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AI-Based Emergency Vehicle Detection and Smart Traffic Signal Prioritization Using YOLOv8 and Arduino

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Abstract: Traffic congestion is a major challenge in modern urban environments, often causing delays for emergency vehicles such as ambulances and fire trucks. Traditional traffic management systems operate on predefined signal timing schedules and lack mechanisms to prioritize emergency vehicles. This paper presents a Smart AI Traffic Assistance System that combines Computer Vision, Artificial Intelligence, and Internet of Things (IoT) technologies to automate traffic signal prioritization.
The proposed system utilizes the YOLOv8 object detection framework to identify emergency vehicles from live video streams. Additional verification is performed using HSV-based red light detection and optional siren detection. Upon successful identification, the system communicates with an Arduino-based traffic controller to create a green corridor. A Streamlit dashboard provides real-time monitoring, status visualization, and event logging.
Experimental evaluation demonstrated an overall detection accuracy of 86%, an average detection latency of 320 ms, and an end-to-end response time of approximately 405 ms. The results indicate that the proposed solution can serve as a cost-effective and scalable alternative for intelligent traffic management in smart city environments.
Keywords: YOLOv8, Computer Vision, Emergency Vehicle Detection, Smart Traffic System, Arduino, IoT, Streamlit Dashboard, Smart City.

I. INTRODUCTION

Urban traffic congestion continues to increase due to rapid population growth and vehicle density. Emergency response vehicles frequently encounter delays at intersections because traditional traffic signal systems are unable to dynamically adapt to emergency situations.
Emergency vehicles such as ambulances and fire trucks require immediate right-of-way to minimize response time. Even a delay of a few minutes can significantly impact patient survival rates and disaster management outcomes.
Recent advancements in Artificial Intelligence (AI), Deep Learning, and Computer Vision have enabled the development of intelligent transportation systems capable of making real-time decisions. By combining AI-based object detection with IoT-enabled traffic controllers, traffic signals can automatically adapt to emergency situations.
This research proposes a Smart AI Traffic Assistance System that detects emergency vehicles using YOLOv8 and automatically prioritizes traffic signals using Arduino-based control.

II. LITERATURE REVIEW

Several techniques have been proposed for emergency vehicle prioritization:

A. GPS-Based Systems

GPS-enabled emergency vehicles communicate their location to nearby traffic controllers. Although effective, these systems require dedicated infrastructure and communication networks.

B. RFID-Based Systems

RFID tags installed on emergency vehicles interact with RFID readers at intersections. However, hardware installation costs are significant.

C. Infrared-Based Systems

Infrared communication provides direct interaction between emergency vehicles and traffic controllers but requires line-of-sight operation.

D. Computer Vision-Based Systems

Modern research increasingly utilizes camera-based vehicle detection using deep learning algorithms. YOLO-based models have become popular due to their speed and accuracy.

Despite these developments, many systems focus only on detection and lack complete end-to-end traffic signal control and monitoring functionality.

III. PROPOSED SYSTEM

A. System Overview

The proposed architecture consists of four layers:

- Sensing Layer
- Processing Layer
- Control Layer
- Presentation Layer

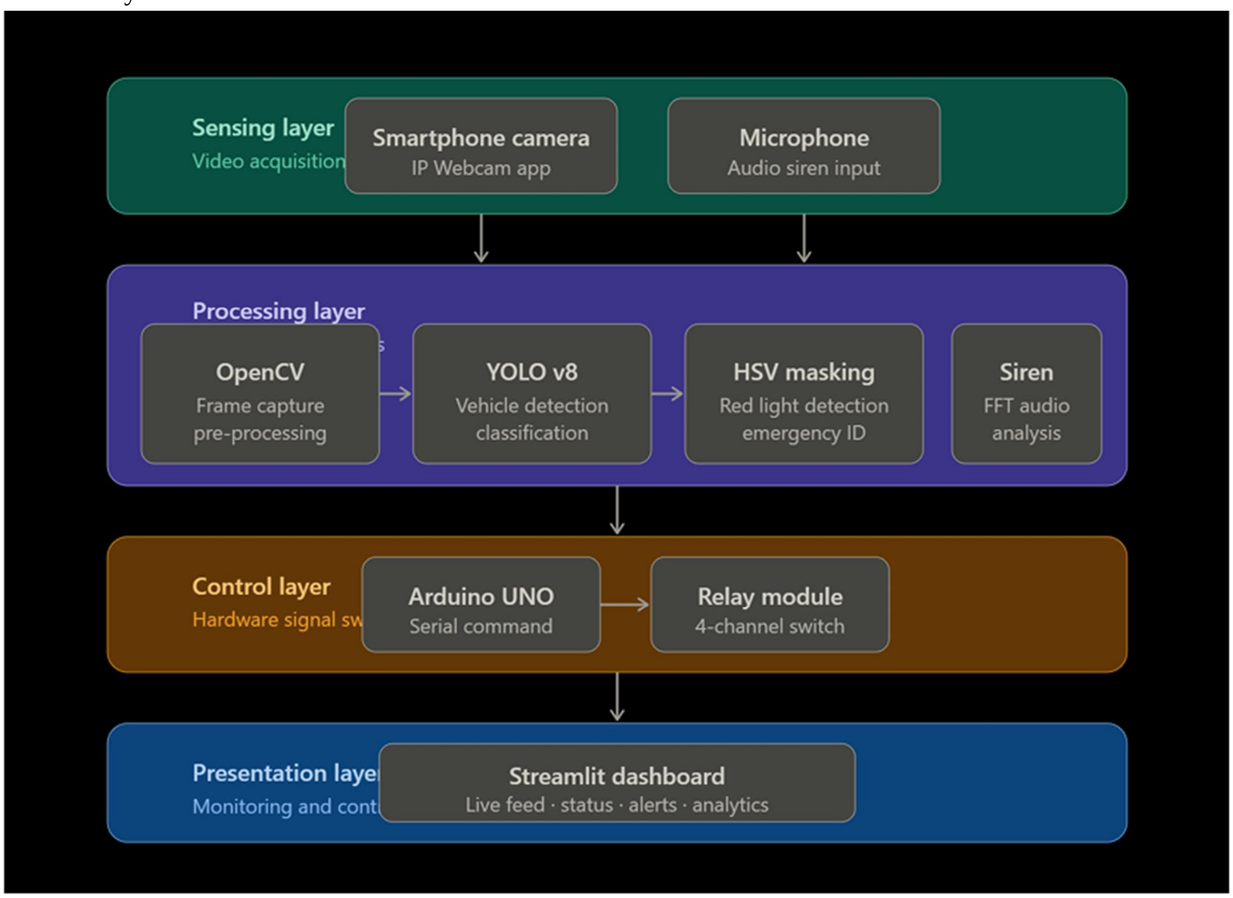

Figure 1. System Architecture Diagram

1) Sensing Layer

Captures video streams through a Smartphone IP camera and audio signals through a microphone.

2) Processing Layer

Performs:

- OpenCV preprocessing
- YOLOv8 object detection
- HSV emergency light verification
- Siren detection

3) Control Layer

Uses Arduino Uno and relay modules to control traffic signals.

4) Presentation Layer

Provides a Streamlit-based dashboard for monitoring and analytics.

IV. SYSTEM WORKFLOW

The operational workflow consists of:

1) Capture frame from IP camera
2) Preprocess frame
3) Detect vehicles using YOLOv8
4) Verify emergency indicators using HSV analysis
5) Optional siren verification
6) Send command to Arduino
7) Activate green corridor
8) Update dashboard

