Project Report

On

Intelligent Traffic Management And Optimizing Urban Mobility

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2024

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We hereby declare that this submission is our own work that, to the best ofour knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text.

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This is to certify that project report entitled "**Intelligent Traffic Management and Optimizing Urban Mobility**" which is submitted by **Siddhant Gogia, Vipin Kumar and Vivek Bansal** in partial fulfilment of the requirement for the award of degree B.Tech. in Department of Computer Science & Engineering-AML of Dr. A.P.J. Abdul Kalam, Technical University, is a record of the candidates' own work carried out by them under my supervision. The matter embodied in this thesis is original and has not been submitted for the award of any other
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ABSTRACT

Traffic congestion is a widespread issue in urban areas, resulting in longer travel times and increased pollution. This research aims to develop intelligent software that can control traffic lights based on real-time vehicle counts in various lanes. By utilizing cameras to track the number of motorcycles and cars, the software will modify traffic light durations to allocate more green light time to the lane with the highest volume of vehicles. For instance, if one lane is heavily trafficked while another is relatively empty, the software will favor the busier lane.

Moreover, the system will incorporate features to manage special scenarios, such as when VIPs are traveling or when emergency vehicles like ambulances and fire trucks require passage. By tackling these issues, this software seeks to enhance traffic flow, alleviate congestion, and improve road safety, representing a significant advancement in smart city traffic management.

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CHAPTER 1. INTRODUCTION

Urbanization and population growth have led to a significant rise in the number of vehicles on the roads, making effective traffic management a crucial concern for modern cities. Traffic congestion not only causes delays and frustration for commuters but also results in fuel wastage, increased emissions, and negative economic effects. Traditional traffic management systems often depend on fixed or time-based signal cycles that do not adapt to real-time traffic conditions, resulting in inefficiencies and a poor commuting experience. Given these challenges, the necessity for an intelligent and adaptive traffic management system has become clear. Advanced technologies such as computer vision, real-time data processing, and smart algorithms present new opportunities to transform traffic control systems. By integrating these technologies, we can tackle pressing issues like uneven traffic distribution across lanes, delays in emergency vehicle movement, and the need to prioritize specific lanes during VIP or high-priority situations.

1.1 Problem Statement and Objectives

Problem Statement
Current traffic signal systems operate on pre-set timing schedules, which are insufficient for the dynamically changing traffic conditions. These systems are unable to detect or respond to critical situations such as:

- High-density traffic in one or more lanes.
- The movement of emergency vehicles like ambulances or fire services.
- Special requirements for VIP convoys or other prioritized events.

For example, imagine a four-lane intersection where vehicle density varies greatly across lanes. A static signal cycle would allocate equal time to all lanes, regardless of the number of vehicles waiting. This leads to underutilization of signal time for less crowded lanes and excessive delays for congested ones. Additionally, emergency vehicles may become stuck in traffic without any prioritization, resulting in potentially life-threatening delays.

Objective

1. Real-Time Traffic Density Measurement: Utilizing integrated cameras and image processing algorithms to identify and categorize vehicles as two-wheelers or four-wheelers, allowing for accurate traffic density calculations for each lane.
2. Dynamic Signal Timing: Modifying the duration of traffic signals based on real-time density data to enhance traffic flow and reduce delays.
3. Emergency Response Mechanisms: Recognizing and prioritizing emergency vehicles (such as ambulances and fire trucks) to ensure they can pass through intersections without obstruction.

4. Special Event Handling: Coordinating VIP convoys and other high-priority movements while minimizing disruption to regular traffic.
5. Scalability and Adaptability: Developing a solution that can be seamlessly integrated with existing infrastructure and adjusted for complex intersections and future smart city projects. This project aims to leverage the capabilities of artificial intelligence, machine learning, and computer vision to establish a traffic management system that not only addresses current inefficiencies but also sets the stage for a smarter and more sustainable urban transportation network.

1.2 **Scope Of Project**

This project focuses on creating an intelligent traffic management system that can adapt in real-time to traffic conditions, promoting smoother traffic flow and minimizing delays. The main areas addressed by the project include:

1. **Real-Time Traffic Density Measurement**
    - Installation of cameras at intersections to monitor traffic across various lanes.
    - Utilization of image processing and classification algorithms to count motorcycles and cars.
    - Assessment of traffic density for each lane based on the gathered data.
2. **Dynamic Traffic Signal Management**
    - Creation of algorithms to adjust signal durations dynamically according to lane-specific traffic density.
    - Real-time prioritization of lanes with higher vehicle counts to alleviate overall congestion.
3. **Emergency Vehicle and VIP Movement Management**
    - Identification of emergency vehicles (like ambulances and fire trucks) and VIP convoys through camera feeds or other sensors.
    - Automatic prioritization and modification of traffic signals to establish green corridors for their passage.
4. **Scalability and Adaptability**
    - Development of a modular system that can be integrated with current traffic management infrastructure.
    - Ability to incorporate additional features, such as pedestrian crossings or multilane highways.
5. **Simulation and Testing**
    - Design of virtual traffic scenarios to assess the system's effectiveness in managing various real-world situations.
    - Analysis of system performance under different traffic densities and special circumstances.
6. **Future-Ready Design**
    - Possibility of integrating machine learning models to forecast traffic patterns and enhance signal timings.

