PERCEPTION AND SENSING FOR AUTONOMUS VEHICLE UNDER ADVERSE WEATHER CONDITIONS

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ABSTRACT

The development of perception and sensing systems for autonomous vehicles in adverse weather conditions is crucial for ensuring safety and reliability in transportation. Challenges such as heavy rain, snow, and fog impair sensor performance, posing safety concerns for Automated Driving Systems (ADS). Overcoming these challenges requires costly sensor technology, ongoing data updates. Machine learning offers a powerful solution to this challenge. By leveraging vast amounts of sensor data captured by LiDAR, cameras, and radar under various weather scenarios, AVs can build a comprehensive understanding of their surroundings. Most of the existing system that has been done to detect traffic congestion used vehicular ad-hoc network (VANET) but of late data mining approach has been applied. This project looks at how data mining compares with VANET in performing road traffic congestion detection, control and prediction. By coordinating the calculation ability of a cloud worker with that of vehicles these days, we propose a framework for road traffic congestion detection, control, and prediction using a Support Vector Machine (SVM) algorithm. The framework consists of three levels: vehicles, roadside units (RSUs), and a cloud worker. Vehicles collect data about their own driving behavior and the driving behavior of other vehicles around them. RSUs collect data from vehicles and transmit it to the cloud worker. The cloud worker uses the SVM algorithm to train and deploy a model for detecting traffic congestion and identifying reckless vehicles.

Keywords: *Automated Driving Systems, Light Detection and Ranging, Vehicular Ad-hoc Network, Systems, Support Vector Machine, Roadside Units.*

1. INTRODUCTION

1.1 OVERVIEW

Intelligent Transportation Systems (ITS) have become an integral part of modern urban infrastructure, revolutionizing the way people and goods move from one place to another. With the ever-increasing urbanization and the resulting congestion on road networks, efficient traffic management has become a critical necessity. In this, traffic prediction plays a pivotal role in enhancing the performance and effectiveness of ITS. By harnessing advanced technologies such as data analytics, machine learning, and real-time data feeds, traffic prediction not only provides valuable insights into current traffic conditions but also enables proactive measures to optimize traffic flow, reduce congestion, and improve safety. In smart cities and connected vehicles, the development and implementation of accurate traffic prediction models are pivotal in shaping the future of transportation systems for the benefit of both individuals and society as a whole. The System explores the significance and implications of traffic prediction within the realm of Intelligent Transportation Systems.

1.2 PERCEPTION AND SENSING

Autonomous vehicles have emerged as a transformative technology with the potential to revolutionize transportation systems, offering improved safety, efficiency, and convenience. Central to the functioning of autonomous vehicles is their ability to perceive and sense their environment accurately and in real-time. The perception and sensing systems of autonomous vehicles enable them to understand their surroundings, identify obstacles, and make informed decisions for safe navigation. In this survey, we explore the field of perception and sensing for autonomous vehicles, focusing on the technologies and techniques that enable vehicles to perceive and interpret their environment. We delve into the various sensor modalities used in autonomous vehicles, including cameras, LIDAR, radar, and ultrasonic sensors, as well as their integration and fusion strategies. The survey begins by providing an overview of the fundamental principles of perception and sensing. We discuss the importance of data acquisition, pre-processing, and calibration techniques to ensure accurate and reliable sensor measurements. Understanding the characteristics, strengths, and limitations of each sensor modality is crucial for designing effective perception systems.

1.3 ADVERSE WEATHER CONDITIONS

Autonomous vehicles hold great promise in revolutionizing transportation by providing efficient, safe, and convenient mobility solutions. However, one of the significant hurdles to overcome for their widespread adoption is their ability to operate effectively under adverse weather conditions. Adverse weather, including rain, snow, fog, and low visibility scenarios, poses unique challenges to the perception and sensing systems of autonomous vehicles, necessitating specialized solutions to ensure reliable and safe operation. In this, we delve into the impact of adverse weather conditions on autonomous vehicle perception and sensing capabilities. We explore the specific challenges posed by different adverse weather scenarios and examine the strategies and technologies that have been developed to mitigate these challenges. Firstly, we shed light on the adverse weather conditions that pose significant obstacles to autonomous vehicles. Rainfall can create visual distortions and occlusions, snow can accumulate on sensors, fog can limit visibility to a few meters, and reduced ambient light can degrade sensor performance. Understanding the nature of these challenges is essential for developing effective solutions. Next, we explore the various sensor modalities commonly employed in autonomous vehicles and analyze their vulnerabilities and limitations under adverse weather conditions. Cameras, lidar, radar, and ultrasonic sensors are widely used for perception, and each has its strengths and weaknesses. These algorithms leverage sensor data and weather information to adapt the perception and sensing strategies in real-time. We discuss techniques such as sensor data fusion, sensor calibration, and data-driven modeling that enable autonomous vehicles to make informed decisions even in the presence of adverse weather conditions.

