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Enhancing Road Safety: Machine Learning-Driven Vehicle Speed Monitoring and Alerting in VANET Environments-A Review

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Abstract

Inexperienced and fast driving poses a significant threat to the safety of innocent people, resulting in severe automobile accidents. Presently, most efforts have been made in detecting the driver behavior, as traditional methods show limited success the researchers have delved into the machine learning and the deep learning methods for predicting the vehicle speed and as well as altering. This review explores at the manner in which machine learning and the deep learning can be used to improve road safety using Vehicle Ad-hoc Networks. The primary objective revolves around a Machine Learning-Driven Vehicle Speed Monitoring and Alerting System, which is intended to reduce the dangers associated with variable speeds in VANET environments. The paper reviews the existing research, approaches, and breakthroughs in the use of machine learning algorithms for real-time vehicle speed monitoring. This analysis intends to provide insights into the emerging environment of intelligent transportation systems, with a focus on the role of artificial intelligence in identifying and responding to potential risks. It presents an in-depth review of the challenges,

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opportunities, and future prospects for using machine learning to improve road safety within the VANETs.

Keywords: Traffic Environment, Machine Learning, Intelligent Transportation Systems (ITS), Transportation System

1. Introduction

1.1 Overview

The real-time monitoring and alerting of vehicle speeds have become increasingly crucial in the present-day scenario, as it stands out as a major contributor to road fatalities. To tackle this issue, several researchers have proposed various methods utilizing sensors in vehicles, such as ECG sensors and cameras, to collect data on how a vehicle is being driven. The research then analyzes the gathered data to assess vehicle performance, including speed and driver behavior. Additionally, these systems have been designed to monitor external factors like climatic conditions and traffic congestion, which can impede regular traffic flow. Despite the effectiveness of these systems in monitoring driver behavior, there are instances where accidents occur as drivers may not willingly share their behavior. Hence, there is a growing need for a driving defensive alerting system, emphasizing proactive measures to help drivers avoid safety threats from approaching reckless vehicles [3].

1.2 Traffic Environment

The traffic environment, as it exists in urban and rural scenarios, is a complex and dynamic ecosystem in which a variety of elements interact to affect how people and vehicles interact on the roads. It includes not only the actual physical infrastructure of roads, highways, and crossings but also the actions of pedestrians and drivers as well as the impact of constantly advancing technology on transportation. In today's world, safety and efficiency are paramount, and this requires a thorough awareness of the traffic environment. The need to thoroughly assess and improve the traffic environment is becoming more and more important as urbanization spreads and the strain on our transportation infrastructure increases [2]

1.3 Machine Learning

It encompasses algorithms and models that improve performance over time through experience. Applications range from image recognition and natural language processing to predictive analytics in various fields. Machine learning plays a crucial role in enhancing the prediction of the vehicle speeds and sending an alter by capturing the video frames using the surveillance cameras, applying the vehicle detection methods and tracking the vehicles and estimating the speed of the vehicle. This technology improves object recognition, road tracking, and decision-making, ensuring reliable performance even in unpredictable scenarios. The application of machine learning in predicting the speed addresses a key aspect of intelligent transportation system. [4].

1.4 Intelligent Transportation Systems (ITS)

It is an integrated advanced technology used in enhancing the transportation efficiency, safety, and sustainability. These systems employ real-time data, communication networks, and smart algorithms for improved traffic management, congestion reduction, and enhanced traveler information. ITS plays a pivotal role in creating smarter and more responsive transportation infrastructures. Machine learning and deep learning algorithms enable these systems to interpret sensor data, enhancing object recognition and road tracking capabilities.

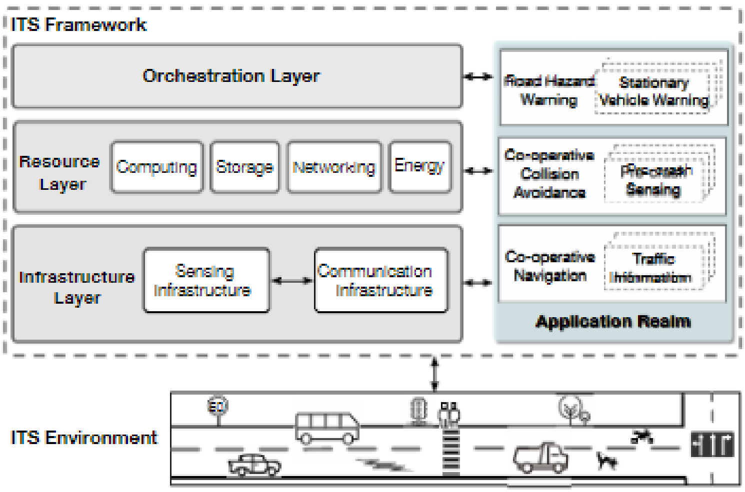

Figure 2. Intelligent Transportation System [5]

