RESEARCH ARTICLE OPEN ACCESS

Traffic Light Analysis and Signal Adaptation

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ABSTRACT

The integration of Internet of Things (IoT) technologies in urban traffic management has paved the way for innovative approaches to addressing the challenges of congestion and emergency vehicle response time. This project introduces a comprehensive and adaptive Smart Traffic Control and Emergency Vehicle Prioritization System. Leveraging strategically deployed cameras and IoT devices throughout the road network, real-time data is collected and transmitted to a centralized server for analysis. The system employs algorithms to adjust traffic signal timings based on the current traffic density at a junction, continuously monitoring the flow of vehicles through each lane. The system incorporates a specialised emergency vehicle prioritisation feature. Upon detection of an approaching emergency vehicle, the system anticipates its arrival by analysing data from a considerable distance and selectively grants a green signal to the dedicated emergency vehicle lane while temporarily halting other traffic, facilitating a swift and unimpeded passage for the emergency response unit. The system takes traffic density as input from cameras which is abstracted from Digital Image Processing technique and transmits real-time data. The data is then processed through the IoT framework, enabling timely decision-making and adjustment of traffic signals. The intelligent traffic control and emergency prioritisation contribute to the overall goal of creating a safer and more responsive urban transportation infrastructure.

Keywords –Traffic signal , Ambulance , Priority vehicle,Vehicle detection

I. INTRODUCTION

In urban traffic management, the demand for efficient and adaptive solutions is ever-growing to alleviate congestion and reduce wait times for commuters. Our project introduces a novel approach –a dynamic traffic signal system powered by machine learning. Unlike conventional fixed-time traffic signals, this system adapts in real-time based on the current traffic conditions. Leveraging machine learning algorithms, the system continuously analyzes traffic patterns, volume, and congestion levels on each lane, dynamically adjusting signal timings to optimize traffic flow. Prioritising emergency vehicles is also a feature of the project. Thus this innovative approach not only aims to enhance overall traffic efficiency but also contributes to a more sustainable and responsive urban transportation system.

II. OBJECTIVE

The primary objective of this project is to develop an AI-based real-time traffic signal control system that leverages cutting-edge machine learning techniques, specifically deep learning and computer vision, to optimize traffic flow intelligently. The system aims to dynamically adjust traffic signal timings based on real-time analysis of traffic data, utilizing advanced object detection algorithms like You Only Look Once (YOLO). By accurately tracking vehicles, calculating traffic density, and employing an intelligent algorithm, the project seeks to reduce congestion, minimize delays, and enhance the overall efficiency of traffic management.Through real-world experiments and performance assessments, the objective is to demonstrate the system' s precision, reliability, and its ability to outperform traditional traffic management systems, offering a cost-effective, adaptive, and efficient solution to urban traffic challenges.

III. LITERATURE REVIEW

A research which introduces an innovative AI-based Real-Time Traffic Signal Control System utilizing computer vision and machine learning techniques to tackle urban traffic congestion [1]. Employing the You Only Look Once (YOLO) object detection algorithm, the system captures and tracks vehicles in live camera footage at traffic junctions, dynamically assessing traffic density by analyzing vehicle count and speed. This methodology aims to alleviate congestion, minimize delays, and consequently enhance transit times while reducing fuel consumption and air pollution. Experimental validation using real-world traffic data demonstrates the system's precision in vehicle detection and tracking, along with reliable real-time traffic density calculations. The implemented traffic light switching algorithm significantly reduces congestion, leading to improved traffic flow. Noteworthy advantages of the proposed system include lower implementation and maintenance costs, enhanced accuracy and efficiency, and adaptability to changing traffic conditions in real-time, differentiating it from traditional traffic management systems.

S. S. R and L. Rajendran delves into the development of a Real-Time Adaptive Traffic Control System tailored for smart cities, with a specific emphasis on addressing the traffic challenges prevalent in densely populated regions like India [2].Recognizing the significant impact of daily commuting issues on the quality of life, the study advocates for innovative solutions, pointing to projections that indicate a 15-20 percent reduction in commuting cycles through the implementation of smart mobility systems by 2025. Identifying the limitations of traditional traffic control systems with pre-programmed signal timings, the research proposes an Adaptive Traffic Control System (ATCS) that dynamically adjusts signals based on real-time traffic demand, utilizing a combination of hardware (sensors for traffic density) and software (data analysis). The study presents a camera-based traffic monitoring and processing system as an illustrative example, showcasing reduced cycle times and specialized provisions for emergency vehicles. The research suggests that the ATCS model holds promise for alleviating traffic congestion, improving overall traffic flow, and enhancing the efficiency of urban mobility, with potential benefits including reduced commute times and minimized environmental impact.

