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Smart Traffic Management System

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Abstract

Traffic congestion is a growing concern in urban areas, leading to increased travel time, fuel consumption, and environmental pollution. Traditional traffic light systems operate on fixed timers, which often fail to adapt to real-time traffic conditions, causing unnecessary delays. This project aims to develop a smart traffic management system that dynamically adjusts traffic signals based on vehicle density. The system utilizes a USB webcam to capture live road images, which are processed using YOLOv5 object detection to count the number of vehicles on each road. An Arduino UNO controls the traffic lights based on the detected vehicle count, ensuring efficient traffic flow. IR proximity sensors are integrated as a secondary detection mechanism to improve accuracy, especially in low-light conditions. The system also includes an OLED display to show real-time traffic signal status and countdown timers for improved user awareness. By implementing this intelligent traffic control mechanism, the system reduces waiting time, prevents unnecessary stoppages, and improves overall road efficiency. The use of machine learning for vehicle detection and a microcontroller-based traffic light system makes it a cost-effective and scalable solution for modern cities. This project contributes to the advancement of smart city infrastructure, promoting better traffic management and reducing congestion-related issues.

Introduction

Traffic congestion is one of the biggest challenges in urban transportation, leading to delays, increased fuel consumption, and environmental pollution. Conventional traffic light systems operate on predefined timers, which do not consider real-time traffic conditions, often causing inefficient traffic flow. To address this issue, smart traffic management systems are being developed to dynamically adjust traffic signals based on real-time vehicle detection.

This project introduces a smart traffic light system that uses a USB webcam, YOLOv5 object detection, and an Arduino UNO to control traffic signals efficiently. The USB webcam captures live traffic images, which are processed using YOLOv5, a deep learning-based vehicle detection model, to count the number of vehicles on each road. The Arduino UNO then adjusts the traffic light durations accordingly to optimize traffic movement. Additionally, IR proximity sensors serve as backup detection units to enhance accuracy, especially in low-visibility conditions. An OLED display is used to show real-time traffic signal status and countdown timers, improving driver awareness.

The system is designed to reduce waiting times, improve traffic flow, and minimize congestion, making it an efficient solution for modern cities. By integrating computer vision, microcontroller-based automation, and real-time traffic analysis, this project contributes to the development of intelligent transportation systems that can be easily implemented in urban environments.

Literature Review

1. Smart Traffic Management System

Authors: Bhuvan S T, Manjunath H.R, Abhiman H.R, Ranjan Kumar, Sachin G Rao

Summary: This paper highlights IoT integration in traffic management to alleviate congestion. It proposes a hybrid model combining centralized and decentralized traffic control strategies, utilizing AI-based predictive techniques for improved efficiency.

2. Vehicle Detection Algorithms (YOLO and Others)

Authors: Md. Jahin Alam et al.

Summary: The paper explores modern vehicle detection using machine learning models such as YOLO. The YOLOv5 Nano version provides real-time, efficient object detection, making it ideal for embedded systems like ESP32-CAM.

3.Smart Traffic Control Using AI

Authors: Paul Shruti Kanaila et al.

Summary: This research discusses video-based AI traffic analysis, improving congestion management through real-time vehicle categorization and signal optimization.

Methodology

The smart traffic management system dynamically adjusts traffic signals based on real-time vehicle detection. The working process includes the following steps:

Image Capture & Vehicle Detection

- A **USB webcam** captures live traffic images.
- The images are processed using **YOLOv5**, which detects and counts vehicles.

Traffic Signal Control

- The vehicle count data is sent to the **Arduino UNO**, which adjusts signal durations.
- The road with **higher traffic density** gets a **longer green light**.

Backup Detection using IR Sensors

- **IR sensors** detect vehicles as a backup in case of low visibility.

Real-Time Display Updates

- An **OLED display** shows traffic signal status and countdown timers.

Continuous Monitoring & Safety

- The system continuously updates signals based on traffic conditions.
- **Proper wiring and power management** ensure stable and safe operation.

This approach improves **traffic flow, reduces waiting times, and enhances urban mobility** efficiently.

Existing System

Conventional traffic management systems operate on **fixed-time signal cycles**, which do not adjust based on actual traffic conditions. These systems follow a **predefined schedule**, often causing unnecessary delays and increased congestion. Some traffic control methods rely on **Inductive Loop Sensors** embedded in roads to detect vehicles, but these solutions are expensive to install and maintain. In certain areas, **manual traffic control** by police officers is still used, but this approach is inefficient and subject to human error. Overall, the current system **lacks real-time adaptability, AI-driven decision-making, and efficient traffic flow management**, making it ineffective in handling unpredictable traffic variations.

