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DYNAMIC TRAFFIC SIGNAL SYSTEM IN URBAN AREAS YOLO Vs MOG2

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Abstract
Efficient traffic management is essential for ensuring safe and secure travel in high-traffic urban areas. Delays caused by congestion in densely populated regions with high mobility and commercial population adversely affects the day-to-day life of the public directly or indirectly. This project focuses on implementing a dynamic signal control system that leverages AI-driven technology to adjust traffic signal timings based on real-time traffic density. Using YOLO-based object detection and MOG2-moving object detection algorithm, the system processes video feeds from CCTV cameras to calculate vehicle density and optimize signal flow dynamically. By calculating the density at the signal, congestion can be cleared in optimized usage of time. This system mitigates delays, particularly during peak hours, ensuring smoother urban transportation without requiring manual intervention.

Keywords: Dynamic Traffic Signal Control, Object detection algorithms – YOLO (You Only Look Once), MOG2(Mixture Of Gaussians)

1. INTRODUCTION

The rapid growth of urban populations and private vehicles has overwhelmed urban transportation systems, particularly in metropolitan areas. Traffic congestion during peak hours poses significant challenges for the public, leading to increased commute times, frustration, and inefficiencies in daily activities, especially in densely populated urban areas. Traditional traffic management systems, with static signal timings, fail to adapt to real-time traffic conditions, further exacerbating these delays.

This paper presents an Optimized Intelligent Transport System designed to prioritize emergency vehicle movement in urban areas. By integrating real-time object detection algorithms (YOLO and MOG2), the proposed system dynamically adjusts traffic signal timings based on traffic density. This innovative solution addresses the pressing need for dynamic, efficient traffic management in today's urban environments.

2. LITERATURE SURVEY

Road Traffic Management over several decades has been an important topic and their attempts to propose an efficient system are found in the literature review. Sangeetha R.G, Hemanth C, Roshan Dipesh, Kanothara Samriddhi, Venetha S, Abbas Alif M, Arjun S, and Varshithram K.S, in their research, proposed a fully automated traffic management system based on traffic density using machine learning algorithms. They used foreground-background subtraction techniques to detect vehicles in each lane and employed the K-nearest neighbor (KNN) algorithm to compute traffic density, achieving an accuracy of 99.04% and a recall of 73.18%.

The system dynamically adjusted traffic signals using NodeMCU by fetching density values stored in a cloud database. Additionally, they integrated the YOLO object detection algorithm to identify and prioritize emergency vehicles like ambulances, clearing traffic congestion for their passage. While the system showed promising results in terms of efficiency and automation, its feasibility in the context of highly dense and complex traffic scenarios, such as those in India, was not extensively addressed.

Paper [2] Sandeep Kumar Pradhan, Uday Kumar A, B Sri Sharan, Vinod V, and Prof. Bharathy Vijayan of Dayananda Sagar University, Bengaluru, India, developed a Smart Traffic Management System (STMS) leveraging Internet of Things (IoT) technology to optimize traffic flow and reduce congestion at intersections. Their system integrates sensor networks and advanced algorithms to adjust traffic signals dynamically based on real-time vehicle proximity.

The STMS detects approaching vehicles using sensors, transmitting data to a central control unit that prioritizes oncoming traffic by turning signals green. Once the vehicle has passed, the system reverts to normal signal operations, ensuring a balanced distribution of green time and minimizing disruptions. The integration of STMS into existing infrastructure offers a scalable and efficient solution for urban traffic management.

By reducing travel delays, improving road safety, and lowering vehicle emissions, STMS represents a significant advancement in traffic management technology. However, the system's adaptability to complex, high-density traffic scenarios, such as those in India's metropolitan areas, requires further exploration for large-scale deployment.

Paper[3]Paul Shruti Kanailal, Lavanya E, G. Anbu Selvi, and N. Senthamilarasi from Sathyabama Institute of Science and Technology, Chennai, India, explored AI-powered transportation systems to revolutionize urban traffic management. Their research emphasizes the ability of AI to dynamically adjust traffic flow by leveraging real-time data processing, significantly reducing fuel consumption, emissions, and idling times.

Paper[4]Lavanya E, Paul Shruti Kanailal, G. Anbu Selvi, and N. Senthamilarasi, from Sathyabama Institute of Science and Technology, Chennai, India, developed a Smart Traffic Control System using Artificial Intelligence to revolutionize urban mobility management. The system leverages real-time data processing to dynamically adjust traffic flow, reducing fuel consumption, emissions, and accidents.

