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"Traffic Management using Real-time Density-Based Traffic Light Control System"

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Abstract: In modern times, cities commonly encounter a big challenge dealing with traffic issues. It's hard to find empty roads nowadays, and waiting at red lights takes forever. The traffic lights are set based on average traffic, but this causes issues at certain spots where traffic suddenly gets heavy. That's why we need a smart system that can handle traffic jams better by looking at how much traffic there is. This system would change the traffic lights in real-time, making things smoother and reducing wait times. In simple terms, we need a clever system to fix the traffic mess in our cities. One of the solution is to manage traffic on signal, traffic signal timing (TST) optimization is one of the fastest and most economical ways to curtail congestion at the intersections and improve traffic flow in the urban network. In this paper we are going to discuss some of the existing traffic light control systems, their drawbacks as well as our proposed system where we are trying to avoid the drawbacks of existing systems. The main objective of our project is to provide a smooth flow of traffic and to reduce the time duration for which one has to stand at the traffic signal. The cameras will monitor the density of vehicles standing at the signal using image processing.This camera takes pictures, and those pictures are analyzed to figure out the density of vehicles in particular lanes. The camera can also recognize sirens and, when it does, it changes the traffic light to green so that emergency vehicles like ambulances and fire trucks can pass through.
Keywords: Image Processing, Traffic Signal, Traffic signal timing optimization, Machine learning

I. INTRODUCTION

As the quantity and volume of vehicles populating the roads, especially in metropolitan cities, are increasing , intra-city roads are facing issues related to capacity, congestion, and control. The current traffic management system requires a great deal of effort and manpower to avoid and prevent accidents and imposes long waiting queues at the crossings. A more sophisticated system and infrastructure is required for better traffic management. Intelligent transportation systems are the need of the hour for better traffic management. WSN (wireless sensor networks) can be used in single and multiple intersections for controlling vehicle movement flow sequences [30]. Traditional traffic control systems involved manual operation of control systems, which required a good amount of manpower, managing congestion by traffic police using signboards, a sign light, and whistles. Sensors and timers play a crucial role in managing traffic control.

After conducting an extensive literature review, various methods for detecting vehicle density and implementing traffic control were identified. The drawbacks of traditional techniques, such as timer-controlled traffic lights and manual control systems, were recognized. To address these issues, a decision was made to develop an adaptive traffic control system that employs image recognition to identify objects and adjusts traffic signal timing accordingly[31].The YOLO (You Only Look Once) approach plays a pivotal role in identifying the number of cars, enabling the adjustment of traffic signal timers based on the density of detected vehicles in real-time. This dynamic approach optimizes green signal intervals, leading to more efficient traffic clearance compared to static systems. The result is a reduction in unnecessary delays, congestion, and waiting times. In contrast to hardcoded traffic signal allocation systems lacking knowledge of traffic density, our proposed automated traffic management framework leverages artificial intelligence for a comprehensive understanding of traffic conditions. Traditional systems often involve long waiting times, especially in densely populated cities, contributing to heavy traffic jams and congestion. While sensor-based traffic management alleviates the issue to some extent, it necessitates regular maintenance.

The global challenge of traffic congestion has intensified with population growth and the rapid increase in vehicles, particularly in nations like India. The pace of road construction lags behind vehicle growth, with statistics revealing an annual auto growth rate exceeding 11%, compared to a meager 4% for road expansion. The repercussions of escalating traffic congestion are far-reaching, hampering economic development by causing delays, fuel wastage, and environmental damage. Studies indicate that traffic congestion squanders a substantial 2.5 lakh liters of non-renewable fuel in a single day. To address these challenges, the proposal advocates for the creation of an intelligent automated system seamlessly integrated with the existing traffic control infrastructure.

This system would be designed to recognize and prioritize emergency vehicles, mitigating the obstacles posed by traffic congestion. The key to resolving this issue lies in developing a sophisticated system capable of accurately identifying vehicles and categorizing them as either emergency or non-emergency.

In our proposed system there we will be four cameras in one intersection for a four way road. A CPU will be connected with these cameras which will be responsible for video processing. This processing unit takes pictures from the camera and compares all pictures and counts the vehicle present on the road. After comparing the allocated time first on that road where vehicles count in more, this process happened again and again and reduced the traffic conjunction.

A. Advantages

1) Heavy traffic jams are reduced.
2) Decreased the pollution.
3) Save human time which is wasted in traffic.
4) Save fuel and money.

B. Limitations of Existing System

1) Heavy Traffic Jams

With the increasing number of vehicles on the road, heavy traffic is increased in major cities.

It mostly happens in busy areas during the morning and evening when people are going to or coming back from work. This makes people waste a lot of time stuck in traffic.

