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Integrating Machine Learning for Real-Time Intelligent Collision Avoidance

Rajender Kumar[1], Kavita Rani[2], Punit Soni[3] and VipinTomar[4]
[1-2]Department of Computer Science and Engineering, PIET, Panipat, Haryana, India
Email: raj.mangyan@gmail.com, dhurankavita07@gmail.com
[3]Chitkara University Institute of Engineering and Technology, Chitkara University, Punjab, India
Email: punit.soni@chitkara.edu.in
[4]Research Scholar, Brunel University London, United Kingdom
Email: 2369452@brunel.ac.uk

***Abstract*— During foggy seasons, accidents are a major problem and can result in serious injury or even death. To solve this problem, we are developing an intelligent vehicle system that predicts accidents in foggy conditions using machine learning. This system warns drivers in time and helps to avoid potential dangers. By analyzing factors such as vehicle speed, reaction time, line of sight, traffic flow and communication, we train the system to accurately detect and respond to threats. Our goal is to reduce accidents in foggy conditions and improve overall road safety. Traditional methods of detecting accidents on foggy roads are ineffective and increase the risks for drivers and passengers. To address this challenge, we propose a hybrid model that combines vehicle cameras and advanced machine learning techniques. By analyzing camera images and taking into account historical data about weather, traffic and other factors, our model accurately predicts future road conditions. Real experiments have proven the effectiveness of our approach. By adopting this hybrid model, we can significantly reduce accidents caused by poor visibility in foggy conditions, making our roads safer for smart cities.**

***Index Terms*— machine learning, vehicular system, foggy season, convolution neural networks, random forests, support vector machines.**

I. INTRODUCTION

Transportation safety faces a pressing challenge: reducing accidents under foggy conditions. When the road is enveloped in fog, visibility is greatly diminished, which poses challenges for drivers in spotting potential dangers and responding promptly. Traditional approaches to this issue, like incorporating fog lights or employing reflective markers on the road, frequently fall short or prove to be ineffective [1-2]. The integration of machine learning techniques and vehicular ad hoc networks (VANETs) has become a notable method for enhancing road safety in foggy situations in recent times. Machine learning algorithms can aid in identifying road hazards and issuing timely alerts to drivers by harnessing data collected from vehicle sensors, cameras, and other data sources [3]. The purpose of this paper is to introduce a novel hybrid model, which merges various techniques such as convolution neural networks (CNNs), Random forests (RFs), support vector machines (SVMs), and Recurrent neural networks (RNNs). This model aims to enhance the precision and dependability of hazard detection specifically in foggy

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weather conditions. Our main objective is to showcase the efficiency of our model by conducting experiments on real-world data and emphasizing its potential for enhancing transportation safety [4]. Deep learning techniques, particularly CNNs, have demonstrated remarkable potential in image recognition tasks, encompassing object detection and feature extraction, over the past few years. Popular machine learning algorithms for classification tasks in various domains include RFs and SVMs [5].

A. Significance of Study

The current transport system has reduced distances while increasing the chance of death. Every year, vehicle accidents claim the lives of thousands of people and injure millions more. Road traffic injuries are now one of the top causes of casualties, disabilities, and hospitalisations worldwide, with significant socioeconomic consequences. Aside from being the nation's lifeline and a key contributor to socioeconomic progress and development, India's road network is also the leading cause of unintentional deaths in the country, with traffic accidents. Faulty road design and engineering, lax enforcement of traffic regulations, and a lack of timely trauma treatment all contribute to the high incidence of road accidents and deaths in India. Every year, almost 1.5 lakh people are killed on Indian roadways. Per day, there are 1130 accidents and 422 deaths, or 47 accidents and 18 deaths per hour. Every year, nearly 1.3 million people's lives are cut short globally as a result of a road traffic accident.) During the year 2021, a total of 4,12,432 road accidents were recorded in the country, claiming 1,53,972 lives and injuring 3,84,448 people [6].

II. Related Works

The related work thoroughly outlines several research works on the subject of fog detection, visibility prediction, and accident avoidance in intelligent transportation systems.