Their research highlights the use of machine learning algorithms to preemptively address traffic bottlenecks, optimize commute times, and refine traffic dynamics. By facilitating seamless vehicle-infrastructure communication, the system offers personalized route recommendations, optimized traffic signal timings, and rerouting strategies.

This AI-powered approach creates a smart, interconnected urban ecosystem prioritizing efficiency, safety, and sustainability, significantly transforming transportation management. However, the scalability of the system in densely populated urban areas, such as those in India, requires further evaluation to ensure widespread implementation.

3. METHODOLOGY

The methodology for this study is designed to optimize urban traffic management and to ensure smooth urban transport in peak hours through the use of advanced technologies. The system works by reducing delays and improving overall traffic efficiency.

- **Goal**: Optimize traffic flow and reduce congestion by adjusting traffic signals dynamically based on real-time data.
- **Implementation**:
  - Deploy video cameras at key intersections for live traffic monitoring.
  - Use AI-based algorithms like YOLO to classify and count vehicles, calculate traffic density, and adjust signal timings.
  - Conduct manual surveys to validate AI-based predictions and fine-tune the system.

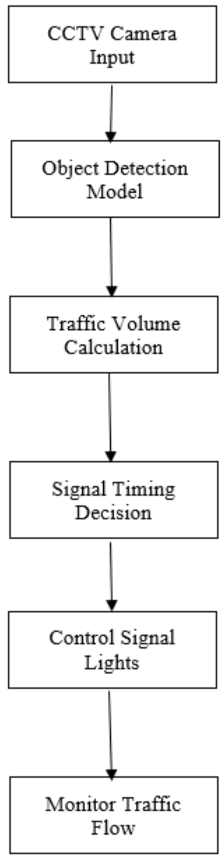

Fig.1 Flow diagram for dynamic signal system.

3.1. DATA COLLECTION METHODS

Data collection is vital to the operation of the traffic management system, providing real-time monitoring and enabling timely adjustments to traffic signals. The system gathers data through various sensors and technologies.

1. **Video-Based Data Collection**: CCTV cameras installed at key intersections capture live traffic footage. The video data is processed using advanced computer vision algorithms, such as YOLO (You Only Look Once), MOG2 (Mixture of Gaussians), to assess traffic density, vehicle classification, and flow patterns. The insights from this data allow dynamic adjustments to signal timings.
2. **Manual Observations**: Surveys and manual data collection during both peak and off-peak hours are conducted to provide ground-truth data. These observations help to understand traffic volume, congestion levels, and vehicle behaviors, and they serve as a validation mechanism for the AI-based video analysis.
3. **GPS Data**: Real-time GPS data from mobile applications (e.g., Google Maps, Waze) and vehicles equipped with GPS systems provide additional traffic insights, such as vehicle speeds, congestion, and preferred routes, which help refine signal adjustments.

3.2. TOOLS AND TECHNOLOGIES USED

This section outlines the hardware and software tools employed in the project.

1. **Video Sensors and AI Algorithms**: Cameras capture real-time traffic data, which is processed by AI algorithms like YOLO, MOG2 to identify and count vehicles. This enables dynamic adjustment of signal timings based on real-time traffic density and flow patterns.
2. **Raspberry Pi Microcontroller**: The Raspberry Pi microcontroller processes data from video cameras and controls the traffic signal adjustments based on the processed data, acting as the central processing unit for the system.
3. **Communication System**: Wired communication between the Raspberry Pi and traffic lights ensures that the system can dynamically adjust the signal timings based on the data from the camera.

4. IMPLEMENTATION

The implementation of the smart traffic management system is divided into two primary phases: **Dynamic Traffic Signal Control** and **Emergency Vehicle Prioritization**. Below is a streamlined implementation approach to achieve the desired objectives.

4.1. System Design Overview

The system integrates various technologies such as **Raspberry Pi**, **CCTV cameras**, **AI algorithms (YOLO) and MOG2 (Mixture of Gaussians)** for effective traffic management.

- **Raspberry Pi**: Acts as the central microcontroller for managing the system, processing data, and controlling traffic signal timings.
- **CCTV Cameras**: Capture real-time traffic footage for vehicle classification and density analysis using AI-driven algorithms like YOLO.
- **YOLO:** real-time object detection system that processes images in a single evaluation, enabling rapid and accurate identification of multiple objects within a scene.
- **MOG2:** (Mixture of Gaussians Version 2) is an advanced background subtraction algorithm that models each pixel with a mixture of Gaussian distributions, allowing for effective differentiation between foreground and background elements in video streams.

