

Traffic Signal Control Using Density Based Adaptive Heuristic Algorithm

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Abstract - Traffic congestion has become a major issue in modern urban areas due to rapid population growth and the increasing number of vehicles. Traditional traffic signal systems operate on fixed-time schedules and cannot adapt to real-time traffic conditions, resulting in unnecessary delays, increased fuel consumption, and higher pollution levels. To overcome these limitations, an intelligent traffic management system is required. This project presents Traffic Signal Control Using Density Based Adaptive Heuristic Algorithm to dynamically regulate traffic flow at intersections. The system uses computer vision techniques to detect, track, and count vehicles from live video streams captured by roadside cameras. Based on the calculated traffic density in each lane, an adaptive heuristic algorithm determines the optimal green signal duration to ensure fair and efficient traffic movement. The backend of the system is implemented using the Flask framework with Python, while the frontend interface is developed using HTML, CSS, Bootstrap, and JavaScript for real-time monitoring and visualization. Hardware components such as microcontrollers, traffic lights, and LCD displays are integrated to control signal operations. The proposed system reduces congestion, minimizes waiting time, improves road efficiency, and lowers fuel consumption and emissions. Overall, the system contributes to the development of smart transportation infrastructure and supports the vision of intelligent and sustainable urban mobility.

Keywords-Artificial Intelligence, Traffic Signal Control, Computer Vision, Vehicle Detection, Traffic Density Estimation, Smart Traffic Management, Real-Time Camera Feed, Intelligent

1. INTRODUCTION

Traffic congestion has become a major challenge in urban areas due to rapid population growth and increasing vehicle ownership. Conventional traffic signal systems generally rely on fixed-time signal control, where signal timings remain constant regardless of real-time traffic conditions. This approach is inefficient because it does not consider variations in traffic flow across different lanes. As a result, vehicles often wait unnecessarily at signals even when other lanes are empty. Advancements in artificial intelligence and computer vision have enabled the development of automated traffic monitoring systems. Cameras installed at road intersections can capture live video feeds that can be processed to detect and count vehicles. These technologies allow traffic management systems to analyze traffic density in real time and make intelligent decisions regarding signal timings.

Smart city initiatives around the world emphasize the need for digital technologies to improve urban infrastructure and transportation systems. AI-based traffic signal control systems play an important role in reducing congestion, improving road safety, and enhancing transportation efficiency. By integrating camera-based monitoring, web platforms, and embedded control systems, intelligent traffic management solutions can provide centralized monitoring and dynamic signal control.

This article proposes an **Traffic Signal Control Using Density Based Adaptive Heuristic Algorithm** to address the limitations of traditional traffic systems. The system automatically analyzes traffic conditions and adjusts signal timings to ensure fair and efficient vehicle movement.

2. LITERATURE REVIEW

The author in[1] proposed an AI-based smart traffic management system using camera feeds and deep learning models. The system uses CNN and LSTM algorithms to detect vehicles and analyze traffic patterns. The method improved traffic flow efficiency and significantly reduced vehicle waiting time at intersections.

The study in[2] focused on AI-based urban traffic management using real-time traffic monitoring. Machine learning techniques were used to analyze traffic density and optimize signal timing. The system reduced congestion and improved transportation efficiency in urban areas.

The authors in[3] developed an intelligent traffic monitoring system using IoT sensors and computer vision. Vehicle detection algorithms were used to estimate traffic density and control traffic signals dynamically. The system improved traffic flow and minimized delays at busy intersections.

The study in[4] proposed an IoT-based smart traffic management system for smart cities. Adaptive traffic signal control algorithms were used to adjust signal timings based on traffic density. The proposed system reduced traffic congestion and improved road utilization.

The author in[5] presented an AI-driven traffic signal control system using real-time traffic monitoring. Reinforcement learning algorithms were used to optimize traffic signal timing. The system showed improved traffic signal efficiency and reduced average waiting time.

The authors in[6] proposed an AIoT-based smart traffic management system combining artificial intelligence and IoT devices. Deep learning algorithms were used to detect vehicles from camera feeds and analyze traffic density. The system achieved better performance than traditional fixed-time traffic signal systems.

