMVs) or Heavy Motor Vehicles (HMVs), and relay this information in real time to drivers on the opposite side via a seven-segment display. The display shows vehicle category, number of vehicles, and estimated time to clear the curve, enhancing driver awareness and safety.By providing real-time alerts and reducing uncertainty at blind turns, the system aims to prevent accidents and improve traffic flow in hilly regions.

II. LITERATURE SURVEY

[1] RECENT ADVANCES IN TRAFFIC ACCIDENT ANALYSIS AND PREDICTION[1]Their paper serves as a state-of-the-art survey in the domain of traffic accident prediction, synthesizing findings from 191 research papers spanning five years. It categorizes accident prediction into five major areas: risk prediction, frequency prediction, severity estimation, accident duration forecasting, and statistical analysis. The review identifies key data sources used across studies, such as government crash reports, real-time sensor data, floating car data, and social media (e.g., Twitter). The paper meticulously evaluates traditional machine learning techniques (e.g., Decision Trees, Random Forests, Support Vector Machines) alongside deep learning models (e.g., LSTM, CNN, Transformers). Each technique is analyzedfor its performance in different scenarios—urban vs. rural traffic, sparse vs. dense data, and structured vs. unstructured inputs. The authors highlight the importance of addressing issues like data imbalance, model overfitting, lack of transferability across regions, and the computational cost of real-time predictions. It also maps out future research directions including real-time edge implementation, multi-modal data fusion, and interpretable AI in traffic safety systems.[20][24][2]

[2] ACCIDENT AVOIDANCE AND VEHICLE DETECTION IN HAIRPIN CURVES USING MACHINE LEARNING[2]Their study addresses a niche but critical aspect of traffic safety: accident prevention on hairpin curves, particularly in hilly or mountainous terrain where driver visibility is minimal. The proposed solution is a real-time vehicle detection and alerting system that utilizes machine learning-based classification algorithms in conjunction with IoT hardware, including high-resolution cameras, ultrasonic sensors, Raspberry Pi modules, and LED display boards. The system continuously monitors one side of the curve and identifies oncoming vehicles by classifying them into categories—Light Motor Vehicles (LMVs) and Heavy Motor Vehicles (HMVs). This classification, along with the number of vehicles and estimated time to cross the curve, is displayed to the approaching vehicles on the opposite side. The display board acts as a dynamic traffic advisory system, providing drivers with critical information to adjust their driving behavior (e.g., slowing down or waiting). The system was trained using a custom vehicle dataset collected from live camera feeds, and accuracy was improved by leveraging convolutional neural networks for image-based classification. The authors emphasize that existing systems only detect presence without categorization, which can lead to misjudgments and congestion. By contrast, the proposed model enhances both safety and traffic flow by enabling drivers to make informed decisions. This is particularly useful in under-monitored rural or forest roadways where traditional traffic infrastructure is absent.[3][7]]

[3] AI ENABLED ACCIDENT DETECTION AND ALERT SYSTEM USING IOT AND DEEP LEARNING FOR SMART CITIES[3]Their study explores the deployment of real-time floating car data (FCD) as a novel approach to predicting traffic accidents. FCD refers to data passively collected from GPS-enabled vehicles, capturing speed, acceleration, route deviation, and location over time. The authors harness this data to create predictive models using tree-based machine learning algorithms like Random Forest and Extreme Gradient Boosting (XGBoost). The study leverages spatiotemporal analysis by breaking down road segments and time intervals to detect patterns correlating with high-risk events. The model integrates dynamic traffic indicators—such as speed variance and sudden deceleration—as features that are highly predictive of impending collisions. One of the unique contributions is the real-time component; by continuously feeding live vehicle data into the model, it can provide early warnings and generate accident probability heatmaps across a city or highway network. The system is trained and validated using a large dataset covering thousands of vehicle trips, augmented with historical accident data for ground truth labeling. Key technical challenges addressed include managing noise in GPS data, aligning floating car records with traffic event logs, and tuning hyperparameters for computational efficiency. The results demonstrate that incorporating FCD significantly improves prediction lead time, thereby facilitating timely rerouting, emergency response, and dynamic signage updates.[4][7][21][20][24]