4.2. Step-by-Step Implementation Process

1. **Infrastructure Setup**:
   - Install **CCTV cameras** at key intersections for continuous traffic monitoring.
   - Set up **RF sensors** at strategic roadways to detect emergency vehicles.
   - Deploy **Raspberry Pi microcontrollers** to process data and control signal adjustments.
2. **Data Collection**:
   - **Video data** from cameras is processed using either **YOLO or MOG2** algorithms to detect vehicles and analyze traffic flow.
3. **Signal Control**:
   - **Dynamic signal adjustments** are made based on real-time vehicle density.
4. **Testing and Validation**:
   - **System tests** are conducted under different traffic conditions to assess signal efficiency and emergency vehicle response time.
   - The system is optimized to ensure minimal delays and efficient traffic management, based on real-world data.

4.3. Software and Hardware Tools Used

- **Software**: YOLO (for vehicle detection) / MOG2 (Mixture of Gaussians), Python (for programming), OpenCV (for video processing), Raspberry Pi OS (for microcontroller management).
- **Hardware**: Raspberry Pi, CCTV cameras, Traffic signal.

4.4. System Architecture

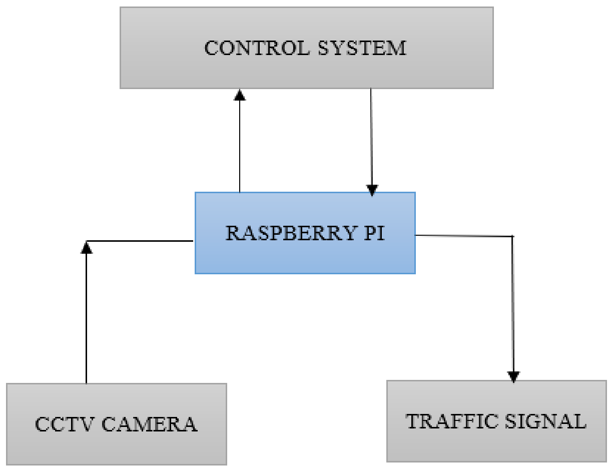

Fig.2 System Architecture of dynamic signal.

5.RESULTS AND DISCUSSION

5.1. Key Findings

I. Optimized Traffic Flow Through Dynamic Signal Control:
The dynamic signal control, driven by real-time video analysis and GPS data, proved highly effective in reducing congestion, particularly during peak traffic hours. By using both YOLO and MOG2 for vehicle detection, the system dynamically adjusted signal timings based on traffic density, significantly improving traffic throughput. Manual observations validated AI-based predictions, ensuring the accuracy of vehicle counting and density calculations.

II. MOG2 vs YOLO: Both the algorithms work their best in object detection for dynamic traffic signal control systems. The choice of object detection algorithm may vary depending on the operating system used and its compatibility.

III. Effectiveness of Video-Based Data Collection: The use of CCTV cameras for video-based data collection was instrumental in monitoring the traffic movements. YOLO-based vehicle detection enabled accurate counting and density measurement, allowing for optimal traffic signal adjustments. The synergy between video and RF sensor data ensured a balanced approach to both traffic flow optimization and emergency vehicle prioritization.

5.3. Comparative Analysis

Table.1. Analysis on traditional and dynamic signal at specific routes

Route	Traditional System	Dynamic SIgnal System
Saravanampatti to Gandhipuram	Red Signal Duration: 151 secs	Red Signal Duration: 120 secs
	Green Signal Duration: 40 secs	Green Signal Duration: 30 secs
	Longer waiting time, congestion	Reduced waiting times, smoother traffic flow
Gandhipuram to Saravanampatti	Red Signal Duration: 120 secs	Red Signal Duration: 100 secs
	Green Signal Duration: 24 secs	Dynamic Green Signal Duration: 20 secs
	Increased delays	Balanced flow of traffic, reduced delays

5.4 Chart Represent Timing Of Traffic Signal:

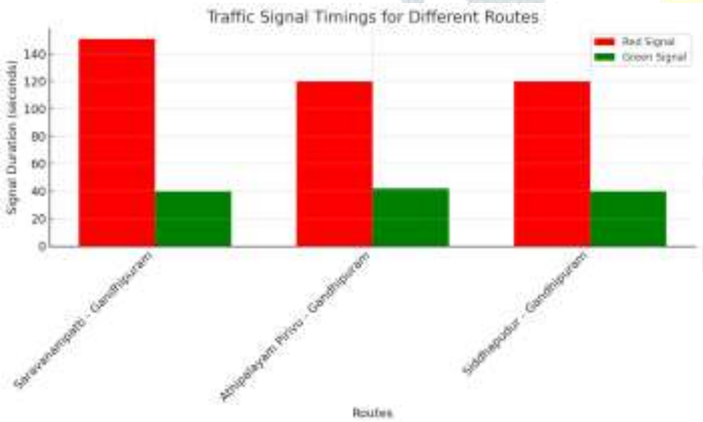

Fig.3 Graphical representation of waiting tie and moving time of vehicles.

