ISSN 2319-5991 www.ijerst.com
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Peer Reviewed, Referred & Indexed Journal

Research Paper

A Decentralized V2V Communication Framework with Traffic Prediction and Accident Severity Detection

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Abstract: This paper presents an intelligent Vehicle-to-Vehicle Communication system integrated with Machine Learning techniques to enhance road safety and traffic efficiency. The proposed system predicts accident severity, suggests optimal routes based on traffic congestion and weather conditions, and dynamically controls traffic signals. A decentralized communication framework enables real-time data exchange among vehicles, reducing latency and improving responsiveness.

The system utilizes algorithms such as Decision Tree and Random Forest to achieve high prediction accuracy using real-world datasets. Simulation results demonstrate improved traffic flow and reduced congestion through adaptive signal control. Overall, the proposed approach provides a scalable and efficient solution for next-generation intelligent transportation systems.

Index terms - *— Vehicle-to-Vehicle Communication (V2V), Machine Learning, Traffic Prediction, Accident Severity Analysis, Intelligent Transportation Systems, Random Forest, Decision Tree, Traffic Signal Control.*

1. INTRODUCTION

In recent years, the rapid growth of intelligent transportation systems has increased the demand for efficient and real-time communication among vehicles. Vehicle-to-Vehicle Communication has emerged as a key technology that enables vehicles to exchange critical information such as speed, location, and road conditions. This direct communication helps in reducing accidents, improving traffic flow, and enhancing overall road safety. However, traditional traffic management systems are mostly centralized, which leads to delays, scalability issues, and vulnerability to failures.

To overcome these limitations, the integration of Machine Learning with V2V communication has gained significant attention. Machine learning techniques can analyze large volumes of traffic and

accident data to predict congestion, suggest optimal routes, and estimate accident severity. By combining real-time communication with intelligent prediction models, vehicles can make faster and more accurate decisions, leading to improved efficiency in transportation systems.

In this paper, we propose an intelligent V2V communication system that incorporates machine learning algorithms such as Decision Tree and Random Forest for traffic prediction and accident severity analysis. The system also includes dynamic traffic signal control based on vehicle density using simulation techniques. The decentralized nature of the proposed system ensures real-time data exchange without relying on a central authority, making it more robust and scalable. This approach aims to provide a smart, efficient, and reliable solution for next-generation transportation systems.

2. LITERATURE SURVEY

a) Effect of Vehicle-to-Vehicle Communication Latency on a Collision Avoidance Algorithm for Heavy Road Vehicles:

Because big road vehicles have a comparatively greater number of deaths in their accidents, active safety is crucial. Vehicle-to-Vehicle (V2V) technology, which is anticipated to be a part of connected cars in the future, may be used in conjunction with onboard sensors to shorten detection times and design routes using data from roadside units (RSU). This study examines how a collision avoidance system designed for large road vehicles is affected by latency in (V2V) communication. The impact of latency for different scenarios was assessed through experiments conducted on a Hardware-in-Loop (HiL) system. It was discovered that latency had a counterbalancing impact on relative longitudinal speed and vehicle spacing, resulting in negligible variations in the ultimate spacing. Furthermore, the requirement for a variable time headway was shown by a sensitivity analysis conducted at various host vehicle longitudinal speeds.

b) CAN gateway for fast vehicle to vehicle (V2V) communication:

Information and communication technologies are used by intelligent transport systems (ITS) to enhance traffic flow management and vehicle safety on roads. A car uses wired or wireless communication technology to connect with other cars and/or infrastructures. Numerous electronic control units (ECUs) based on the kind of service in different domains (such as the engine, body, and chassis domains) make up in-car networks. Low latency requirements should be met by vehicle-to-vehicle (V2V) communications pertaining to vehicle safety. Furthermore, the data in V2V communications is linked to particular ECUs. We should think of a new approach that responds to the required ECUs for a particular V2V message in order to facilitate communication between V2V communications and in-car networks. We present an efficient controller area network (CAN) gateway technique in this study. In order to find a network table based on the CAN frame for a V2V communication, this approach makes use of a CAN gateway. The suggested approach can be an excellent solution that easily manages the ECUs due to its straightforward structure and methodology. Additionally, it can send V2V communications quickly.

c) Vehicle to Vehicle Communications at Suburban Environment using IEEE 802.11af compliant Devices