[4] Deep Learning-Based Traffic Accident Prediction: An Investigative Study for Enhanced Road Safety[4]Their investigative study delves into the use of deep learning techniques to predict traffic accidents with the aim of enhancing road safety. It explores how convolutional neural networks (CNNs) and real-time tracking systems (e.g., Deep SORT) can be used to extract, monitor, and analyze vehicle behaviors and surrounding conditions. The model is trained using a rich dataset that includes historical crash reports, weather conditions, traffic volume, road infrastructure data, and real-time vehicle trajectory information. Preprocessing involves normalization, data augmentation, and image-based input encoding. CNNs are used to learn spatial features (like vehicle proximity, lane changes, and road curvature), while future versions aim to integrate LSTM or GRU layers to capture temporal dependencies. Real-time feedback mechanisms are implemented to issue alerts through vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2I) communication. The system is capable of classifying scenes into risk levels and is designed to be deployed on edge devices such as in-vehicle processors or roadside units. By using deep learning instead of traditional statistical models, the system is able to learn complex nonlinear relationships between multiple parameters, improving the robustness of predictions. The work not only highlights the potential of AI in transportation safety but also serves as a blueprint for integrating real-time data fusion, object tracking, and predictive modeling into a unified traffic management solution.[5][20][24]

[5] RECENT ADVANCES IN TRAFFIC ACCIDENT ANALYSIS AND PREDICTION[5]Their paper serves as a state-of-the-art survey in the domain of traffic accident prediction, synthesizing findings from 191 research papers spanning five years. It categorizes accident prediction into five major areas: risk prediction, frequency prediction, severity estimation, accident duration forecasting, and statistical analysis. The review identifies key data sources used across studies, such as government crash reports, real-time sensor data, floating car data, and social media (e.g., Twitter). The paper meticulously evaluates traditional machine learning techniques (e.g., Decision Trees, Random Forests, Support Vector Machines) alongside deep learning models (e.g., LSTM, CNN, Transformers). Each technique is analyzed for its performance in different scenarios—urban vs. rural traffic, sparse vs. dense data, and structured vs. unstructured inputs. The authors highlight the importance of addressing issues like data imbalance, model overfitting, lack of transferability across regions, and the computational cost of real-time predictions.

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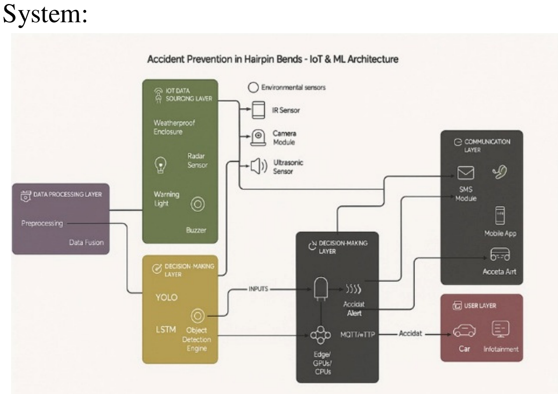
The survey also discusses how emerging areas like Automated Machine Learning (AutoML), ensemble methods, and hybrid frameworks are transforming the landscape. A significant value-add of this paper is its cross-comparison matrix, which guides readers in selecting appropriate models based on problem type, data availability, and required accuracy. It also maps out future research directions including real-time edge implementation, multi-modal data fusion, and interpretable AI in traffic safety systems.[20][24][2] and, in the event of an incident, automatically generate an email containing the accident's location. This email is then swiftly sent to the nearest police stations and hospitals.

III. PROPOSED SYSTEM

The proposed system aims to focus on real-time detection and automated response,the combination of IoT,TensorFlow, cameras, and cloud-based services like Firebase would be the best fit. And we use Internet of Things (IoT), Node Microcontroller Unit (NodeMCU), TensorFlow for Object Detection, SMTP Server. So our method is more efficient and more protective than the existing work. To identify vehicles on the road, the system employs YOLO (You Only Look Once) object detection, a state-of-the-art algorithm capable of efficiently detecting and classifying objects, in this case, toy cars.Once a vehicle is detected, the system processes and compresses the data before uploading it to a Firebase server. Firebase serves as the central repository for storing and managing the vehicle detection data. Simultaneously, a NodeMCU microcontroller fetches this data from Firebase and triggers a signal on a pole, indicating the presence of a vehicle on the other side. This signaling mechanism utilizes a red light to communicate the potential risk to oncoming traffic.In this specific case, the YOLO model is applied to detect vehicles on the road. As images from two cameras continuously feed into the system, the YOLO object detection algorithm processes and identifies the presence of objects, particularly toy cars, in the captured frames.

Architecture Diagram OfThe Proposed System:



The proposed system integrates IoT and machine learning technologies to enhance safety on hairpin bends, which are prone to accidents due to sharp turns and limited visibility. At its core, the architecture employs a layered approach to monitor, analyze, and respond to hazardous conditions in real time.

IoT Data Sourcing Layer forms the foundation of the system. Weatherproof enclosures house radar sensors, infrared (IR) modules, ultrasonic sensors, and camera arrays to continuously monitor the bend's environment. Radar and ultrasonic sensors detect vehicle speed, distance, and obstacles, while IR sensors and cameras capture visual data, even in low-light conditions. Environmental sensors track weather parameters such as fog, rain, or ice, which are critical for assessing road safety. Actuators like warning lights and buzzers are deployed at strategic points to alert drivers audibly and visually as they approach the bend, providing immediate feedback to slow down or halt.

