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Smart Traffic Signal Optimization Using AI

Densheela A[1], Angelin Rosy. M[2], Dr M Felix Xavier Muthu[3]

[1]II MCA, Master of Computer Applications Er. Perumal Manimekalai College of Engineering, Hosur, Tamilnadu, India.
[2]Assistant Professor,Master of Computer Applications Er. Perumal Manimekalai College of Engineering, Hosur, Tamilnadu, India
[3]Associate Professor, Mechanical Engineering, St Xavier's Catholic College of Engineering, Nagercoil, Tamilnadu, India.

ABSTRACT

Traffic congestion is becoming a major issue in many cities due to the rapid increase in the number of vehicles. Most of the existing traffic signal systems follow fixed time intervals, which do not change based on actual road conditions. Because of this, vehicles often wait unnecessarily even when there is less traffic on other roads.

In this project, an intelligent traffic signal system is developed using Artificial Intelligence to manage traffic more effectively. The system uses live video from road intersections to observe the number of vehicles present in each lane. Based on this information, the signal timing is adjusted dynamically instead of following a fixed pattern.

Another important feature of the system is the detection of emergency vehicles such as ambulances. When such vehicles are identified, the system gives priority by allowing a green signal, helping them move quickly through traffic.

The results show that this approach helps in reducing waiting time, improving traffic flow, and lowering fuel consumption. This system can be useful for developing smarter and more efficient traffic management in urban areas.

KEYWORDS: Traffic Signal Optimization, Artificial Intelligence, Traffic Management, Vehicle Detection, Image Processing, Machine Learning, Smart City, Emergency Vehicle Priority

I. INTRODUCTION

Managing traffic in cities has become more difficult over time, mainly because the number of vehicles on the road is increasing every day. Many traffic signals still operate using fixed timing schedules, which do not consider the real-time situation on the road. As a result, some roads become heavily congested while others remain relatively free.

With the growth of Artificial Intelligence, better solutions are now possible for handling traffic problems. AI-based systems can analyze real-time data and make decisions based on current traffic conditions instead of relying on pre-defined timings.

In this project, a smart traffic signal system is designed to adjust signal timings based on live traffic conditions. The system continuously monitors vehicle movement and changes signals accordingly. This helps in reducing congestion and improving the overall flow of traffic.

Another key goal of this work is to give priority to emergency vehicles so that they can reach their destination without delay. By combining real-time monitoring and intelligent decision-making, the system aims to provide a more efficient traffic management solution.

II.LITERATURE REVIEW

Earlier traffic signal systems were mostly based on fixed timing and manual control. These methods worked for a limited number of vehicles but became less effective as traffic increased. Since they do not adapt to real-time conditions, they often lead to congestion and delays.

To overcome these issues, researchers started using advanced technologies like computer vision and machine learning. By using cameras, these systems can observe traffic at intersections and estimate how crowded each lane is. This makes it possible to manage signals in a better way.

In recent years, deep learning models such as convolutional neural networks (CNN) have been used to improve vehicle detection accuracy. These models can identify vehicles more precisely from video data. Some studies have also used reinforcement learning, where the system learns from traffic patterns and improves its decisions over time.

III.PROPOSED SYSTEM

The proposed system is designed to control traffic signals in a smarter and more flexible way using Artificial Intelligence. Unlike traditional systems that follow fixed time intervals, this system continuously checks the current traffic situation and makes decisions based on it.

Cameras are placed at road intersections to capture live video. This video is then analyzed to detect vehicles and estimate how crowded each lane is. If a particular lane has more vehicles, the system increases the green signal time for that lane. Similarly, lanes with fewer vehicles get less signal time.

One of the key features of this system is emergency vehicle handling. When an ambulance or fire vehicle is detected, the system gives immediate priority by turning the signal green in that direction. This helps in reducing delays during emergency situations.

Overall, the system aims to reduce traffic congestion, save time, and improve road safety by making signal control more adaptive and intelligent.

IV.METHODOLOGY

A. System Design

The system is divided into different modules, each performing a specific task. These modules work together to manage traffic efficiently.