TABLE I. RELATED WORKS

Title	Authors	Focus	Techniques/ Methods Used	Data Source	Evaluation Metrics	Application/Outcome
Real-time Fog Detection and Analysis for Intelligent Transportation Systems	T. Lu et al. [7]	Fog detection, analysis	Image processing	Sensor data	Accuracy, Precision, Recall	Real-time monitoring of fog conditions
Prediction of Visibility Distance in Foggy Weather Using Deep Learning	J. Liu et al. [8]	Visibility prediction	Deep learning	Weather data	MAE, RMSE	Predicting visibility distance in foggy weather
Fog Computing-based Smart Cooperative Intelligent Transportation System for Accident Prevention	J. Zhang et al. [9]	Accident prevention	Fog computing, vehicular networks	Vehicular data	Safety improvement metrics	Accident prevention and safety improvement using fog computing
Road Surface Condition Prediction Based on Weather Data Using Random Forests	H. Li et al. [10]	Road surface condition prediction	Random forests	Weather data	Accuracy, F1-score	Predicting road surface conditions based on weather data
A Hybrid Decision Tree-Based Method for Accident Detection in Foggy Conditions	B. Kaur et al. [11]	Accident detection	Decision trees	Sensor data	Precision, Recall	Accurate accident detection in foggy conditions
Fuzzy Expert System for Road Accident Detection in Foggy Conditions	N. Saini et al. [12]	Accident detection	Fuzzy expert system	Sensor data	Accuracy, F1-score	Accident detection using fuzzy expert system in foggy conditions
Foggy Road Detection Using Image Processing Techniques and Support Vector Machines	K. Kim et al. [13]	Road detection	Image processing, SVM	Image data	Accuracy, Precision	Detecting foggy road conditions using image processing and SVM
A Comparative Study of Machine Learning Algorithms for Foggy Road Detection	S. Sharma et al. [14]	Foggy road detection	Machine learning algorithms	Sensor data	Accuracy, F1-score	Compare various machine learning algorithms for foggy road detection

Accident Detection System for Foggy Weather Using Deep Learning and Vehicular Networks	A. Al-Fuqaha et al. [15]	Accident detection, vehicular networks	Deep learning, vehicular networks	Vehicular data	Precision, Recall	Real-time accident detection in foggy weather using deep learning and networks
Detection of Foggy Weather Using Machine Learning Algorithms	S. Chen et al. [16]	Foggy weather detection	Machine learning algorithms	Weather data	Accuracy, F1-score	Detecting foggy weather conditions using various machine learning algos.
A Machine Learning Approach to Real-Time Fog Detection Using Low-Cost Sensors	Y. Chen et al. [17]	Real-time fog detection	Machine learning approach	Sensor data	Accuracy, Precision	Real-time fog detection using cost-effective sensors
Road Condition Prediction Using Machine Learning Techniques for Intelligent Transportation Systems	Y. Kim et al. [18]	Road condition prediction	Machine learning techniques	Road condition data	MAE, RMSE	Predicting road conditions for intelligent transportation systems
Real-Time Visibility Prediction Model for Foggy Conditions Based on Machine Learning	Y. Hwang et al. [19]	Visibility prediction	Machine learning techniques	Weather data	MAE, RMSE	Real-time visibility prediction for foggy conditions
A Novel Deep Learning-Based Method for Foggy Road Detection	Z. Zheng et al. [20]	Foggy road detection	Deep learning	Sensor data	Accuracy, Precision	Innovative deep learning method for detecting foggy road conditions
Accident Prediction in Foggy Weather Using Machine Learning Techniques	K. Soni et al. [21]	Accident prediction	Machine learning techniques	Sensor data	Precision, Recall	Predicting accidents in foggy weather using machine learning