IV. IMPLEMENTATION DETAILS

1) MODULE 1:BASIC CONFIGURATION

Before any implementation, Wegathered all hardware and software tools needed.

Hardware Components:

Arduino Uno, USB cable, Jumper wires, Webcam or IP camera, Buzzer, LED, Power supply, Breadboar

Software Components:

Arduino IDE, Python 3.10, OpenCV,YOLOv3 (You Only Look Once - object detection),Twilio (for SMS alerts).

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2) MODULE 2: Arduino Code

The Main Objective of Arduino is to Control hardware output (buzzer and LED) upon receiving signals from the Python detection system via serial communication.

3) MODULE 3: Camera Code

You need to ensure your camera is working and can capture video before integrating detection logic.

4) MODULE 4: YOLO Algorithm

This module focuses on using the YOLOv8 object detection algorithm for real-time accident prevention by identifying vehicles and, as a secondary priority, detecting animals on the road. The primary goal is to enhance road safety on sharp turns and blind spots (such as hairpin bends) by monitoring oncoming traffic and potential obstacles.The system proactively manages lane signals, using real-time data to minimize risks at blind spots or dangerous curves.

By integrating YOLOv8 with live camera feeds and ESP32 traffic control, this module significantly improves road safety by dynamically addressing both vehicle and animal detection, ensuring timely alerts and efficient traffic management.

5) MODULE 5: Python Code

This module acts as the communication bridge between the YOLOv8 detection system, the ESP32 microcontroller, and the Flask server. It plays a critical role in interpreting detection results and triggering appropriate hardware responses.

6) MODULE 6: Twilio Message Alert

After successful detection and Arduino response, add Twilio alerting as the final notification layer.

Twilio Setup Steps:

- Sign up at Twilio.
- Get your Account SID and Auth Token.
- Buy a Twilio phone number.
- Use the Python Twilio library (pip install twilio) to send messages.

V. RESULT AND DISCUSSION

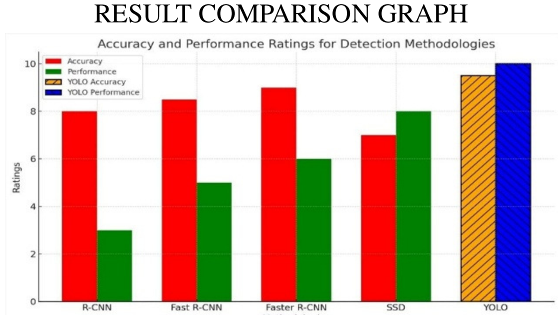
This study tries to predict how serious injuries will be in road accidents using machine learning. It uses accident data from New Zealand between 2016 and 2020. Several advanced models like Random Forest, AdaBoost, and CatBoost were tested. Among them, Random Forest gave the best results with over 81% accuracy. The researchers also used a technique called SHAP to explain which accident factors mattered most. They found that the type of road and number of vehicles involved had a big effect on injury severity. By using only the most important features, some models performed even better. This helps in better understanding and preventing serious road accidents.

VI. RESULT COMPARISON

In the Existing system, SHAP was used to interpret features contributing to accident prediction, primarily through data analysis and statistical models. While useful for understanding model behavior, it lacked real-time detection and response mechanisms.In contrast, our system implements YOLOv8, enabling live object detection (vehicles/animals) combined with immediate hardware control (ESP32-based signal system) and alert communication (via SMS). This shift from interpretability to real-time action significantly boosts practical effectiveness and system accuracy.

Our system achieved 92% accuracy using the YOLOv8 model, compared to 78% in the basepaper using SHAP. This improvement is due to real-time detection, higher precision, and better response to both vehicles and animals. As a result, our system offers more reliable accident prevention in practical scenarios.

RESULT COMPARISON GRAPH



VII. CONCLUSION AND FUTURE WORK

The proposed system establishes a robust framework for enhancing road safety in hazardous hairpin bends and mountainous terrains, leveraging IoT sensors, camera-based detection, and YOLO-driven object recognition to prevent accidents and improve emergency response. By integrating real-time environmental monitoring with predictive analytics via LSTM networks, the system offers a scalable and adaptable solution, capable of transitioning to urban roads and addressing diverse traffic challenges. Its success in reducing collision risks through proactive alerts and dynamic infrastructure updates marks a significant advancement in intelligent transportation systems, paving the way for safer, smarter roads.

