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Smart AI-Based Traffic and Parking Management System Using Machine Learning and Computer Vision

Syed Thousif [1], Kambam Nithin Kumar Reddy [2], Gajjula Ashok Vardhan Reddy [3], and Kummara Sruthi[4]

[1234]*Dept. of Computer Science and Engineering, Presidency University, Bengaluru, India*
syedthousif498@gmail.com, kambamnithin@gmail.com, ashokreddy2248@gmail.com
k.sruthi@presidencyuniversity.in

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***Abstract*— Traffic congestion and difficulties in parking have become common problems in contemporary cities due to the rapid urbanization. The conventional traffic control systems are dynamic and do not reflect the actual traffic conditions. The present paper suggests a Smart AI-Based Traffic and Parking Management System which will combine the concepts of machine learning and computer vision to forecast traffic jams and find vacant parking spots in real-time. The system relies on the algorithm of the Random Forest to compare historical and real- time traffic data, as a result of which intelligent traffic movement forecasts and adaptive traffic lights control are possible. The use of computer vision can be used to track the parking space and aid an early reservation of parking. The suggested system is more efficient in traffic, it lowers down congestion, the travel time is also minimized and emergency vehicles are also prioritized. The solution offers scalable and cost-effective solution to smart city transportation system.**

***Keywords*— *Computer Vision, Emergency Vehicle Prioritization, Intelligent Transportation Systems (ITS), Machine Learning, Random Forest Algorithm, Smart Cities., Traffic Prediction*.**

I. INTRODUCTION

The fast urbanization process and the rising vehicle count have greatly contributed to traffic jams and parking problems in contemporary cities. The old system of traffic manage- ment is based on predetermined timings and processing of signals by hand, which is not always efficient to deal with dynamic and unpredictable traffic flows. This has led to the commuters spending more time on the road, consuming more fuel, having more pollution and slow emergency response. The recent trends of the development of Artificial Intelligence (AI), Machine Learning (ML), and Computer Vision gave the intelligent transportation system the opportunity to turn the traditional principles of managing traffic into smart, adaptable, and information-driven solutions. Machine learning models have the capability to process both past and current traffic data to forecast the trends of congestion, control the timing of traffic lights, and enhance routing decisions. In the same vein, computer vision methods allow automatic tracking of parking spots, which saves time and effort to search available parking spots. The current paper suggests a proposal of a Smart AI- Based Traffic and Parking Management System that will com- bine the traffic prediction based on the random forest with the real-time parking slot detection. The system gathers various data which includes traffic cameras, IoT cameras, and past traffic data and uses them to come up with precise congestion projections. It also gives intelligent parking suggestions and enables the users to reserve parking spaces upfront. Adaptive routing and signal control are used to prioritize emergency vehicles, be it slower and safer response. Compared to most of the currently existing solutions, which are limited to traffic prediction or parking management only, the suggested system will include both of these features into a single framework that enables real-time decision-making and interaction with the user. The proposed solution would result in the efficiency of traffic flow, the reduction of congestion, better use of parking spaces, and the creation of intelligent and sustainable transportation systems in cities.

II. LITERATURE REVIEW

A in traffic congestion control system based on an emergency-aware reinforcement learning and a non-dominated sorting genetic algorithm were suggested by Al-Heety et al. (2026) [1]. Their algorithm learns adaptive Q-learning and optimized communication infrastructure to dynamically tune the traffic lights and give priority to emergency vehicles. The system has shown that it is efficient in traffic flow, decreased delays before traffic, and emergencies in urban traffic with multi-interception.

Another proposed next-generation smart traffic management system that is anticipated to alleviate congestion in Indian metropolitan cities was proposed by Goswami and Kadao (2025) [2]. Their platform combines IoT sensors, artificial intelligence, and machine learning algorithms to display traffic status and actively regulate the timings of the signals. Predictive analytics and adaptive signal control in the model considerably minimized travel time and congestion levels and emissions of traffic.