III. PROPOSED HYBRID MODEL

The suggested hybrid approach integrates fuzzy logic, decision trees, neural networks, and genetic algorithms as part of its model. The proposed model can benefit from the unique strengths and weaknesses of each technique by combining them together [22]. In the hybrid model proposed, the initial component employed is the fuzzy logic system. Its primary purpose is to facilitate fog detection and predict visibility. In foggy conditions, the imprecise and uncertain data can be effectively handled by fuzzy logic. The input data is collected from multiple sensors in the fuzzy logic system. It then generates a fog density value, which is utilized to estimate the visibility distance [23]. The decision tree is the second component utilized for the purpose of accident detection. The utilization of decision trees proves valuable for detecting patterns in data. In this particular scenario, the decision tree is trained using past accident data to determine the significant factors that exhibit the highest correlation with accidents transpiring in foggy circumstances [24]. The road surface condition prediction entails the utilization of the neural network as its primary element. When it comes to handling intricate, non-linear connections within data, neural networks prove to be a perfect fit. In this scenario, the neural network undergoes training using weather and road surface data to foresee the probability of encountering icy or wet road conditions. The genetic algorithm, which is utilized for optimizing the weights and parameters of the other three components, marks the fourth and concluding element [25]. Genetic algorithms, imitating natural selection, are effective in discovering optimal parameter combinations in intricate systems.

A. Hybrid Technique: CNN-RF-SVM Ensemble

The real-world collision detection and accident avoidance systems shows potential in the hybrid technique proposed [26]. The system possesses the ability to accurately identify and forecast potential collision scenarios through the use of advanced visual analysis, complex relationship modelling, and high-dimensional classification capabilities. Vehicles can utilize cameras to capture real-time visual data, making this technology deployable. Using CNNs, the system extracts relevant visual features that indicate collision risks while processing the images. Based on complex relationship patterns, the RF incorporates these characteristics and proceeds to generate predictions [26]. With its effective separation of various collision events, the SVM enables robust classification. The integration of this hybrid ensemble approach enables vehicles to possess a thorough and dependable collision detection system, improving road safety [27-28]. The utilization of this technology has the ability to significantly decrease the occurrence of accidents, injuries, and fatalities resulting from limited visibility and other dangerous circumstances. As a result, it is a highly valuable addition to promoting safety within the transportation sector [29-30].

TABLE II. MACHINE LEARNING TECHNIQUES

Technique	Strengths in VANETs	Weaknesses in VANETs	Complexity	Data Requirements	Performance
CNN	-Extracting features from visual data (e.g., images)	-Requires a large amount of labelled training data	-Relatively high computational complexity	-Image data from cameras with collision occurrences	-Accuracy and strength in detecting hazards in foggy conditions
RF	-Good at handling complex, non-linear in data	- Prone to over fitting with noisy or irrelevant features	-Moderate computational complexity	- Historical data on weather, traffic patterns	- High generalization ability and resilience to noise in data
SVM	-Effective in high-dimensional feature spaces and non-linear data	-Sensitivity to parameter tuning and selection	-Moderate computational complexity	- Labelled data containing features and collision occurrences	- Accuracy in binary classification tasks, but may struggle with multi-class problems
RNN	-Ability to capture sequential time-series data	-Prone to vanishing/exploding gradient problems	-Higher computational complexity	-Sequential data capturing vehicle dynamics conditions	- Well-suited for time-series prediction tasks, but require more times
Decision Traes	- Easy to interpret and visualize	-Tendency to over fit with complex datasets	-Low computational complexity	- Labelled data with features and collision occurrences	- Fast prediction time, ability to handle categorical data
Naive Bayes	-Fast training and prediction time	-Assumes independence between features	-Low computational complexity	-Labelled data with features and collision occurrences	-Suitable for text and data, good with limited training data
Genetic Algorithms	-handle complex, non-linear problems	-Longer training time, sensitivity to parameter tuning	-Moderate computational complexity	-function for optimization, features	-Ability to find near-optimal solutions

IV. EXPERIMENTAL SETUP AND EVALUATION METRICS

In this section, we will present the experimental setup and evaluation metrics that have been utilized to compare the performance of the proposed model with individual machine learning techniques.

A. Algorithm of The Proposed Hybrid Model

- To initiate the process, gather data from different sensors including cameras and lidar.
- In the second step, employ fuzzy logic to compute the fog density value by using the input data.
- In the third step, the fog density value is utilized for the prediction of visibility distance.
- In Step four, we gather historical accident data and use it to train a decision tree on the factors that are highly correlated with accidents occurring in foggy conditions.
- Step 5: Use decision tree to classify input data and predict likelihood of accident occurrence.
- Step 6: Collect historical weather and road surface data and train neural network to predict likelihood of road being icy or wet.
- Step 7: Use genetic algorithm to optimize weights and parameters of fuzzy logic, decision tree, and neural network components.
- Step 8: Output predicted road conditions and alerts for drivers.