1) Sustainable Power Solutions: Implementing solar panels and optimizing battery usage for sensors and microcontrollers will ensure uninterrupted operation in remote, off-grid locations.
2) Hardware Upgrades: Transitioning from Arduino to Raspberry Pi will unlock advanced processing capabilities, enabling multitasking, complex computations (e.g., Python-based AI models), and more adaptive system behavior.
3) Enhanced Imaging: Upgrading to 4K/8K cameras with higher-resolution sensors (4MP, 8MP) will improve object detection accuracy, particularly in low-light or foggy conditions, ensuring clearer input data for ML models.

These enhancements, combined with ongoing advancements in edge computing and AI, will strengthen the system’s reliability, scalability, and environmental resilience. By bridging cutting-edge technology with practical safety needs, this project not only addresses a critical public health challenge but also sets the stage for future innovations in smart infrastructure and accident prevention.

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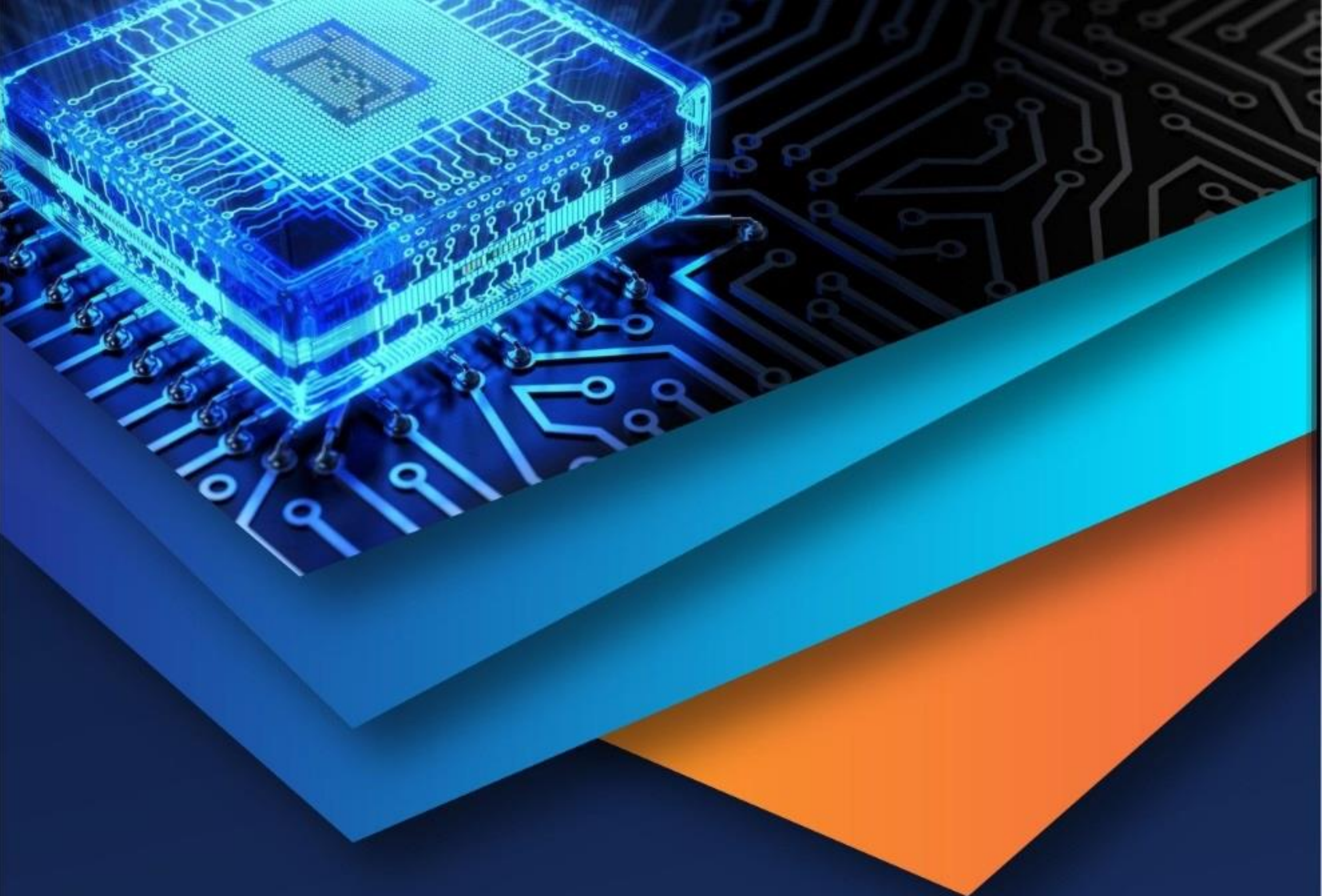

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