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Dynamic Traffic Control System Using Video and Image Processing

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Abstract

Traffic congestion is a serious problem in cities, leading to delays, wasted fuel, and more accidents. Current traffic signal systems often use fixed timing, which doesn't change based on traffic levels. This makes managing traffic less effective. The motivation behind this project is to create a better traffic control system that adapts to real-time traffic. By using live camera feeds and image processing, we can count vehicles at intersections and adjust traffic lights based on the number of cars present. This helps traffic flow more smoothly, reduces waiting times, and saves fuel. The outcome of this system is improved traffic management. Traffic lights will be smarter, only turning green when needed, and preventing empty roads from having green lights. This saves time and fuel, making travel easier and safer. The innovation in this project comes from using image processing instead of old sensor-based systems. Image processing gives a clearer and more accurate view of traffic, making the system more reliable and effective for modern cities.

Keywords: *Traffic Congestion, Traffic Signal Systems, Real-Time Traffic, Traffic Light, Image & Video Processing, AI, Automate.*

1. Introduction

The vehicle population in the world is growing rapidly. Urban traffic is increasing in parallel. These days, traffic congestion is a major issue. Megacities are the ones most affected by it, but the fact that it appears to be present everywhere. Furthermore, due to its constantly growing nature, real-time knowledge of the road traffic density is essential for improved traffic management and signal control. Traffic congestion can be caused by a variety of factors, including excessive red light waits, uncontrolled demand, and insufficient capacity. Although there is a correlation between uncontrolled demand and insufficient capacity, traffic does not affect the hardcoding of the corresponding light's delay. Thus, in order to better handle this rising demand, traffic control needs to be optimized and simulated. The research objectives of this study include designing an adaptive traffic signal control mechanism that dynamically adjusts signal durations based on vehicle count, improving traffic flow efficiency, and reducing congestion. The system aims to incorporate computer vision and artificial intelligence techniques, specifically using deep learning models such as YOLO, for accurate vehicle detection and classification. Additionally, priority is given to emergency vehicles such as ambulances and fire brigades. When these vehicles are detected, the system automatically activates the green signal in their lane to ensure uninterrupted passage. This enhances emergency response times and improves overall traffic safety. The scope of the study extends to urban road networks where real-time traffic monitoring can significantly enhance traffic signal control. This system is designed to be scalable, making it applicable to multiple intersections within a city. The research also considers the integration of the proposed system with existing smart city infrastructure, ensuring compatibility with various traffic management policies. However, challenges such as varying weather conditions, system scalability, and hardware limitations are considered within the scope to assess the feasibility of real-world deployment. The contributions of this research include the development of an AI-driven real-time traffic monitoring system, implementation of an optimized traffic signal control algorithm, and enhancement of traffic flow efficiency through data-driven decision-making. By employing video-based detection instead of traditional sensor-based approaches, the study introduces a more flexible and accurate method of traffic management. The proposed system aims to minimize congestion, reduce fuel wastage, and improve road safety, contributing to the advancement of smart and sustainable urban mobility solutions [1-3].

2. Method

The Dynamic Traffic Control System is an AI-powered solution that uses video-based traffic analysis to monitor and adjust traffic signals in real-time. By integrating image processing and computer vision, the system optimizes traffic flow and reduces congestion efficiently. The system starts with data acquisition, where high-resolution cameras capture real-time traffic conditions. Edge computing preprocesses the data before it is sent for analysis. The video is processed at 4 frames per second (FPS), and labeled data is used to train machine learning models for accurate traffic detection. For traffic analysis, the system employs YOLO (You Only Look Once) for real-time vehicle detection and classification. It identifies different types of vehicles and calculates traffic density by counting vehicles per frame. A Moving Average Method smooths fluctuations, ensuring precise congestion estimation. The Traffic Control Algorithm dynamically adjusts signal durations based on congestion levels. High-density lanes receive extended green light times, while low-traffic lanes have shorter signals. Emergency vehicles are prioritized by switching signals instantly to provide an unobstructed path. This ensures efficient traffic flow and reduces overall waiting times. The system's performance is evaluated based on traffic flow efficiency, detection accuracy, processing speed, and scalability. It continuously improves using AI models and adaptive strategies to enhance real-time traffic management. By dynamically adjusting signals based on real-time conditions, the system minimizes congestion, improves travel efficiency, and provides a smarter urban traffic control solution. The architecture follows a cyclic loop, ensuring continuous operation of the system. The process begins with the camera component being activated. This component is responsible for capturing live video footage of the road and traffic conditions in real time. Once the video is captured, it undergoes processing where the system analyzes the footage to determine the density of vehicles on the road. This analysis is performed using image and video processing techniques, which help in identifying the number of vehicles present in a particular lane or intersection. Based on the calculated traffic density, the system then proceeds to the decision-making phase. Here, the system determines the optimal duration for each traffic signal by prioritizing lanes with higher congestion to reduce traffic buildup effectively. After the decision has been made, the traffic lights are adjusted accordingly. The signal timings are dynamically set based on the detected traffic conditions, ensuring smooth and efficient traffic management. This entire process is continuously repeated for all signals, ensuring real-time adaptive traffic control to improve overall road efficiency and reduce congestion, Shown in Figure 1 [4-7].