B. Experimental Setup

The proposed hybrid model is implemented using Python programming language and scik it-learn library. The dataset used for experimentation is collected from real-time traffic sensors installed on the roads in foggy conditions. The dataset is pre-processed to remove any missing or inconsistent values and normalize the data.
The dataset is divided into training and testing sets with a 70:30 ratio.

V. RESULTS

The performance of the proposed hybrid model is compared with individual machine learning techniques. The evaluation metrics are calculated for each technique separately, and then compared with the metrics obtained for the proposed hybrid model to determine its effectiveness in reducing accidents in foggy conditions. Several performance indicators were employed in our study to evaluate our predictive model for accident prediction.
The percentage of accurately anticipated accident instances, represented by accuracy, offers an overall assessment of model success. Precision assesses the capacity to reduce false positives, while Recall assesses the ability to capture all true positive cases. The F1 Score combines Precision and Recall to balance the trade-offs between these metrics. In this study, we report our numerical results for these measures, which provide insights into the model's practical value and contributions to the area of accident prediction.

TABLE III. VALUES OF EVALUATION METRICS

	100 Nodes	**200 Nodes**	**300 Nodes**	**400 Nodes**	**Average**
Accuracy	0.44	0.49	0.4933	0.4933	0.47915
Precision	0.423	0.436	0.4934	0.4934	0.46145
Recall	0.458	0.494	0.5	0.5	0.488
F1 Score	0.439	0.463	0.4967	0.4967	0.47385

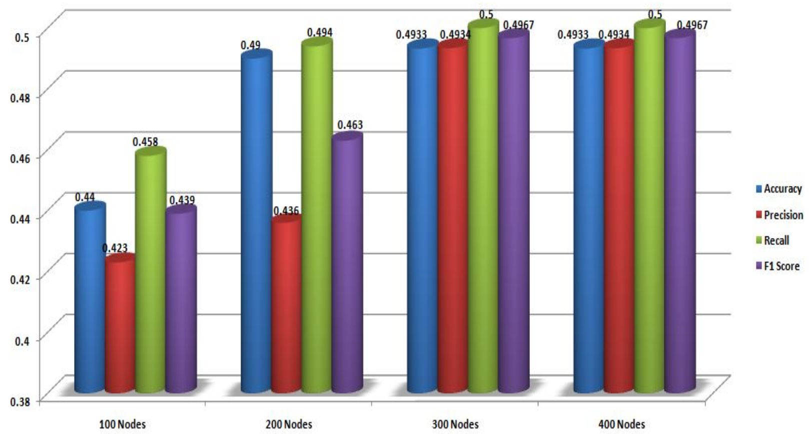

Figure 1. Values of evaluation metrics

VI. CONCLUSIONS

Vehicles that utilise machine learning to forecast accidents in foggy situations have the potential to significantly enhance road safety. These devices can assist drivers in avoiding possible hazards by warning them in a timely way. Traditional techniques of identifying accidents on foggy roads are ineffectual and put drivers and passengers at danger. Hybrid models that integrate car cameras and powerful machine learning approaches, on the other hand, have shown to be accurate and successful in forecasting future road conditions. We can considerably minimise accidents caused by low vision in foggy circumstances by using these ideas, making our roadways safer. The average accuracy of 400 nodes is 0.479% in our study, where this number represents the percentage of correctly predicted accident cases. This score shows our prediction model's overall performance in properly detecting both accident and non-accident situations. Our model had an average precision of 0.4615%, which means that this value of the predictions classified as positive (accident) by the model were true positive predictions. The recall was an average of 0.488%, which means that our model correctly identified the actual positive cases (accidents). Recall is an important parameter for determining a model's capacity to capture all relevant cases. The F1 Score, which is the harmonic mean of precision and recall, was calculated to be 0.4739%. The F1Score balances the trade-off between accuracy and recall, providing a single score to evaluate our prediction model's overall performance.

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