TraffIQ

Capstone Project Proposal

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Project Overview

The Traffic Light Optimization project addresses the pressing issue of traffic congestion in urban environments through the development of an intelligent traffic light control system. By leveraging real-time traffic data and advanced machine learning algorithms, the system aims to dynamically adjust signal timings at intersections, optimising traffic flow and minimizing congestion. Through the integration of diverse data sources, including traffic cameras, sensors, and connected vehicles, the system collects and analyzes real-time traffic information to inform decision-making and adaptive control strategies.

Key features of the system include dynamic signal timing, adaptive control strategies, and real-time data integration. Dynamic signal timing ensures that signal timings are adjusted in response to changing traffic conditions, while adaptive control strategies prioritize high-traffic routes and manage traffic queues efficiently. Real-time data integration allows the system to collect and analyze traffic data from various sources, enabling informed decision-making and optimization of traffic flow.

Expected outcomes of the project include reduced congestion, improved safety, enhanced efficiency, and environmental benefits. By optimizing traffic flow and minimizing delays, the system aims to reduce travel times for commuters and enhance overall transportation efficiency. Additionally, by prioritizing safety measures and providing priority clearance for emergency vehicles, the system enhances safety and minimizes response times in critical situations. Moreover, by reducing congestion and promoting smoother traffic flow, the system contributes to environmental sustainability by decreasing fuel consumption and emissions in urban areas.

Problem Statement

Traffic congestion is a pervasive issue in urban areas worldwide, leading to increased travel times, fuel consumption, and environmental pollution. Traditional traffic light control systems, often operating on fixed timing schedules, struggle to adapt effectively to dynamic traffic conditions, exacerbating congestion and gridlock at intersections. As a result, commuters experience frustration, productivity losses, and negative impacts on overall quality of life. To address these challenges, there is a pressing need for intelligent traffic light optimization systems capable of dynamically adjusting signal timings based on real-time traffic data.

Traditional traffic light control systems often operate on fixed timing schedules, which may not adapt effectively to dynamic traffic conditions. The aim of this project is to develop an intelligent traffic light optimization system that dynamically adjusts signal timings based on real-time traffic data to minimize congestion, improve traffic flow, and enhance overall transportation efficiency.

Objectives

1. Learning and Researching Image Signal Processing (ISP) and Detection Technologies:

This involves studying various ISP techniques such as image filtering, segmentation, feature extraction, and object detection.Researching machine learning models used in computer vision tasks, such as convolutional neural networks (CNNs), object detection algorithms like YOLO (You Only Look Once) or Faster R-CNN, and image classification models like ResNet or MobileNet.

2. Framework Development for Real-Time Traffic Data Collection and Integration:

Designing a modular framework capable of collecting real-time traffic data from diverse sources like traffic cameras, sensors embedded in roads, and connected vehicles.Integrating data collection components with communication protocols such as MQTT, HTTP, or WebSocket to ensure seamless data transmission.

3. Development of Advanced Machine Learning Algorithms for Traffic Density Analysis:

Designing machine learning algorithms, possibly based on convolutional neural networks (CNNs) or other deep learning architectures, to analyze traffic density from images captured by traffic cameras.Training and fine-tuning the models using annotated traffic image datasets to accurately detect and quantify traffic density.

5. Validation and Verification of Developed Algorithms for Real-Time Data:

Conducting rigorous testing and validation of the developed algorithms using real-world traffic data collected from various sources.Evaluating the performance of the image processing and machine learning algorithms in detecting and analyzing traffic density accurately..

