IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Automatic Traffic Light Management System Using Computer Vision

[1]Preet Shah, [2]Dhruvil Shah, [3]Pusti Shah, [4]Rishita Joshi, [5]Dhara J Sangani
[1]Student, [2]Student, [3]Student, [4]Student, [5]Assitant Professor
[1]Electronics and Communication,
[1]Vishwakarma Government Engineering College, Ahmedabad, India

Abstract:

In metropolitan areas, traffic congestion at intersections presents a major challenge to both efficiency and safety. This study proposes a real-time traffic management system that leverages computer vision and artificial intelligence to optimize traffic signal timings based on dynamic vehicle density analysis. The system employs four strategically placed cameras at a crossroad, capturing live video feeds from each approach. Real-time vehicle detection and tracking are performed using OpenCV, a widely adopted computer vision library. By analysing vehicles within predefined regions of interest (ROIs) in each camera feed, the system calculates vehicle densities for all approaches. An AI-driven algorithm integrates the data from all cameras to dynamically adjust traffic signal timings, prioritizing green light durations for roads with higher vehicle densities. The primary objective is to enhance traffic flow, minimize congestion, and improve overall intersection efficiency. Experimental results demonstrate the system's effectiveness and feasibility, highlighting its potential for practical implementation in smart city infrastructures.

Key Words: Computer Vision, Real time vehicle detection, Data analysis, Region of Interest, Smart city infrastructure

I.INTRODUCTION

Efficient urban traffic management is crucial for optimizing transportation flow and minimizing congestion at intersections. Traditional traffic signal systems often struggle to adapt to dynamic traffic patterns, leading to inefficient green signal allocation across intersection approaches. One key issue is the uniform distribution of green signal time, which fails to account for varying vehicle densities. High-density approaches may suffer from congestion due to insufficient green time, while low-density approaches may experience delays caused by excessive green time. To overcome these limitations, this research proposes a real-time traffic management system that leverages computer vision and artificial intelligence (AI). The system utilizes cameras and advanced algorithms to detect vehicles and analyze traffic density, enabling dynamic adjustments to traffic signal timings based on real-time conditions. By prioritizing green signals for high-density approaches, the system optimizes traffic flow and improves intersection efficiency. The primary objective is to design and implement a prototype system that demonstrates superior traffic management performance compared to traditional fixed-time signal systems. This study highlights the potential of computer vision and AI technologies to transform urban transportation infrastructure, paving the way for intelligent and adaptive traffic signal control in modern cities.

Existing System

Traffic signal control systems in India predominantly operate using fixed red, yellow, and green lights with predefined time intervals for each phase. Unlike systems in many developed nations, these fixed-time signal plans lack advanced detectors and adaptive technologies, resulting in significant inefficiencies in managing traffic flow. The inability of fixed-time systems to adjust to real-time traffic conditions exacerbates congestion and delays. Intersections allocate green signal times uniformly, regardless of varying traffic volumes. This often leads to long queues and delays in high-density areas, while low-density areas experience unnecessary idle times, wasting valuable resources and road capacity. The reliance on outdated fixed-time signal systems underscores the urgent need for modernization. Introducing intelligent and adaptive traffic control technologies can optimize signal timings based on actual traffic demand, significantly improving traffic flow efficiency and enhancing overall safety at intersections.

Proposed System

This research presents an innovative real-time traffic management system aimed at overcoming the limitations of conventional fixed-time traffic signal control systems in India. The proposed system integrates cutting-edge technologies such as OpenCV for computer vision, ESP32 microcontroller boards for efficient data processing, and dedicated controllers for managing LED signals and signal timing. The key components and functionalities of the proposed system are as follows:

Camera Deployment and Data Processing:

Deployment of Cameras: Cameras are strategically installed at intersection approaches to capture live video streams of traffic movements, ensuring comprehensive coverage of all lanes.

Vehicle Detection and Tracking: OpenCV, a powerful computer vision library, is employed to implement vehicle detection and tracking algorithms. These algorithms run efficiently on microcontroller boards such as the ESP32.

Real-Time Data Processing: The ESP32-CAM module processes the live camera feeds in real-time, calculating vehicle densities and analysing traffic patterns dynamically. This data serves as the basis for adaptive traffic signal control.