Xu and Li (2025) suggested a real-time forecast-traffic congestion model, which relies on dynamic risk field modeling and the multi-source data fusion [3]. They use a combination of deep learning methods and models of physically explainable risk fields to understand spatiotemporal traffic patterns. The framework makes correct predictions of congestion and helps in the proactive management of traffic systems of complex urban networks.

The paper by Prathiba et al. (2025) proposed a real-time traffic and power grid control system with a digital twin enabling it to work in smart cities [4]. A strategy based on predictive analytics, real-time data processing, and the dual-level digital twin architecture is employed to achieve simulations of urban infrastructure behavior. By optimally distributing resources and decision making, the system made the traffic flow more efficient and decreased the congestion.

Wairagade et al. (2025) came up with an AI-based smart traffic management system that can help alleviate enhancing urban congestion through machine learning and computer vision technology [5]. Their system gathers real-time traffic data between sensors and cameras with the help of the IoT and then processes it with the help of AI algorithms to make signal durations change dynamically. The strategy contributed to the efficiency of traffic flow, consumption of less fuel, and emergency vehicle movement.

A proposal was made (Naramdeo et al., 2025) in the form of an intelligent traffic management system that dynamically regulates the traffic lights according to the number of vehicles and the sensor that detects emergency vehicles on the road [6]. Their system involves sensor-based vehicle detection, and communication networks to ensure traffic density is monitored, and adjust the timings of signals on-the-fly. Simulation outcome has demonstrated the effectiveness on traffic flow performance as compared to traditional setting of fixed time signals.

Laanaoui et al. (2024) proposed the real-time anomaly detection and load balancing system of urban traffic control [7]. They involve their algorithm based on machine learning and parallel processing of data to predict the traffic density and identify abnormal traffic situations. The system enhances traffic management by offering optimum route guidance and alleviating the traffic jams in urban roadways.

Raghunath et al. (2024) proposed a traffic supply and traffic control mechanism based on Temporal Convolutional Networks with Federated Learning [8]. They have a decentralized approach which enables several traffic sensors and cameras to analyze traffic data collectively without exchanging raw information. The system enhances prediction accuracy of congestion and ensures privacy of data in distributed traffic monitoring systems.

Fadila et al. (2024) engaged in an in-depth literature review of technologies of smart urban traffic management within the framework of the Fourth Industrial Revolution [9]. Their work emphasized the need to combine the use of artificial intelligence, IoT, blockchain, and intelligent transportation system to enhance urban mobility and sustainable transportation management.

Wang et al. (2024) suggested a cyber-physical system structure to control the intersections of the roadways in the city based on a Model- Based Systems Engineering [10]. Their architecture combines the elements of sensing, communication, and computation so as to facilitate the efficient monitoring and control of traffic lights. The system enhances coordination and reliability of traffic on complex intersection settings.

Xu et al. (2023) have designed an urban traffic system cloud-based digital twin platform, which provides an opportunity to have real-time situational awareness and cyber-physical control of the system [11]. They have a system that combines both IoT sensor and sophisticated analytics to give the smart city transportation infrastructure traffic monitoring, predictive analytics, and signal optimization.

Jin et al. (2022) online suggested an agent-based traffic recommendation system as an efficient method of strategic traffic management of the city [12]. Their system involves a multi-agent architecture to dynamically produce operational strategies to control traffic at cross-road. The method allows making traffic decisions automatically, and can coordinate intersection better.

The system developed by Oliveira et al. (2021) to fully monitor a traffic control system in real-time is based on wire-less communication networks [13]. Their system can create centralized monitoring and dynamic control over traffic lights in various intersections which enhances better coordination by the traffic signals and reduces the congestion.

In an article by Nagapragna and Joshi, the authors suggested a smart-traffic management system whereby intersections are detected by using Arduino and infrared sensors [14]. They have an embedded system that dynamically controls traffic signals in response to vehicle density and offer a cost effective and scalable solution to enhancing traffic flow in cities.