- Compatibility with smart city frameworks and IoT devices for improved traffic monitoring and control.

7. **Environmental and Economic Impact**

- Decrease in fuel consumption and emissions by reducing idle time at traffic signals.
- Enhanced efficiency in urban traffic flow, resulting in economic advantages for commuters and the city.

This project seeks to provide a practical, scalable, and efficient solution to contemporary traffic issues, positioning it as a significant enhancement to urban infrastructure and smart city development efforts.

CHAPTER 2. LITERATUE REVIEW

2.1 Overview of existing Traffic Management System

Traffic management systems are created to control the flow of vehicles and pedestrians at intersections and along roadways. Both traditional and modern systems utilize a variety of technologies and strategies to manage traffic effectively. Here's an overview of these systems, outlining their advantages and disadvantages:

1. **Fixed-Time Traffic Signal Systems**

   Description: These systems operate on predetermined timing cycles for traffic lights, regardless of current traffic conditions.

   Advantages: They are straightforward to implement and budget-friendly.

   Limitations:

   - They can be inefficient during peak hours or in unusual traffic situations.
   - They lack the ability to adjust to real-time traffic changes.

2. **Sensor-Based Traffic Management**

   Description: This approach employs sensors, such as inductive loop detectors, infrared sensors, or radar, placed in or around roadways to detect the presence of vehicles.

   Advantages:

   - They offer some adaptability to real-time traffic flow.
   - They are generally more efficient than fixed-time systems.

   Limitations:

   - The installation and maintenance of sensors can be costly.
   - They may be susceptible to errors caused by environmental factors (e.g., weather conditions, sensor damage).

3. **Adaptive Traffic Signal Control Systems (ATSC)**

   Description: These systems use real-time data to adjust traffic signal timings dynamically, optimizing traffic flow.

   Examples:

   - SCOOT (Split Cycle Offset Optimization Technique)
   - SCATS (Sydney Coordinated Adaptive Traffic System)

   Advantages:

   - They respond effectively to changing traffic conditions.
   - They help reduce congestion and delays.

   Limitations:

- They often require significant infrastructure investment.
- They may struggle with special scenarios, such as emergency vehicles or VIP convoys.

4. **AI-Based Traffic Management Systems**

   Description: These systems utilize machine learning and computer vision to analyze traffic patterns, predict congestion, and adjust signals accordingly.

   Advantages:

   - They are highly adaptable and scalable.
   - They can integrate seamlessly with other smart city technologies.

   Limitations:

   - They can be computationally demanding and expensive to implement.
   - They require high-quality training data to make accurate predictions.

5. **IoT-Enabled Smart Traffic Systems**

   Description: Implement IoT devices such as connected cameras, GPS, and vehicle-to-infrastructure communication to optimize traffic management.

   Advantages:

   - Real-time data exchange allows for accurate traffic control.
   - Facilitates vehicle prioritization and improved monitoring.

   Limitations:

   - Relies heavily on dependable connectivity and infrastructure.
   - Requires a significant initial investment and ongoing maintenance costs.

2.2 Limitation Of Current Approaches

- High Costs: Advanced systems like ATSC and IoT-enabled solutions come with high deployment and maintenance expenses.
- Limited Scalability: Numerous systems are not built for easy integration into larger networks or complex intersections.
- Environmental Factors: Sensor-based systems and cameras often struggle in poor weather conditions.
- Inability to Handle Special Scenarios: Many systems find it challenging to effectively prioritize emergency or VIP vehicles.

Need for an Improved System

Although current systems have made notable progress in traffic management, they still encounter difficulties in managing dynamic and complex situations, such as variations in multi-lane traffic density, emergency vehicle prioritization, and real-time adaptability. An intelligent system that integrates AI, computer vision, and adaptive algorithms could fill these gaps, leading to a more efficient and responsive traffic management framework.

CHAPTER 3. System Overview

The intelligent traffic management system actively adjusts traffic signals according to real-time traffic conditions. It employs cutting-edge technologies such as computer vision, adaptive algorithms, and emergency prioritization to enhance traffic flow. Here's a more detailed overview, including the steps for implementation and the necessary tools.