In order to serve the objectives of the intelligent transportation system, vehicle-to-vehicle (V2V) communications have been created, where cars share data, such as traffic information, to provide better traffic management to reduce traffic congestion and vehicle accidents. The ITS band of 5.9 GHz (5.85–5.925 GHz), which is more prone to attenuation and restricted to shorter-range communications, has historically been used for V2V communications. V2V communications in the television white space (TVWS) spectrum have previously been shown and used because to their superior propagation characteristics and larger coverage. This study assessed and analyzed V2V communications over TVWS in a suburban setting using IEEE 802.11af-compliant devices in terms of received signal strength and throughput as a function of the two cars' separation distance. The trials were carried out at the hilly University of San Carlos Talamban Campus in Cebu City, Philippines. Because of the buildings, topography, and foliage there, it resembles a suburban setting. A maximum throughput of 4.87 Mbps has been observed at -51 dBm of received power using 20 dBm or 100 mW of transmit power with 64-QAM payload modulation and 2/3 coding rate. The aforementioned information was gathered while the vehicles' effective speeds were 8.68 m/s and their separation was 37 m. The packet loss rate had an impact on throughput; in this investigation, a packet loss rate of less than 10% was achieved at received signal strengths between -88 and -33 dBm in each MCS. Additionally, non-line-of-sight communication and multipath propagation, which are impacted by local locations, topography, buildings, and other infrastructures, have an impact on received signal strength and throughput. The findings indicated that TVWS might be used to support the objectives of the intelligent transportation system in vehicle wireless communications.

d) IWCM: Infrastructure Wireless Communication Module for vehicle communication with recharge infrastructure:

The goal of the R&D partnership initiative CENIT VERDE was to create a fully functional electrical vehicle together with the necessary infrastructure. This involved researching a dependable link between the PHEV/EV and recharge infrastructure. As a consequence, ICWM (Infrastructure Wireless Communication Module), a standardized communication interface module between the vehicle and the recharge infrastructure, was created. Because it makes use of parts that are already present in the car, this makes it possible to implement many specialized services for electric vehicles at a reasonable cost.

e) Small Scale Field Study of Vehicle-to-Vehicle (V2V) Communications for Safety Applications:

The development of driverless cars has received significant attention worldwide this decade. The advancement of autonomous and linked mobility research and development is greatly aided by a variety of sensor types, communication systems, computer hardware, and new AI technologies. Vehicle-to-everything (V2X) communication is the term used to describe the technologies that researchers are currently developing to allow cars to interact with one another and with other objects in the environment. Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) are the two primary

components of V2X. These make it possible for cars to communicate with one another or with roadside installations. In order to investigate the inner workings of the technology, a small-scale field experiment was set up using the V2V hardware platform from Savari, an automotive communication technologies firm with commercially viable V2X products. Research and preliminary experimental test findings show that the technology is feasible to increase road vehicle safety.

3. METHODOLOGY

i) Proposed Work:

The goal of the proposed study is to create a cognitive agent-based system that makes it possible to efficiently retrieve pertinent code elements from sizable, unstructured software libraries. In order to eliminate stopwords, special characters, and extraneous noise from code comments, the system first gathers program files and preprocesses them. After the data has been cleaned, each program is represented as a structured matrix of word frequencies in a vector space model. The system can efficiently compare and examine the relationships between various code components thanks to this representation.

The system incorporates unsupervised learning methods including K-Means, Hierarchical Clustering, Self-Organizing Maps (SOM), and Principal Component Analysis (PCA) to increase retrieval intelligence and accuracy. To find pertinent code logic, user queries are processed and transformed into test vectors, which are then compared to the repository vectors. The cognitive agent reduces noise, increases accuracy, and facilitates quicker and more dependable software reuse by predicting and retrieving just those components that closely match the necessary functionality.

ii) System Architecture:

The query processing flow and the data processing flow are the two primary flows that make up the system architecture of the cognitive agent-based code retrieval system. These flows communicate with one another via a central Code2Vec representation module. First, the user uploads data or submits a query. Programs that are uploaded are preprocessed in the data flow to eliminate noise before being transformed into code vectors (Cv1, Cv2,..., Cvn). The user query is converted into a query vector (Qv1) in the query flow. The proximity between the query and stored code components is then determined by comparing these vectors using cosine similarity. The system determines that a relevant component exists and obtains it if similarity over a threshold; if not, it either offers the closest matching component or asks the user to refine the query. The system may also be made adaptable by adding new components to the repository, which will increase retrieval accuracy over time.

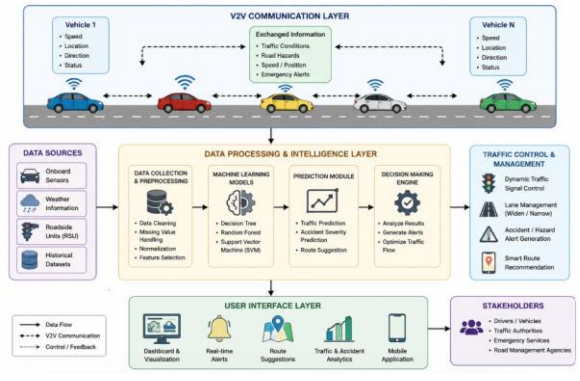


Fig1 proposed architecture

iii) Modules:

1. Data Collection Module

Collects real-time data from vehicles, sensors, weather sources, and traffic datasets. This data includes speed, location, traffic density, and environmental conditions.