The research focused on smart city traffic monitoring using AI and image processing techniques[7]. Object detection algorithms were used to identify vehicles and monitor traffic flow. The proposed system enhanced traffic monitoring accuracy and reduced congestion.

The authors in[8] proposed an intelligent traffic control system using camera-based monitoring. YOLO object detection algorithm and reinforcement learning were used for vehicle detection and signal control. The system improved traffic efficiency and reduced delays at intersections.

The study developed a smart traffic surveillance system using deep learning techniques[9]. The YOLO algorithm was used to

detect vehicles and estimate traffic density. The system successfully optimized traffic signal timing and improved intersection performance.

The authors in [10] proposed a deep learning-based adaptive traffic signal control system. Advanced deep learning models were used to analyze traffic data and optimize signal timing. The system achieved high accuracy in traffic prediction and improved traffic flow management.

3. PROPOSED METHODOLOGY

Density based adaptive traffic signal algorithm is proposed this algorithm follow several steps to achieve intelligent traffic signal control as shown in fig[1]fig

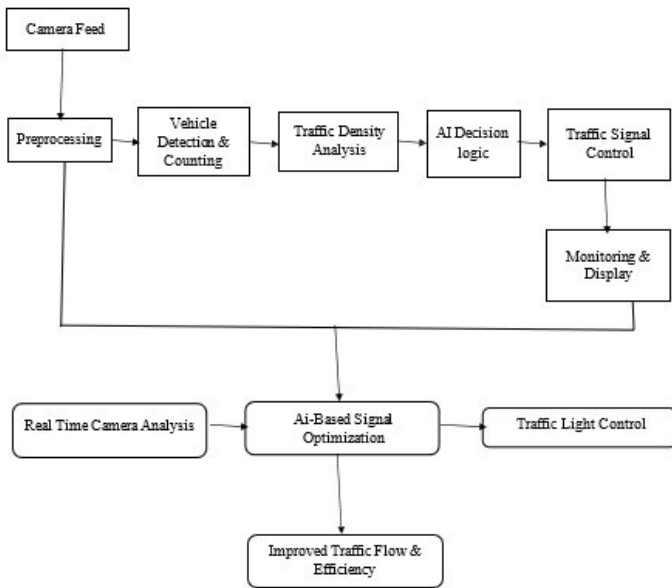


Figure1:workflow diagram • Data

Acquisition

Roadside cameras capture real-time video feeds of traffic movement at intersections.

These video streams serve as the primary input for the system.

- **Video Preprocessing**

Captured video frames are processed using computer vision techniques such as resizing, grayscale conversion, and noise removal. This improves image quality and detection accuracy.

- **Vehicle Detection and Tracking**

Vehicles are detected using contour detection and object recognition methods. Each detected vehicle is assigned a tracking ID to prevent duplicate counting.

- **Traffic Density Estimation**

The number of vehicles in each lane is calculated to determine traffic density. This data is continuously updated in real time.

- **AI-Based Decision Making**

An adaptive algorithm analyzes traffic density and calculates optimal green signal durations. High-density lanes receive longer signal times.

- **Signal Control**

The calculated signal timings are transmitted to the traffic light controller. Red, yellow, and green signals are activated accordingly.

- **Hardware Integration**

Microcontrollers, LEDs, and LCD displays are integrated with the software system to physically control traffic lights and display real-time information.

- **Monitoring and Visualization**

A web interface provides real-time monitoring, graphical analysis, and traffic statistics for authorities.

3.1 Density-Based Adaptive Traffic Signal algorithm

- Step 1 : Initialize the system and activate IoT cameras/sensors at each lane of the intersection.
- Step 2: Capture real-time images or sensor data of vehicles present in each lane.
- Step 3: Process the captured data using image processing techniques to count the number of vehicles.
- Step 4: Calculate the traffic density for each lane.
- Step 5: Compare densities of all lanes.
- Step 6: Assign green signal time to the lane with the highest traffic density.
- Step 7: After the green time ends, the system recalculates density for all lanes again.
- Step 8: Repeat the process continuously for realtime traffic control.