Lanke and Koul (2013) presented a smart traffic management system (RFID-based) that was to dynamically manage traffic lights depending on the frequency of vehicles being detected [15]. Their system employs RFID tagging and controllers that recognize vehicles and control timing of the signals based on them, allowing identification of congestions early and better management of the traffic.

III. OBJECTIVES

In the given research, the key task will be the design and development of Smart AI-Based Traffic and Parking Management System that will enhance the efficiency of traffic flow and the use of parking space would be made possible by utilizing machine learning and computer vision algorithms. The objective of the system is to forecast and estimate real time traffic congestion, optimize decisions involving traffic control and offer intelligent solutions to parking problems using real time and past traffic statistics. To make sure that machine learning algorithms like the Random Forest algorithm predict congestion rates reasonably well, IoT sensors, traffic cameras, and traffic records are used to guarantee the accuracy of congestion forecasting. According to these forecasts, the system dynamically aids the traffic control measures and optimal route to minimize traveling delays and congestion. In particular, the following goals are the objectives of the research:

A. Prediction of Traffic Jamming

We will create a predictive model that can predict the level of traffic congestion in urban centers based on the information obtained through the use of traffic cameras, GPS signals, IoT devices, and past traffic patterns.

B. Real-Time Data Integration

The system will be configured to incorporate real time traffic information to give immediate updates on the state of traffic. This allows the system to be able to respond to the sudden change like accidents, peak-hour congestion and road closures.

C. Smart Parking Management

To introduce the system of computer vision-based parking detection that will enable a user to see the parking spaces available in real time and book the parking slot with ease

D. Dynamic Traffic Control

To work out an intelligent traffic control system that can dynamically change the timing of signals and paths recommendations depending on the extent of congestion predicted, enhancing general traffic flow.

E. Emergency Vehicle Prioritization

To facilitate priority routing and using faster signal clearance by emergency vehicles, to ensure faster response time and make travel safe.

F. Support and System Scalability: Smart City

To develop scalable and cost-effective solution that may be introduced into the smart city infrastructure, supporting its further development and practical implementation.

IV. METHODOLOGY

The approach to the development of the Smart AI-Based Traffic and Parking Management System can be divided into the systematic steps that combine the technologies of machine learning, computer vision, and real-time data processing. This system is meant to track the traffic environment, the level of congestion, and control the parking space based on smart automation. The initial step entails the collection of data, during which real-time and past data on traffic is obtained through traffic cameras, IoT, and GPS sources, and traffic data bases. These sources of data give details on the level of vehicle congestion, speed, and road occupancy and the patterns of the traffic. The data obtained get relayed to a central processing unit where they are analyzed. Second stage is the data preprocessing which involves cleaning and refinement of the raw traffic data. This step involves eliminating noises, managing missing values, filtering irrelevant data and useful features of congestion intensity, peak-hour tendencies and density indicators of the traffic. These processes are what comprise the machine learning model input. The third stage involves prediction of the traffic congestion by utilizing the Random Forest algorithm. The Random Forest model is built over various decision trees that make use of different subsets of the traffic data and these trees independently predict the level of congestion. The overall output of most of the decision trees is added to calculate the final traffic prediction and enhance accuracy of predictions and minimize overfitting. The model is trained with historical data of traffic and tested with real-time inputs in order to be reliable. At the same time, a parking slot detector module on the base of computer vision is also deployed on the OpenCV and camera feeds. This module uses real-time video frames to determine free and occupied parking space, which will allow effective parking space availability measurements. The identified parking data is constantly updated and offered to the users in the form of the web-based interface. It is also a system that features a dynamic traffic control system in which the estimated congestion is used to modify the timing of traffic signals, as well as prescribe other routes in real time. This adaptive control will reduce the waiting time at the intersections and enhance the efficiency of the overall traffic flow. Moreover, there is the emergency vehicle priority module that will provide the emergency vehicle with better signal clearance and optimal routing in case of an emergency. A monitoring and feedback system is used to measure the performance of the system on the basis of the accuracy measures like the accuracy in prediction and the response time. Training the model is done through continuous feedback to improve the performance of the system with time. The offered methodology will result in scalability and adaptability, as well as efficient real-time management of traffic and parking, which is why it can be applied to smart cities.

