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# SIGNAL CONTROL MEASURING USING TRAFFIC DENSITY

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**ABSTRACT:**
Urban traffic congestion has become a major problem worldwide, leading to long delays, wasted fuel, and harmful emissions. Traditional traffic light systems, which often run on fixed cycles or rely on basic sensors, struggle to manage the flow effectively, especially during rush hours or in busy city centers. This paper presents a smarter, AI-powered traffic control system designed to ease these issues by adapting to real-time traffic conditions at intersections.
Using live video feeds from CCTV cameras at intersections, the system leverages computer vision and machine learning techniques to monitor traffic density. The YOLO (You Only Look Once) algorithm identifies and categorizes vehicles—such as cars, buses, and motorcycles—in each lane. Based on the number and type of vehicles present, the system adjusts green light timings dynamically to prioritize lanes with heavier traffic and reduce waiting times in others. In testing, this adaptive approach improved intersection efficiency by around 23% compared to standard fixed-timer systems.
Built to work with existing infrastructure, this cost-effective solution minimizes extra hardware needs by using CCTV cameras already in place, making it a scalable option for cities of various sizes. In the future, this system could also support features like accident detection, emergency vehicle prioritization, and synchronized signals across multiple intersections, creating smoother traffic flows citywide. This AI-driven solution not only enhances traffic management but also helps reduce pollution and energy use, offering a more sustainable approach to urban mobility.

**Keywords:**
Traffic congestion, Urban traffic management, AI-powered traffic control, Real-time traffic adaptation, Intersection efficiency, Traffic density monitoring, YOLO algorithm, Computer vision, Machine learning, Adaptive signal timing, CCTV camera integration, Vehicle detection and classification, Green light optimization, Cost-effective traffic management, Emergency vehicle prioritization, Traffic flow optimization, Signal synchronization.

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## I. Introduction:

Traffic congestion has become one of the biggest challenges in rapidly growing cities, as more vehicles crowd limited roadways. This congestion leads to longer travel times, higher fuel use, and more pollution, affecting both the environment and commuters' quality of life. Traditional traffic systems, which mostly rely on fixed signal timers, struggle to handle these constantly changing conditions and often can't respond quickly enough to prevent backups. This issue is especially serious in large, densely populated cities like Mumbai and Bangalore, where congestion is often intense and prolonged.
Current methods of traffic control, like manual direction, fixed-timer signals, and electronic sensors, all have their own drawbacks. Manual control isn't practical on a large scale, while fixed timers lack flexibility for real-time conditions. Advanced sensors can be effective but are often too costly to install widely.
Thanks to advances in computer vision and AI, new Intelligent Transport Systems (ITS) are emerging as effective solutions. These systems can analyze live video from CCTV cameras at intersections to assess traffic in real-time. This paper introduces an AI-powered traffic light system that uses live footage from existing CCTV cameras to manage signal timings dynamically. By running the YOLO (You Only Look Once) object detection algorithm, it can detect and categorize different types of vehicles to estimate traffic density. The system then adjusts green light durations for each lane based on the number of vehicles, prioritizing high-density lanes to improve traffic flow.
The solution is cost-effective and scalable, making use of existing CCTV cameras, so it doesn't require much additional hardware. Simulations show that it significantly improves traffic flow compared to traditional systems. Future improvements could include prioritizing emergency vehicles, synchronizing signals across multiple intersections, and detecting traffic violations in real-time, offering a modern and versatile approach to traffic management.

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# II. Review Of Related Literature:

The paper [1] proposes an Intelligent Traffic Control System using IoT, cloud computing, and the YOLO algorithm for real-time traffic management. By incorporating IoT sensors and cameras at intersections, the system adapts traffic light timing based on vehicle flow, reducing waiting times by 60%. Machine learning with Q-learning further optimizes decision-making, enhancing efficiency in traffic control.
The research paper [2] "Smart Traffic Management System Using IoT and AI" proposes a system to dynamically adjust traffic flow based on real-time data. This system addresses challenges like urban congestion, inefficiency, and emergency response. The study highlights the potential of STM to enhance urban mobility and safety.Pinar Kirci and team [3] proposed a hand gesture detection method that leverages computer vision and image processing techniques.
This paper by [3] Y. R. S. Kumar and A. N. G. Reddy presents a real-time video monitoring system for traffic management using Raspberry Pi, aiming to optimize traffic light timings based on vehicle density. It uses image processing techniques such as background subtraction and morphological operations to detect and track vehicles.
Maria Crystal E. Orozco et al. [4] presented a novel method to detect real-time vehicular detection and classify them using deep learning and the Faster R-CNN model. The model was trained on a vehicle image dataset, which helped in increasing the accuracy and performance of the model. Then they analysed video feeds from traffic cameras and
predicted vehicle count, type, and traffic flow which was utilized to manage traffic and congestion control.
K Vidhya et al. [5] proposed a process for analysing flow that entails capturing an image at a traffic signal and converting it to grayscale.
Behrad et al. [6] proposed a method that employs ongoing video analysis of traffic frames captured through a camera. This approach utilizes image analysis to determine the vehicular density in each lane.