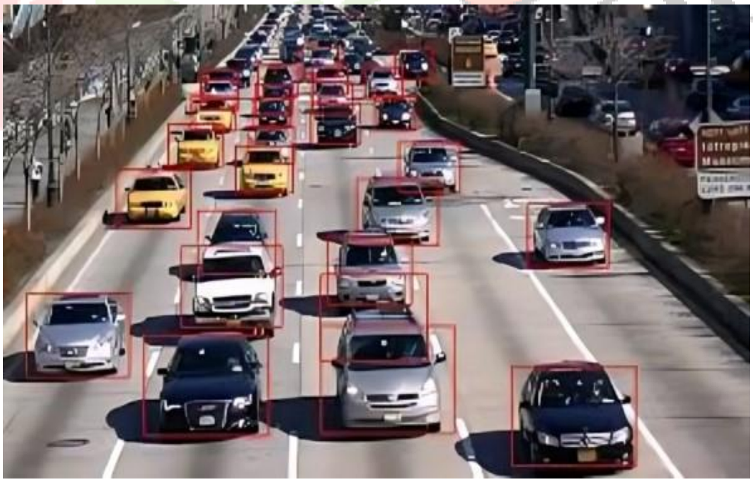

fig 1: vehicle detection using computer vision

Traffic Density Analysis: Algorithms are implemented on the ESP32 to calculate vehicle density for each intersection approach by detecting vehicles within predefined regions of interest (ROIs)The system performs continuous monitoring of traffic density, enabling dynamic assessment of traffic demand and congestion levels in real time.

Dynamic Signal Timing Adjustment: A control system is developed using dedicated controllers to dynamically adjust traffic signal timings based on the analysed traffic density data. This adaptive approach ensures efficient signal allocation, prioritizing high-density approaches to optimize traffic flow and minimize congestion.

Integration of traffic density information: Traffic density information calculated by the ESP32 is seamlessly integrated into the signal control system. This data-driven approach enables the optimization of green signal allocation, ensuring efficient traffic flow by dynamically prioritizing high-density approaches.

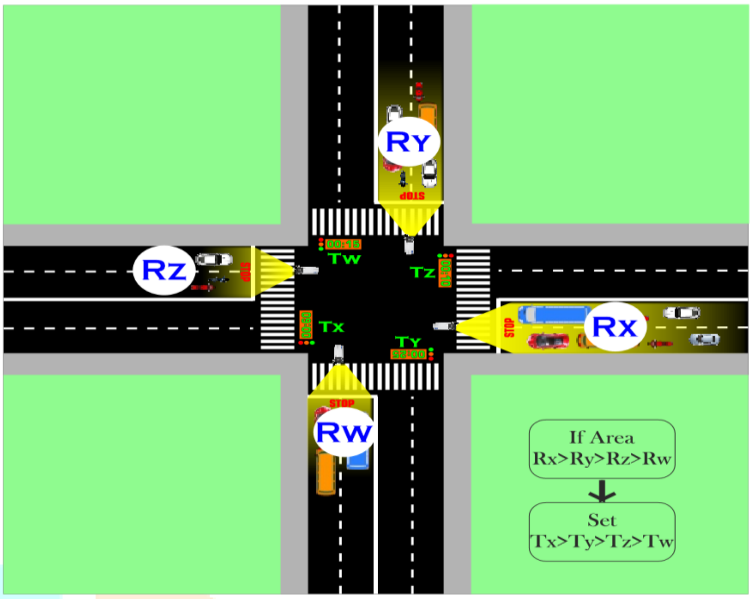

fig 2: timing adjustment logic

Adaptive Control Strategy: An adaptive control strategy is designed and implemented to utilize real-time traffic data from the ESP32 for dynamically adjusting signal timings. This ensures the system responds effectively to changing traffic conditions, enhancing intersection efficiency . Historical traffic data and predictive analytics are incorporated into the system to optimize signal plans for varying traffic volumes and patterns. This enables proactive traffic management by anticipating peak periods and adjusting signal timings accordingly.

User Interface and Monitoring: A user-friendly interface is developed for monitoring and visualizing traffic data, such as vehicle counts, traffic densities, and current signal statuses in real time. The interface empowers traffic operators by providing tools to monitor system performance and, if necessary, manually override signal settings to address specific traffic scenarios or emergencies.