3.1 Steps Of Implementation

Step 1: Requirement Analysis and System Design

- Identify key intersections for deployment.
- Design the system architecture, incorporating both hardware and software components.
- Define scenarios to address (e.g., emergency vehicles, varying traffic conditions).

Step 2: Camera Installation and Integration

- Install high-resolution cameras at strategic points to monitor all lanes effectively.
- Configure cameras to ensure complete coverage of the intersection withxc minimal blind spots.

Step 3: Vehicle Detection and Classification Development

- Utilize computer vision algorithms with tools like OpenCV or TensorFlow to detect and classify vehicles.
- Train models on datasets to differentiate between two-wheelers, four-wheelers, and emergency vehicles.

Step 4: Traffic Density Calculation and Signal Control

- Create algorithms to assess vehicle density in each lane.
- Integrate these algorithms with traffic signal controllers to adjust signal timings dynamically based on density data.

Step 5: Emergency Vehicle and VIP Management

- Implement visual markers (e.g., flashing lights or distinct colors) or RFID technology for emergency vehicle detection.
- Program the system to prioritize specific lanes for unobstructed passage.

Step 6: Monitoring Dashboard Development

- Develop a user-friendly dashboard for operators to oversee traffic density, signal timings, and emergency situations.
- Incorporate features for manual overrides when necessary.

Step 7: Testing and Simulation

- Simulate various traffic scenarios to evaluate system efficiency and reliability.
- Conduct field tests at selected intersections to ensure functionality.

Step 8: Deployment and Maintenance

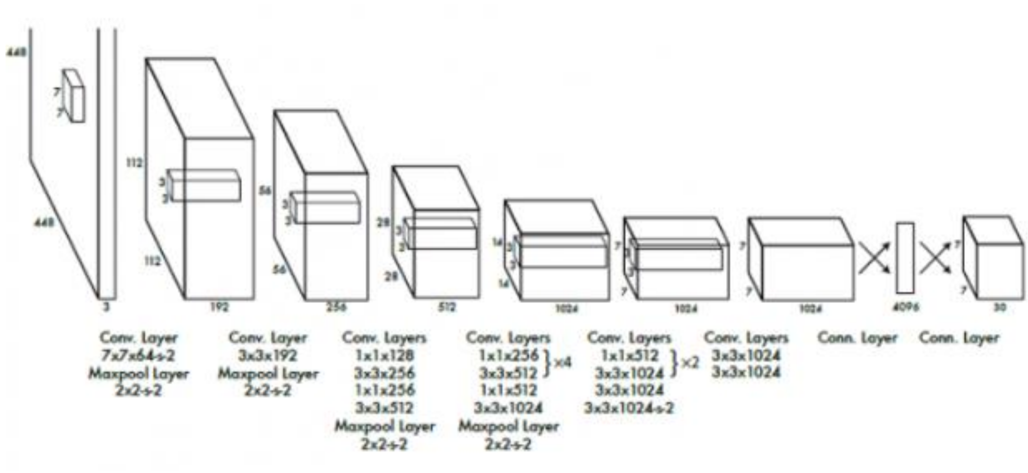
- Deploy the system at the identified locations.
- Establish a schedule for regular maintenance to keep hardware and software updated.

3.2 Tools Required

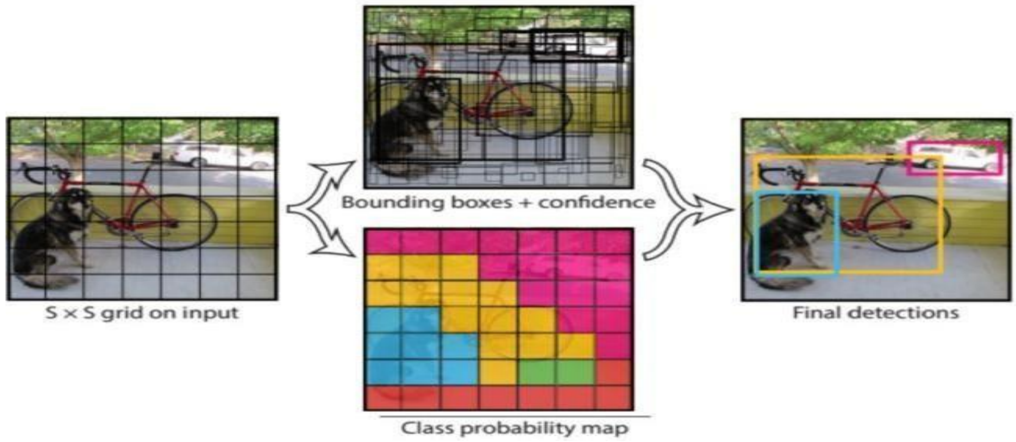
3.2.1 Software Requirements

- Programming Languages: Python for creating detection algorithms.
- Computer Vision Libraries: OpenCV, TensorFlow, or PyTorch for vehicle detection and classification.