At the same time, a parking management module which is built on computer vision will be present to monitor parking lots and identify vacant parking lots in real time to facilitate the smart use of space and convenient booking. The system also integrates dynamic traffic signal optimization and emergency vehicle priority to guarantee the implementation of a more efficient traffic flow and quicker emergency response. The system will be scalable and effective in managing transportation in modern smart cities due to its dynamically updated predictions and control strategies, done through continuous feedback and monitoring the performance. Moreover, the Fig.1 shows Smart AI-Based Traffic and Parking Management System that is suggested to be implemented requires the incorporation of cloud-computing infrastructure and edge processing units. The edge devices, which are traffic cameras and IoT sensors that are mounted at road crossings and parking spaces, process real-time data and do preliminary preprocessing before sending the processed data to the central cloud server. This design minimizes latency and guarantees quicker response to traffic signal adjustments and parking detection. Cloud platform also saves huge amounts of historical traffic information and allows continuous model training and performance enhancement due to scalable computing resources.

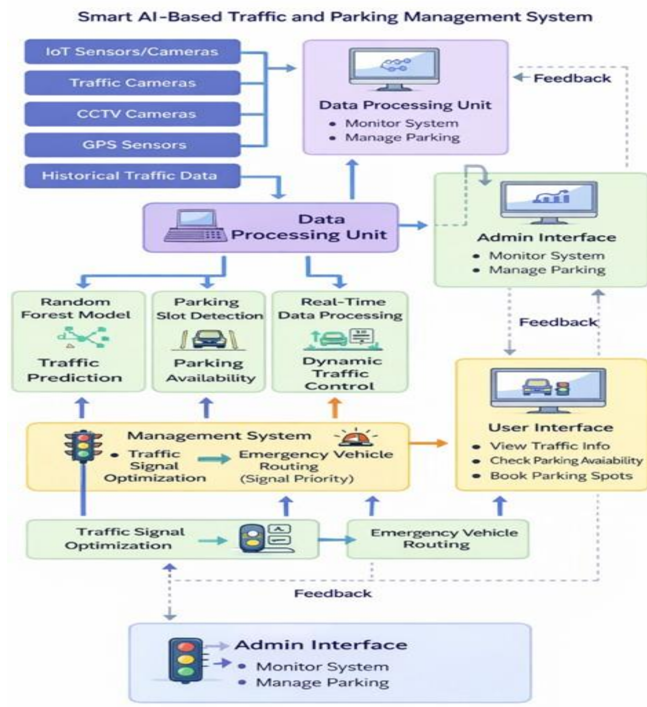

Fig. 1. Architecture of the Proposed Smart AI-Based Traffic and Parking Management System

Besides this, the system has a user interaction module that will enable commuters and traffic authorities to have real-time traffic and parking information by a mobile or web based application. The interface shows the level of congestion, parking spaces, optimal routes, and estimated time of travel. The system assists in eliminating needless vehicle traffic by giving information to the drivers beforehand, thereby enhancing the efficiency of the traffic in general.

Predictive analytics is a technology that can be integrated with intelligent traffic control to make proactive decisions in urban traffic management. The system also predicts traffic behavior and responds dynamically to changes in traffic lights and routes to accommodate congestion as it occurs, rather than responding to congestion as it happens. This predictive ability greatly minimizes the time spent in intersection delays and avoids the occurrence of serious congestion during peak hours. In addition, the system is friendly to expansion and flexibility, and can be deployed both in large metropolitan settings and in small urban settings. The modular design enables the introduction of other modules like environmental monitoring sensors, integration of public transportation data and accident detection systems in the future developments. This adaptability is going to make the system adapt as the technologies of smart cities develop.