A Study which introduces an Adaptive Traffic Control System (ATCS) utilizing the You Only Look Once (YOLO) object detection algorithm, addressing the escalating challenges posed by the increasing population and vehicle numbers on the roads[3]. With the rise in population, traffic congestion has emerged as a critical issue, leading to time wastage, reckless driving, and a subsequent increase in air pollution. The inefficiencies of traditional traffic control systems contribute significantly to this problem. In response, the research advocates for a shift towards an Adaptive Traffic Control System, which dynamically adjusts traffic signal timings based on real-time traffic density. The proposed system employs image processing and artificial intelligence, utilizing traffic cameras at junctions to detect vehicles on the road. The signal switching algorithm relies on real-time traffic density calculations derived from live images captured by these cameras, aiming to alleviate traffic congestion and enhance overall traffic flow. This approach seeks to mitigate the adverse effects of prolonged vehicle halts, promote safer driving practices, and contribute to a reduction in air pollution.

The paper addresses a significant challenge in developing countries where transportation infrastructure struggles to keep pace with burgeoning travel demand, despite utilizing state-of-the-art urban design methodologies commonly applied in developed nations[4]. The conventional approach of designing arterial roads intersected with orthogonal branches faces difficulties in regulating the diverse and heterogeneous traffic flow characteristic of developing countries. Unlike their developed counterparts, these nations experience a mix of vehicle types utilizing all lanes. The paper proposes a novel solution that involves implementing a reinforcement learning-based control mechanism specifically tailored for arterial roads. Notably, this approach aims to optimize traffic flow without necessitating modifications to the existing urban road network. Through experimentation, the results demonstrate the superiority of the proposed control mechanism over existing methods across various urban design network structures, showcasing its effectiveness in handling real-world, heterogeneous traffic scenarios using only real-time data. This innovative approach offers promise in enhancing transportation efficiency and addressing the challenges posed by evolving travel demands in developing countries.

The escalating challenge of traffic congestion in cities, exacerbated by a rising population and the proliferation of automobiles, has become a pressing concern [5]. The adverse effects of traffic jams extend beyond mere delays and stress for drivers, contributing to increased fuel consumption and air pollution. Megacities, in particular, bear the brunt of this issue, necessitating real-time road traffic density calculations for optimal signal control and efficient traffic management. The traffic controller emerges as a pivotal element influencing traffic flow, emphasizing the urgency for optimization to cope with the growing demand. In response to this, our proposed system leverages live camera feeds from traffic junctions, employing image processing and artificial intelligence for real-time traffic density calculation. A key focus lies in the algorithm designed for traffic light switching based on vehicle density, with the overarching goal of alleviating congestion, facilitating quicker transit for individuals, and ultimately reducing environmental pollution. This innovative approach aligns with the imperative to address the dynamic challenges posed by urban traffic, offering a potential solution for more effective and sustainable traffic control systems.

Automatic traffic accident detection in urban intersections can be done using computer vision techniques[6].With many intersections equipped with surveillance cameras linked to traffic management systems, the proposed framework offers an efficient three-step process. First, it employs the YOLOv4 method for accurate object detection. Second, it utilizes a Kalman filter and the Hungarian algorithm for object tracking, introducing a novel cost function to handle challenges like occlusion and overlapping objects. Finally, accident detection is accomplished through trajectory conflict analysis, considering vehicle-to-vehicle,vehicle-to-pedestrian and vehicle-to-bicycle scenarios. The method is validated using real traffic video data, demonstrating its real-time applicability with a low false alarm rate and high detection rate for trajectory conflicts and accidents at urban intersections. Robustness is further evaluated using diverse YouTube video sequences, showcasing the framework's effectiveness under varying illumination conditions. The proposed framework stands as a promising solution for enhancing traffic surveillance systems, offering a valuable contribution to the field. The dataset used in the experiments is publicly available for reference.

IV. METHODOLOGY

In the context of our smart traffic monitoring and management system, the methodology outlines a systematic workflow leveraging Internet of Things (IoT) technologies and decentralized approaches to optimize traffic on road networks. The process commences with the deployment of cameras and sensors for real-time data collection, which is transmitted to a centralized server for analysis. he algorithmic approach involves looking traffic density and prioritizing emergency vehicles using Object detection.The proposed system will be validated through a prototype deployment in a junction, demonstrating its effectiveness in road planning and congestion management.