2. V2V Communication Module

Uses Vehicle-to-Vehicle Communication to enable direct data exchange between vehicles. It shares critical information like road conditions, alerts, and vehicle status in real-time.

3. Data Preprocessing Module

Cleans and processes raw data by handling missing values, normalization, and feature selection. Ensures data is suitable for accurate prediction using Machine Learning models.

4. Traffic Prediction Module

Analyzes traffic and weather data to predict congestion and suggest optimal routes. Helps drivers avoid traffic and reduce travel time.

5. Accident Severity Prediction Module

Uses machine learning algorithms (Decision Tree, Random Forest) to predict accident severity levels (low, medium, high) based on historical accident data.

6. Traffic Signal Control Module

Controls traffic signals dynamically using vehicle density. Simulation (Pygame) adjusts green/red signals to optimize traffic flow.

7. Decision-Making Module

Combines outputs from prediction models and generates intelligent decisions such as alerts, route suggestions, and traffic control actions.

8. User Interface Module

Displays results through dashboards, alerts, and route suggestions. Provides real-time updates to drivers and traffic authorities.

iv) Algorithms:

1. Support Vector Machine (SVM)

Support Vector Machine is a supervised machine learning algorithm used for classification by finding an optimal boundary (hyperplane) between different classes. In this system, SVM is applied to traffic prediction and accident analysis by separating data into categories based on features like congestion and weather. However, based on experimental results, SVM showed lower accuracy compared to other models, making it less suitable for this application.

2. Decision Tree

Decision Tree is a simple yet powerful supervised learning algorithm that splits data into branches based on feature conditions. It works like a flowchart where each node represents a decision rule. In this project, it is used for traffic prediction and accident severity classification. It achieved high accuracy (around 90%) and is easy to interpret, making it effective for real-time decision-making.

3. Random Forest

Random Forest is an ensemble learning algorithm that combines multiple decision trees to produce more accurate and stable predictions. It reduces overfitting by averaging the results of different trees. In this system, Random Forest is used for both traffic prediction and accident severity analysis and provides the best performance among all algorithms with high accuracy and reliability.

4. Data Preprocessing Algorithm

Data preprocessing is a crucial step that prepares raw data for machine learning models. It includes handling missing values, normalization of data, and

converting categorical data into numerical form. In this project, preprocessing ensures that datasets such as traffic and accident data are clean and structured, which improves the performance of prediction models.

5. Traffic Signal Control Algorithm

This algorithm dynamically adjusts traffic signal timings based on vehicle density at different lanes. Using simulation (Pygame), it continuously monitors the number of vehicles and allocates more green signal time to heavily congested lanes. This helps in reducing waiting time and improving overall traffic flow efficiency.

6. Route Prediction Algorithm

The route prediction algorithm analyzes traffic congestion and weather conditions using trained machine learning models to suggest the best possible path. It helps drivers avoid crowded routes and reach their destination faster. This algorithm plays a key role in improving travel efficiency and reducing traffic congestion in smart transportation systems.

4. EXPERIMENTAL RESULTS

The proposed system was evaluated using real-world traffic and accident datasets to measure the performance of different machine learning algorithms. The dataset was preprocessed and divided into training (80%) and testing (20%) sets. Three algorithms—Support Vector Machine (SVM), Decision Tree, and Random Forest—were applied for traffic prediction and accident severity analysis. Among them, SVM showed poor performance with approximately 30% accuracy, indicating its limitation for this dataset.

In contrast, Decision Tree and Random Forest achieved significantly better results, with accuracy values around 90% and 90.06% respectively. The performance was further validated using confusion matrix and ROC curve analysis, where Random Forest showed fewer misclassifications and better prediction capability. Additionally, the traffic signal simulation using Pygame successfully demonstrated dynamic signal control based on vehicle density, improving traffic flow efficiency. Overall, the results confirm that Random Forest is the most effective algorithm for this system, providing accurate and reliable predictions for intelligent transportation applications.

Accuracy: A test's accuracy is its capacity to distinguish healthy from ill cases. Find the percentage of instances with genuine positives and negatives to assess test accuracy.