1.4 INTELLIGENT TRANSPORTATION SYSTEMS (ITS)

Intelligent Transportation Systems represent a visionary paradigm shift in the way we design, manage, and interact with transportation networks. These systems combine data-driven insights, and advanced communication systems to create a more efficient, safe, and sustainable transport infrastructure. By seamlessly integrating information technology, sensors, and smart devices, ITS offers innovative solutions for tackling the ever-growing challenges of urban congestion, traffic safety, and environmental impact. As our world becomes more interconnected, the importance of ITS cannot be overstated, as it not only enhances the quality of transportation services but also plays a pivotal role in shaping the future of smart cities and the way we move people and goods from one place to another. In this article, we delve into the multifaceted domain of Intelligent Transportation Systems, exploring their significance, key components, and their potential to revolutionize the way we navigate our increasingly complex urban landscapes.

1.5 TRANSPORTATION SYSTEM

The modern world's transportation system is the lifeblood of our global society, facilitating the movement of people and goods on an unprecedented scale. From bustling city streets to vast transcontinental networks, transportation infrastructure comprises a complex web of roads, railways, airports, and seaports that connect communities, enable commerce, and drive economic growth. It encompasses a diverse array of vehicles, from cars and buses to trains, planes, and ships, all of which are supported by a vast network of technologies and logistics. As our planet becomes more interconnected, the efficiency, sustainability, and safety of our transportation system have become paramount concerns. This article explores the multifaceted nature of transportation systems, their historical evolution, the challenges they face, and the innovations that are propelling us toward a more integrated, sustainable, and intelligent future in the realm of transportation.

2. LITERATURE SURVEY

2.1 VEHICLE TELEMATICS FOR SAFER, CLEANER, AND MORE SUSTAINABLE URBAN TRANSPORT: A COMPREHENSIVE REVIEW

In their study, Omid Ghaffarpasand [1] et al. propose that urban transport is a significant contributor to global greenhouse gas emissions, accounting for more than a quarter of these emissions. Additionally, it is a major source of air pollution. Furthermore, vehicle collisions result in the deaths of 1.35 million people and serious injuries to 60 million people worldwide each year. This paper aims to review the potential of vehicle telematics in promoting safer, cleaner, and more sustainable urban transport. The authors examine various data collection methods, focusing on the technical challenges associated with data processing, storage, and privacy concerns.

2.2 SUPPORT VECTOR MACHINES FOR BUS TRAVEL TIME PREDICTION IN HIGH VARIANCE CONDITIONS

Anil Kumar [2] et al. propose in their project that real-time bus travel time prediction has been a challenging problem, particularly in India, over the past decade. Traditional methods for travel time prediction, such as time series analysis, regression methods, Kalman filter method, and Artificial Neural Network (ANN) method, have been widely used. However, these methods do not adequately account for the high variance situations that arise from varying traffic and weather conditions, which are common in heterogeneous and lane-less traffic conditions, such as those found in India. The objective of this study is to analyze the variance in bus travel time and accurately predict travel time under such conditions. Literature suggests that the Support Vector Machines (SVM) technique performs well in these situations, and therefore, it is employed in this study. Specifically, Support Vector Regression (SVR) using a linear kernel function is selected. Two models, namely spatial SVM and temporal

SVM, are developed to predict bus travel time. The results indicate that in sections with high mean and variance, temporal models outperform spatial models.