1.5 Transportation System

Transportation systems involve the movement of people and goods, encompassing infrastructure, vehicles, and management to ensure efficient mobility. Machine learning algorithms process real-time data, enhancing object recognition and road tracking, enabling proper vehicle monitoring and avoid mishappening and traffic congestion. This integration ensures safer and more reliable transportation in our day to day lives.

The proposed model aims at developing a machine learning driven speed monitoring and alerting systems as a proactive measure to help the approaching vehicles and the careless drivers.

2. Literature Survey

As careless driving poses a significant danger, Lan et al. [3] have developed a defensive alerting system capable of monitoring speed, alerting drivers, and assisting them in avoiding recklessly driven vehicles. The method relies on a 'cooperative driving performance rating' and automates the process of detecting vehicles being driven carelessly using a three-layer architecture that includes a unit on the roadside, a cloud server, and the vehicle. The system is designed to collect the driving controls of vehicles using the roadside unit, while the cloud server assesses vehicle performance by applying machine learning algorithms such as SVM and decision trees for accurate prediction of vehicle speed. It then alerts drivers on the opposite side.

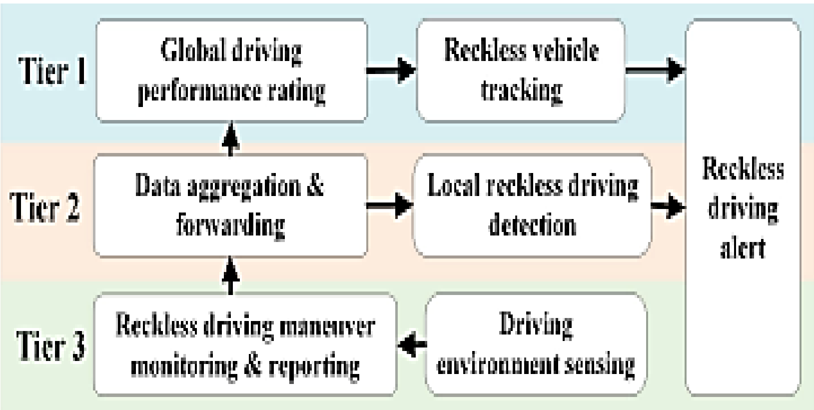

Figure 2. Three-layer System for Vehicle Speed Monitoring [3]

Andrej, et al [3] in his work suggests a method to accurately predict the vehicle speed using the YOLO algorithm and the ID-CNN, the authors suggest a novel "changing bounding box area (CBBA)" that is determined by the estimating the bounding box area from one frame to another as the vehicle approaches the camera. The shape of the CBBA curve is nearly identical for all vehicles, with variations determined by the observed vehicle's speed.

The article [5] presents a comprehensive survey of machine learning algorithms in Intelligent Transportation Systems (ITS) services and applications. This encompasses cooperative driving, road condition warnings, and the utilization of machine learning perception in various aspects, including vehicles, users, and the network. It addresses factors such as traffic conditions, driver behavior, and road hazards. Machine learning proves capable of effectively managing the infrastructure and resources within ITS. Furthermore, the article delves into applications and provides use case examples of machine learning in road safety, cooperative traffic management, and local services, as well as GIS service.