Accuracy = TP + TN /(TP + TN + FP + FN)

$$Accuracy = \frac{(TN + TP)}{T}$$

Precision: Classification accuracy or positive cases constitute precision. The formula for accuracy is:

Precision = True positives/ (True positives + False positives) = TP/(TP + FP)

$$\Pr e\ cision = \frac{TP}{(TP + FP)}$$

Recall: A model's recall measures its ability to recognize all appropriate machine learning class instances. The ratio of accurately predicted positive observations to total positives indicates a model's class instance detection skill.

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$$Recall = \frac{TP}{(FN + TP)}$$

mAP: Mean Average Precision ranks quality. It considers the number and order of relevant ideas. Calculating MAP at K uses the arithmetic mean of each user or query's Average Precision (AP).

$$mAP = \frac{1}{n}\sum_{k=1}^{k=n} AP_k$$

$$AP_k = \text{the AP of class } k$$

$$n = \text{the number of classes}$$

F1-Score: A high F1 score suggests an accurate machine learning model. Integrating recall and precision improves model correctness. Accuracy measures how often a model predicts a dataset correctly.

$$F1 = 2 \cdot \frac{(Recall \cdot \Pr e\,cision)}{(Recall + \Pr e\,cision)}$$

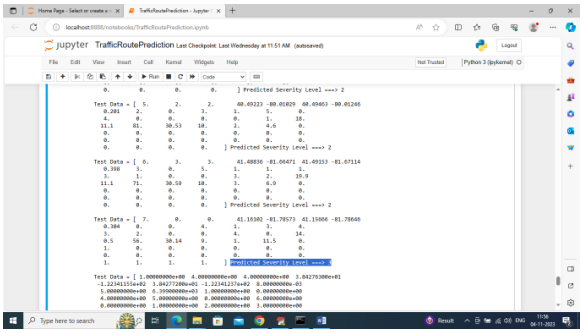


Fig.2. input

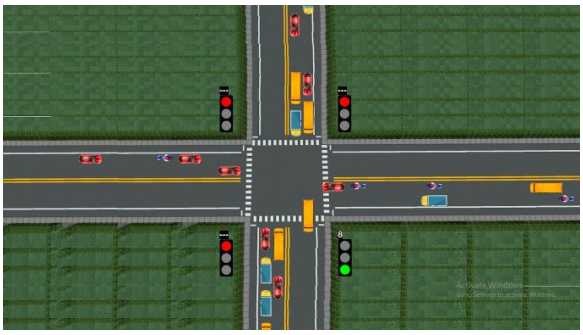


Fig.3. output page

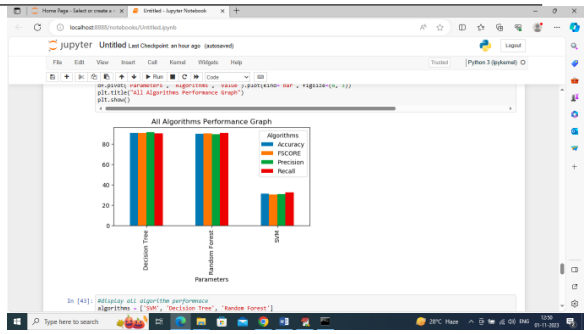


Fig4 accuracy graph

5. CONCLUSION

This paper presents an intelligent Vehicle-to-Vehicle Communication system integrated with Machine Learning techniques to improve road safety and traffic management. The proposed decentralized framework enables real-time communication between vehicles, allowing efficient sharing of traffic and environmental information. The system successfully predicts traffic congestion, suggests optimal routes, and estimates accident severity using machine learning models.

Experimental results show that Decision Tree and Random Forest algorithms achieve high prediction accuracy, with Random Forest performing the best. The dynamic traffic signal control further enhances traffic flow by adjusting signal timings based on vehicle density. Overall, the proposed system provides a scalable, efficient, and reliable solution for next-generation intelligent transportation systems, contributing to reduced congestion and improved road safety.

6. FUTURE SCOPE

The proposed Vehicle-to-Vehicle Communication system can be further enhanced by integrating advanced Machine Learning and deep learning

models to improve prediction accuracy for traffic congestion and accident severity. Real-time deployment using IoT-enabled sensors and edge computing devices can make the system more responsive and suitable for smart city environments. Additionally, incorporating real-time GPS and live traffic APIs can further improve route prediction and decision-making.

Future work can also focus on improving system security by integrating blockchain or encryption techniques to prevent data breaches and cyber-attacks in V2V communication. Hardware-based implementations such as smart traffic signals and vehicle-mounted communication devices can make the system fully practical. Moreover, extending the system to Vehicle-to-Infrastructure (V2I) communication can enhance coordination between vehicles and road infrastructure, leading to a more intelligent and autonomous transportation ecosystem.

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