Methodology

The methodology for creating an integrated IoT and ML project involves several key steps to ensure a systematic approach from planning to deployment. Initially, the project begins with defining clear objectives and requirements, identifying the problem to be addressed, and understanding the data sources and infrastructure needed. Following this, a careful selection of IoT devices and sensors is made, considering factors such as data collection capabilities, environmental conditions, and connectivity requirements. Subsequently, a comprehensive design of the data collection and processing pipeline is established, detailing the flow of data from IoT devices to ML models. This includes preprocessing steps such as cleaning, feature engineering, and real-time stream processing to prepare the data for analysis. Concurrently, ML models are selected and trained using appropriate algorithms and techniques tailored to the specific problem domain. Evaluation of model performance is conducted rigorously, utilizing metrics relevant to the task at hand, ensuring that the chosen models meet the desired criteria. Integration of ML models with the IoT system follows, where mechanisms for real-time inference and decision-making based on incoming sensor data are implemented. Thorough testing and validation of the integrated system are then carried out to assess its functionality, performance, and robustness under various conditions. Finally, the system is deployed in a production environment, with ongoing monitoring and feedback mechanisms in place to support iterative improvements and ensure the continued success of the project. This iterative methodology fosters a structured and methodical approach, allowing for the creation of effective and scalable solutions that leverage the synergies between IoT and ML technologies to address real-world challenges.

1.Overall Description

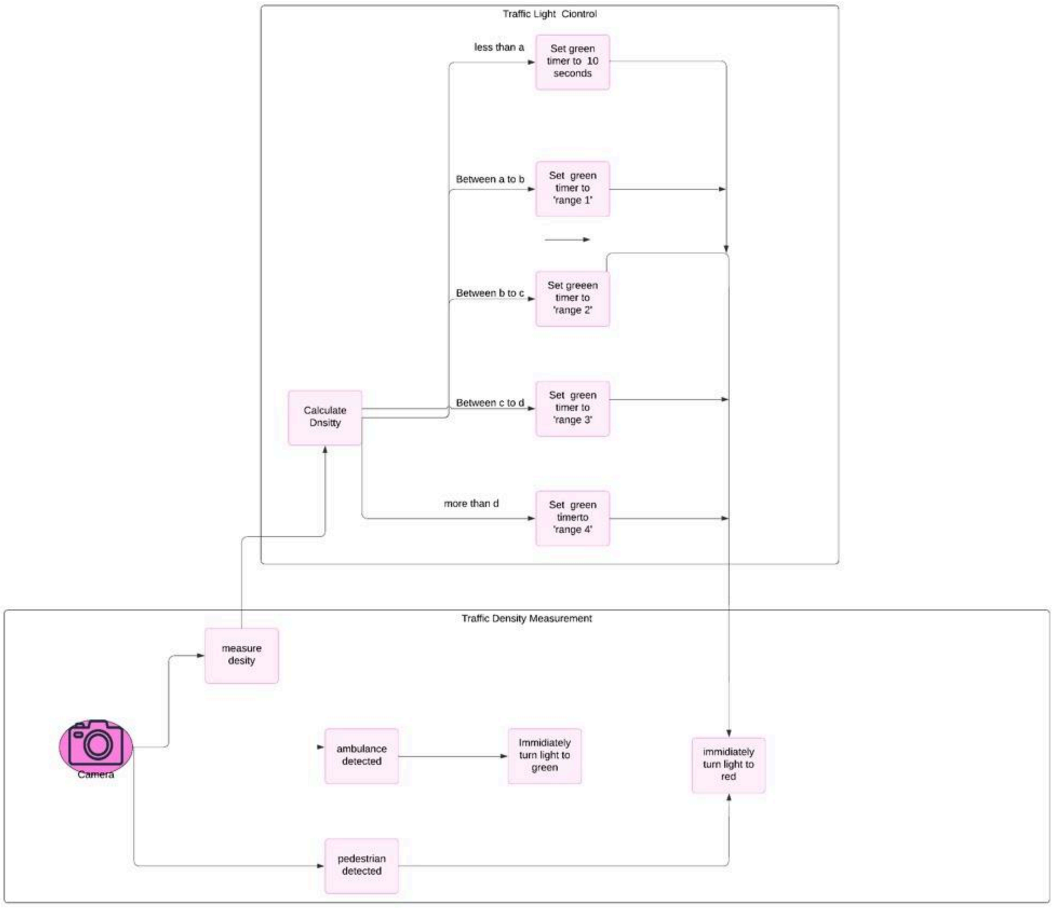
1.1Product Perspective:

- **Target Users:**
  - Municipal transportation departments
  - Traffic management authorities
  - Smart city initiatives
- **Value Proposition:**
  - Reduces traffic congestion, leading to shorter travel times, improved fuel efficiency, and lower emissions.
  - Enhances overall traffic flow and network efficiency.
  - Provides valuable real-time traffic data for informed decision-making.
  - Improves emergency response times by prioritizing emergency vehicles.
  - Offers a scalable solution for managing traffic lights in growing cities.
- **Product Differentiation:**
  - Focuses on real-time data and network-wide optimization compared to traditional fixed-time systems.
  - Employs advanced traffic prediction techniques using machine learning.
  - Prioritizes security measures for a robust and reliable system.

1.2 Product Features:

- **Real-time Traffic Data Collection:** Implementing deep learning algorithms to gather data on vehicle presence, speed, lane occupancy, and potentially vehicle types.
- **Dynamic Signal Timing Adjustment:** Continuously analyzes real-time traffic data and adjusts traffic light timings based on predicted congestion levels.
- **Traffic Prediction Engine:** Leverages historical data and machine learning to forecast future traffic patterns for proactive traffic management.
- **Network-wide Optimization:** Optimizes signal timings across a network of intersections, ensuring coordinated traffic flow.
- **Prioritization for Emergency Vehicles:** Provides priority control for emergency vehicles by adjusting signal timings for faster response times.
- **Data Visualization and Monitoring:** Offers a user interface for authorized personnel to view real-time and historical traffic data, monitor system performance, and identify potential issues.
- **Security Measures:** Employs firewalls, intrusion detection systems, and secure communication protocols to safeguard the system against cyberattacks.
- **Scalability:** Designed for modular expansion to accommodate a growing network of traffic lights.

Use Case Diagram



Use Case Template:

Identifier 01

Description Traffic density captured by camera is less than a certain number 'a'

Goal Green light timer should be set for 10 seconds

Preconditions
1. there is no ambulance in any direction
2. pedestrian is not crossing with possible chances of collision
3. Light is red currently

Basic Course
1. light turns green
2. camera captures traffic density
3. timer for green light is set to 10 seconds.
4. Light turns to red

Alternate Course A:
Condition: Ambulance is on this road

1. Light immediately turns green for specific time , turns all other signals red

Condition: Pedestrian is crossing road with chance of collision and light is green
1. Light immediately turns Red for specific time.

Post conditions
1. Traffic passes in specified time of green light
2. Signal turns red.

Identifier 02

Description Traffic density captured by camera is between a certain number 'a' and 'b'

Goal Green light timer should be set for Range1 amount of time

Preconditions

1. there is no ambulance in any direction
2. pedestrian is not crossing with possible chances of collision
3. Light is red currently

Basic Course

1. light turns green
2. camera captures traffic density
3. timer for green light is set between a range 'Range1'
4. Light turns to red

Alternate Course A:

Condition: Ambulance is on this road

1. Light immediately turns green for specific time , turns all other signals red

Condition: Pedestrian is crossing road with chance of collision and light is green

1. Light immediately turns Red for specific time.

Post conditions

1. Traffic passes in specified time of green light
2. Signal turns red.

Identifier 03

Description Traffic density captured by camera is between a certain number ‘b’ and ‘c’

Goal Green light timer should be set for Rang2 amount of time

Preconditions

1. there is no ambulance in any direction
2. pedestrian is not crossing with possible chances of collision
3. Light is red currently

Basic Course

1. light turns green
2. camera captures traffic density
3. timer for green light is set between a range ‘Rang2’
4. Light turns to red

Alternate Course A:

Condition: Ambulance is on this road

1. Light immediately turns green for specific time , turns all other signals red

Condition: Pedestrian is crossing road with chance of collision and light is green