- Database Management: MySQL, PostgreSQL, or MongoDB for storing traffic data.
- YOLO(You Look Only Once)
- Monitoring Dashboard Development: Web-based frameworks such as Django or Flask for building the interface.



3.2.1 Fig i Yolo Method



3.2.1 Fig ii Yolo Use

3.2.2 Hardware Requirements

- High-resolution CCTV or IP cameras equipped with night vision capabilities. Wide-angle lenses to provide broader coverage.
- Processing Unit: Servers or edge devices for real-time data processing (e.g., NVIDIA Jetson, Raspberry Pi).
- Emergency Detection Devices: RFID sensors or GPS trackers for monitoring emergency vehicles.
- Networking Equipment: Routers and switches to connect cameras and processing units to the central system.
- Power Supply: Uninterruptible power supplies (UPS) to guarantee continuous operation.

CHAPTER 4. SPECIAL SCENARIOS

To create a robust and efficient traffic management system, it needs to address unique situations that extend beyond standard traffic control. Here are the special scenarios that the system will tackle:

4.1 Handling VIP And Emergency Vehicle Movement

1. **Emergency Vehicle Management**
Scenario: Ambulances, fire trucks, or police vehicles need to pass through an intersection urgently.
Solution:

- Utilize visual markers (like flashing lights) or GPS/RFID technology to identify emergency vehicles.
- Override normal traffic signal operations to establish a green corridor, giving priority to the lane with the emergency vehicle.
- Alert nearby intersections to extend the green signal, facilitating a smooth passage.

2**. VIP Movement Management**
Scenario: High-priority convoys, such as government officials or dignitaries, require minimal disruption.
Solution:

- Pre-program traffic signals along the convoy's route to ensure synchronized green lights.
- Temporarily stop traffic in intersecting lanes to allow for uninterrupted passage.
- Equip traffic operators with a dashboard feature to monitor the situation and manually intervene if necessary.

CHAPTER 5. IMPLEMENTATION AND TESTING

5.1 Software Integration And Testing

The intelligent traffic management system combines various software components to ensure smooth operation, including vehicle detection, data processing, and dynamic traffic signal control. By utilizing advanced computer vision tools like YOLOv5 for real-time object detection, the system's efficiency and accuracy are significantly improved.

1. **Software Integration Steps**

   Step 1: Vehicle Detection and Classification
   - Tool Used: YOLOv5 (You Only Look Once, Version 5).
   - Integration:
     - Train the YOLOv5 model on a custom dataset that includes images of two-wheelers, four-wheelers, and emergency vehicles.
     - Deploy the trained model on an edge device (such as an NVIDIA Jetson or server) for real-time detection.
     - Extract data like vehicle count, type, and location for each lane.

   Step 2: Traffic Density Calculation
   Algorithm:
   - Aggregate the data from YOLOv5 to calculate vehicle density for each lane.
   - Assign weights to different vehicle types (for instance, four-wheelers have a greater impact on density than two-wheelers).

   Step 3: Adaptive Signal Timing Algorithm
   Logic:
   - Create a rule-based or machine-learning algorithm to dynamically allocate signal durations based on density.
   - Incorporate conditions for special scenarios (such as emergency vehicles or VIP movement).

   Step 4: Signal Control Interface
   Integration:
   - Develop APIs or utilize standard communication protocols (like NTCIP) to connect with traffic signal controllers.
   - Transmit computed signal timings to control devices in real-time.

   Step 5: Monitoring Dashboard
   Development:
   - Create a user-friendly interface using web frameworks such as Django or Flask.
   - Show real-time lane densities, signal timings, and alerts for emergencies.

2. **Testing Procedures**

   Testing Goals:
   - Ensure the system operates accurately in real-world conditions.
   - Validate the seamless integration of all components.

   Step 1: Functional Testing
   Test each module independently:
   - YOLOv5: Verify the accuracy of vehicle detection and classification.
   - Density Calculation: Validate the algorithm's performance with predefined test cases.

- Signal Timing: Check if the system allocates appropriate green signal durations based on input data.

Step 2: System Integration Testing

Combine all components and test end-to-end functionality:

- Simulate real-world traffic scenarios using tools like SUMO (Simulation of Urban Mobility).
- Ensure data flows correctly between detection, processing, and control units.

Step 3: Stress Testing

- Assess system performance under high traffic volumes and complex intersections.
- Evaluate YOLOv5's real-time detection capabilities during peak loads.