# III. Proposed System:

A. Overview of the Proposed System

The proposed system uses live CCTV footage from traffic junctions to calculate real-time traffic density through image processing and object detection. This visual data is processed using a vehicle detection algorithm based on the YOLO (You Only Look Once) model. This model identifies and counts different types of vehicles, such as cars, bikes, buses, and trucks, allowing the system to assess traffic density at each intersection. Based on this information, the signal-switching algorithm adjusts green light timings for each lane, while also updating red light durations for other lanes. To prevent any lane from being neglected, the green light times are kept within preset minimum and maximum limits. Additionally, a simulation was developed to demonstrate and evaluate the effectiveness of this adaptive system compared to traditional fixed-timer systems.

B. Vehicle Detection Module

For vehicle detection, the system utilizes the YOLO algorithm, which is optimized for both accuracy and speed. YOLO applies a single neural network to the entire image and divides it into regions, predicting bounding boxes and assigning probabilities for each region. This approach allows YOLO to detect multiple objects in real-time, making it ideal for monitoring traffic at busy intersections. The backbone neural network framework for YOLO is Darknet, an open-source tool that supports both CPU and GPU computation. Darknet achieves high accuracy on image datasets, using filters and pooling techniques to extract and process image features quickly.
The model was trained on a customized dataset prepared by collecting images of various vehicles and labeling them manually using the LabelIMG annotation tool. This training data was then used to fine-tune a YOLO model, setting it up to detect four classes of vehicles: cars, bikes, heavy vehicles (like buses and trucks), and rickshaws. Adjustments were made to the YOLO configuration file to reflect these vehicle types, and training continued until the model achieved a stable level of accuracy. Once trained, the model was incorporated into the system to detect vehicles in live images, and the detections are output in JSON format, containing the vehicle type, confidence score, and bounding box coordinates. OpenCV was used to draw bounding boxes around detected vehicles on the images, creating a visual representation of the traffic situation.

C. Signal Switching Module

The Signal Switching Module calculates green light duration based on the traffic density data from the Vehicle Detection Module and updates the red light durations of the other lanes. The switching algorithm receives JSON data about the detected vehicles, parses it to determine the total count of each vehicle type, and calculates a green signal time for each lane accordingly.

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Several key factors are considered in this module:
Processing Time: The time needed to analyze traffic density and adjust the green light duration determines how frequently the system can update signal timings.
Lane Count: The number of lanes at an intersection affects how green light time is distributed.
Vehicle Count by Type: Counts of cars, trucks, and motorcycles help to estimate the traffic load.
Traffic Density Calculation: Using the above factors, the algorithm calculates a density-based timing adjustment.
Start-Up Delay for Each Vehicle: The time vehicles need to accelerate and clear the intersection, especially those further back in line.
Average Vehicle Speed: The average time required for each vehicle type to cross the intersection helps inform timing decisions.
Minimum and Maximum Timing Limits: To prevent any lane from being ignored, green light times are kept within set minimum and maximum limits.
When the system is initiated, default times are set for the first cycle, while future cycle timings are dynamically adjusted by the algorithm. The system operates with two threads: one that manages vehicle detection for each lane and another that manages the current signal timer. When the current green light timer reaches five seconds, the detection module captures an image of the next direction. This way, the system can seamlessly update the timer for the next green light without introducing lag. When the current green light ends, the next lane turns green for the calculated time.
To allow time for processing, the system captures an image of the lane about to receive a green light five seconds before it turns green. The traffic density is assessed, the green signal time is calculated, and the red signal timings for other lanes are adjusted accordingly. The green light duration is calculated using a formula that factors in the number of each vehicle type and the average crossing time for each type. The result is an optimized signal time that can be further refined based on local traffic data to improve accuracy. The signals follow a set sequence, maintaining a predictable order (Red → Green → Yellow → Red), which aligns with traditional traffic systems and avoids confusion.