1. Light immediately turns Red for specific time.

Post conditions

1. Traffic passes in specified time of green light
2. Signal turns red.

Identifier 04

Description Traffic density captured by camera is between a certain number 'c' and 'd'

Goal Green light timer should be set for Range3 amount of time

Preconditions

1. there is no ambulance in any direction
2. pedestrian is not crossing with possible chances of collision
3. Light is red currently

Basic Course

1. light turns green
2. camera captures traffic density
3. timer for green light is set between a range 'Range3'
4. Light turns to red

Alternate Course A:
Condition: Ambulance is on this road

1. Light immediately turns green for specific time , turns all other signals red

Condition: Pedestrian is crossing road with chance of collision and light is green

1. Light immediately turns Red for specific time.

Post conditions

1. Traffic passes in specified time of green light
2. Signal turns red.

Identifier 05

Description Traffic density captured by camera is more than a number 'd'

Goal Green light timer should be set for maximum amount of time- 90 seconds

Preconditions

1. there is no ambulance in any direction
2. pedestrian is not crossing with possible chances of collision
3. Light is red currently

Basic Course

1. light turns green
2. camera captures traffic density
3. timer for green light is set between a range 'Range3'
4. Light turns to red

Alternate Course A:

Condition: Ambulance is on this road

1. Light immediately turns green for specific time , turns all other signals red

Condition: Pedestrian is crossing road with chance of collision and light is green

1. Light immediately turns Red for specific time.

Post conditions

1. Traffic passes in specified time of green light
2. Signal turns red.

Identifier 06

Description Ambulance is detected in one of the lanes

Goal Immediately turn lights to green for that lane

Preconditions

1. pedestrian is not crossing with possible chances of collision
2. Light is red currently

Basic Course

1. light turns green immediately
2. All other signals turn red

Post conditions

1. Ambulance smoothly passes
2. Resume normal traffic flow

Identifier 07

Description Pedestrian is detected crossing in one of the lanes with possible chances of collision