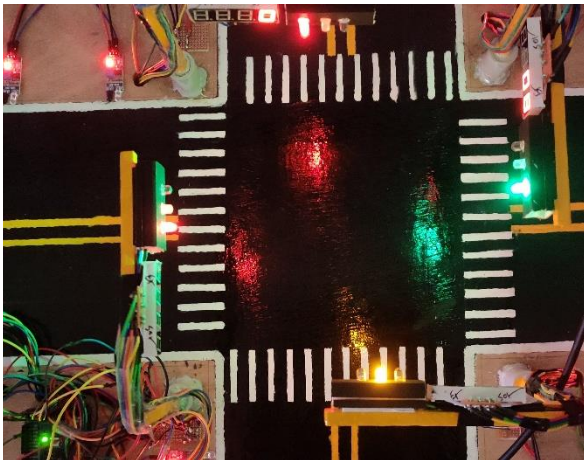

Fig: 1 Existing System

Disadvantages of the Existing System

- **Predefined Signal Cycles:** Traffic lights operate on fixed timing, causing inefficiencies when some lanes experience heavy congestion while others remain empty.
- **Limited Vehicle Sensing:** IR sensors only detect vehicles near the stop line, making them unsuitable for monitoring traffic flow over long distances.
- **Lack of AI-Based Processing:** The system does not utilize real-time image recognition, preventing it from distinguishing vehicle types or accurately assessing congestion.
- **Poor Scalability:** Expanding the system to accommodate new roads or modifying traffic rules requires manual adjustments, making it less adaptable.
- **No Intelligent Prioritization:** While emergency vehicle detection can be integrated, the system lacks AI-driven recognition to automatically prioritize essential vehicles in real time.

Proposed System

The proposed **AI-Based Traffic Light Control System** utilizes image-based vehicle detection to optimize traffic signal timing dynamically. A **laptop camera** captures live traffic footage, and an AI model processes the images to detect and count vehicles in real time. Based on the vehicle density, an **Arduino UNO** adjusts the green light duration for each road while maintaining synchronization with the red light on the opposite side.The system alternates signal control between the two roads, ensuring fair traffic distribution. A **countdown timer** displays the remaining signal time, providing clear information to drivers. By continuously monitoring traffic conditions, this system enhances road efficiency, reduces congestion, and improves overall traffic management.

Advantages

- **Real-Time Traffic Optimization:** The system uses a **laptop camera with AI-based vehicle detection** to dynamically adjust signal timing based on traffic density, reducing unnecessary wait times.
- **Efficient Traffic Flow:** By prioritizing the road with higher vehicle density, the system ensures **smooth and balanced** traffic movement.
- **Accurate Vehicle Detection:** Image-based processing provides **precise vehicle counting**, improving traffic signal efficiency.

- **Energy Efficient & Cost-Effective:** Unlike fixed-timing systems, **dynamic signal control** optimizes energy consumption and reduces idle time at signals.
- **Scalability & Flexibility:** The system can be **expanded to multiple intersections** and adapted to different traffic patterns without major reconfiguration.
- **Improved Road Safety: AI-driven monitoring** helps reduce congestion and potential accidents caused by inefficient signal timing.

FLOW CHART

The **AI-Based Traffic Light Control System** begins by capturing road images using a **laptop camera**, which are processed by an **AI model** to detect and count vehicles. The count is sent to **Arduino UNO**, which checks if the vehicle number exceeds a set threshold. If traffic is heavy, the **green signal duration is extended**; otherwise, the default timing is applied. Finally, the **Arduino updates the traffic lights**, ensuring **real-time, dynamic, and efficient traffic management**.

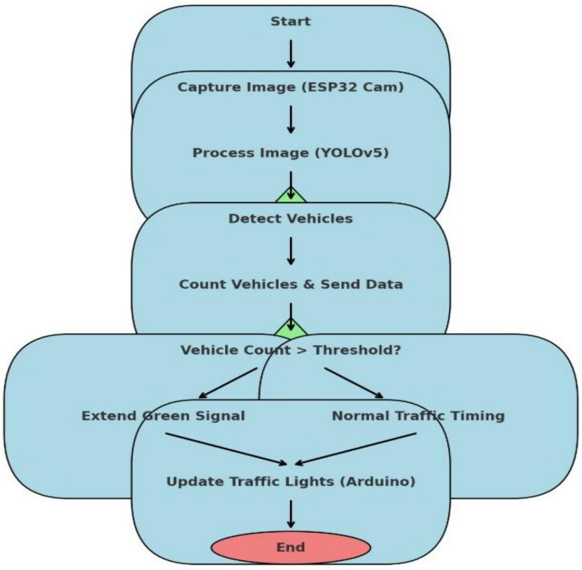

Fig: 2 Flow chart

Use Case Diagram

The **UML use case diagram** represents the **AI-Based Traffic Light Control System**, where a **laptop camera** captures real-time traffic images, and an **AI model** processes and detects vehicle count. The data is sent to **Arduino UNO**, which analyzes traffic density to determine the appropriate signal timing. Finally, the **Arduino dynamically adjusts the traffic lights**, displaying the countdown timer to optimize traffic flow efficiently.

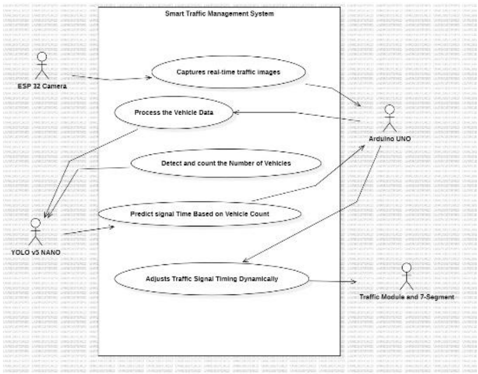

Fig:3 Use Case Diagram

Conclusion

The AI-Based Traffic Light Control System successfully enhances traffic management by utilizing real-time image processing and AI-based vehicle detection. By dynamically adjusting signal timings based on traffic density, the system reduces congestion, minimizes wait times, and improves road efficiency. The integration of Arduino UNO and a laptop camera ensures a cost-effective and scalable solution adaptable to various intersections. This project demonstrates the potential of AI-driven automation in smart city infrastructure, leading to safer, smarter, and more efficient traffic control systems.

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