Altogether, the suggested methodology offers a full-fledged approach to the intelligent traffic and parking management, which integrates machine learning routines, computer vision strategies, and real-time data processing. The system improves traffic mobility, optimized parking use, and leads to the creation of sustainable and effective smart city transportation systems through efficient monitoring, predictive modeling and adaptive control.

V. RESULT ANALYSIS AND VALIDATION

A. Result Analysis

The proposed Smart AI-Based Traffic and Parking Management System is checked on the basis of its efficiency to predict the traffic congestion, optimize traffic flow, and enhance parking management. The main object of the assessment is to evaluate the possibility of the system to predict the level of congestion with accuracy and increase the effectiveness of the urban traffic. The Table 1 shows analysis of performance is performed with the help of both quantitative and qualitative observations, focusing on the decrease of travel time, fuel consumption, traffic delays, and environmental emissions. The system is tested in the context of the historical traffic data, as well as real-time traffic data that is provided by the simulated IoT sensors, traffic cameras and GPS-based data sources. The findings indicate that traffic prediction model using the Random Forest algorithm gives accurate and dependable forecasts of congestion at different traffic conditions.

B. Prediction Accuracy of Traffic

Standard evaluation measures including Mean Absolute Error (MAE), RMSE, and R-squared (R^2) are used to measure the accuracy of the prediction of the machine learning model. These measures are used to measure the discrepancy between the predicted and actual level of traffic congestion. Random Forest model is very accurate in its predictions because of the ensemble nature of its decision making system, which reduces the degree of overfitting as well as enhancing its generalization with respect to various types of traffic conditions. The congestion levels in terms of low, moderate, and high traffic are also evaluated on a confusion matrix to determine the success of the classification. The model exhibits high classification property with high congestion detection and prediction accuracy.

C. Traffic Congestion Alleviation

The effect of the system on the reduction of congestion is considered through the comparison of pre and post implementation conditions of traffic flow. Performance improvements can be measured by such metrics as average vehicle speed, length of queue at intersections, and density of traffic. The outcomes denote that there is a considerable decrease in the levels of congestion, and there is less vehicle congestion, and the waiting time is less during the peak hours. The system will assist in more efficient distribution of traffic loads by dynamically changing the timing of the traffic signals, and suggesting alternative ways to avoid traffic congestion in congested regions.

D. Travel Time and Route Optimization

Travel time optimization is measured with the average time taken to arrive at the destinations in a congested and a non-congested situation. The system utilizes dynamic real-time traffic projections to propose the best routes to follow and make signal schedule changes dynamically. The experimental data indicate a certain decrease in travel time, enhancing the convenience of commuters and the efficiency of transportation in general. Also, route optimization will also provide benefits in terms of less idle time at crossroads, which will result in a better flow of traffic and driving experience.

E. Parking Performance Management

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The parking detection system that is being analyzed is a computer vision-based parking detection system, which is tested according to the capabilities of recognizing free and occupied parking spots correctly. The system has a high detection accuracy in different lighting and environmental conditions. The availability of parking in real-time will assist the users in locating parking spaces more effectively, which will decrease the unnecessary movement of vehicles and will also lead to the congestion in parking lots.

F. Environmental Impact

The environmental sustainability of the system is deter- mined by examining the fuel consumption decreases and carbon emission reduction. Traffic flow is made better and the time spent at crossing points is reduced leading to less fuel wastage as well as less emission. The results show that, the application of smart traffic and parking management systems can hugely contribute to the green nature of urban transport.