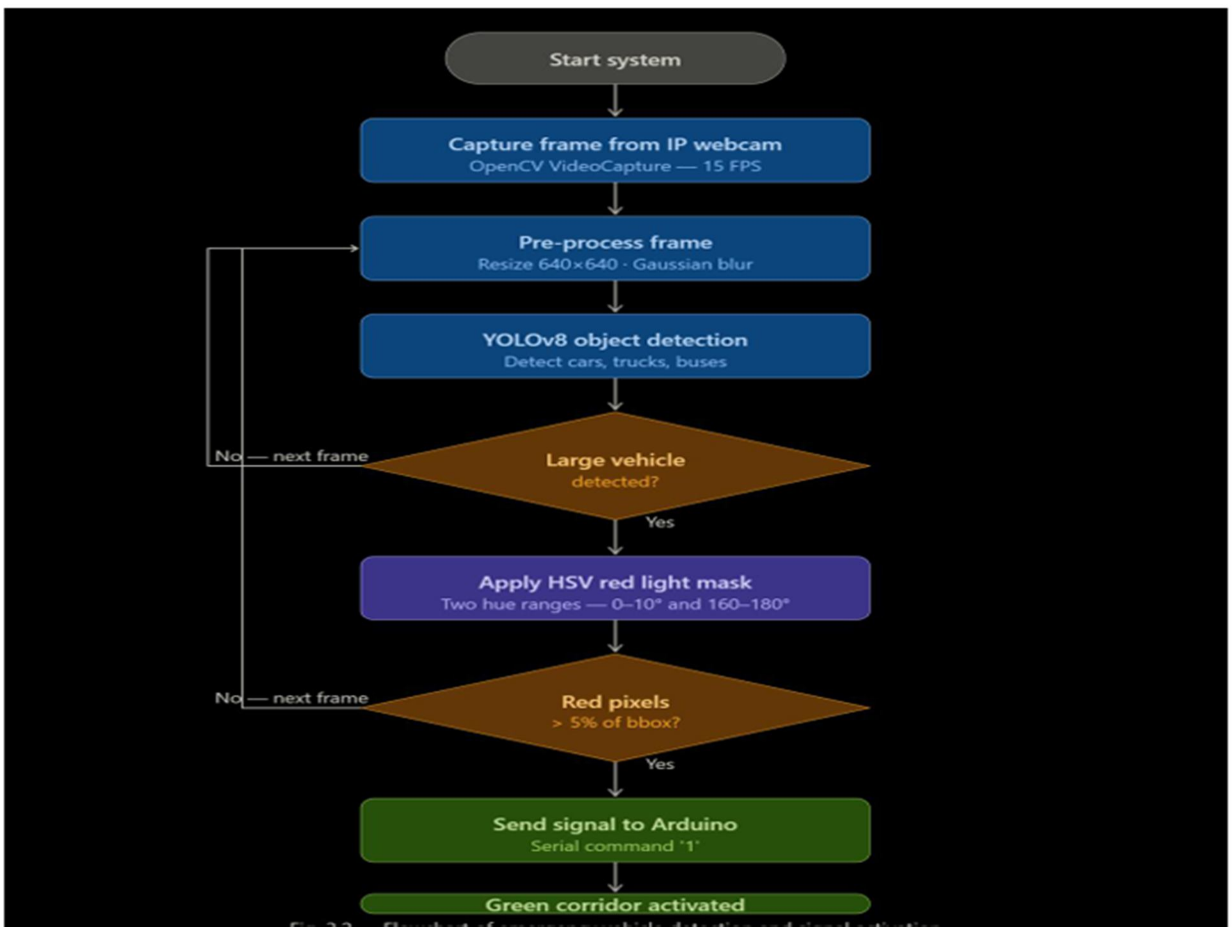

Figure 2. Workflow Diagram

V. METHODOLOGY

A. YOLOv8 Vehicle Detection

YOLOv8 serves as the primary object detection framework.
Detected classes include:

- Car
- Truck
- Bus
- Motorcycle

The model performs real-time inference on incoming video frames.

B. HSV-Based Emergency Light Verification

HSV color masking is applied to detect emergency vehicle warning lights.
Two red color ranges are used:
Range 1:

- Hue: 0–10

Range 2:

- Hue: 160–180

Morphological filtering reduces noise.

C. Siren Verification

Audio data is analyzed using Fast Fourier Transform (FFT).
Frequency characteristics associated with emergency sirens are extracted to improve reliability.

D. Traffic Signal Control

After emergency vehicle confirmation:
Arduino receives serial commands.

Commands:

- '1' → Emergency Mode
- '0' → Normal Mode

Emergency mode activates a green corridor.

VI. HARDWARE DESIGN

A. Hardware Components Used

Component	Purpose
Arduino Uno	Traffic signal control
Breadboard	Circuit implementation
LEDs	Signal representation
Smartphone	IP Camera
Laptop	AI processing
USB Cable	Communication

