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Intelligent Traffic Control System: A Fusion of IoT, Image Processing, and Supervised Learning

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Abstract

The issue of urban traffic congestion is becoming more and more prevalent, causing time wastage, higher fuel usage, and environmental harm in cities across the globe. To make matters worse, traditional traffic signal systems find it difficult to adjust to changing traffic patterns. To precisely estimate vehicle counts and identify patterns of traffic congestion in urban areas, the suggested smart traffic management system makes use of image processing techniques, including supervised learning. Real-time traffic data is gathered and sent for analysis via IoT connectivity. To maximize traffic flow and reduce wait times, the system's adaptive traffic light control automatically modifies signal timing based on traffic density. To maximize traffic flow and reduce wait times, the system's adaptive traffic light control automatically modifies signal timing based on traffic density. Improved features that enable drivers to make educated judgments, such as emergency vehicle provisions and an intuitive GSM interface, further increase traffic efficiency. The system's advantage over traditional fixed-time traffic light control systems is shown by comparative performance evaluations, indicating a promising development in urban traffic management techniques. The integration of autonomous cars, predictive analytics for proactive modifications, multi-modal transportation integration, and dynamic route optimisation are among the future possibilities for smart traffic management. Furthermore, using the system to track environmental effects might provide insightful information for resolving issues with sustainability and urban congestion.

Keywords: Supervised Learning, Internet of Things, Image Processing, Vehicular Density

INTRODUCTION

Traffic congestion has grown to be a serious issue in recent years. Adding extra lanes to prevent congestion was an effort at an early solution, but this is becoming less and less practical. To make greater use of the current infrastructure, modern systems emphasize improved information and control. Better vehicle detection, such as wide-area detectors, is required due to the increasing reliance on traffic surveillance and the quest for better traffic information. On the other hand, non-invasive detectors placed beyond the pavement's edge are being sought after due to the high costs and safety risks associated with lane closures. Vehicle tracking using image processing [1] is one method that shows promise. It can provide new and classic traffic characteristics including lane shifts and vehicle trajectories, in addition to flow and velocity

As opposed to only recording detector occupancy, actual density may be calculated since the vehicle tracks, or trajectories, are monitored across a portion of the highway[2]. The conventional traffic characteristics are more stable than similar readings from point detectors, which can only average over time since they average trajectories across space and time.

By identifying lane change maneuvers or acceleration/deceleration patterns [3] that are suggestive of incidents outside the camera's field of view, as well as by detecting stopped vehicles within the camera's field of view, the additional information from the vehicle trajectories may improve incident detection.

Through the application of image processing techniques, including supervised learning, the suggested smart traffic management system offers an advanced resolution to issues related to urban congestion. Supervised learning techniques are

used to collect and interpret real-time traffic data when there is Internet of Things connectivity. To maximise traffic flow and reduce wait times, the system's adaptive traffic light control automatically modifies signal timing based on traffic density. Improved features that enable drivers to make educated judgments, such as emergency vehicle provisions and an intuitive GSM interface, further increase traffic efficiency. The system's advantage over traditional fixed-time traffic light control systems is shown by comparative performance evaluations, indicating a promising development in urban traffic management techniques.
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II. PROPOSED METHODOLOGY

One major issue that affects economies, communities, and the environment is urban traffic congestion. Conventional traffic signal systems sometimes have trouble adjusting to changing traffic patterns, which causes annoyance and inefficiency. In order to address this issue, our suggested solution combines real-time data collection, sophisticated picture processing, and dynamic traffic management via an Internet of Things network in a synergistic manner..

Intelligent Image Processing
The system's eyes are strategically positioned cameras at important junctions, which record a constant stream of video data. Subsequently, advanced image processing methods are used to this raw visual data. By using supervised learning models that have been trained on extensive picture datasets, the system converts these video frames into insightful information. With exceptional accuracy, individual cars may be identified using high-precision object identification and counting algorithms, which provide a quantitative picture of the number of vehicles at each junction.