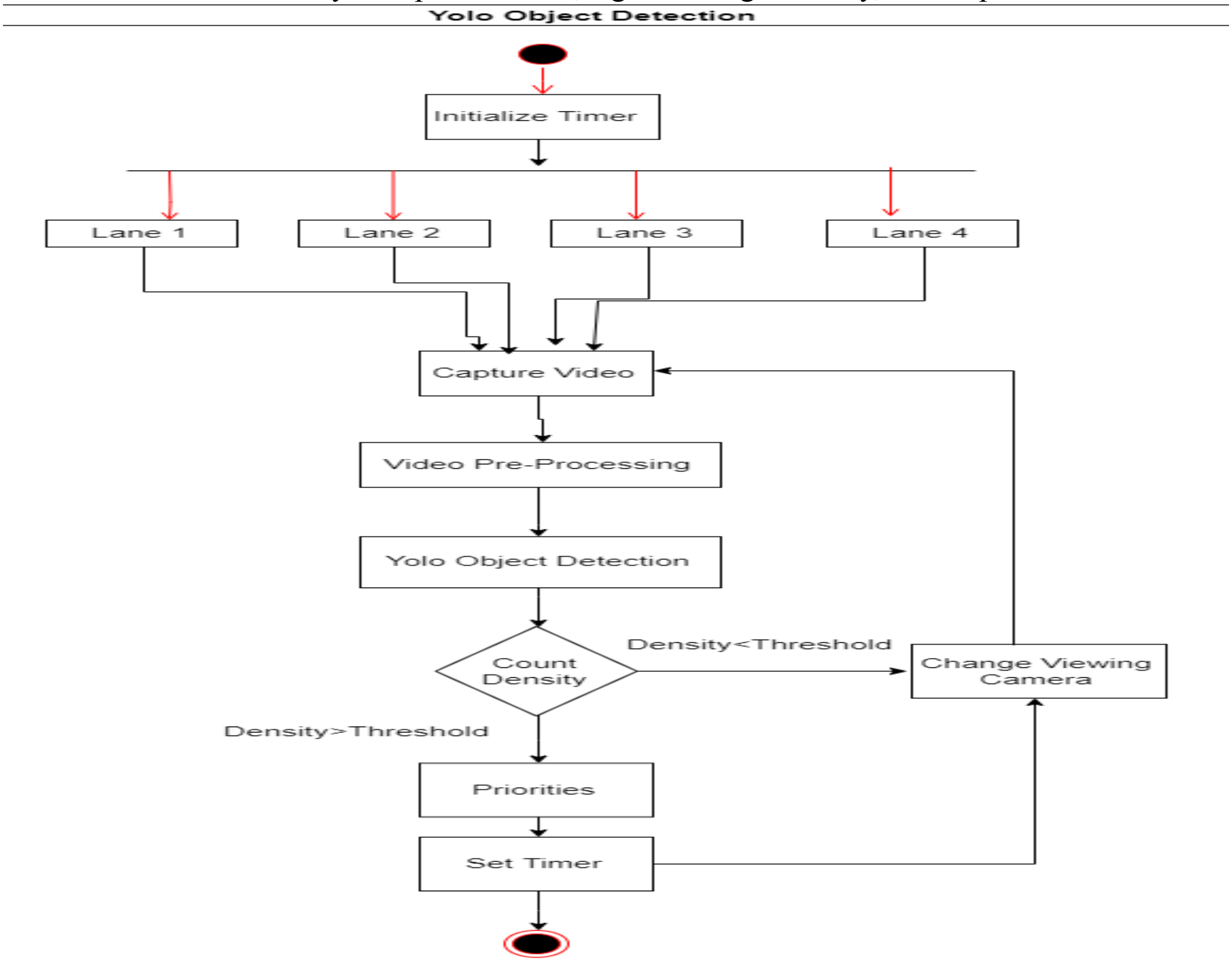
Step 4: Special Scenario Testing

Simulate scenarios such as:

- Emergency vehicle detection and priority handling.
- Lane prioritization during VIP movement.
- Traffic control during pedestrian crossing surges.