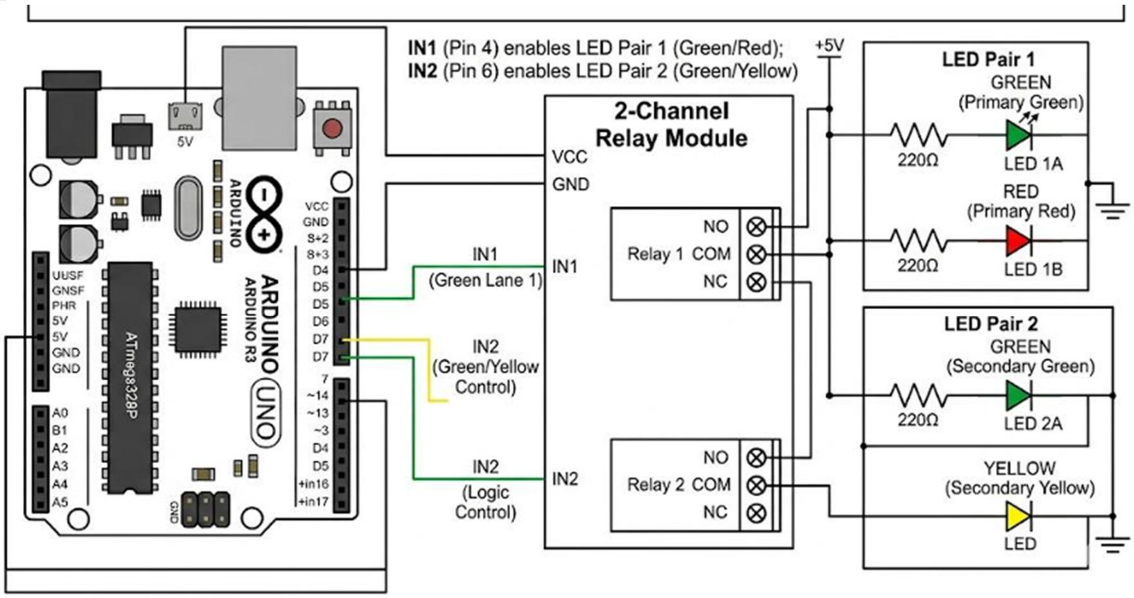

Figure 3. Arduino Circuit Diagram

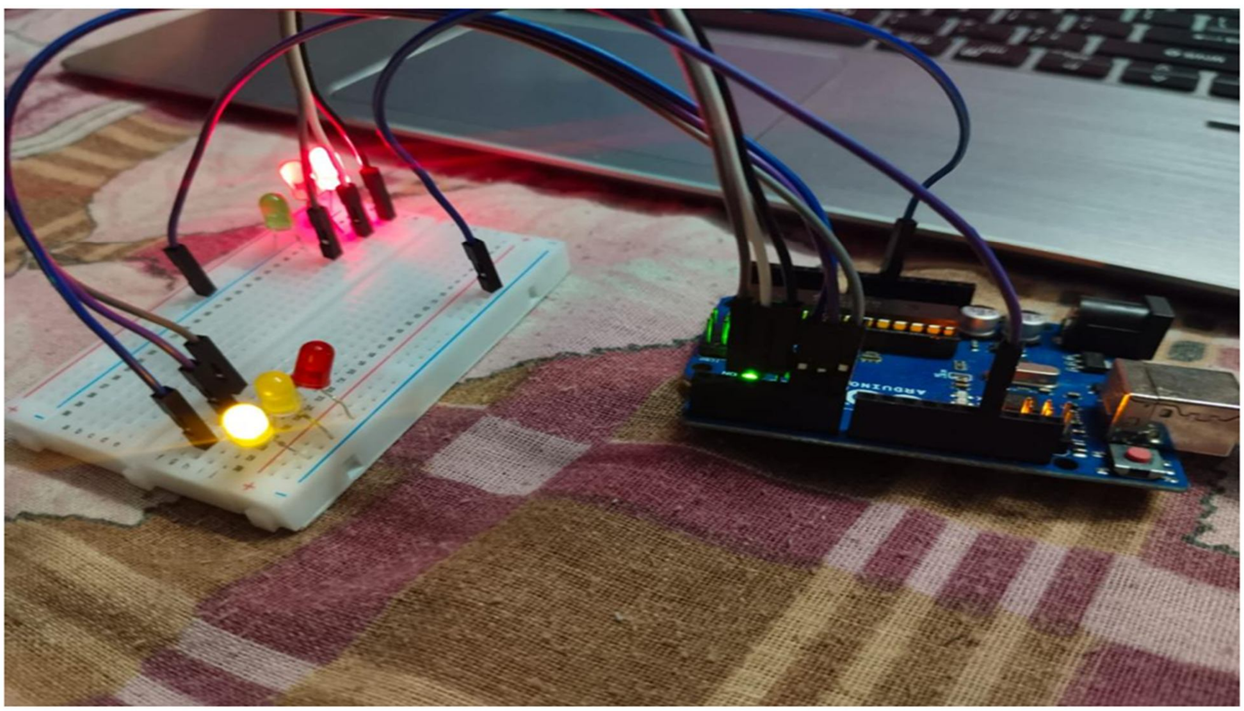

Figure 4. Hardware Prototype Setup

VII. DASHBOARD DESIGN

A. A Streamlit-based dashboard was developed to provide

1) Live status monitoring
2) Detection statistics
3) Emergency alerts
4) System analytics

