SMART INDIA HACKATHON 2024

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- **Problem Statement ID** - SIH1607
- **Problem Statement Title** - A Smart AI-based solution for traffic management on routes with heavy traffic from different directions with real time monitoring and adaptation of traffic light timings.
- **Theme** - Smart Automation
- **PS Category** - Software
- **Team Name** - THENEXUSSS
- **GitHub Link** -

  https://github.com/asmitgh/team-nexus

NEXUS
Navigation Engineering Xperience for User Solutions

AI BASED TRAFFIC MANAGEMENT SYSTEM

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Detailed Explanation Of The Proposed Solution :

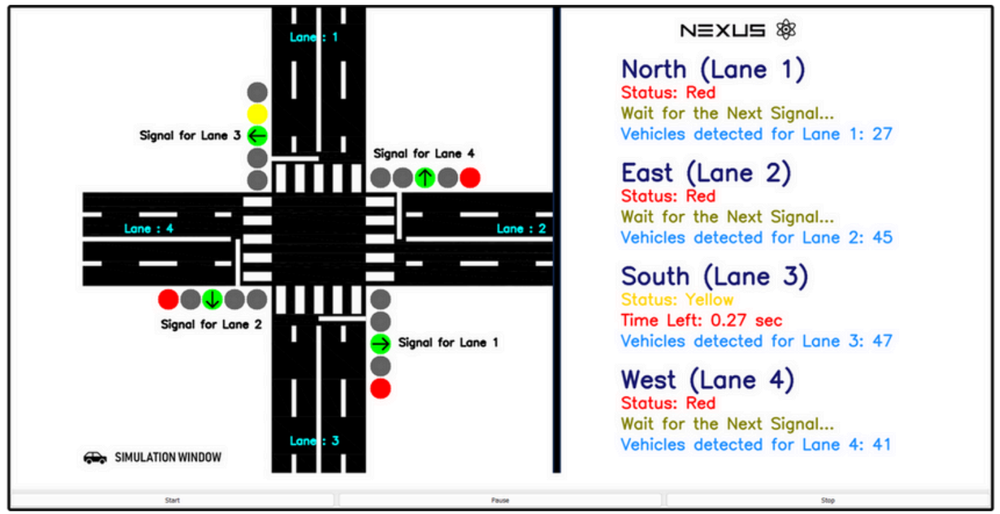
- **AI-Based Traffic Light Control**
  - Uses machine learning algorithms to adjust traffic light timings dynamically.
  - Continuously adapts to real-time traffic conditions rather than following fixed schedules.
- **Real-Time Traffic Monitoring**
  - Gathers data from sensors, cameras, and GPS devices at intersections.
  - Analyzes traffic volume, speed, and patterns to detect congestion early.
- **Dynamic Adjustment of Traffic Light Timings**
  - AI adjusts signal durations based on traffic density, optimizing the flow at congested intersections.
  - Prioritizes heavily trafficked routes and adapts in real time.
- **Multi-Directional Traffic Management**
  - Balances traffic flow from different directions, redistributing signal time according to real-time demand.
  - Minimizes delays by ensuring efficient traffic movement from all directions.
- **Environmental Impact Reduction**
  - Reduces vehicle idle times, decreasing fuel consumption and emissions.
  - Smoother traffic flow leads to fewer stop-and-go movements, further reducing pollution.
- **Real-Time Data Integration**
  - The system continuously processes live traffic data, allowing accurate and timely decisions.
  - Minimizes inefficiencies typically caused by static, pre-programmed traffic systems.

Future Aspects

1. **GPS Integration**
   - Track vehicle locations to optimize traffic light timings.
2. **User App:**
   - Provide live updates on signals and traffic for better route planning.
3. **Autonomous Vehicle Support:**
   - Seamless interaction with self-driving cars for efficient flow.
4. **Vehicle-to-Infrastructure (V2I):**
   - Real-time communication between vehicles and traffic signals.
5. **Smart City Expansion:**
   - Integrate with other smart infrastructure systems like parking and emergency services.
6. **Predictive Traffic Management:**
   - Use data to forecast and prevent congestion.
7. **Cloud-Based Control:**
   - Centralize monitoring and traffic control across cities.
8. **Environmental Tracking:**
   - Monitor and report on reduced emissions and fuel savings.