S.NO	PARAMETERS	DISCRIPTION
1.	Vehicle Count	Number of vehicles detected in each lane.
2	Traffic Density	Measure of how crowded a lane is.
3.	Green Signal Time	Time duration allocated for vehicles to move.
4.	Camera / Sensor Input	Data collected from IoT devices such as cameras or sensors.

5.	Lane Priority	Determined based on the lane with the highest traffic density.
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4. EXPERIMENTAL RESULT

The work implemented using javascript css bootstrap & flask These technologies enable real-time traffic monitoring, signal control, and user interface visualization. Fig[2] shows traffic map and density of the vehicle

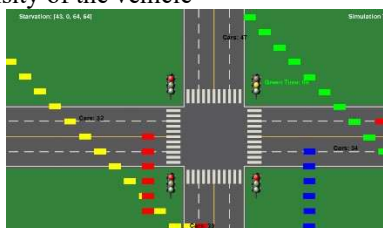


Figure2: Traffic Map

Fig[3] computer vision techniques to detect, track, and count vehicles entering and exiting each lane.

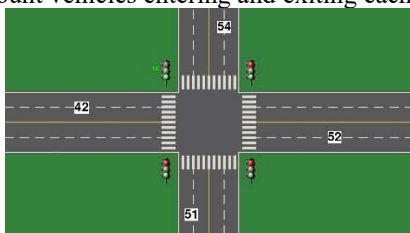


Figure3: vehicle count

Fig[4] shows vehicle density Based on the detected vehicle density, an AI-based decision logic calculates the optimal green signal time for each lane. The system prioritizes lanes with higher congestion while also considering starvation time to ensure fairness across all directions.

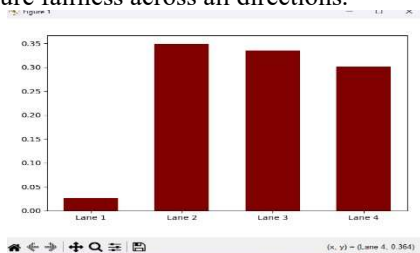


Figure4: vehicle density

5. CONCLUSION

The AI-powered traffic signal control system provides an efficient and intelligent solution to modern traffic management challenges. By using real-time camera feeds and computer

vision techniques, the system can dynamically adjust signal timings based on traffic density. This adaptive approach reduces congestion, minimizes vehicle waiting time, lowers fuel consumption, and decreases environmental pollution. The integration of artificial intelligence, web technologies, and embedded hardware makes the system scalable and suitable for smart city infrastructure. Overall, the proposed system contributes to the development of intelligent transportation networks and promotes safer, greener, and more efficient urban mobility.

6. REFERENCES

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2. **Satheerth P. K. (2024)** developed an AI-based urban traffic management system using machine learning to analyze traffic density and optimize signal timing, reducing congestion in cities.
3. **Samaah and Andrew Edward (2024)** designed an IoT and computer vision-based traffic monitoring system that detects vehicles and dynamically controls signals to reduce delays.
4. **Muskan Raj (2024)** introduced an IoT-based smart traffic management system using adaptive signal control algorithms to reduce congestion and improve road usage.
5. **Xuanning Zhang (2025)** proposed an AI-driven traffic signal system using reinforcement learning to optimize signal timing and reduce vehicle waiting time.
6. **Ahmed Mahmoud Elbasha and Mohammad M. Abdellatif (2025)** developed an AIoT-based traffic system using deep learning for vehicle detection, improving performance compared to fixed-time signals.
7. **Anita Mohanty et al. (2025)** presented a smart traffic monitoring system using AI and image processing to detect vehicles and reduce traffic congestion.
8. **A. Parimala et al. (2025)** proposed a camera-based intelligent traffic control system using YOLO and reinforcement learning to improve traffic efficiency.
9. **S. Nandhini et al. (2025)** developed a deep learning-based traffic surveillance system using YOLO for vehicle detection and signal timing optimization.
10. **Mirabela Melinda Medvei et al. (2026)** proposed a deep learning based adaptive traffic signal system that analyzes traffic data and improves traffic flow management.