G. Validation

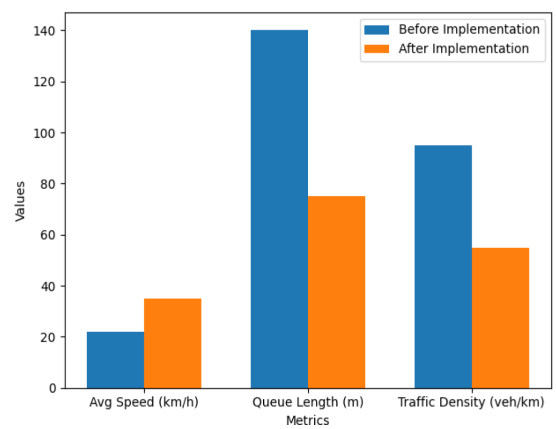
In order to confirm the efficiency of the suggested system, the simulation-based testing as well as pilot-scale test and the comparison of the proposed system with the traditional methods of traffic regulation is performed. The performance of the system is compared to the performance of the traditional fixed-timing traffic signal systems to show improvements in the prediction accuracy and congestion control. The accuracy score, F1-score, confusion matrix, and error rate are some of the validation metrics that indicate that the proposed approach is reliable and statistically significant to improve the management of traffic.

The Fig.2 shows bar graph evaluates the key performance indicators of the traffic performance in the pre-implementation period and in the post-implementation period of the proposed AI- based traffic management system. It has been found out that the average vehicle speed has increased significantly, as well as the queue length and the traffic density has been

TABLE 1: SUMMARY OF RESULT ANALYSIS

Evaluation Metric	**Description**	**Expected Outcome**
Traffic Congestion Prediction Accuracy	Accuracy of ML model (Random Forest / AI model) in predicting congestion levels using historical and real-time traffic data	High prediction accuracy with low MAE, RMSE, and high R^2 score
Parking Slot Detection Accuracy	Accuracy of computer vision model in detecting available parking spaces from camera feeds	Precise detection with minimal false positives and false negatives
Traffic Signal Optimization	Evaluation of adaptive signal timing based on congestion levels	Reduced waiting time and smoother vehicle flow at intersections
Average Travel Time Reduction	Comparison of travel time before and after system implementation	Noticeable reduction in travel time during peak hours
Queue Length Reduction	Measurement of vehicle queue length at major junctions	Decrease in average queue length after AI-based control
Emergency Vehicle Prioritization	Dynamic adjustment of signals/routes for emergency vehicles	Faster clearance and reduced response time
Parking Utilization Efficiency	Optimized parking allocation and reservation system analysis	Better parking space usage and reduced search time
Environmental Impact	Measurement of fuel consumption and emission levels	Reduced fuel usage and lower carbon emissions

Fig. 2. Comparison of traffic performance metrics before and



after AI-based traffic management implementation.

decreasing. This implies that the system has been successful to maximize traffic flow, reduce congestion and general efficiency of transportation. The Fig.3 shows line graph how the emission of CO_2 decreased over the years after the implementation of the AI-based traffic optimization system. An overall reduction can be seen after the implementation of a system although the amount of emission does not change prior to the implementation. This goes to show that increased traffic movement and decreased congestion lead to the lessening of fuel usage and environmental effect. The trend presented in the graph brings out the environmental sustainability aspect of

AI-based traffic management systems. Other than congestion minimization, the suggested model can also benefit the smart cities efforts, advancing cleaner transportation, enhancing air quality, and decreasing the total carbon imprint of the mobility systems in the cities.

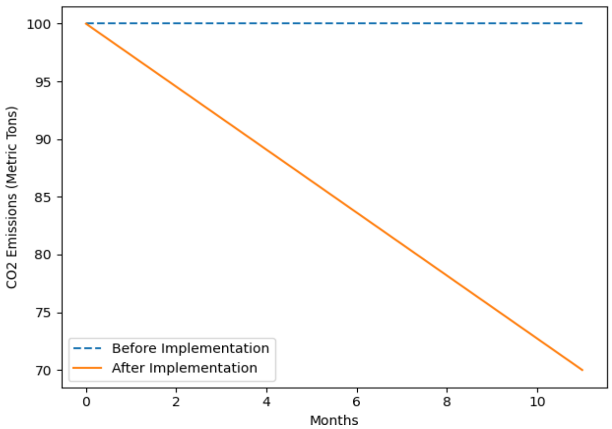


Fig. 3. Reduction in CO_2 emissions over time after implementing the AI-based traffic optimization system