A.SOFTWARE REQUIREMENT

1. TOOL : ARDUINO IDE
    a. Utilizes Visual Studio as the primary integrated development environment (IDE) for software development.
    b. Known for its feature-rich environment, supporting efficient coding and application design.
2. OPERATING SYSTEM : WINDOWS 10 OR HIGHER
    a. Designed to operate seamlessly on Windows 10 and subsequent versions.
    b. Ensures compatibility and optimal performance within the Windows ecosystem.
3. EMBEDDED C PROGRAMMING
4. FIREBASE:CLOUD SERVER

B.HARDWARE REQUIREMENTS

1. ESP8266

It is a microcontroller-based development board that is commonly used for integrating IoT applications.It is used for WiFi connectivity and integration.

2. LEDs

LEDs (Light Emitting Diodes) are semiconductor devices that emit light when an electric current passes through them. LEDs are often utilized in IoT projects for visual feedback, status indication.

3. JUMPER WIRES

Jumper wires are used in electronics for quick and temporary connections between components on a circuit or breadboard. They simplify the process of building and testing electronic circuits.

4. POWER MODULE

They provide a convenient and portable power source.

C. ALGORITHM

1. The default time configuration is initially set for all signals.
2. Capture the video feed of the next lane where the signal is supposed to turn green. Transmit the feed to the local system for analysis. The resulting data is used to set the timer of the green signal.
3. The current vehicle density in the monitored lane.
4. Adjust the green light timer:

If the density is low, reduce the green light timer.

- If the density is high, maintain the usual green light timer.
- If an emergency vehicle is detected, then that particular lane will be set green.

5. Repeat the process cyclically for continuous adaptation to changing traffic conditions.

D.VEHICLE DETECTION MODULE

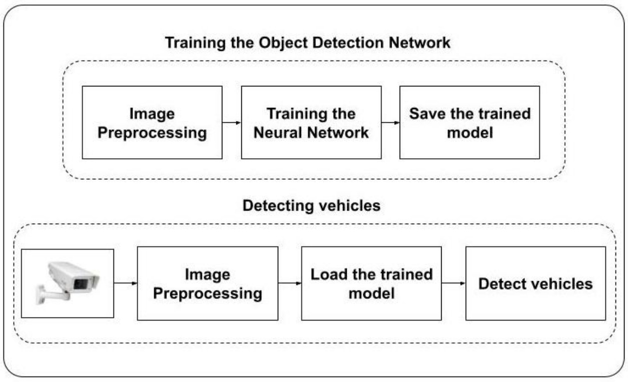

Fig. 1- Vehicle Detection

E. SIGNAL SWITCHING MODULE

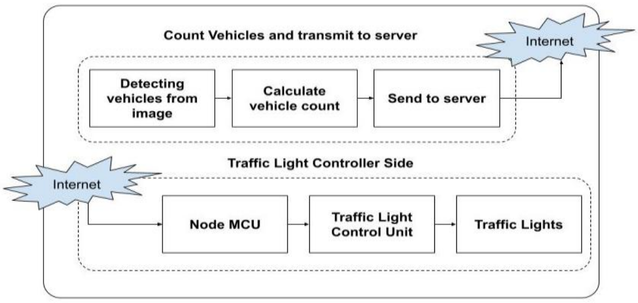

Fig. 2- Signal Control

V. CONCLUSIONS

The proposed smart traffic management system represents a significant leap forward in optimizing urban traffic flow through the implementation of an intelligent algorithm. By dynamically adjusting traffic signals based on calculated traffic density, the system ensures that green signals are allocated longer durations during periods of higher traffic volume, thereby reducing congestion, minimizing delay time, and alleviating waiting times for commuters. The adaptive nature of the algorithm positions the system as a key player in addressing contemporary challenges associated with urban mobility. Through real-time monitoring and data-driven decision-making, the proposed solution contributes to a more responsive and efficient traffic management infrastructure.

VI. ACKNOWLEDGMENT

We would like to express our sincere gratitude to LBS Institute of Technology for Women for encouraging us to go forward and providing all the necessities for the completion of this work. We express our sincere gratitude to Prof. Diliya M Khan and Prof. Sumithra M D for helping us and providing their valuable insights and guiding us in the right path. We are also grateful to the ambulance drivers who helped us collect images for the dataset. Furthermore, we would like to thank police officers for helping us understand the working of the traffic light system, which was instrumental in shaping the direction of this research. Finally, we extend our thanks to all those who provided encouragement, feedback, and assistance throughout the course of this project.We would like to express our sincere gratitude to LBS Institute of Technology for Women for encouraging us to go forward and providing all the necessities for the completion of this work.

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