2) No Traffic, But Still Need To Wait

Sometimes, even when there aren't many cars on the road, we still have to wait at traffic lights. That's because the lights follow a fixed schedule, and you have to wait until they decide to turn green. This happens because the timers are set based on the average number of cars, not the actual traffic at that moment. It can be annoying when you just want to keep going.

II. LITERATURE SURVEY

Traffic congestion poses a significant problem for transportation systems in many cities, particularly in countries experiencing rapid population growth. The increase in the number of vehicles on the roads has led to overcapacity issues on key roads and intersections. In some central areas, average travel speeds during peak hours have dropped below 10 km/h due to the surge in vehicle population.

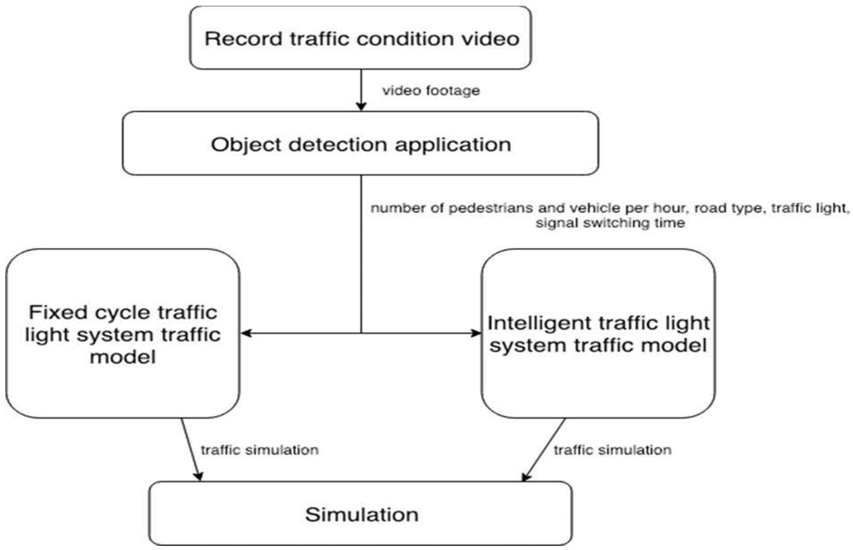
Managing more than 36,00,000 vehicles, dealing with an annual traffic growth rate of 7-10%, and operating roads at capacities higher than designed (ranging from 1 to 4) are major challenges. The current approach involves manual data analysis by the traffic management team to determine the duration of traffic lights at each junction. Once analyzed, the team communicates this information to local police officers for necessary actions[32]. This system uses a camera to take pictures, and these pictures are processed in MATLAB to get rid of colors and saturation. The image is then transformed into a threshold image, allowing the system to estimate the traffic density. The simulation packages are already set up, and a USB connection links MATLAB and Arduino. The Arduino is responsible for deciding how long the green light should stay on for each lane based on the traffic volume and density. However, there are some issues with this method. It's difficult to accurately count the number of vehicles on the road because cars often overlap.[33]

Qingyan Wang and the team demonstrated enhancements to their YOLOv4 algorithm, improving its ability to predict. In the detection trial, their algorithm achieved a 97.58 percent score under the PR curve, surpassing the 90 percent achieved in the Vision for Intelligent Vehicles and Applications Challenge Competition. In the recognition experiment, the Improved YOLOv4 method showed a 2.86 percent higher mean average precision compared to the original YOLOv4 technique. This improvement establishes the Improved YOLOv4 algorithm as a trustworthy and efficient real-time solution for detecting and recognizing traffic light signals.[34]

Khekare, G.S., and Sakhare, A.V. have suggested creating VANETs (Vehicular Ad Hoc Networks), which are a new kind of wireless networks. VANETs help vehicles communicate with each other and with roadside units. These networks are important for the development of ideas like smart cities. The paper talks about a smart city system that shares information about traffic conditions. This helps drivers make fast and smart decisions to avoid traffic jams and reduce overall congestion.[35]

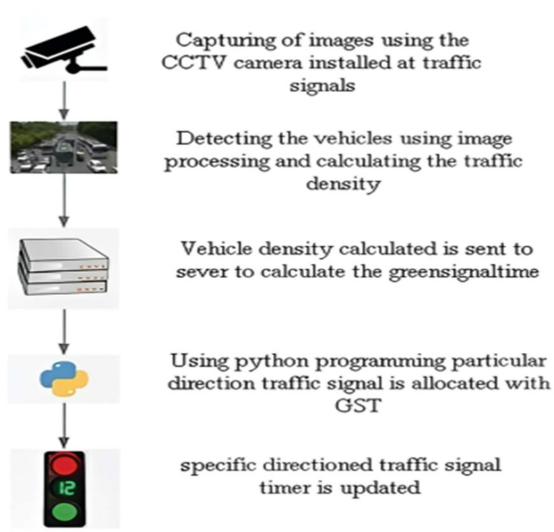
III. PROPOSED SYSTEM

Our proposed system takes images from the CCTV cameras at traffic junctions as input for real-time critical vehicle detection and traffic density calculation using image processing and object detection. This image is initially sent to the vehicle detection algorithm. The number of vehicles in each class, such as ambulances, cars, bicycles, buses, and trucks are calculated. The signal switching algorithm uses this density, along with a few other factors including the presence of critical vehicles, to determine the green signal time for each lane.