2.3 THE EFFICIENT AUTOMATIC WATER CONTROL LEVEL MANAGEMENT USING ULTRASONIC SENSOR

C. K. Geometry [3] et al. In our daily lives, a significant amount of water is wasted due to overflowing and excessive usage. In order to minimize this wastage, it is necessary to implement overflow control techniques. To address this issue, we propose the implementation of a Smart Water Level Management System. This system utilizes an ultrasonic sensor to detect the water level, and based on the sound produced by the flow of water, it calculates the water level in percentage and displays the value on an LCD screen. The system is capable of calculating the water level up to 100% in intervals of 10%, with each interval value being displayed on the LCD screen. Additionally, the system is connected to a relay switch which automatically turns on and off based on the water level.

2.4 EVALUATION ON ETHERNET BASED PASSIVE OPTICAL NETWORK SERVICE ENHANCEMENT THROUGH SPLITTING OF ARCHITECTURE

C.K. Gomathy [4] et al. have proposed a survey study on the fully distributed Ethernet over Star coupled PON (Passive Optical Network) Architecture in this project. The architecture utilizes a collision-free DBA scheme, where the Optical Line Terminal (OLT) is not involved in the time slot assignment implementation. To achieve a distributed architecture, Optical Network Units (ONUs) need to be deployed without imposing any constraints on the PON Topology. Furthermore, the paper discusses the reliability and performance improvements when using a decentralized Ethernet-based PON architecture with bandwidth allocation algorithms. Ethernet-based Passive Optical Network (E PON) is emerging as a preferred choice for high-speed broadband access. A PON is a point-to-multipoint fiber optical network that does not have any active elements in the signal path.

2.5 BLOCKCHAIN BASED HIERARCHICAL SEMI-DECENTRALIZED APPROACH USING IPFS FOR SECURE AND EFFICIENT DATA SHARING

In this project, [5] Smita Athanere and colleagues propose a solution to the increasing amount of data being stored on cloud servers. To protect the security and concealment of data, it is commonly stored in the form of cipher text. However, when a consumer requests access to encrypted data, a third party must provide an access key, which can compromise the system's security if the third party or internal personnel are dishonest. To address this issue, the researchers propose a novel block chain-based secure decentralized system using IPFS for secure data transfer. This system records every action on the chain, making it difficult to modify any block without being detected.

3. EXISTING SYSTEM

The goal of automated driving systems (ADS), a developing technology in the automotive sector, is to offer passengers comfortable and effective travel. It has long been a concern for ADS to perceive and navigate in poor weather conditions due to considerable restrictions. Autonomous vehicles often relies on a combination of LiDAR, radar, cameras, and sensor fusion for perception. Machine learning algorithms analyze sensor data to detect and identify objects, and high-definition maps assist in navigation. However, adapting to extreme weather conditions and ensuring full autonomy in adverse weather remains a challenge for these systems. The challenges include the need for robust testing and validation in diverse weather conditions, as well as addressing potential vulnerabilities in sensor systems during adverse weather and also in developing autonomous vehicles for adverse weather conditions include sensor limitations, dynamic weather data, and real-time decision-making. Unfavorable weather impacts sensor performance, raising concerns about autonomous vehicles' safety. To improve ADS perception under varying weather circumstances, several methods, including as sensor fusion and deep learning, have been developed. Research aims to overcome the constraints caused by unfavorable weather conditions and to encourage additional developments in ADS technology by analyzing already-existing datasets, simulators, and experimental facilities. By examining already-existing datasets, simulators, and experimental facilities, the effort aims to enhance further advancements in ADS technology and overcome the limitations imposed by poor weather.

4. PROPOSED SYSTEM

The purpose of the proposed order is to offer a precise alarm system for careless driving. In terms of detection, control, and forecast of road traffic congestion, this study compares data mining with VANET. The suggested system uses an SVM algorithm for road traffic congestion detection, control, and prediction by combining the processing power of cloud workers and cars. Cars collect information about speed, position, acceleration, and other driving characteristics from other cars as well as from themselves. It incorporates advanced all-weather sensors, such as all-weather LiDAR and radar, to provide consistent data even in challenging weather. Deep Learning models, trained on diverse datasets, enhance object recognition and classification, making the vehicle more adaptable to poor visibility conditions. Cloud computing resources provide high-performance data processing and access to extensive computational capabilities for real-time decision-making. It aims to increase the reliability and safety of autonomous vehicles in adverse weather, ensuring that they can navigate challenging conditions more effectively and with greater resilience.