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B. Dashboard Metrics Include

1) Frames per second
2) Detection count
3) Latency
4) Uptime

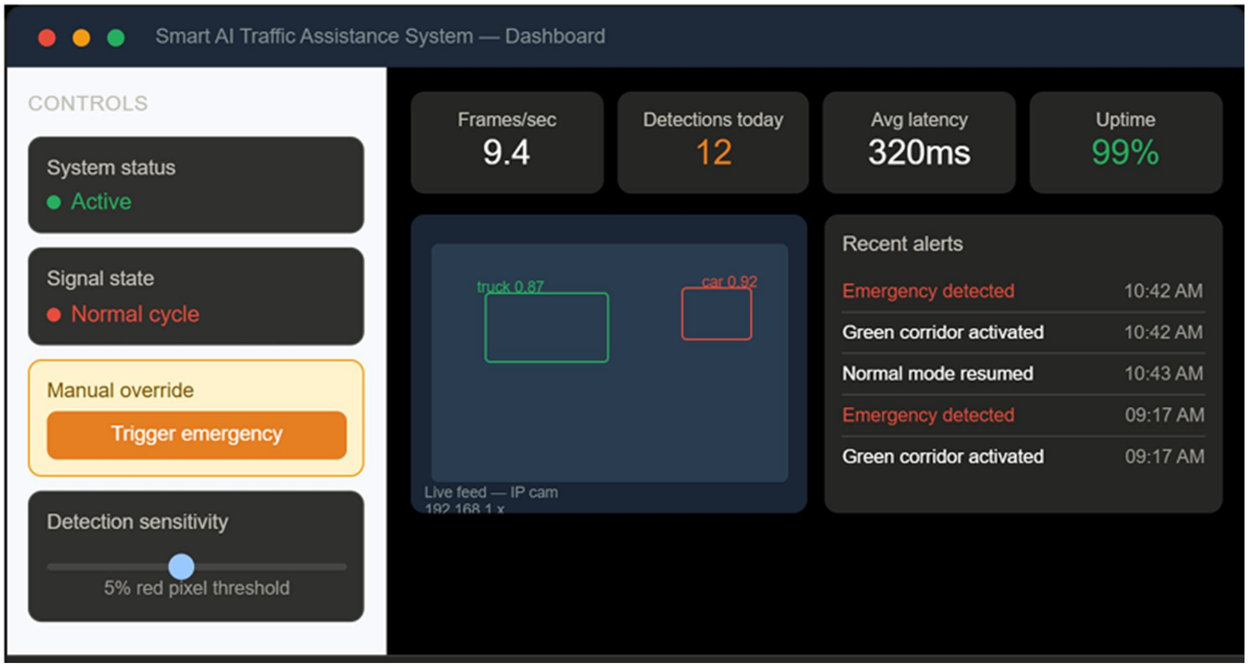

Figure 5. Dashboard Screenshot

VIII. EXPERIMENTAL RESULTS

The system was tested under multiple environmental conditions.

A. Detection Accuracy

Condition	Accuracy
Bright Daylight	94%
Indoor Lighting	88%
Low Light	76%
Overall Average	86%

B. Performance Metrics

Metric	Value
Detection Latency	320 ms
Signal Switching Time	85 ms
End-to-End Response Time	405 ms
Processing Rate	9.4 FPS
False Positive Rate	6.7%
System Uptime	99.2%

IX. DISCUSSION

The proposed system successfully demonstrates the integration of Artificial Intelligence and IoT for emergency vehicle prioritization.

A. Advantages

1) Low-cost implementation
2) Real-time detection
3) Automated traffic control
4) Scalable architecture
5) Smart city compatibility

B. Limitations

1) Performance reduction under poor lighting
2) Siren detection sensitivity to noise
3) Single intersection prototype

X. FUTURE SCOPE

Future enhancements include:

1) Custom-trained emergency vehicle datasets
2) GPS integration
3) Vehicle-to-Infrastructure (V2I) communication
4) Edge AI deployment using NVIDIA Jetson
5) Multi-intersection traffic coordination
6) Cloud-based traffic management
7) Government traffic system integration

XI. CONCLUSION

This paper presented a Smart AI Traffic Assistance System that combines YOLOv8, OpenCV, Arduino, and IoT technologies to prioritize emergency vehicles at traffic intersections. Experimental evaluation demonstrated reliable performance with an overall accuracy of 86% and an end-to-end response time of 405 ms. The proposed solution offers a practical and cost-effective approach toward intelligent transportation systems and smart city infrastructure.

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