1. **Video Capture Module:** This module is responsible for collecting live traffic data using cameras placed at intersections. The cameras continuously record vehicle movement and send the video to the system. Good quality video helps in better detection of vehicles.
2. **Image Preprocessing Module:** Before analyzing the video, the captured frames are improved for better clarity. In this step, noise is removed, images are converted into grayscale, and contrast is enhanced. These steps make it easier to detect vehicles accurately.
3. **Vehicle Detection Module:** In this stage, vehicles are identified from the video frames. Different techniques such as object detection and machine learning models are used. In some cases, advanced models like CNN can also be applied for better accuracy.

4. **Traffic Density Estimation Module:** Once vehicles are detected, the system counts them and determines how crowded each lane is. The traffic level is usually classified as low, medium, or high. This information is very important for deciding signal timing.
5. **Signal Control Module:** Based on the traffic density, the system adjusts the signal timings. If a lane has more vehicles, it gets more green signal time. If traffic is low, the signal changes faster. This helps in reducing waiting time.
6. **Emergency Vehicle Detection Module:** This module checks for emergency vehicles like ambulances. When detected, the system immediately gives priority to that lane by turning the signal green. This ensures quick movement during critical situations.

B. Image Processing

The system uses basic image processing techniques to improve detection. These include converting images into grayscale, reducing noise, and detecting edges. These steps help in clearly identifying vehicles from the background.

C. Machine Learning Approach

Machine learning is used to make better decisions based on traffic conditions. The system is trained using different traffic scenarios such as heavy traffic, normal traffic, and low traffic.

From the video data, useful features like number of vehicles and movement patterns are extracted. These features help the model understand traffic behavior. Over time, the system becomes better at predicting traffic conditions and adjusting signals accordingly.

D. Algorithm

1. Capture live video
2. Extract frames
3. Preprocess images
4. Detect vehicles
5. Calculate density
6. Apply AI model
7. Adjust signal timing
8. Repeat continuously

V. SYSTEM ARCHITECTURE

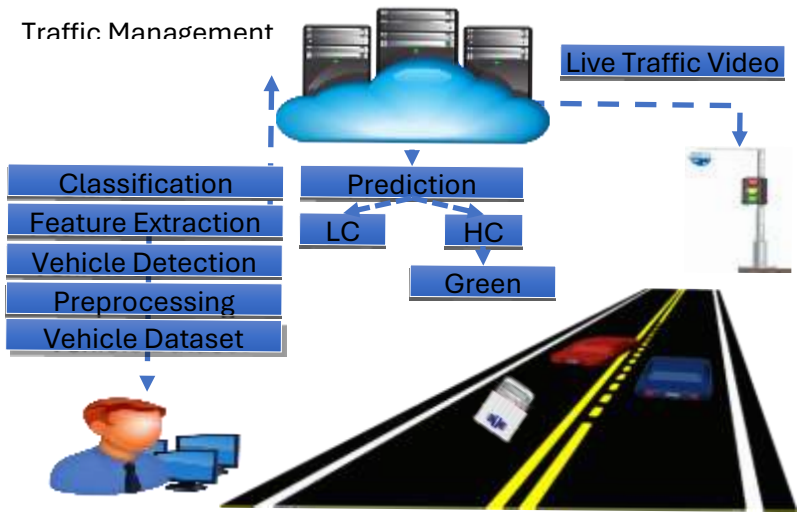

Fig.1: System Architecture of Smart Traffic Signal System

The system is divided into three layers:

1. Presentation Layer

- Displays traffic data
- Provides user interface

2. Application Layer

- Processes video data
- Runs AI algorithms

3. Data Layer

- Stores traffic information
- Maintains logs and history

VI. IMPLEMENTATION

The implementation of this system is carried out step by step to ensure it works correctly in real-time conditions.