This work [6] provides a real-time vehicle speed prediction method based on a lightweight deep learning model powered by large amounts of temporal data, which outperforms state-of-the-art statistical modeling methods and deep learning models. The contemporary design of modern vehicles tries to improve driving performance while adhering to emission requirements, which results in complex power systems. Accurate and real-time vehicle speed prediction is critical in autonomous driving systems to ensure automation. Predicting driver behavior in uncertain and dynamic driving conditions presents issues. To solve these issues, a real-time vehicle speed prediction method is suggested, based on a lightweight deep learning model and vast temporal data. The method entails first reducing temporal data into a feature matrix using empirical mode decomposition (EMD), then developing an informer model with an attention mechanism to extract crucial information. The informer goes through repeated training to remove superfluous parameters for real-time inference. Experimental results show that the method outperforms state-of-the-art statistical and deep learning methods in terms of speed prediction. This research presents a method for predicting vehicle speed in real time using a lightweight deep learning model and large amounts of temporal data. First, the temporal data acquired by automobile sensors is converted into a feature matrix using empirical mode decomposition (EMD). Then, an informer model based on the attention mechanism is created to extract critical information for learning and prediction. The informer's recurrent training procedure removes unnecessary parameters using importance measurement criteria to accomplish real-time inference. Finally, experimental results show that the suggested strategy outperforms cutting-edge statistical modeling methods and deep learning models in terms of speed prediction. As a regression problem, the model faces challenges in terms of accuracy and inference time. The use of a lightweight model framework aids in vehicle speed prediction when implemented in practical circumstances. To the best of our knowledge, this is the first attempt to construct and deploy a lightweight deep learning model designed exclusively for temporal feature learning and real-time vehicle speed prediction, which was tested on the edge computing device EAIDK-310.

The research work carried out by Khan et al [7] devised a speed detection frame work to detect vehicle speeds using only two speed guns, which may report speed even when the vehicle is not in the camera's line of sight. The model was particularly designed for the irregular traffic congestion that often happens. The average speed of every vehicle travelling in a specific region is determined. The model is cost efficient as it employs a low-cost Raspberry Pi module and a usual camera to detect the vehicle using its registration number. The system is supported by developing an application to send alert message to the vehicles.

The proposed solution [8] recommends leveraging IoT devices in automobiles to connect with a cloud server. This machine learning-enabled server analyzes data on engine status, driving behavior, and driver condition. In extreme cases, the system automatically sends vital information to police and medical personnel via SMS and calls for help. The Arduino Uno is a compact single-board computer that transfers detailed vehicle data to a cloud server for centralized management. Users can get extra car information via a mobile app that is linked to the data center.

The method [9] suggests an automatic traffic management system that is integrated with the accident alert system to manage the traffic flow and stop the mis happenings. The model is totally aided by the machine learning to have a secure early traffic related event detection. The ATM model continuously modifies traffic signal timing based on traffic flow and predicted movements at surrounding junctions. This means that traffic signals are timed to prioritize traffic flow based on the actual number of automobiles on the road and expected movements at nearby junctions. By dynamically permitting automobiles to pass through green signals, the technology greatly decreases travel time and traffic congestion by ensuring a smooth transition. This [10] study proposes an intelligent transportation system for IOVs-based vehicular network traffic in a smart city setup that uses ensemble learning and averages the selection of crucial features to give high detection accuracy at minimal computational costs, as demonstrated by the simulation results.

An autonomous and automated system to govern the speed control by taking use of improvements in technology available can help to cut down the infractions of the law and so bring the law enforcement at a tougher fashion [11].

The proposed Automatic Speed Surveillance and Vehicle Alerting System employs Internet of Things (IoT) technology to enforce speed restrictions without interfering with traffic flow by integrating multiple components. The system may link and communicate with various devices and sensors via IoT to collect and process data on vehicle speed and traffic conditions in real time. This allows for exact monitoring of vehicle speeds and alerts drivers when speed limits are exceeded. Furthermore, IoT technology offers seamless connection between the surveillance system, vehicles, and traffic infrastructure, allowing for a coordinated approach to speed limit enforcement. Using IoT connectivity, the system may transmit real-time alerts to drivers via connected vehicle systems or mobile devices, providing immediate feedback on speed violations without disrupting traffic flow. Furthermore, IoT technology enables the collection and analysis of vast amounts of data, which can improve the accuracy and efficacy of speed limit enforcement. The incorporation of IoT allows the Automatic Speed Surveillance and Vehicle Alerting System to function as a complex and interconnected network, effectively enforcing speed restrictions while minimizing disturbances to traffic flow. Ahsan et al [12] states that the sensor-based vehicle speed monitoring system has a lot of potential for wirelessly monitoring vehicle speed. This research paper [13] introduces an innovative approach for vehicle speed detection using video-based techniques instead of traditional radar methods. The process involves six key components within a video frame system. Initially, real-time video of vehicles is captured, and moving objects are identified using the Haar cascade method as they enter the frame. Each detected vehicle is assigned a unique ID, and the system calculates the movement between consecutive frames to measure the final speed. The results are displayed in a streaming web application and stored in a CSV file, including the vehicle's speed and detection time. The primary goal of this project is to enhance road safety by reducing the risk of accidents. Vehicle speed computation, a crucial aspect of traffic inspection systems, is highlighted, and the generated data can be utilized for traffic control and law enforcement, providing highly accurate speed information for passing vehicles. The table below illustrates the summary of the related study.