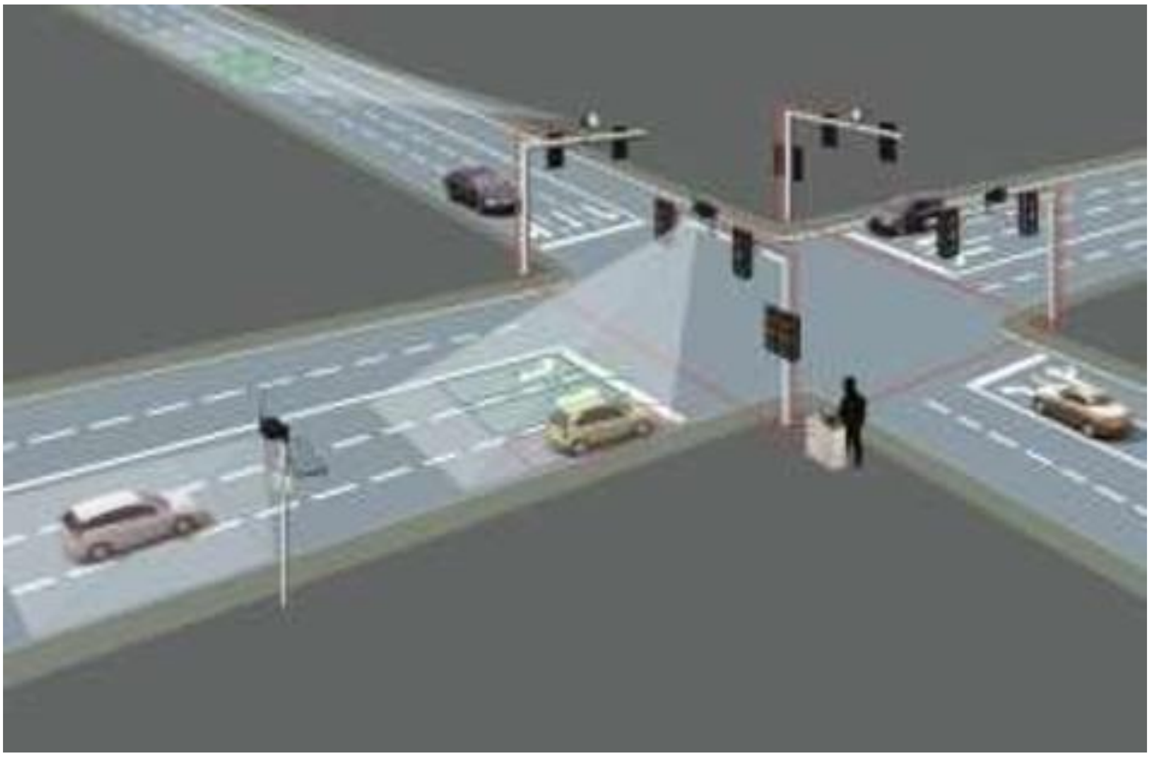
Step 5: Field Testing

- Deploy the system at selected intersections for real-world testing.
- Monitor system performance, signal timing accuracy, and response times.



5.1 Fig i Yolo Working

Working



5.1 Fig Working

CHAPTER 6. Challenges and Future Enhancements

6.1 Technical and Deployment Challenges

Implementing an intelligent traffic management system, particularly with advanced tools such as YOLOv5, presents various technical and deployment challenges. Here's an outline of the main challenges and some potential strategies to tackle them.

1. Technical Challenges
1.1. Real-Time Data Processing
Challenge: Processing large volumes of data from multiple cameras at the same time in real time can be quite demanding on computational resources.
Solution: Utilize edge computing devices (e.g., NVIDIA Jetson) to handle data processing locally, which helps to minimize latency. Enhance the YOLOv5 model for quicker inference by applying techniques such as quantization or model pruning.
1.2. Accuracy of Vehicle Detection
Challenge: YOLOv5 may misidentify vehicles in certain situations, like poor lighting or heavy rain.
Solution: Train the YOLOv5 model on a varied dataset that includes images taken in different weather and lighting scenarios. Implement additional preprocessing methods, such as histogram equalization, to improve image quality prior to detection.
1.3. Emergency Vehicle Detection
Challenge: Accurately identifying emergency vehicles in crowded or noisy settings can be challenging.
Solution: Integrate sound-based sensors to detect sirens alongside visual indicators. Employ GPS or RFID tracking systems to prioritize emergency vehicles.
1.4. Adaptive Signal Timing Algorithms
Challenge: Creating algorithms that can manage complex traffic patterns without causing delays in other directions is difficult.
Solution: Apply reinforcement learning or optimization algorithms to dynamically adjust timing decisions. Conduct thorough testing of algorithms using traffic simulation tools like SUMO.
1.5. Integration with Legacy Systems
Challenge: Current traffic control systems may not accommodate advanced integrations or real-time updates.
Solution: Create custom APIs or middleware to facilitate communication between the new system and older signal controllers. Gradually upgrade legacy hardware to modern, IoT-enabled devices.