IoT connectivity
The information highway that allows for the quick transmission of these vital density estimations is a strong Internet of Things network. The system can make deft judgments in real time because of this real-time data stream, which presents a dynamic picture of traffic situations across the city. Envision a metropolis where traffic information pulses via unseen arteries, continuously providing the central nervous system with the most recent data.**Adaptive traffic control**
Our solution's core, adaptive traffic management, makes the most of the collected data. Sophisticated algorithms thoroughly examine the vehicle density data in real-time, offering a detailed comprehension of traffic flow patterns. Equipped with this knowledge, the system dynamically modifies the timing of the traffic lights at every junction. This clever orchestration reduces wait times and eases congestion by optimizing traffic flow. Imagine it as a conductor deftly altering an orchestra's speed, making sure every instrument contributes to the perfect flow.

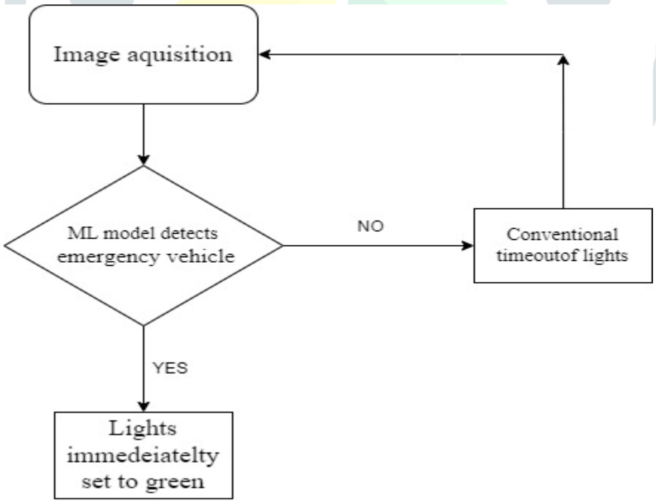

Figure1:Block Diagram of Proposed Adaptive Traffic System

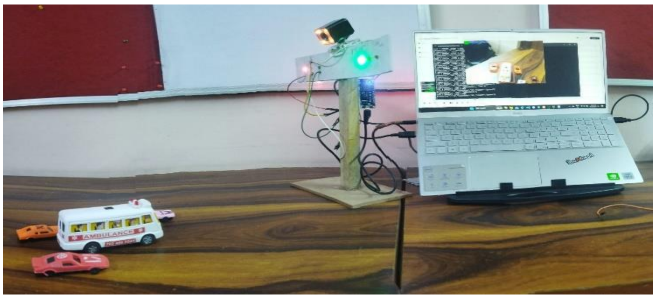

Figure2: Adaptive Traffic System Model

The depicted model showcases an adaptive traffic system, characterized by a stand housing traffic signals equipped with a fixed camera. To develop this system, our team utilized a machine learning (ML) model trained on miniature toy automobiles. These models were essential for simulating real-world traffic scenarios and training our ML algorithms effectively. Additionally, we integrated LED lights controlled by an ESP microcontroller into the system. The microcontroller receives signals from the ML model and orchestrates the responses by manipulating the LED lights accordingly. This setup effectively demonstrates how the ML model's decisions translate into real-time control of traffic signals, showcasing the adaptability and efficacy of our developed system..

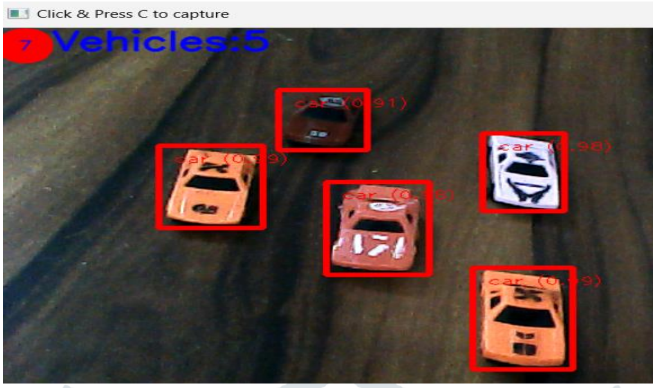

Figure3 : Detection of 5 vehicles with display of vehicle count

The given image demonstrates how the ML model works for counting and detecting vehicles. The machine learning model has been trained to precisely identify vehicles in its range of view and then count how many of them there are through supervised learning. Since no emergency vehicles have been spotted in this situation, the traffic signal lights function according to a conventional set timeout, which is normally set at 20 seconds.