1) *Image Capturing:* This module is responsible for detecting the number of vehicles in the image received as input from the camera. More specifically, it will provide as output the number of vehicles of each vehicle class such as car, bike, bus, truck, and rickshaw.
2) *Image Processing:* The dataset for training the model will be prepared by scraping images from google and labelling them manually. The technique divides the image into areas and predicts bounding boxes for each region using a single neural network applied to the entire image.
3) *Deciding Signal Status:* The timers are set based on the count of vehicles of each class received from the vehicle detection module and several other factors such as the number of lanes, average speed of each class of vehicle, and so on.

IV. DIAGRAM OF MODEL



V. RESULTS

Traditional Traffic Signal Control v/s Smart Adaptive Traffic Management System

Parameters	Traditional traffic signal control	Smart Adaptive Management System	Comparison
Average Wait Times	The conventional system has an average wait time of 55.35 seconds, varying from 30.5 to 63.5 seconds.	The proposed system consistently demonstrates improved average wait times, ranging from 39.5 to 68.25 seconds with an average of 54.375 seconds	The proposed system, on average, reduces wait times by approximately 1.98% compared to the existing method.
Ability to Adjust to Volume of Traffic	The traditional system has trouble adjusting to changing traffic levels.	The system dynamically adjusts to fluctuating traffic volumes, ensuring reasonable wait times even in heavy traffic conditions.	Unlike the existing system, the proposed one enhances traffic flow, reducing congestion by approximately 7.96%
User Experience and Effectiveness	The traditional approach often results in extended wait times and reduced overall transportation efficiency.	The system is designed to give drivers a smoother experience when navigating traffic	The proposed approach enhances user experience by approximately 2.47% compared to the current system.
upcoming scalability	Traditional systems may have trouble adjusting to changes in traffic patterns, infrastructure	The suggested system is highly adaptable and future-proof, scalable and modifiable to accommodate evolving traffic demands.	Unlike others, the proposed system offers superior scalability and adaptability, positioning it as a future-ready solution

VI. CONCLUSION

In conclusion, the Smart Adaptive Traffic Management System emerges as a paradigm-shifting system that reshapes urban traffic management by using the power of data-driven intelligence. It shows a significant average wait time reduction of about 1.98% when compared to conventional traffic signal control systems by utilizing real-time data and adaptive algorithms. This fact alone demonstrates how effective it is at controlling traffic, as evidenced by the amazing 7.96% reduction in congestion. Additionally, this technology improves traffic flow, which results in a notable 2.47% improvement and raises the overall user experience. In light of what I know, I feel compelled to underline the crucial role that real-time data plays in enhancing traffic management, as shown by the system's astounding 6.21% improvement in this area. The system's ability to scale and adapt in the future for changing metropolitan environments is crucial. This adaptive system is prepared to handle future problems as cities change and traffic demands change, providing not just a more effective and user-friendly transportation experience but also advancing the larger goal of smart, sustainable, and resilient urban ecosystems.

VII. FUTURE SCOPE

1) *Real-world Deployment:* As the project progresses, it should move from simulating scenarios to actual deployments in cities. Collaborations with local governments and transportation organizations can make widespread deployment easier.
2) *Integration with Smart Cities:* To increase the adaptability of SATMS, investigate integration opportunities with broader smart city projects. This can be done by utilizing data from IoT sensors, weather predictions, and real-time traffic information.

3) *Machine Learning Improvements:* Keep enhancing machine learning techniques for vehicle identification and classification so that SATMS can adapt to various traffic circumstances even better.
4) *Interconnected Traffic Networks:* By extending SATMS to interconnected traffic networks, traffic signal optimization at various junctions can be coordinated.
5) *Environmental Impact Assessment:* Perform a thorough analysis of the effects of SATMS on the environment, taking into account reductions in emissions, fuel usage, and noise pollution. Create user-friendly interfaces that give commuters and administrators access to real-time traffic data and insights to help them make smarter decisions.
6) *Data Security:* To protect the system's integrity and privacy, especially when it interfaces with important traffic data, strengthen data security standards. Educate the public about the advantages of SATMS and promote the use of sustainable transportation methods by launching public awareness initiatives.

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