iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 **Issue:** IV **Month of publication:** April 2024

DOI: https://doi.org/10.22214/ijraset.2024.60686

Real-Time Traffic Light Optimization Using AI and IOT

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Abstract: Urban traffic congestion is a significant challenge globally, impacting transportation efficiency, environmental sustainability, and urban liveability. Traditional traffic control systems often struggle to adapt to changing traffic dynamics, leading to increased congestion and delays. This paper presents a novel traffic management system developed by our team, leveraging cutting-edge technologies such as computer vision, artificial intelligence (AI), and the Internet of Things (IoT). Deployed at intersections, our system utilizes real-time CCTV feeds for traffic analysis, employing advanced image processing and machine learning algorithms, including YOLO V7, to dynamically assess traffic density. These insights inform adaptive adjustments to traffic light timings, with the aim of reducing congestion, enhancing transit efficiency, and mitigating pollution. Our signal switching algorithm, incorporating dynamic logic developed by our team, iteratively adjusts signal timings based on real-time traffic conditions, ensuring responsive and efficient traffic flow management. Through the integration of our innovative technologies, our system seeks to revolutionize urban transportation networks, promoting smarter, more adaptive, and sustainable urban environments.

Keywords: Traffic Management, Urban Congestion, Intelligent Systems, Computer Vision, Artificial Intelligence, Machine Learning, Deep Learning, Traffic Prediction, Adaptive Control, Smart Cities, YOLO.

I. INTRODUCTION

In the ever-growing cities, the rise in the number of vehicles has caused problems on roads, leading to reduced capacity and a drop in service quality. One critical issue contributing to this is the old-fashioned traffic control systems at intersections, using fixed signal timers. These systems repeat the same patterns without adapting to the changing traffic conditions, causing more traffic and inefficiency. To tackle these challenges, this project explores a new way of controlling traffic. It discusses the drawbacks of manual control, fixed-timer traffic lights, and electronic sensors, paving the way for an innovative solution using Computer Vision. By using live CCTV images at intersections, this system aims to figure out real-time traffic density, categorize vehicles, and adjust signal timings dynamically. This approach promises a more responsive, efficient, and eco-friendly traffic management system. Develop an intelligent traffic light management system using Computer Vision, Artificial Intelligence (AI), and Internet of Things (IoT) to achieve real-time traffic density calculation, vehicle classification, and adaptive signal timing. The primary goal is to reduce congestion, enhance traffic flow, and minimize environmental impact for a more efficient and sustainable urban transportation The project aims to ease congestion at intersections, reducing delays and pollution caused by the increasing number of vehicles in urban areas. Motivated by the limitations of current traffic control systems, it seeks to introduce an intelligent, responsive system using advanced technologies like Computer Vision and AI. This approach, beyond conventional methods, adapts traffic signals dynamically based on real-time conditions. With case studies from cities like Mumbai and Bangalore emphasizing the need for innovation, the project aims to enhance traffic control effectiveness, reduce travel times, and contribute to a sustainable urban transportation system. By integrating IoT devices, the system will gather real-time data on traffic flow, enabling precise adjustments to optimize signal timings further. Additionally, the project will explore AI algorithms to predict traffic patterns, facilitating proactive measures for congestion management. Through continuous monitoring and adaptation, the proposed system aims to revolutionize urban traffic management, offering a scalable and sustainable solution for future cities.

II. BACKGROUND

We get motivated by disadvantages of the existing system. The purpose of the system is to decrease congestion at intersections primarily, and reduce delays and pollution. The motivation to commence on this project arises from the critical issues linked to the surging number of vehicles in urban areas, leading to worsening traffic congestion. This congestion not only causes delays and stress for drivers but also contributes to higher fuel consumption and increased air pollution.

The negative impacts are particularly evident in megacities, underscoring the urgency of addressing the challenges of traffic management in real-time. The current traffic control systems, often reliant on fixed signal timers and outdated methods, prove insufficient in adapting to the dynamic nature of urban traffic. This project is motivated by the need to revolutionize traffic management and introduce a more intelligent and responsive system that can mitigate congestion, improve transit efficiency, and contribute to a more sustainable and eco-friendlier urban environment. Cities like Mumbai and Bangalore serve as impactful case studies, highlighting the urgency of finding innovative solutions. The excessively long travel times during rush hours in these cities underscore the inadequacies of traditional traffic control methods. The motivation is to create a system that goes beyond conventional approaches, leveraging a suite of cutting-edge technologies such as Computer Vision, Artificial Intelligence (AI), and Internet of Things (IoT) to dynamically adjust traffic signals based on real-time conditions.