Goal Immediately turn lights to red for that lane

Preconditions

1. Light is green currently

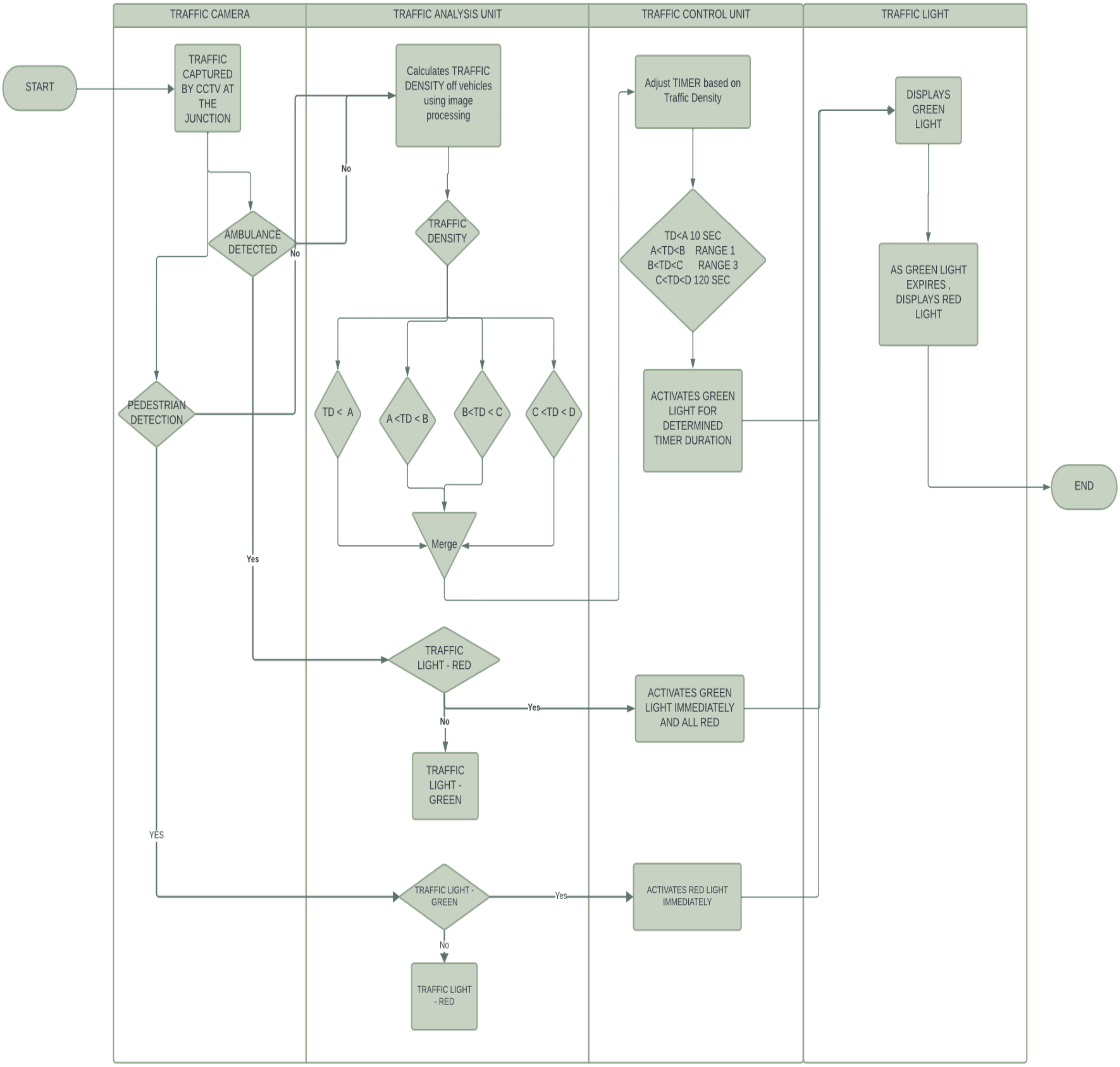
Basic Course

1. light turns red immediately
2. All other signals function normally

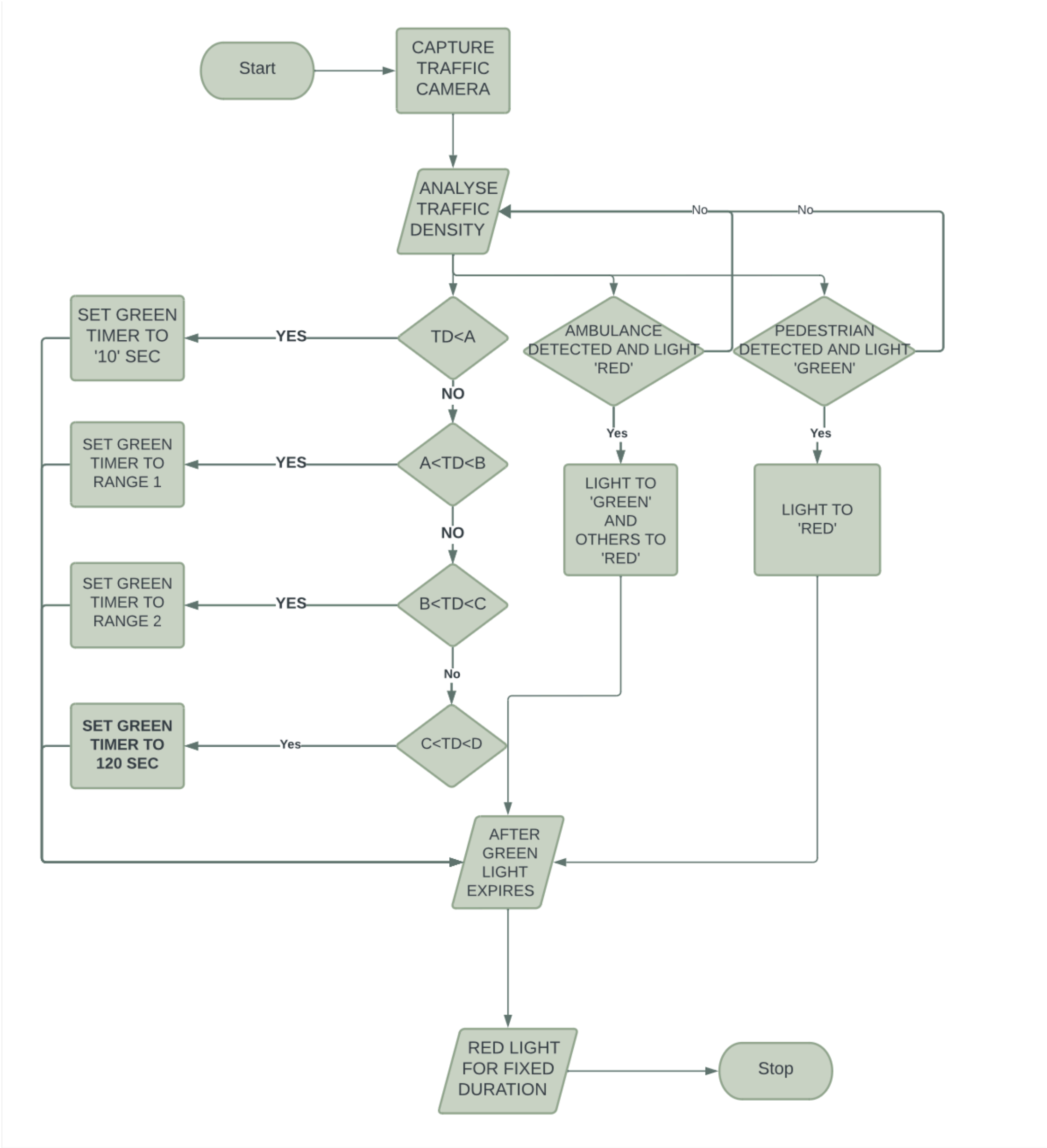
Post conditions

1. Collision is prevented
2. Resume remaining green light timer (if any) for that lane
3. Continue normal traffic flow

Swimlane Diagram:



Activity Diagram:



5. Project Requirements

5.1 Functional Requirements:

1. **Image Processing**: Implement algorithms for image processing to analyze traffic density at intersections.
2. **Traffic Density Detection**: Develop a mechanism to detect and quantify traffic density accurately.
3. **Dynamic Timing Adjustment**: Implement logic to adjust traffic light timings based on real-time traffic density data.
4. **Traffic Light Control**: Control the switching of traffic lights based on the adjusted timings.
5. **Emergency Vehicle Priority:** Provide a mechanism to prioritise emergency vehicles by giving them green signal preference when detected.
6. **User Interface:** Develop a user interface for monitoring and managing the system, including configuring settings and viewing traffic data.
7. **Data Logging**: Log traffic density data over time for analysis and optimisation purposes.
8. **Fault Tolerance**: Ensure the system can handle errors gracefully, such as sensor failures or communication issues.

5.2 Non-Functional Requirements:

1. **Performance:** The system should respond to changes in traffic density quickly and adjust timings within a reasonable timeframe.
2. **Accuracy:** The traffic density detection algorithms should be accurate to ensure precise timing adjustments.
3. **Scalability:** The system should be scalable to handle varying numbers of intersections and traffic loads.
4. **Reliability:** The system should operate reliably under normal conditions as well as adverse weather conditions.
5. **Security**: Implement security measures to prevent unauthorized access to the system and ensure data integrity.
6. **Maintainability**: Design the system with modularity and documentation to facilitate easy maintenance and updates.
7. **Compatibility**: Ensure compatibility with existing traffic infrastructure and protocols to facilitate integration.
8. **Power Efficiency**: Optimize power consumption to reduce operational costs and environmental impact.
9. **Usability**: The user interface should be intuitive and user-friendly for administrators and operators.
10. **Regulatory Compliance**: Ensure compliance with relevant traffic regulations and standards.