How it Addresses the Problem

- **Traffic Congestion Reduction:** The system constantly analyzes traffic in real time and adjusts accordingly, significantly reducing bottlenecks at busy intersections.
- **Minimizing Delays:** By dynamically controlling the traffic lights based on real-time data, delays are reduced for all vehicles, ensuring smoother traffic flow and improving efficiency.
- **Optimization for Peak Hours:** During rush hours or periods of high traffic density, the AI system can allocate more time to high-demand routes, easing congestion during these peak times.
- **Real-Time Adaptation:** Unlike traditional systems that rely on pre-programmed light intervals, the AI model adapts instantly to the current conditions, which is crucial for intersections with unpredictable or fluctuating traffic patterns.
- **Scalability:** The system can be scaled across multiple intersections or integrated into a city's larger traffic management framework, making it versatile for a wide range of urban areas with heavy traffic.



Simulation Window

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TECHNICAL APPROACH

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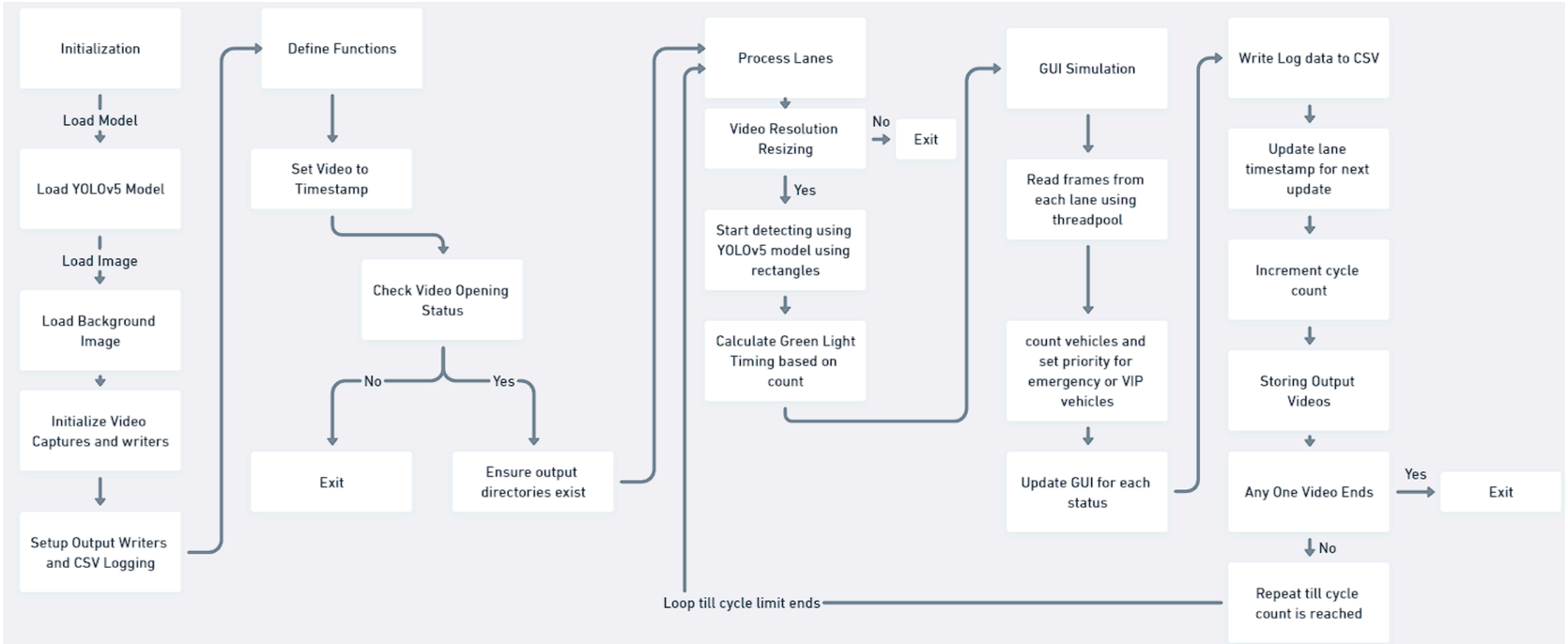
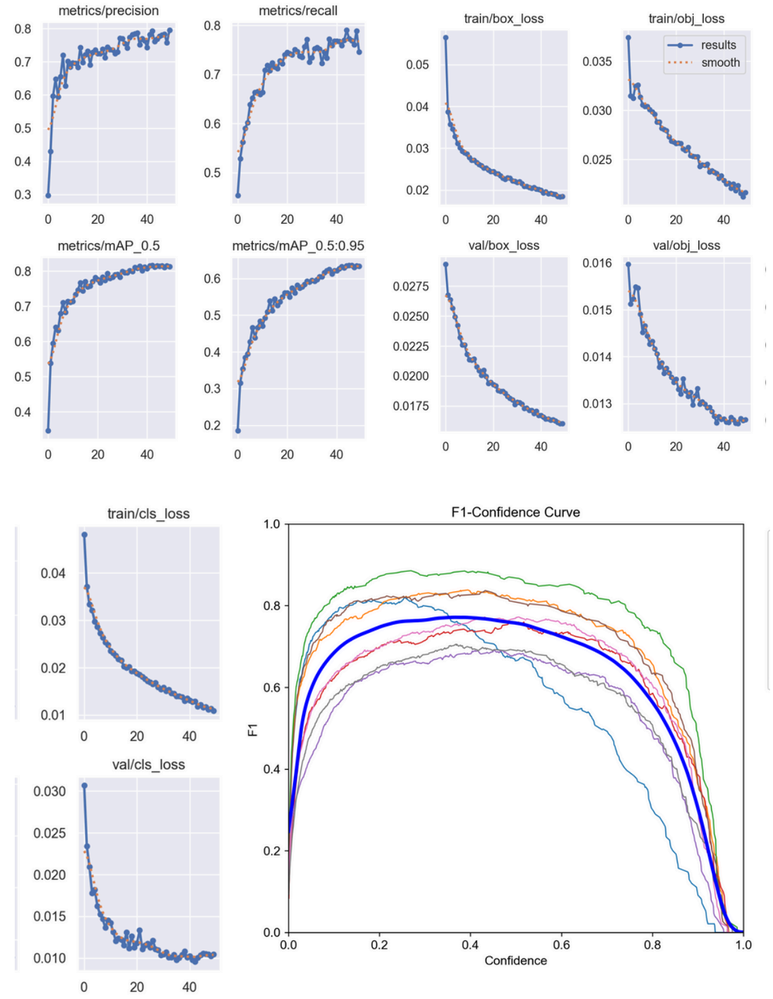
Programming Languages & Frameworks:

PYTHON | OPEN CV | PYTORCH | YOLOV5 | SCIKIT-LEARN | PANDAS | SEABORN | NUMPY

Detailed Flowchart:



Results of our Fine-Tuned YOLOv5 Model



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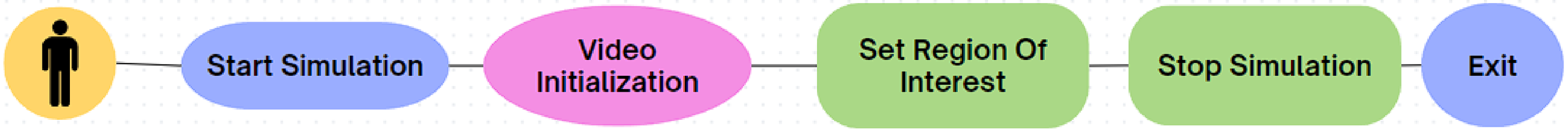
FEASIBILITY AND VIABILITY

Use Case Diagram

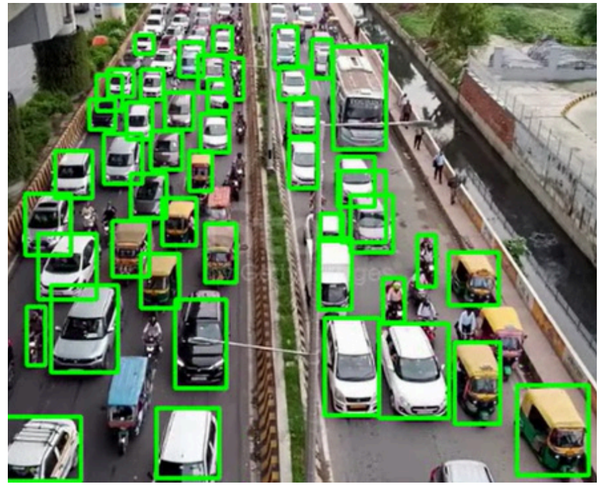


Potential Challenges and Risks:

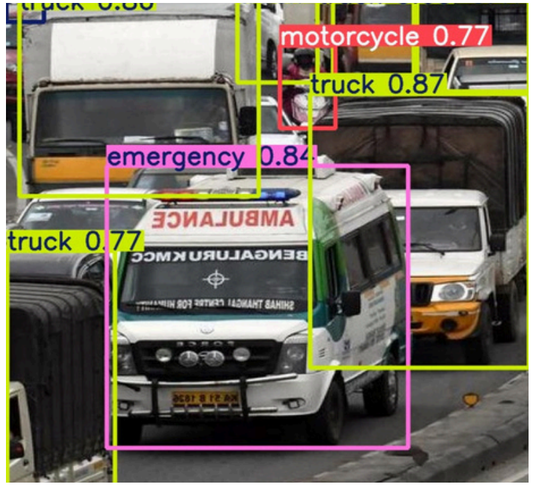
- **Real-Time Performance**: Maintaining low-latency processing while handling multiple video streams.
- **Detection Accuracy**: Handling variations in lighting, weather, and video quality for accurate vehicle detection.
- **Scalability**: Adapting the solution to work with different numbers of lanes and varying traffic patterns.

Strategies for Overcoming These Challenges:

- **Optimization**: Use ThreadPoolExecutor and frame skipping techniques to optimize real-time performance.
- **Model Fine-Tuning**: Fine-tune the YOLOv5 model using additional training data to improve detection accuracy under different conditions.



Model Detection
Figure 1



Model Detection
Figure 2

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IMPACT AND BENEFITS

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Benefits of Our Model

Reduced Traffic Congestion
- Dynamically adjusts traffic light timings to prevent bottlenecks and reduce waiting times.
- Optimizes vehicle flow at congested intersections, ensuring smoother commutes.

Improved Traffic Efficiency
- Balances traffic across multiple directions, improving movement during peak hours.

Environmental Benefits
- Decreases idle time, leading to lower fuel consumption and reduced greenhouse gas emissions.

Real-Time Responsiveness
- Adapts to changing traffic conditions in real-time, ensuring timely responses to sudden congestion or traffic incidents.

Enhanced Public Safety
- Reduces the likelihood of traffic accidents by improving flow and minimizing sudden stops at intersections.
- Ensures safer driving conditions by managing traffic flow smoothly.

Scalable and Future-Proof
- Can be easily integrated into existing traffic infrastructure and scaled to additional intersections or road networks.
- Supports future smart city initiatives with flexible, data-driven traffic management.

Economic Efficiency
- Saves costs associated with congestion, including fuel expenses, vehicle wear, and time lost in traffic.
- Increases overall productivity by minimizing time spent commuting.

Advantages of the Proposed Solution

Enhanced Traffic Flow
- Dynamically adjusts traffic lights based on real-time data, improving overall vehicle movement and reducing congestion in busy intersections.

Real-Time Decision Making
- The AI-driven system processes live traffic data for immediate adjustments, similar to autonomous vehicle decision-making, ensuring efficient traffic handling.

Improved Precision and Efficiency
- Uses advanced machine learning techniques to detect, prioritize, and manage traffic, ensuring accurate decisions for controlling light signals based on the traffic density.

Support for Autonomous Vehicles
- Integrates well with autonomous vehicle technology by providing real-time traffic data, helping self-driving cars make decisions such as when to stop, turn, or accelerate safely.

Real-Time Detection of Traffic Participants
- The system can detect both static and dynamic objects such as vehicles, barriers, and traffic cones, crucial for adapting to changing conditions in urban traffic environments.

Optimized for Indian Traffic Conditions
- Trained on a custom dataset that includes images from Indian traffic scenarios, making it highly suitable for handling complex, congested, and often unpredictable traffic patterns.

Higher Accuracy with YOLOv5-NEXUS
- Achieves better precision (81%), recall (80%), and mAP (83%) compared to traditional models, offering more reliable and efficient traffic management.

RESEARCH AND REFERENCES

- Ultralytics YOLOv5 Repository:
  - https://github.com/ultralytics/yolov5
- OpenCV Documentation:
  - https://docs.opencv.org/4.x/index.html
- PyTorch Documentation:
  - https://pytorch.org/docs/stable/index.html
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