4.1.1 ADVANTAGES

- The proposed system is able to detect traffic congestion and identify reckless vehicles in real time. This means that drivers can be warned of upcoming congestion and reckless vehicles, so that they can take appropriate action.
- The system is able to predict future congestion. This information can be used to optimize traffic flow and to reduce travel time for drivers.
- It is able to share information about congestion and reckless vehicles with other vehicles. This information can be used by drivers to make informed decisions about their routes.
- The proposed system uses a SVM algorithm to detect traffic congestion. SVM algorithms are known for their high accuracy and efficiency.

4.2 PREPROCESSING

To predict recurrent congestion events, the data mining approach is preferred over VANET because it can make use of vast historical datasets. The collection of trajectory data that includes latitude, longitude, and a timestamp is required. There should be congestion events in the dataset. Next, preprocessing is applied to the route data in order to reduce or eliminate mistakes and missing values. Vehicles in the same space and moving at the same time are identified by clustering their trajectories both geographically and chronologically. The speeds of each cluster are found by dividing the distance by the time, and the distances between two trajectory points are computed using the timestamps of each point.

4.3 RSU BASE TRAFFIC CONGESTION DETECTION

Traffic jam prediction is possible by the extraction of patterns from data collected by sensors positioned across the roadways. The gathered data is first preprocessed to remove any mistakes, missing values, or unrealistic values. The same data sample is used to compare the implementation of the AI models for decision trees (DT) and support vector machines (SVM). An attribute of the data is created by the SVM algorithm and chosen to be the root. Until the last node, the process is repeated for each possible value of the attribute, forming a branch.

4.4 INTELLIGENT TRANSPORTATION CLOUD SERVER

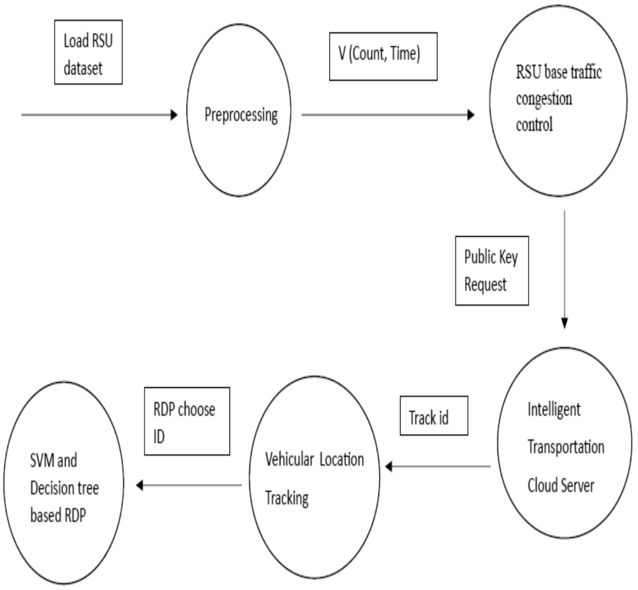
Intelligent transportation clouds have the potential to offer a range of services, including autonomy, mobility, decision support, and the creation of a standard development environment for traffic management strategies, among others. By utilizing mobile agent technology, it is possible to develop an urban-traffic management system that is based on Agent-Based Distributed and Adaptive Platforms for Transportation Systems (ADAPTS), which proves to be both feasible and effective. However, the widespread implementation of mobile agents will result in the establishment of a complex and powerful organizational layer that necessitates significant computing and power resources. To address this issue, the authors propose the utilization of a prototype urban-traffic management system that relies on multi-agent based intelligent traffic clouds.

4.5 VEHICULAR LOCATION TRACKING

The speeds acquired from all vehicle trajectories will be used to compute the average speed of each cluster. In order to detect congestion, the cluster speeds will be compared to a speed threshold determined by the capacity of the route. The detected event's duration will be compared to a preset time threshold by the model, which will discriminate between congestion and normal stoppages, like traffic signal pauses or passenger pick-ups and drop-offs. In order to anticipate recurrent congestion events, the model will next log the coordinates and time interval for each congestion event that is observed. It will then use the Jaccard formulas (1) and (2) to find similar congestion events whenever new data is received.

4.6 SVM BASED TRAFFIC PREDICTION

As a convex optimization problem is involved in SVM training, a global optimum is the best solution that can be found. No relationship exists between the problem's dimensionality and the upper bound of the generalization error. Features and labels with h21 dimensions make up the input data used by SVM and decision-tree models to evaluate a car's driving performance.