2. Deployment Challenges
2.1. Infrastructure Costs
Challenge: The expense of deploying high-resolution cameras, edge devices, and sensors at various intersections can be significant.
Solution: Initiate pilot projects in key areas to showcase effectiveness before broader implementation. Pursue funding from government or private entities for smart city projects.
2.2. Installation and Calibration

Challenge: Accurately positioning and calibrating cameras to eliminate blind spots and enhance coverage demands precision.
Solution: Utilize 3D modeling tools to visualize camera placements prior to installation. Perform field tests to adjust camera angles and ranges effectively.
2.3. Network and Connectivity Issues
Challenge: Dependence on stable internet or intranet connections for real-time data transfer can result in delays or outages.
Solution: Adopt edge computing to reduce reliance on centralized networks. Incorporate redundant connectivity options (such as 4G/5G or fiber) for backup support.
2.4. Public Acceptance and Compliance
Challenge: Resistance from the public or concerns about privacy related to camera usage can impede deployment.
Solution: Conduct awareness campaigns to inform citizens about the advantages of the system. Ensure adherence to privacy regulations by anonymizing the data collected.
2.5. Maintenance and Upkeep
Challenge: Consistent maintenance of hardware (like cameras and sensors) and software updates is crucial for system reliability.
Solution: Create a maintenance schedule for hardware inspections. Implement automated update processes for software components.
2.6. Scalability
Challenge: Expanding the system to cover additional intersections and manage increased traffic volumes without sacrificing performance.
Solution: Employ modular and cloud-based architectures to facilitate scalable deployment. Enhance algorithms for multi-threading and distributed processing.

6.2 Scope for Integration with Smart City Solutions

An intelligent traffic management system can play a crucial role in the advancement of smart cities by working in tandem with various technologies and solutions. This collaboration leads to improved urban mobility, a smaller environmental footprint, and a better quality of life for residents. Here’s a look at the potential for integration with smart city solutions:

1. **Smart Transportation Systems**

   Public Transport Integration:
   - Align traffic signals with public transport schedules to give priority to buses or trams at intersections.
   - Utilize real-time data to enhance routes for public transport vehicles based on current traffic conditions.

   Ride-Sharing and Autonomous Vehicles:
   - Offer dynamic signal timings to reduce delays for ride-sharing services and autonomous vehicles.
   - Enable vehicle-to-infrastructure (V2I) communication for smooth navigation.

2. **Internet of Things (IoT)**

Smart Sensors and Cameras:
- Link traffic cameras and sensors to a central IoT platform for ongoing monitoring and data exchange.
- Employ IoT-enabled devices to assess road conditions, vehicle types, and pedestrian activity.

Real-Time Data Sharing:

- Disseminate real-time traffic data to other smart city systems, such as navigation apps or city dashboards.
- Integrate with parking management systems to direct vehicles to available parking spots, alleviating congestion.

2. **Emergency Response Systems**

   Priority Lanes for Emergency Vehicles:
   - Connect with emergency management systems to identify ambulances, fire trucks, or police vehicles and prioritize their passage.
   - Provide real-time route recommendations for emergency vehicles based on traffic density and signal status.

   Disaster Management:
   - Work alongside evacuation systems during natural disasters or emergencies by modifying traffic flows to facilitate quicker evacuations.

Advantages of Integrating Smart City Solutions

Better Urban Mobility: Improved traffic flow leads to shorter commute times and boosts overall efficiency.

Environmental Advantages: Lower emissions and energy-efficient practices help create a more sustainable city.

Economic Development: Effective traffic management fosters economic activities by minimizing logistical delays and enhancing connectivity.

Improved Citizen Experience: Real-time information and smoother travel enhance the quality of life for residents. By combining intelligent traffic management with smart city solutions, cities can create a cohesive, interconnected urban environment that responds to evolving needs and supports sustainable growth.

CHAPTER 7. CONCLUSION

The intelligent traffic management system is a crucial advancement in tackling the increasing issues of urban traffic congestion, safety, and environmental sustainability. By utilizing cutting-edge technologies like YOLOv5 for real-time vehicle detection, adaptive signal timing algorithms, and IoT integration, this system provides a strong solution for enhancing traffic flow and boosting urban mobility.

Key Takeaways:

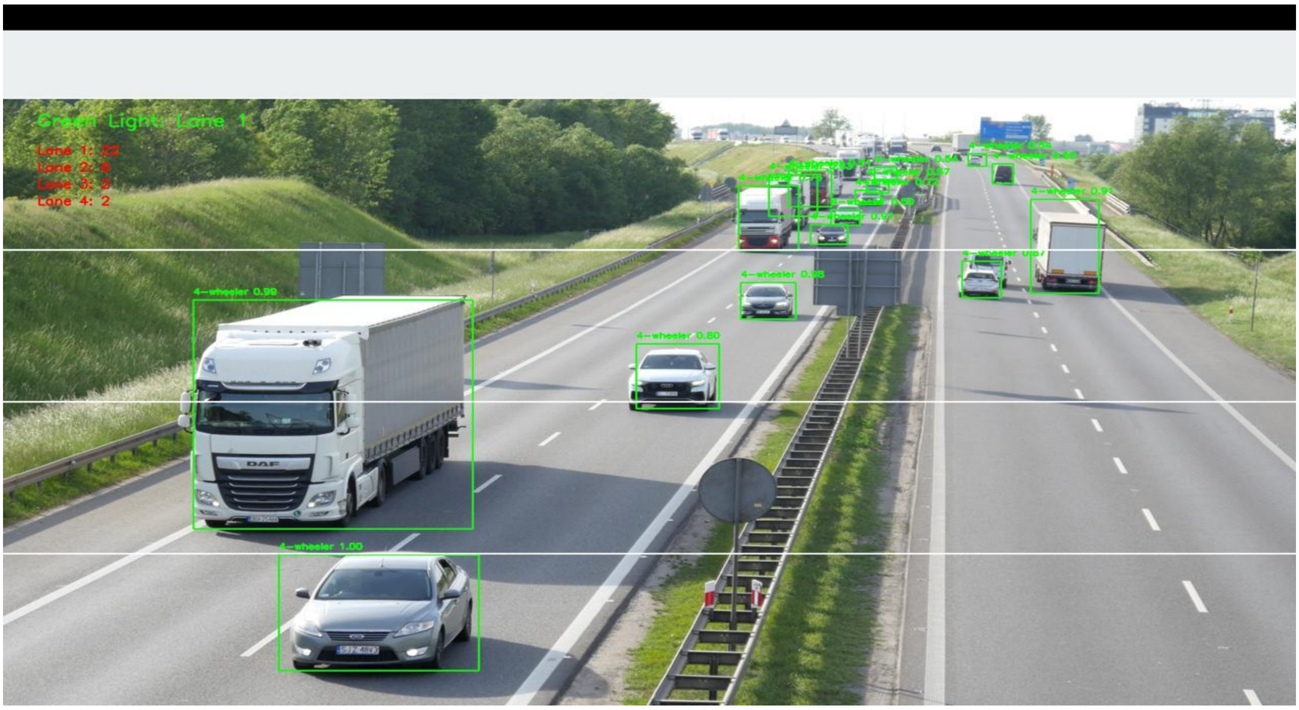
1 Improved Traffic Efficiency: The system adjusts signal timings dynamically based on current traffic density, which helps to reduce delays and enhance overall efficiency at intersections.

2 Enhanced Safety and Emergency Response: By prioritizing lanes for emergency vehicles and managing VIP movement, the system ensures quicker response times and safer road conditions for all commuters.

3 Scalability and Flexibility: With its modular design, the system can be easily integrated with existing traffic infrastructure and scaled to meet the needs of complex intersections or growing urban areas. Environmental Benefits: By minimizing idling times and optimizing vehicle flow, the system reduces fuel consumption and greenhouse gas emissions, supporting sustainable urban development. Smart City Integration: This system acts as a foundational element for smart city projects, facilitating smooth communication with other urban systems, including public transportation, environmental monitoring, and emergency services.

4 Challenges Addressed: Although there are technical and deployment challenges such as real-time processing, emergency detection, and public acceptance, strategic solutions and advanced technologies can effectively address these concerns.

RESULT:



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These references provide the foundation for understanding the technical, practical, and theoretical aspects of developing and implementing an intelligent traffic management system.

APPENDIX

Appendix A: Key Terms and Definitions
YOLOv5: An advanced deep learning model used for real-time object detection.
Density Calculation: The process of determining the number of vehicles (two-wheelers and four-wheelers) in a specific lane to manage traffic signals accordingly.
Adaptive Signal Timing: A traffic control strategy that adjusts signal timings based on real-time traffic conditions.
Edge Computing: Decentralized data processing closer to the source (e.g., traffic cameras) to reduce latency.
IoT (Internet of Things): A network of interconnected devices that share and process data in real time.

Appendix B: System Components
Hardware:

- High-resolution cameras
- Edge computing devices (such as NVIDIA Jetson Nano)
- Traffic signal controllers
- Sensors for detecting emergency vehicles (like sound or RFID-based systems)

Software:

- YOLOv5 for object detection
- Traffic simulation tools (for example, SUMO)
- Python for developing algorithms
- Cloud-based systems for centralized monitoring

Appendix C: List of Acronyms
AI: Artificial Intelligence
IoT: Internet of Things
RFID: Radio Frequency Identification
SUMO: Simulation of Urban Mobility
YOLO: You Only Look Once

Appendix D: Figures and Diagrams

- Yolo Working- Shows Yolo works.
- Yolo Method- Show methods of Yolo.
- Yolo Use- Uses of Yolo.
- Working- Working of the system.

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