Evaluation and Validation: Signal Control Module: Comprehensive evaluation of the proposed. Implement a separate controller responsible for system through field trials and simulations to managing traffic signal timings based on the assess its effectiveness in improving intersection received traffic density data. efficiency and reducing congestion. Validation of the system's performance against within the signal control module to dynamically traditional fixed-time signal control methods to adjust green signal allocation for optimized traffic Management.

Emergency Vehicle Detection: The system can be trained to detect emergency vehicles, such as ambulances, fire trucks, and other emergency

medical services (EMS) vehicles, using advanced video processing techniques. By leveraging OpenCV for real-time vehicle detection, the system identifies these priority vehicles and, after a brief buffer of 5 seconds, adjusts the traffic signal to immediately turn green for the emergency vehicle. This ensures that emergency vehicles can pass through intersections with minimal delay, improving response times during critical situations.

fig 3: detection of emergency vehicle

II.SYSTEM ARCHITECTURE

Camera Deployment: Install multiple cameras at strategic locations near intersection approaches to capture live video feeds of traffic.

Microcontroller (ESP32) for Data Processing*:* Utilize microcontroller boards like ESP32CAM module to receive processed data from the video. Implement algorithms on ESP32 to calculate vehicle density and analyze traffic patterns based on the detected vehicles.

Traffic Density Analysis: Use the data processed by ESP32 to compute real-time traffic density for each intersection approach. Transmit traffic density information to the signal control module for dynamic adjustment of signal timings.

Signal Control Module: Implement a separate controller responsible for managing traffic signal timings based on the received traffic density data. Develop an AI-driven decision-making model within the signal control module to dynamically adjust green signal allocation for optimized traffic flow. Ensure synchronization and coordination between multiple signal controllers for efficient intersection management

Key Components: Cameras, Video Processing Module (OpenCV), Microcontroller (ESP32) , Signal Control Module

Benefits: Real-time optimization of traffic signal timings based on actual traffic conditions. Enhanced traffic flow, reduced congestion, and improved intersection efficiency. Emergency vehicle detection and prioritizing its lane to reduce its wait time. Adaptive control strategies to accommodate varying traffic volumes and patterns.

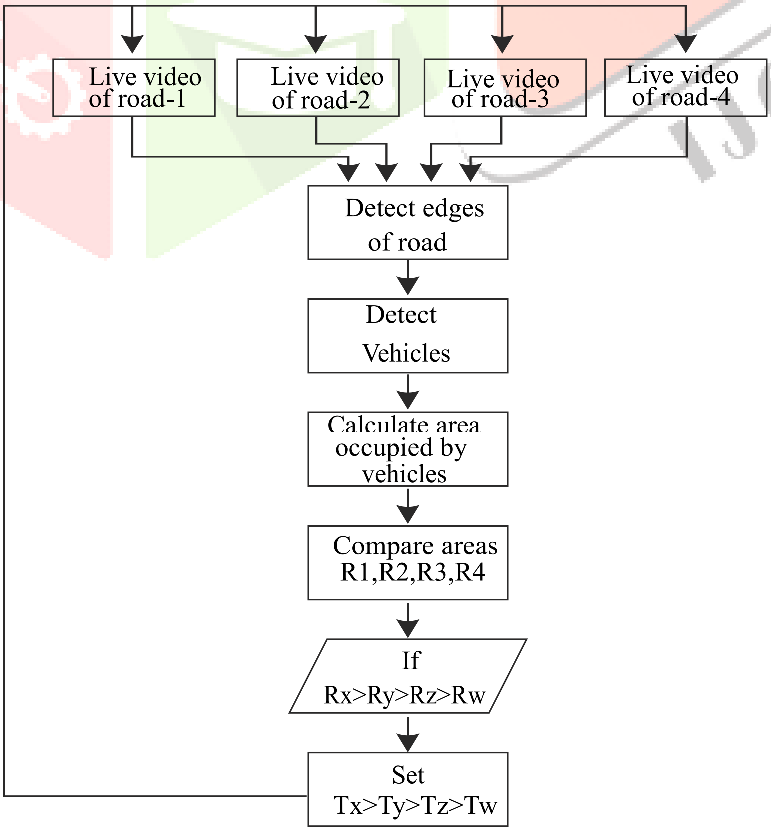

fig.4: flowchart for implementation of logic

III. Working & Calculation:

The components required to get desired outcome are: ESP32 (02), ESR32 CAM(04), AC-DC converter, timer display, lights One ESP module is configured as the master device, tasked with collecting input from four ESP CAM modules as shown in Fig.5. It analyses the data to evaluate real-time traffic conditions and then transmits control commands wirelessly via Bluetooth to a second ESP module operating in slave mode. The slave ESP module is connected to four traffic signal lights, adjusting their timing based on the received commands. By leveraging the built-in Bluetooth capabilities of the ESP modules, this system enables seamless communication and efficiently manages traffic by dynamically adapting signal timing to the captured conditions. The basic data flow diagram is shown as below:

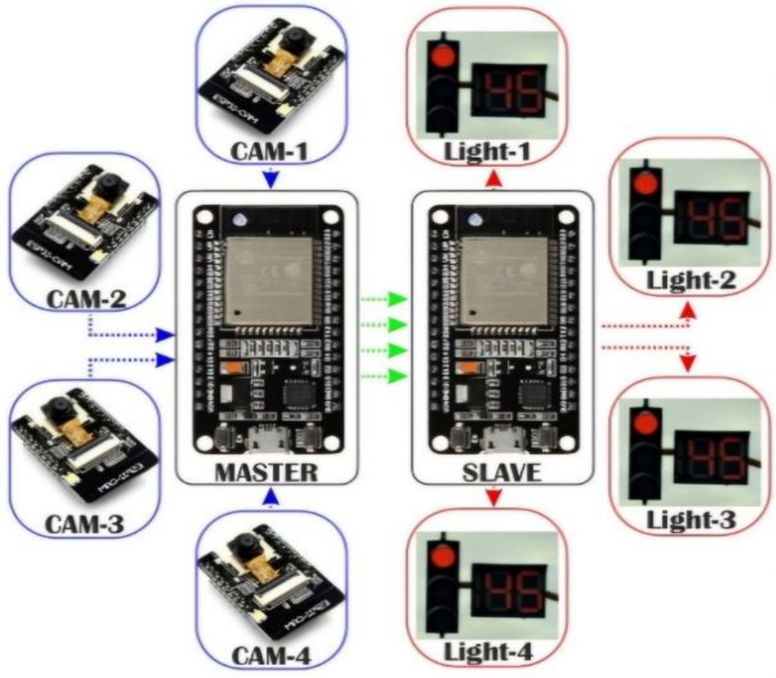

fig 5: basic data-flow diagram

The Python code implements vehicle detection and counting in video streams using the MobileNet SSD (Single Shot Detector) framework. It processes video frames in real time, identifies vehicles, and highlights them with bounding boxes and annotations. The solution is tailored for use in applications such as smart traffic management systems, surveillance, and vehicle monitoring, combining efficiency and accuracy with scalability.

Objective: The code aims to automate the process of detecting vehicles in a video, offering a real-time count of vehicles. This capability is pivotal for optimizing traffic flow, reducing congestion, and enhancing urban mobility in smart city initiatives.

Key Components

Deep Learning Model: The code uses the MobileNet SSD model, which is lightweight and optimized for resource-constrained environments. Pre-trained files (deploy.prototxt for network configuration and mobilenet_iter_73000.caffemodel for model weights) are utilized to detect 21 object classes, including vehicles like "car," "bus," "motorbike," and "truck."

Input and Output: The input is a video file (s6.mp4), processed frame by frame using OpenCV's cv2.VideoCapture(). Each frame is annotated with bounding boxes and labels for detected vehicles. The count of vehicles is also displayed on the frame.

Vehicle Detection Process: Preprocessing: Frames are resized to 300x300 pixels and converted into blobs using cv2.dnn.blobFromImage(). This ensures compatibility with the MobileNet SSD model.

Inference: The blob is passed through the model to extract detections. Only objects with a confidence score greater than 0.4 are considered valid.

Vehicle Identification: Detected objects are cross-checked with predefined vehicle classes, and bounding boxes are drawn around them.

Visualization: Annotated frames are displayed using matplotlib for better compatibility in environments like Jupyter Notebook.