Table 1. Comparative Study

Ref No	Methods	Application	Advantages	Challenges
[3]	Sensors +cloud server + machine learning	Detect driver speed and alert the vehicles that approach the speedy vehicles	Decision Tree has a better predicting accuracy (94%) compared to the SVM	Road conditions, system overhead,
[4]	YOLO Algorithm +1D-CNN	Vehicle speed is determined using the 1D-CNN and the, YOLO does the vehicle tracking and detection	Has improved accuracy in predicting vehicle speed with an average error of 2.76 Km/h	Does not have the prior knowledge of the real-world dimensions, would face difficulty in predicting vehicle speed at different scenario and the effectiveness may be limited to the specific conditions and scenarios present in the dataset used.
[5]	Machine learning methods	Road safety, speed management, ITS life cycle management etc	Accurate road occupancy prediction, infrastructure management	Requires large quantity and high-quality dataset, increased cost of maintenance
[6]	Edge computing +light weight Deep learning +	Vehicle speed detection	Similar to state of art methods, prediction error is negligible as	Significant changes in speed can readily cause a

	empirical mode decomposition		the hyperparameters are tunned	drop in prediction accuracy and cause challenge in predicting the speed.
[7]	Raspberry Pi+ cameras + ALPR	Vehicle speed detection	Stable, cost efficient, accurately identifies the vehicle and	Applicable only in specific region, low resolution cameras used.
[8]	IOT +Machine Learning +Cloud	Vehicle condition detection (engine condition, driving behaviour, driver condition)	Improved Safety, Real-time Alerts, efficient emergency response	False alarms, implementation cost, data security.
[9]	IoT-based ITM + machine learning + Sensors	Traffic congestion detection and accident alert system	Seamless transition, reduces travel time,	potential software or hardware failures, involves additional costs and resources.
[11]	IoT +RFID	Speed monitoring and vehicle alerting	Improved Traffic Flow, Reduced Congestion, Enhanced Safety, resource efficiency	Technical Challenges, cost of implementation
[12]	IoT+ wireless sensors+ central controller	Speed violation monitoring	Safe, convenient accurate	False alarms, data security

2.1 Problem Definition

Vehicle speed detection becomes very essential for avoiding the fatalities and traffic congestion. Ther are very spare existing methods that use the machine learning and deep learning for vehicle speed detection and the research on the use of deep learning and machine learning in the vehicular networks to avoid accidents and traffic congestion are still evolving so the proposed method aims in developing a machine learning model with the support of the sensors IoT and a central controller to manage the vehicle speed on road and alert the vehicles when careless driving is detected in adverse conditions and night time.

2.2 Existing System

The flowchart in Figure 3 shows the workings of the existing system. The system relies on cameras and sensors, determining vehicle speed through various statistical methods in many cases. It also utilizes a cloud architecture to communicate the vehicle speed to the driver and issue warnings for vehicles approaching from the opposite side.