D. Simulation Module
To evaluate and visualize the system's performance, a simulation was created from scratch using Pygame, a library for Python game development. The simulation recreates a four-way intersection with traffic signals for each lane, displaying timers that count down the remaining time for each green, yellow, and red light phase. The simulation also keeps track of the number of vehicles that cross the intersection, showing the effectiveness of the adaptive system.
The simulation includes different types of vehicles entering the intersection from all directions, some of which may turn depending on a randomly generated choice. The entire setup is designed to mimic real-life traffic conditions, giving a realistic view of the system's impact on traffic flow. In addition to monitoring each traffic signal, the simulation also displays a timer indicating the elapsed time since the start, making it easy to compare the adaptive system with a static system.
The Pygame library, used for the simulation, offers a cross-platform set of Python modules that make it easy to develop visual and interactive simulations. Pygame leverages the Simple DirectMedia Layer (SDL) library, allowing developers to create full-featured games and multimedia programs that are highly portable across various platforms and operating systems.

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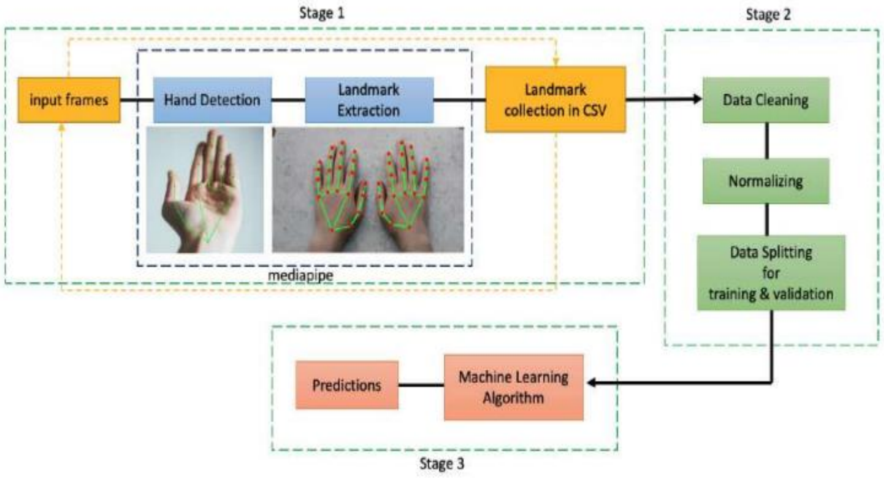


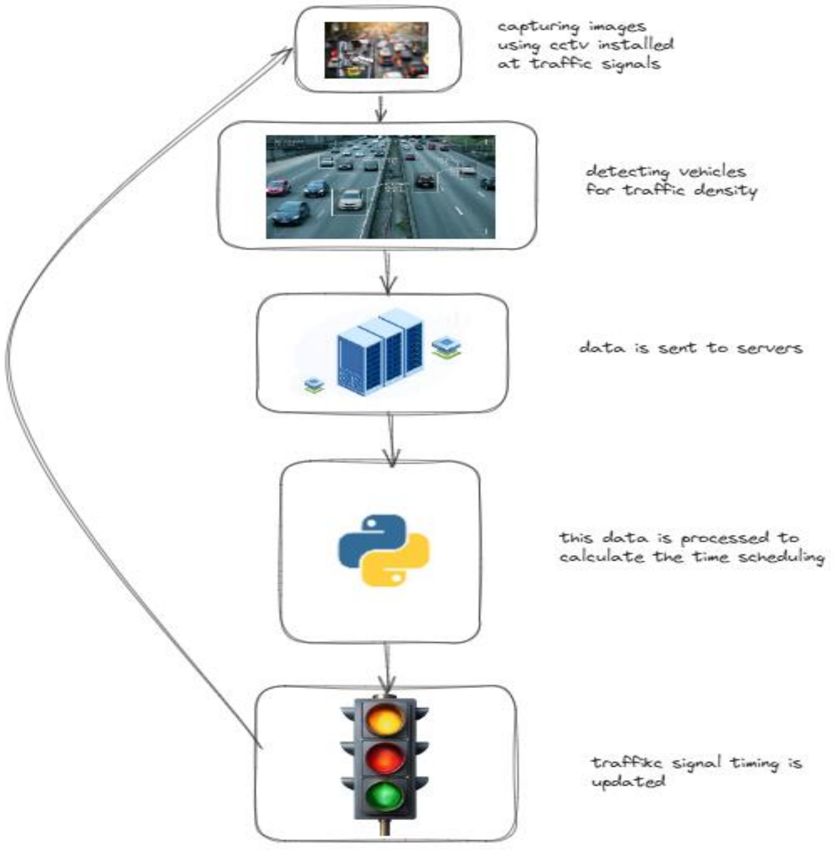


*Fig.1: System Architecture*

## IV. System Overview:

The proposed intelligent traffic control system aims to improve traffic flow at intersections by dynamically adjusting traffic light durations based on real-time conditions. Instead of relying on static timers, this system uses live video feeds from CCTV cameras to calculate traffic density and optimize signal timings accordingly.
Here's how it works: The system captures images from cameras installed at intersections and processes them to detect vehicles. This is done using a neural network-based algorithm called YOLO (You Only Look Once), which can identify

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different types of vehicles—like cars, bikes, buses, and trucks—in a single pass through the image. The model was specifically trained for vehicle detection to ensure high accuracy in identifying the unique traffic characteristics of each lane.