5.4. Specific Intersection Analysis

Table.2. Analysis on traditional and dynamic signal at specific signals

Intersection	Traditional System	Smart System (Optimized)
Sidhapudur Junction	**Red Signal Duration:** 150 secs	**Dynamic Red Signal Duration:** Varies (10-20 secs)
	Green Signal Duration: 60 secs	**Dynamic Green Signal Duration:** Adjusts based on traffic density
Outcome	Long waiting time, high congestion	Optimized signal timings, reduced waiting times
Athipalayam Pirivu Junction	**Red Signal Duration:** 120 secs	**Dynamic Red Signal Duration:** Adjusted based on vehicles
	Green Signal Duration: 42 secs	**Dynamic Green Signal Duration:** Optimized for traffic
Outcome	Delays and long wait times	Reduced delays, optimized traffic flow
Thudiyalur Junction	**Red Signal Duration:** 120 secs	**Dynamic Red Signal Duration:** Adjusted for traffic volume
	Green Signal Duration: 42 secs	**Dynamic Green Signal Duration:** Real-time adjustment
Outcome	Prolonged waiting times	Efficient flow, reduced delays

The above table lists out the comparative analysis of traditional and our proposed dynamic model. This clearly explains the significant improvement in urban transportation with low delay in highly populated areas.

7. FUTURE SCOPE AND CONCLUSION

7.1. Future Work and Research Directions

To enhance the performance and scalability of the system, several avenues for future work can be explored:

7.1.1. Advanced AI Integration

Future research can focus on integrating advanced AI and machine learning models for more accurate vehicle detection, classification, and traffic flow prediction. Implementing deep learning algorithms could further improve the system's ability to adapt to dynamic traffic conditions and varying environments.

7.1.2. Enhanced Sensor Technology

Improving the sensor technology, especially RF sensors, to increase their detection range, accuracy, and reliability will be crucial. Research into new sensor technologies or fusion of multiple sensor types (e.g., infrared, ultrasonic) could lead to better emergency vehicle prioritization and traffic management.

7.1.3. Scalability and Cloud Integration

Expanding the system's coverage to more intersections and cities would require scalable infrastructure. Leveraging cloud computing could allow for centralized monitoring, remote control, and seamless data integration across multiple traffic signals, improving the scalability and cost-effectiveness of the system.

7.1.4. Real-Time Traffic Prediction Models

Incorporating real-time traffic prediction models based on historical data and real-time inputs could help the system anticipate traffic congestion, enabling preemptive signal adjustments before congestion builds up. Integrating data from traffic management platforms like Google Maps or Waze could also improve system accuracy.

7.2. Suggested Enhancements and Features

7.2.1. Integration of Pedestrian and Cyclist Data
To enhance the inclusivity of the system, future versions could integrate pedestrian and cyclist traffic data. By collecting real-time information about pedestrians and cyclists at intersections, the system can dynamically adjust signal timings for safer pedestrian crossings, improving overall traffic safety.

7.2.2. Emergency Vehicle Communication
Integrating vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) communication protocols could further optimize the system. Emergency vehicles could communicate directly with traffic signals, automatically triggering green lights along their route without the need for RF sensors or manual detection.

7.2.3. Adaptive Traffic Flow for Special Events
Incorporating algorithms that can adapt to special events (e.g., concerts, sports events) by dynamically adjusting signal timings based on large crowds or expected traffic surges could further improve the system's flexibility. This would ensure smoother traffic flow during such events, reducing congestion and delays.

7.2.4. Integration with Autonomous Vehicles
As autonomous vehicle technology advances, integrating the system with self-driving cars could enhance overall traffic flow management. Autonomous vehicles could communicate with traffic signals to predict and respond to signal changes in real-time, improving coordination and reducing congestion.

In conclusion, this research highlights the importance of intelligent transport systems in improving urban mobility. The proposed system offers a promising solution to address the growing challenges of traffic congestion and vehicle delays, and it paves the way for future innovations in smart city traffic management.

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