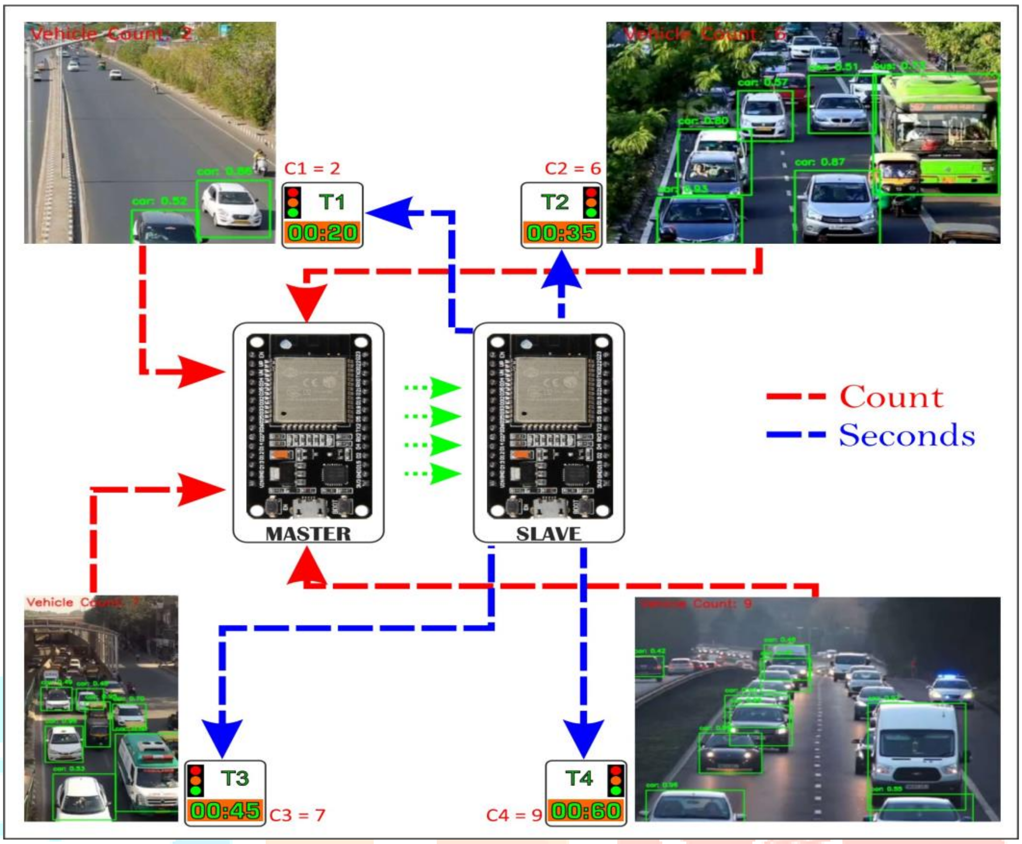

fig 6: algorithm diagram

Calculations :

Total time: 160 sec

Min. green light time: 20 sec

Max. green light time: 60 sec

Red light time = Total time - Green light

Time logic for setting green light time:

If C1< C2 < C3 < C4 ,

then T1< T2<T3 < T4

Thus the desired outcomes are as follows :

C1 = 2 ---> T1 = 20 sec

C2 = 6 ---> T2 = 35 sec

C3 = 7 ---> T3 = 45 sec

C4 = 9 ---> T4 = 60 sec

IV. CONCLUSION:

In summary, this research presents an innovative real-time traffic management system that combines computer vision, artificial intelligence (AI), and microcontroller-based processing to dynamically control traffic signals at intersections. Utilizing technologies such as OpenCV on microcontroller platforms like the ESP32, the system adjusts signal timings based on real-time traffic conditions, thereby enhancing traffic flow and minimizing congestion. The system employs an adaptive control strategy that continuously monitors traffic density and optimizes signal timings, offering a scalable and efficient solution for intersection management. Field trials and simulations have demonstrated its superiority over traditional fixed-time signal control methods in improving traffic efficiency. This advanced traffic management system marks a substantial advancement in smart transportation infrastructure, providing practical and impactful solutions to urban traffic challenges. Future research can explore further optimization and scalability, enabling broader deployment and greater impact in urban traffic management.

V.REFERENCES:

[1] International Research Journal of Engineering and Technology (IRJET) Volume: 08 Issue: 07 July 2021 Pg:(4653-4657

[2] https://www.researchgate.net/figure/Filtering-acquisition-detection-and-identification-of-vehicles-8_fig2_336365551

[3] https://images.app.goo.gl/kKxkbAUJZDKyxmiu5