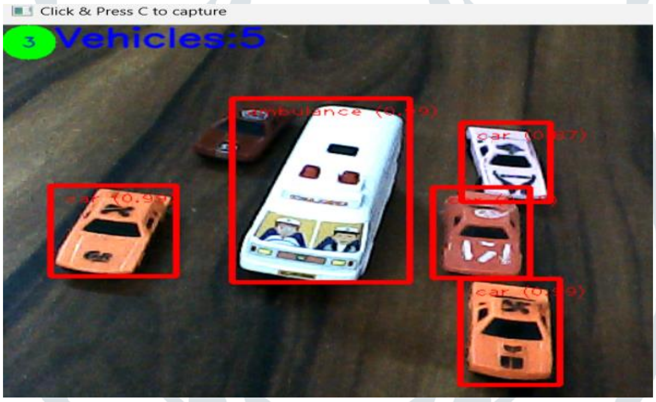

Figure 4: Detection of vehicles and ambulance and vehicle count

In the depicted image, the ML model showcases its capability in detecting vehicles, including emergency vehicles such as ambulances, while also accurately counting their presence. Leveraging supervised learning techniques, the ML model has been trained to swiftly identify emergency vehicles within its observation range. When an ambulance is detected, the traffic signal system dynamically adjusts, immediately switching the lights to green and maintaining this status until the ambulance has safely passed through the intersection.

This real-time response mechanism exemplifies the practical application of supervised learning algorithms in traffic management systems. By prioritizing emergency vehicles, such as ambulances, the ML model contributes significantly to enhancing traffic efficiency and emergency response times. This seamless integration of ML-driven vehicle detection with adaptive traffic control mechanisms underscores the potential for advanced technologies to improve safety and streamline urban mobility

Other Related Works

- Reference [4] proposed an automated traffic signal control system utilizing cameras, IR sensors, and IoT. The study enabled dynamic changes in traffic signal colors through an IR sensor-based method. Data from the sensors, transmitted via Wi-Fi, was received by a Raspberry Pi controller. The system aimed to eliminate unnecessary wait times for vehicles in densely populated areas.

- Reference [1] presents an Internet of Things (IoT)-based traffic control system that uses a Wi-Fi transceiver to send vehicle count data and MATLAB for image processing. This technology uses the density of the previous signal to adapt to the next one, although it may work better if it uses direct cloud communication rather than the Wi-Fi transceiver. Hardware from both Arduino and Raspberry Pi was used in the system.

- Reference [6] proposed traffic congestion control using continuous infrared light sensors, detecting vehicle presence based on reflected light intensity. Although offering a framework for smart traffic routing, the sensors' reliability was compromised by fluctuations in temperature and humidity conditions.

- In reference [3], the two-point time ratio method alongside piezoelectric sensors effectively identifies and classifies vehicles based on pick-up speed. Additionally, implementing a TinyML(ML integrated with sensors) model enhances traffic flow management by accurately forecasting optimal times for green signals.

- In [9] the author has presented three machine learning techniques used for short-term congestion prediction using vehicle trajectory available for connected vehicles. Two types of prediction models were developed i.e. offline models that are built using historical data and online models that are updated in real time.

Experimental Results

Our suggested solution seeks to alleviate the shortcomings of conventional traffic management techniques by utilising the synergistic power of these networked technologies. Among the anticipated advantages are:

1) Decreased congestion is achieved by avoiding delays and enhancing traffic flow with the use of dynamic signal timing.
2) Better air quality: Lower emissions and cleaner air are produced by shorter idling periods..
3) Productivity gains: reduced travel times result in higher output and financial gains.
4) Intelligent city infrastructure: Creating more flexible and data-driven traffic control strategies helps create more intelligent and effective cityscapes

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CONCLUSION

The proposed method, which optimises traffic flow and enhances sustainability by integrating IoT, supervised learning, and image processing, offers a viable solution for urban traffic congestion. The proposed system marks a major development in urban transport management as it solves the economic, sociological, and environmental challenges associated with congestion by dynamically altering traffic signal timings depending on real-time vehicle density.

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