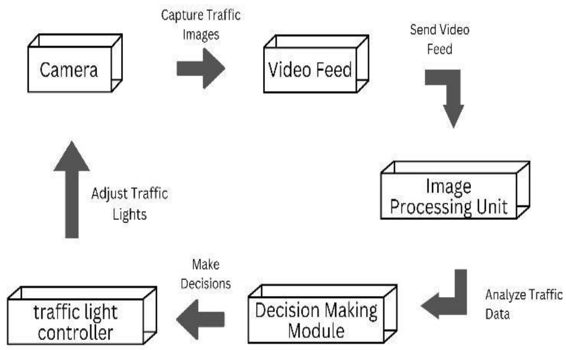

Figure 1 System Architecture

3. Literature Review

Several studies have explored traffic signal optimization using IoT, sensor-based approaches, and AI models. Traditional systems rely on fixed timers or pressure-based sensors, which lack real-time adaptability. Previous works have focused on using neural networks and reinforcement learning techniques for adaptive signal control. However, challenges such as weather conditions affecting sensors and the high cost of implementation remain. Our research differentiates itself by utilizing a video-based AI system with a focus on real-world feasibility and smart city integration. This approach enhances accuracy by eliminating sensor-related errors and ensures better scalability for urban environments. Additionally, integrating cloud-based data processing can further improve decision-making by analyzing long-term traffic patterns.

4. Results and Discussion

4.1. Results

The project successfully implements a Dynamic Traffic Control System using video and image processing to optimize traffic flow. By utilizing YOLO for real-time vehicle detection, it dynamically adjusts traffic signals to reduce congestion, improve travel efficiency, and enhance road safety. The system is scalable, efficient, and more accurate than traditional sensor-based methods [8-10].

4.2. Table

The table 1 represents the density-based traffic signal timings for four cameras installed at intersections. Traffic density is measured in vehicles per frame using video-based image processing. The green signal duration is dynamically adjusted based on traffic density, with higher density lanes receiving longer green signals. The red signal duration is calculated by summing the green signals of the remaining three cameras, following a clockwise sequence from Cam 1 to Cam 4. This method ensures efficient traffic flow, reduced congestion, and quick emergency vehicle passage.

Table 1 Result Analysis

Camera	Traffic Density (vehicles/frame)	Green Signal Duration (seconds)	Red Signal Duration (seconds)
Cam 1	15	40	170
Cam 2	25	55	155
Cam 3	10	35	175
Cam 4	30	65	145

4.3. Discussion

The Dynamic Traffic Control System helps reduce traffic jams by using real-time video analysis instead of old fixed-timer traffic lights. It uses YOLO AI technology to detect and count vehicles, adjusting signal timings based on actual traffic conditions. This system improves traffic flow, reduces waiting times, and saves fuel by preventing unnecessary stops. It is also scalable, meaning it can work across multiple intersections and fit into smart city plans. Additionally, it enhances road safety by giving priority to emergency vehicles and reducing congestion-related accidents. Compared to older sensor-based systems, video-based detection is more accurate and reliable, even in different weather conditions. Overall, this system makes city traffic smoother, faster, safer.

Conclusion

The Dynamic Traffic Light Control System using video and image processing significantly enhances traffic management by optimizing flow, reducing congestion, and improving road safety. Through real time vehicle detection and traffic density estimation, the system adjusts traffic light timings dynamically, prioritizing emergency vehicles when needed. With user-friendly interface and robust data logging, it supports efficient operations and future traffic analysis. This system addresses current traffic challenges and aligns with smart city initiatives, contributing to safer and more efficient urban transportation.

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