Algorithms Used:

Cameras will capture video footage, then video footage will be divided into individual frames, resize frames adjusting road size, then use YOLO or SSD for vehicle detection by creating boxes around vehicles, calculate density (no of vehicles/length of road)*Multiplying factor.

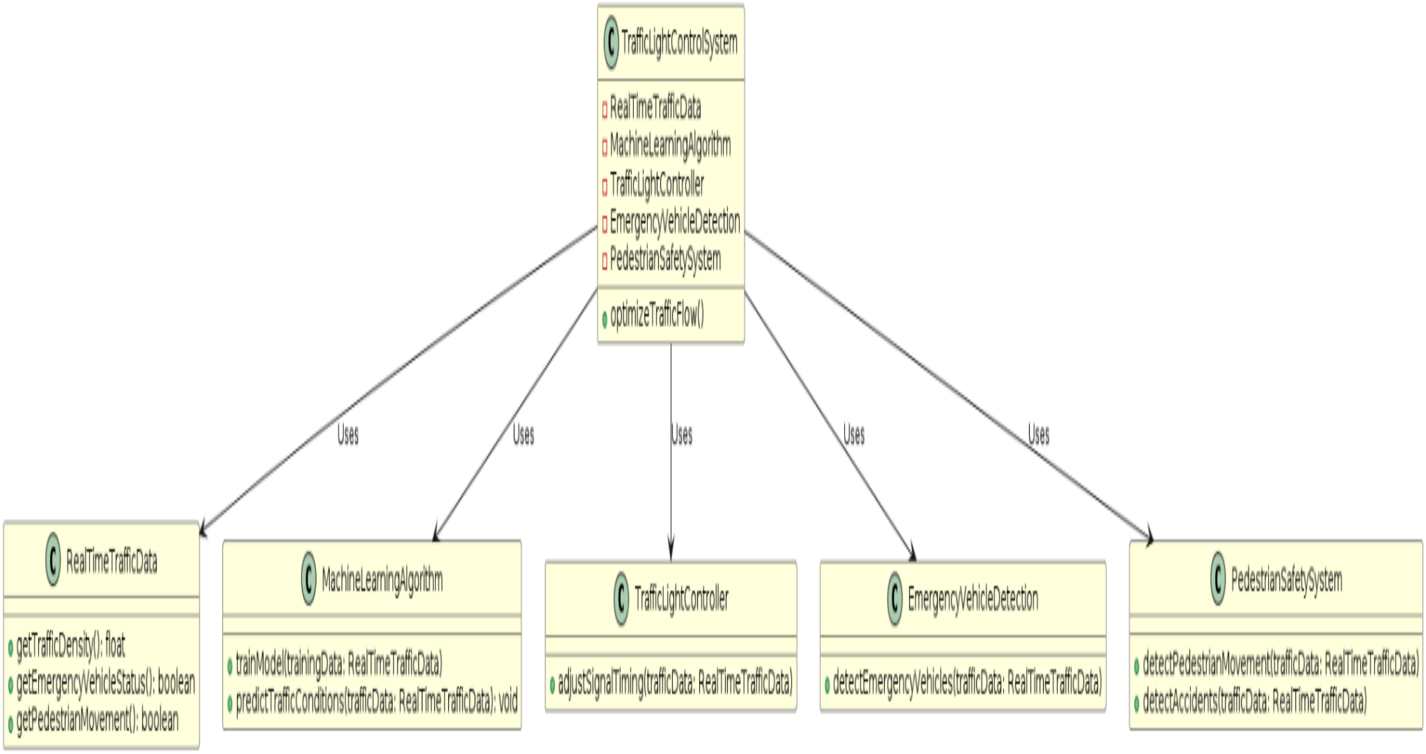
1. YOLO

   Yolo stands for 'You Only Look Once'.It divides the image into a grid. For each grid, some values like class probabilities and the bounding box parameters are calculated. The model works by first splitting the input image into a grid of cells, where each cell is responsible for predicting a bounding box if the centre of a bounding box falls within the cell. Each grid cell predicts a bounding box involving the x and y coordinates indicating the width and height and the confidence. A class prediction is also based on each cell.