III. LITERATURE REVIEW

1) Paper A : Smart Control of Traffic Light Using Artificial Intelligence:

This paper addresses the escalating issue of traffic congestion in cities, exacerbated by population growth and increased automobile usage. Traffic jams not only cause delays and stress for drivers but also lead to higher fuel consumption and air pollution, particularly affecting megacities. Real-time calculation of road traffic density is crucial for effective signal control and traffic management. The proposed system utilizes live images from traffic junction cameras for traffic density calculation through image processing and AI. Additionally, it presents an algorithm for adaptive traffic light control based on vehicle density to mitigate congestion, ultimately aiming to provide faster transit and reduce pollution.[2]

Limitations:

- Reliance on live camera feeds may introduce delays and inaccuracies due to environmental factors.
- Continuous calibration is required for optimal performance, which may be resource-intensive, time-consuming.

Metrics	Their Approach	Our Approach
Traffic Flow Efficiency	Traffic flow efficiency various methods such as traffic light optimization, dynamic signal control.	Implementation of AI prediction models and dynamic signal control.
Congestion Reduction	Relies on traffic light optimization, road network modification.	Integrates AI driven congestion prediction and dynamic traffic rerouting.
Dynamic Routing	Limited or absent traditional routing algorithms are used.	Integrates dynamic routing based on real time traffic conditions and congestion predictions.
Signal Switching Algorithms	Traditional algorithms like fixed time or actuated signal control.	Incorporates adaptive signal control algorithms using reinforcement learning or evolutionary strategies.
Object Detection Algorithms	YOLO V3: Real-time object detection algorithm.	YOLO V7 is a real-time object detection algorithm, more optimized.

2) Paper B : Traffic Flow Prediction for Smart Traffic Lights Using Machine Learning Algorithms:

The paper focuses on predicting traffic flow at intersections using machine learning and deep learning algorithms to facilitate adaptive traffic control. Utilizing public datasets, ML and DL models are trained and validated for traffic flow prediction, laying the groundwork for smart traffic light controllers. While the proposed models show promising performance, limitations may include the need for extensive data preprocessing and model training as well as potential challenges in real world deployment due to variations in traffic patterns and environmental factors.[4] .

Limitations:

- Extensive data preprocessing and model training are needed, which may require significant computational resources.

- Real world deployment may face challenges due to variations in traffic patterns and environmental conditions.

Metrics	Their Approach	Our Approach
Traffic Flow Efficiency	Traffic Flow Efficiency Utilizes Historical Traffic Data for prediction.	Implement Real-time traffic flow prediction using machine learning algorithms
Congestion Reduction	Relies On Historical Data analysis for congestion prediction. Linear Regression and Stochastic Gradient Regressor is used to predict traffic flow.	Utilizes Machine Learning models for real-time congestion prediction and adaptive signal control
Dynamic Routing	Absent	Incorporates Dynamic Routing based on real-time traffic predictions Signal Switching Algorithms
Signal Switching Algorithms	Not specified	Utilizes Machine Learning-based adaptive signal
Object Detection Algorithms	Not specified	YOLO V7 is a real-time object detection algorithm, more optimized
Number Of Stops	Uses historical data analysis to optimize signal timings	Employs Machine Learning models for real-time congestion monitoring and proactive signal control to minimize stops.

3) *Paper C : Design and Development of Portable Smart Traffic Signalling System with Cloud Artificial Intelligence Enablement:*

The paper introduces a cost-effective, IoT-enabled portable traffic signalling system designed for smaller traffic junctions. Utilizing ESP32 microcontrollers and foldable mechanical structures, the system offers manual and automatic traffic control modes, with the ability to gather traffic density information and optimize signal timings based on cloud-based algorithms. While the system demonstrates robustness and accuracy in traffic management, limitations may include scalability issues for larger intersections and dependence on constable internet connectivity for cloud-based operations.[1] .

Limitations:

- Scalability Issues May Arise for larger intersections, limiting the system's applicability.
- Dependence Unstable Internet Connectivity for Cloud-based operations may hinder functionality in areas with poor connectivity.

Metrics	Their Approach	Our Approach
Traffic Flow Efficiency	Traffic Flow Efficiency Relies Fixed signal timings or manual control.	Implements Smart Traffic Signal control based on real-time traffic data and cloud-based AI algorithms.