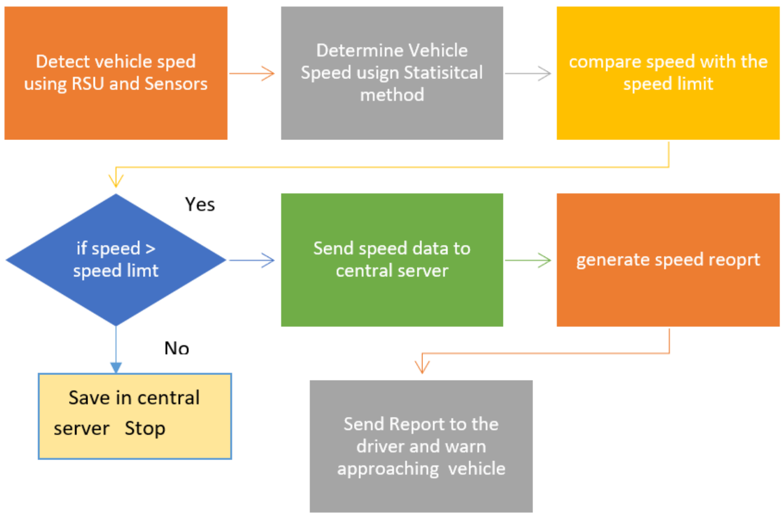

Figure 3. Existing Method

3. Proposed Method

The existing systems heavily relies on sensors and cameras for detecting vehicles and their speeds. Speed monitoring often fails because these systems are trained for specific regions, climatic conditions, and times. A high number of accidents due to careless driving and abnormal vehicle behavior occur primarily at night and during adverse weather conditions. To improve the traffic flow and avoid mishappening during the night time and adverse weather conditions. The proposed model aims in developing a machine learning driven speed monitoring and alerting system. The flow chart in figure .4 below illustrates the working of the proposed.

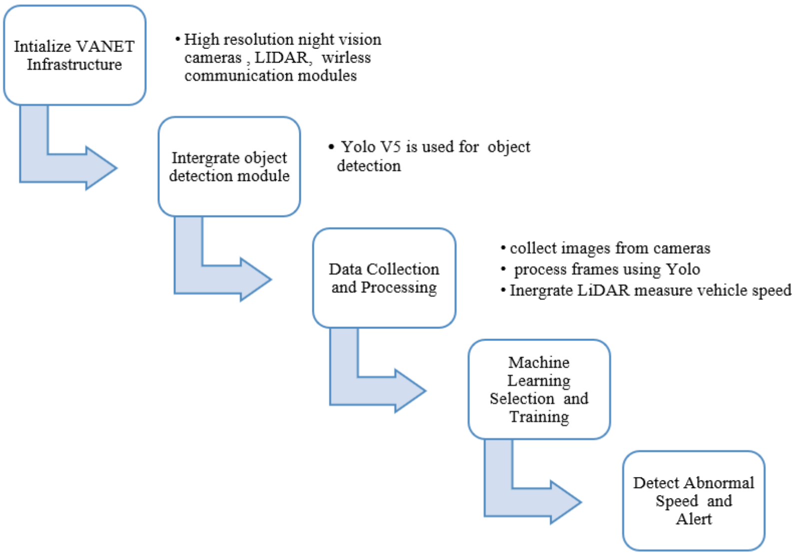

Figure 4. Proposed Block Diagram

4. Discussion

The suggested work is expected to show a better accuracy in detecting the vehicles, monitoring its speed, and the alerting the approaching vehicles. It is expected to provide an improved real-time monitoring as the machine learning algorithms can process real-time data from vehicles in VANETs, allowing for dynamic and instantaneous speed monitoring. The ML models can analyze historical data to predict potential hazards or unsafe conditions, enabling proactive speed adjustments by vehicles. It can also adapt to varying environmental conditions, such as low visibility during the night or adverse weather, by adjusting speed recommendations accordingly. The machine learning helps in identify patterns indicative of potential collisions or unsafe speeds, providing timely alerts to drivers to prevent accidents. By optimizing vehicle speeds based on real-time traffic conditions, ML-driven systems can contribute to smoother traffic flow, reducing congestion and the likelihood of accidents. Machine learning algorithms can personalize alerts based on individual driving behavior, considering factors like driver habits and preference.

5. Current Progress and Future Work

The suggested model for the night time and the adverse condition weather monitoring is in its development stage. The future work leaps into the design and development of the research including the component selection, prototype development, and the implementation of the work.

6. Conclusion

Road safety could be greatly improved by putting into practice driving behavior assessment models based on machine learning algorithms. These models are able to detect drivers who pose a high risk of causing accidents and predict the likelihood of reckless driving. These models' data can be used to provide drivers feedback on how they drive or to take preventative actions, such notifying the authorities. Because machine learning algorithms are capable of discovering intricate patterns in data, they are highly appropriate for this kind of work. When developing and implementing a driving behavior rating model, it is imperative to pay close attention to the requirements for input, output, and system testing.

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