2. SSD

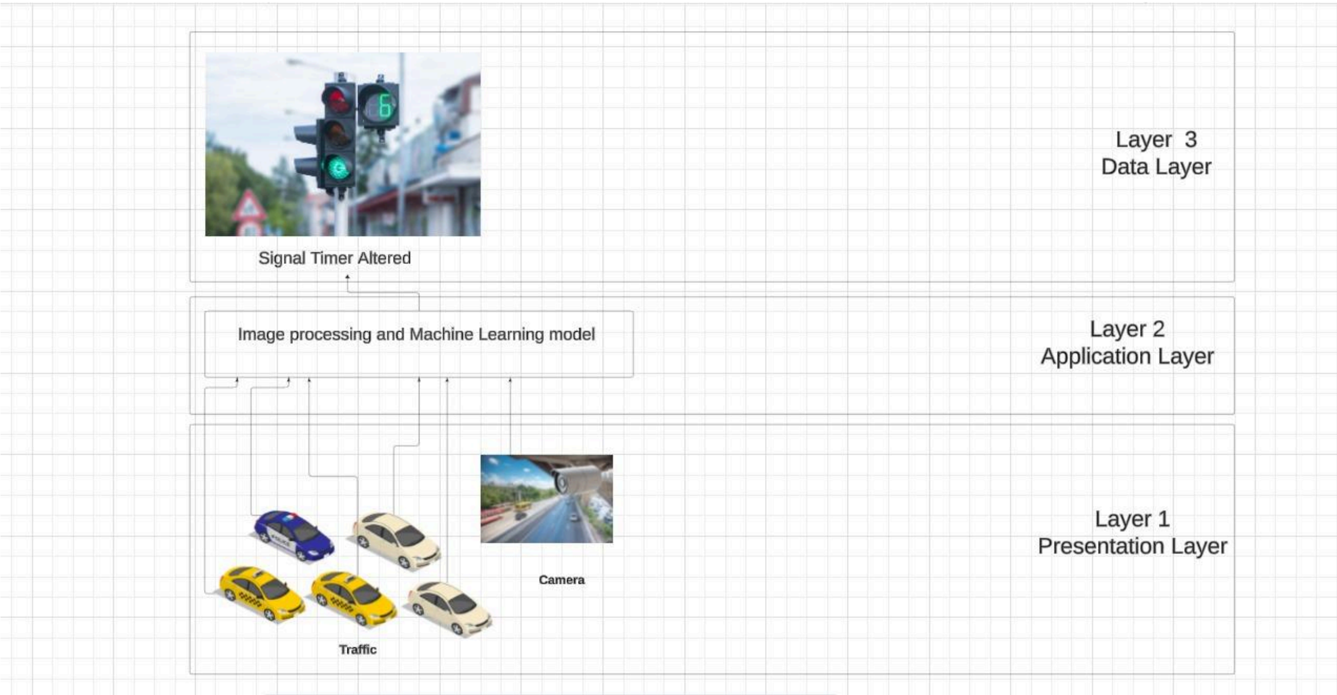
   SSD is a single-shot detector. It has no delegated region proposal network and predicts the boundary boxes and the classes directly from feature maps in one single pass. The SSD object detection consists of 2 parts , Extract Feature Maps and Apply convolution filters.

Class Diagram



Architecture Design

3 - TIER Architecture



Cost Analysis:

S.No	Description	Cost (Rs.)
1.	Camera Module	900
2.	Microcontrollers or single-board computers (SBCs)	1500
3.	Sensors	600