Once vehicle counts are identified, a traffic density measure is calculated for each lane. The signal switching algorithm then uses this data to determine the optimal green light duration for each direction. By adjusting the timing of green and red signals based on the actual number and type of vehicles present, the system can better manage congestion, reducing both wait times and idle periods at intersections.

A crucial feature of the system is that it prevents any single lane from monopolizing the green light by enforcing minimum and maximum green signal durations. This ensures that all directions have fair access to the intersection, while still adapting to varying traffic conditions in real time. The system also operates on a cyclic basis (red to green to yellow), keeping the traditional signal order to avoid confusion among drivers.

To demonstrate the effectiveness of this approach, the developers created a simulation using Pygame, a Python-based library. This simulation replicates a four-way intersection with vehicles entering from different directions and turning at random. It visually tracks the performance of the adaptive system compared to a traditional static system, clearly showing how dynamic adjustments reduce congestion and increase the number of vehicles able to cross the intersection.

In summary, this system leverages real-time video processing and adaptive signal control to better manage urban traffic. By intelligently adjusting green light durations based on traffic density, it minimizes waiting times, lowers fuel consumption, and reduces air pollution—all with a solution that's scalable, cost-effective, and compatible with existing infrastructure.

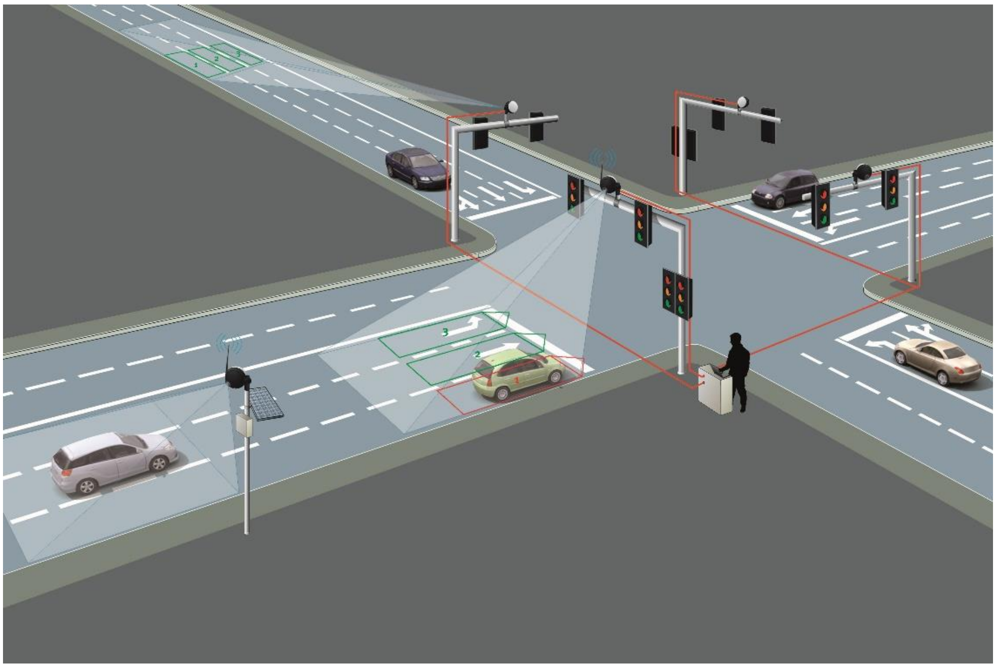

*Fig. 2: System Overview*

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## V. Conclusion:

The proposed system intelligently adjusts green light durations based on real-time traffic density, ensuring that lanes with more traffic receive a longer green light while less congested lanes wait. This approach reduces unnecessary delays and helps manage congestion more efficiently, leading to shorter waiting times and a smoother flow of vehicles. This improvement also brings environmental benefits by lowering fuel consumption and cutting down on pollution. Simulations show that this system improves traffic flow by around 23% compared to traditional systems, a significant increase in the number of vehicles passing through intersections. Further training with real-world CCTV data could make these results even more effective.

Additionally, the system has clear advantages over conventional traffic control solutions, such as pressure mats and infrared sensors. It uses existing CCTV infrastructure at many intersections, reducing setup and maintenance costs while minimizing additional hardware requirements. This makes it a scalable, cost-effective solution for busy urban areas, where it can be seamlessly integrated with current traffic management systems.

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