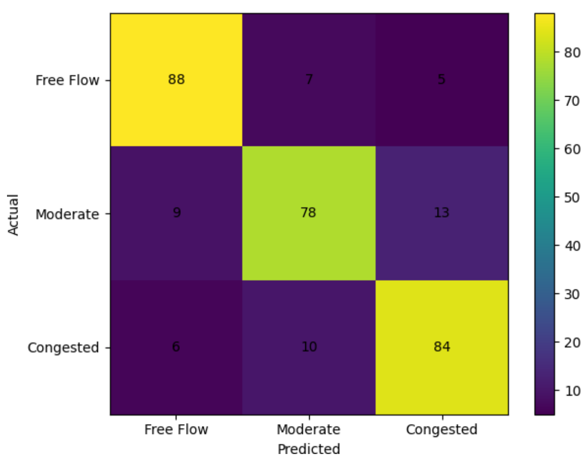


Fig. 4. Confusion matrix representing the performance of the proposed traffic congestion prediction model.

The Fig.4 shows confusion matrix shows classification effectiveness of the proposed traffic congestion prediction model in three classes Free Flow, Moderate and Congested. Large values in the diagonal mean correct prediction and small off-diagonal values mean that the misclassification is minimal. The obtained results demonstrate that the model is rather successful in prediction accuracy and reliability in real- time classification of the state of traffic.

CONCLUSION

To sum up the findings, this study manages to introduce a Smart AI-Based Traffic and Parking Management System based on machine learning and computer vision to enhance the traffic flow and parking space in the city. The system can forecast the congestion of the traffic using the Real-time and historic traffic data to assist in optimizing traffic signals and providing intelligent route directions effectively through the aid of the Random Forest algorithm. The addition of a computer vision-based parking detection system also contributes to the ease of use because it will provide the user with up-to-date data about the parking conditions, minimizing the unwarranted movement and overcrowding in parking lots. As the experimental data show, the suggested system enhances the accuracy of traffic prediction, minimizes the travel time, minimizes the consumption of fuel, and eliminates the environmental emissions considerably. Also, the prioritization of emergency vehicles in the system makes the system be more responsive and safe in emergency situations. The offered solution has a higher degree of adaptability, scalability, and responsiveness in real-time compared to the traditional methods of traffic management that are normally non-dynamic and cannot be altered swiftly. Generally, the system offers a smart, economical, and scalable transport system infrastructure of smart cities. This work can be used in the construction of more efficient, sustainable, and intelligent urban mobility systems by integrating traffic forecasting, parking control and automated control systems in a single platform.

FUTURE WORK

Thus, when developing the Smart AI-Based Traffic and Parking Management System, the future studies can consider more sophisticated and universal solutions of smart transportation. The combination of Deep Learning and Reinforcement Learning (RL) methods can be viewed as one of the paths forward, as it can be further used to optimize traffic lights and make real-time decisions that will yield better results. The system can be assisted by reinforcement Learning to develop adaptive traffic control strategies grounded on ongoing response by the condition of the traffic and enhance the efficiency with time. Additionally, in the future, it can be enhanced with the use of Internet of Things (IoT)-based smart sensors, connected vehicles, and mobile GPS data to capture more and varied information about the traffic. Suggestions This system could be expanded to facilitate vehicle-to-infrastructure (V2I) communication to coordinate traffic lights and smart vehicles in real-time and enhance the management of safety and congestion. Moreover, implementing the system at the city-wide level using real-time mobile applications may offer the users live traffic information, route suggestions, and parking spots. More studies may also be made on how to enhance automation of parking, the inclusion of electric vehicle charging station control and prediction accuracy by employing multiple data through large real life data. Such innovations would enhance the ability of the system to sustain the smart city programs, ensure a sustainable transportation system, and provide smarter, efficient, and more environmentally friendly urban transportation solutions.

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