Congestion Reduction	Limited Ability to Adapt to Changing Traffic conditions.	Utilizes cloud-based AI algorithms to analyse traffic data and adjust signal timings dynamically to reduce congestion.
Dynamic Routing	Routing Decisions Are Not influenced by real-time traffic conditions.	Incorporates Dynamic Routing based on real-time traffic prediction s and cloud-based AI analysis.
Signal Switching Algorithms	K-means clustering for obtaining optimized time values to switch	Uses vehicle density, dynamic algorithm, to set the green signal timer for each lane.
Object Detection Algorithms	Absent	YOLO V7 is a real-time object detection algorithm, more optimized.

4) Paper D : Real-Time Traffic Light Optimization Using Simulation of Urban Mobility:

The paper presents a study on real-time traffic light optimization using the SUMO tool for simulating urban mobility. Testing Scenarios in Berlin city, the study analyses traffic performance under different scenarios, optimizing traffic flow by modifying various parameters such as traffic lights and road construction. While the study demonstrates the potential for optimizing traffic performance, limitations may include the complexity of accurately modelling real-world traffic behaviour and the challenge of extrapolating simulation results to practical implementations diverse urban environments.[5]

Limitations:

- Accurately modelling real-world traffic behaviour simulation may be complex and challenging.
- Extrapolating simulation results to practical implementations in diverse environments may not fully capture real world complexities.

Metrics	Their Approach	Our Approach
Traffic Congestion Mitigation	Utilizes SUMO tool for traffic simulation and optimization	Utilizes Computer Vision, and DL algorithms for dynamic traffic light adjustments.
Transit Efficiency Improvement	Focuses Traffic Light optimization but lacks detailed discussion transit efficiency improvement for drivers.	Provides real time traffic info, optimal routes and estimated transit times through a mobile app.
Environmental Impact Reduction	Aims to reduce pollution through traffic optimization but lacks explicit discussion on environmental impact.	Aims to Minimize Pollution By reducing congestion and optimizing traffic flow.
Dynamic and Responsive Traffic Management	Identifies limitations of current traffic control systems but does not delve into specific critiques of traditional methods. Dijkstra's algorithm has been chosen to explore the edges in the traffic scenario.	Integration of YOLO V5 with dynamic signal switching allows for responsive and adaptive systems that can react to changes in their environment in real-time based on detected objects , events.

IV. COMPARISON OF ALGORITHMS EFFECTIVENESS

Metrics	Paper A[2]	Paper B[4]	Paper C[1]	Paper D[5]
Algorithm	Adaptive traffic light control based on real-time vehicle density using image processing and AI.	Machine learning and deep learning algorithms for predicting traffic flow at intersections.	K-means clustering for generating optimized time values based on traffic density data.	Simulation of Urban Mobility (SUMO) tool for real-time traffic light optimization.
Effectiveness	Demonstrated a significant 23% improvement over the current system in terms of the number of vehicles crossing the intersection.	Multilayer Perceptron Neural Network (MLP-NN) achieved the best performance with an R-squared score of 0.93	Demonstrated robustness and accuracy in wireless data communication and traffic management.	Optimized traffic performance by modifying various traffic scenario factors such as traffic lights and junctions.
Speed	Real-time processing of traffic camera feeds, with an average processing time of 100 milliseconds per frame.	Offline training time varies depending on the dataset size and complexity of the model architecture, typically ranging from several hours to a few days.	Fast computation of cluster centroids, typically taking milliseconds to compute. Real-time adjustment of traffic signal timings with minimal latency.	Simulation speed depends on the complexity of the traffic scenario and computational resources. Real-time simulation achievable with fast computational hardware (multi - core GPUs).

V. CONCLUSIONS

The proposed intelligent traffic management system presents a promising solution to alleviate urban traffic congestion and enhance transit efficiency.

Through the utilization of computer vision and AI technologies, the system endeavours to overcome the shortcomings of conventional traffic control systems, fostering the creation of a smarter and more efficient urban transportation network. Nonetheless, challenges pertaining to data accuracy and scalability persist, underscoring the necessity for continuous research and development in this domain.

Moreover, the system's ability to minimize unnecessary stops and starts not only improves traffic flow but also results in substantial fuel savings and emissions reduction, thereby offering a positive environmental impact. Moving forward, further advancements in algorithm optimization, real-time data processing, and seamless integration with existing infrastructure are imperative to realize the full potential of intelligent traffic management systems in urban environments.