4.7 PERFORMANCE EVALUATIONS

We first describe the dataset preparation before evaluating the efficacy of our defensive alerting system. The assessment of two crucial performance components comes next. First, we assess the driving performance rating's

correctness by contrasting our machine learning-based approach with the traditional statistical-based approach. Second, we look closely at how timely our alerts for irresponsible vehicles were, including how long the alerting process took. We first assess the driving performance rating models that are based on machine learning using the prepared dataset. We first examine the traditional statistical rating approach before examining the impact of parameters and accuracy for the two machine learning-based rating models that were chosen.

5. RESULT ANALYSIS

The outcomes of our tests demonstrate the effectiveness of machine learning-based driving performance evaluation models, which employ multi-modal sensing data and are crucial considering the dynamic nature of driving conditions. If we compare the four metrics, we can see that the precision and recall metrics have the lowest and greatest values, respectively. In compliance with their individual evaluation criteria, their findings verify that, although there are a few false alarms, nearly all reckless vehicles may be identified. This is suitable for our defensive alerting system's safety consideration. It is also necessary to update the rating results quickly in order to remove false alarms and identify the real irresponsible vehicles, as the accuracy of the rating grows with the number of reported incidences of reckless driving.

Rating Model	Precision (%)	Recall (%)	F1 (%)	Accuracy (%)
SVM	89.53	97.05	93.14	92.73
DNN and CNN	89.61	99.98	93.61	90.29

Table 1. Comparison table

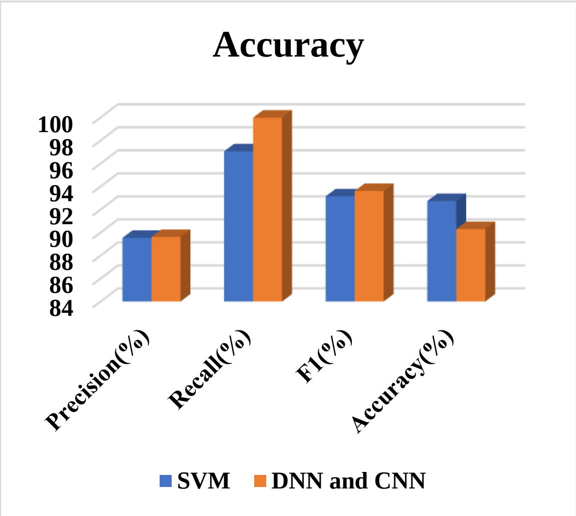


Figure 2. Comparison graph

The table shows the performance metrics of two distinct models in the context of a classification problem: Support Vector Machine (SVM) and a hybrid approach employing Deep Neural Network (DNN) and Convolutional Neural Network (CNN). The measures, Precision, Recall, F1 score, and total Accuracy, provide a comprehensive evaluation of each model's effectiveness. Out of all the instances that were categorized as positive, the SVM model has an excellent Precision of 89.53%, which indicates the percentage of successfully detected positive occurrences. With a recall rate of 97.05%, the model is able to correctly identify the great majority of actual positive events. Overall performance is good with an estimated F1 score of 93.14%, which balances Precision and Recall. The accuracy of the model is 92.73% indicates that it can correctly anticipate both positive and negative occurrences. The combined DNN + CNN model, on the other hand, shows comparable Precision at 89.61%, indicating its accuracy in properly classifying positive instances. Nonetheless, the model attains a remarkable 99.98% Recall, signifying a nearly comprehensive identification of genuine positive events. The resulting F1 score of 93.61% indicates that Precision and Recall performed in a balanced manner. Even with these remarkable results, the overall Accuracy is just 90.29%, which indicates a little greater rate of misclassification than with the SVM model.

6. CONCLUSION

Autonomous vehicles (AVs) represent a significant advancement in transportation technology, offering the potential to revolutionize road safety and mobility. By leveraging sophisticated sensors, machine learning algorithms, and real-time data analysis, AVs can navigate complex traffic environments with precision and efficiency. However, ensuring the safety of AVs in diverse real-world conditions, including adverse weather, remains a critical challenge. Robust perception and sensing capabilities are essential for AVs to accurately interpret their surroundings and make informed decisions. Through continuous innovation and advancements in sensor technology and machine learning algorithms, we can overcome these challenges and realize the full potential of AVs for safer and more efficient transportation systems.

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