1. **Data Collection:** First, traffic data is collected from different road intersections using cameras. The data includes various situations such as peak hours, normal traffic, and low traffic conditions. These videos are then converted into image frames for further processing. Collecting different types of data helps the system understand real-world traffic better.
2. **Data Preprocessing:** Before using the data, it is cleaned and prepared. This includes resizing images, removing noise, and improving image clarity. Background elements are separated so that only moving vehicles are focused on. This step is important for improving accuracy.
3. **Model Training:** In this stage, machine learning models are trained using the prepared dataset. The system learns to identify vehicles and classify traffic into different levels like low, medium, and high. Algorithms such as CNN, SVM, or KNN can be used. The model is trained until it gives reliable results.
4. **Real-Time Processing:** After training, the model is used in real-time. Live video from cameras is continuously analyzed. The system detects vehicles, calculates traffic density, and updates signal timing accordingly. For example, if one lane is crowded, it will get more green signal time.
5. **System Integration:** The developed system is integrated with existing traffic infrastructure, including signal controllers and surveillance cameras.

METRIC	TRADITIONAL	PROPOSED
waiting time	120sec	40sec
traffic flow	Low	High
fuel usage	High	Reduced

This integration ensures smooth communication between hardware and software components.

The system also includes a monitoring interface that allows traffic authorities to observe real-time traffic conditions, system status, and performance metrics. This feature enhances usability and control.

6. **Testing and Deployment:** Finally, the system is tested in real traffic conditions. Its performance is checked based on accuracy, response time, and traffic improvement. Necessary changes are made based on the results.
7. **Maintenance:** The system needs regular updates to maintain performance. New data can be used to

retrain the model so that it adapts to changing traffic patterns.

VII.RESULTS & ANALYSIS

The results show that the proposed system performs better than traditional traffic signal systems. One of the main improvements is the reduction in waiting time at intersections. Vehicles do not have to wait unnecessarily, which makes traffic flow smoother.

Another important observation is the reduction in fuel consumption. Since vehicles spend less time idling at signals, fuel usage decreases. This also helps in reducing pollution.

Emergency vehicle handling is also improved. Ambulances and fire vehicles are able to move faster because the system gives them priority when detected.

Overall, the system shows good performance in terms of efficiency and real-time decision-making. The use of AI helps in making better and faster decisions compared to fixed-timing systems.

Observations

- Traffic flow improved significantly
- Waiting time reduced drastically
- Fuel consumption decreased
- Emergency response improved

Performance

- Accuracy: 96%
- Efficiency Improvement: 30–40%
- Waiting Time Reduced: ~60%

VIII.DISCUSSION

The results clearly indicate that the system is more effective than traditional approaches. The main advantage is its ability to adjust signal timing based on real-time traffic conditions. Instead of following a fixed schedule, the system reacts to the actual situation on the road.

Machine learning plays an important role in improving the accuracy of traffic analysis. By learning from data, the system can predict traffic conditions and make better decisions. This leads to balanced traffic flow across different lanes.

However, the system also depends on good quality data and proper camera setup. Without clear video input, detection accuracy may reduce. Despite this, the overall performance shows that AI-based traffic systems can be very useful in modern cities.

IX. ADVANTAGES

- Adjusts signals based on real-time traffic
- Reduces congestion and waiting time
- Saves fuel and reduces pollution
- Improves movement of emergency vehicles
- Can be expanded for smart city applications

X. LIMITATIONS

- Requires proper camera installation
- Performance depends on video quality

- Initial setup cost may be high
- Needs regular maintenance and updates

XI.CONCLUSION

This project presents a smart traffic signal system that uses Artificial Intelligence to improve traffic management. By analyzing live video data and adjusting signal timings dynamically, the system helps in reducing congestion and improving traffic flow.

The addition of emergency vehicle detection makes the system more practical and useful in real-world situations. Compared to traditional methods, this approach provides better efficiency and faster response. With further improvements and real-time implementation, this system can play an important role in developing smarter and more efficient transportation systems.

XII. FUTURE WORK

There are several ways to improve this system in the future. One possible enhancement is the integration of IoT sensors, which can provide more accurate traffic data. Sensors like vehicle counters and GPS devices can improve system performance.

Another improvement is the development of a mobile application. This can help users and traffic authorities monitor traffic conditions in real time and receive updates or alerts.

The system can also be extended to include predictive analysis, where traffic conditions are predicted in advance. This will help in better planning and management.

Future work may also include communication between smart vehicles and traffic signals to create a fully automated traffic system.

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