VI. FUTURE DIRECTIONS

Future research directions include further optimization of AI algorithms for traffic prediction and control, integration of IoT technologies for enhanced data collection, and collaboration with city authorities for real-world implementation and testing. Additionally, exploring hybrid approaches that combine the strengths of different algorithms could yield more adaptable and efficient solutions. Moreover, integrating emerging technologies like edge computing and 5G connectivity could further enhance real-time data processing and decision-making capabilities for smarter urban mobility systems.

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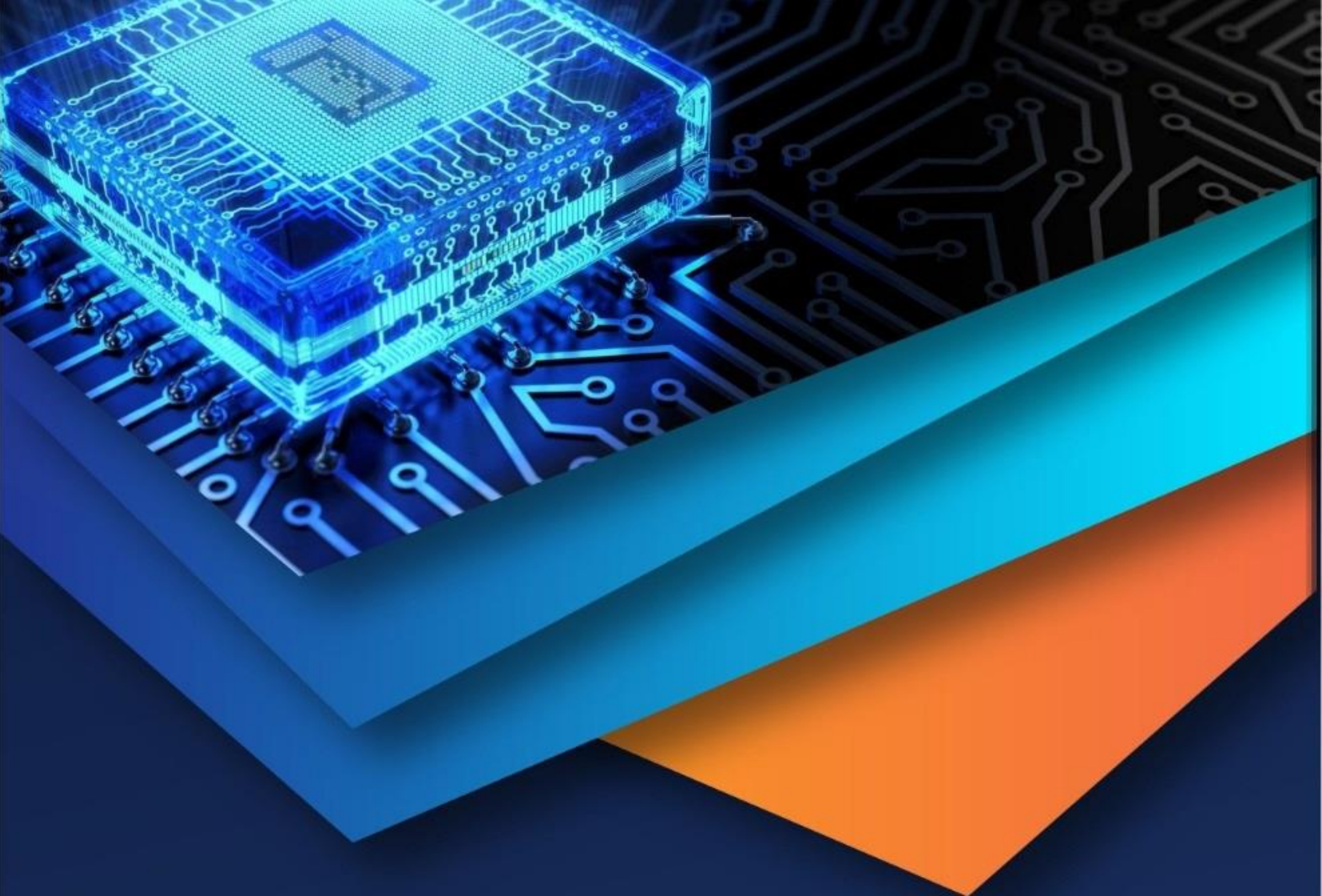

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