SMART TRAFFIC NAVIGATION SYSTEM WITH EMERGENCY VEHICLE PRIORITY USING AI-BASED SIGNAL CONTROL

Divyarani Y S[1], Gowtham C[2], Gagan Gowda G S[3], Vidhya A[4]

Department of Artificial Intelligence and Machine Learning Engineering,

G. Madegowda Institute of Technology, Bharthinagara, Maddur TQ, Mandya dist-571422[1-4]

Abstract: Rapid urbanization and the continuous increase in vehicle population have resulted in severe traffic congestion in metropolitan cities. Conventional traffic signal systems operate on fixed time intervals and fail to adapt dynamically to real-time traffic density, often leading to unnecessary delays. One of the most critical consequences of such inefficiency is the delayed movement of emergency vehicles such as ambulances, fire engines, and police vehicles.

This project presents a Smart Traffic Navigation System that dynamically controls traffic signals based on lane-wise vehicle density and provides absolute priority to emergency vehicles. The system is implemented using Python and Pygame, simulating a real-world four-way intersection with intelligent traffic management. When an emergency vehicle is detected, the system overrides normal traffic flow and creates a clear emergency corridor.

I. INTRODUCTION

Traffic congestion is a major issue in modern cities due to the rapid growth of vehicles and limited road infrastructure. Traditional traffic signal systems operate on fixed timings and are inefficient during peak hours. Emergency vehicles often face delays, resulting in loss of life and property.

The proposed system introduces an AI-based smart traffic control mechanism that dynamically adjusts signal timings and prioritizes emergency vehicles.

II. LITERATU REREVIEW

Early traffic management systems relied on manual signal control or fixed-time scheduling, which required human intervention and lacked flexibility. Although these systems were simple to implement, they were highly inefficient during peak traffic hours.

Later, sensor-based traffic systems were introduced using inductive loops, infrared sensors, and RFID technology to detect vehicle presence. While these systems improved traffic flow to some extent, they required costly infrastructure and frequent maintenance. Moreover, they lacked intelligent decision-making capabilities.

Recent studies have explored **AI-based traffic control systems**, incorporating machine learning, computer vision, and real-time simulation. Density-based signal control using cameras and image processing has proven effective in reducing congestion. Emergency vehicle prioritization systems using GPS and RFID have also been proposed; however, coordination between vehicles and traffic signals remains complex.

III. SYSTEM ARCHITECTURE

The Smart Traffic Navigation System follows a **modular architecture**, where each module is responsible for a specific function. This design improves system scalability, maintainability, and clarity.

Major Components:

1. **Vehicle Generation Module**
   Generates vehicles dynamically with defined speed, size, and direction. Emergency vehicles are generated with higher priority and distinct behavior.
2. **Lane Modeling Module**
   Models a four-way intersection with proper lane structure, stop lines, and road boundaries.
3. **Traffic Density Calculation Module**
   Calculates lane-wise traffic density by counting vehicles waiting at each signal.
4. **Signal Control Module**
   Allocates green signals dynamically based on the highest traffic density.

5. **Emergency Detection Module**
   Detects emergency vehicles entering the system and activates emergency mode.
6. **Emergency Override Module**
   Stops all regular vehicles and allows only emergency vehicles to move through the intersection.
7. **Visualization Module**
   Displays roads, vehicles, signals, emergency alerts, and statistics using Pygame.

IV.   METHODOLOGY

The system operates using the following methodology:

1. **Initialization Phase**
   The simulation environment is initialized with roads, signals, vehicles, and system parameters.
2. **Vehicle Movement Control**
   Vehicles move based on signal state, lane direction, and safe distance from other vehicles.
3. **Collision Avoidance Mechanism**
   Each vehicle continuously checks the distance from the vehicle ahead to prevent overlapping and collisions.
4. **Density-Based Signal Control**
   Lane densities are calculated dynamically, and the lane with maximum density is given green signal priority.
5. **Emergency Vehicle Detection**
   When an emergency vehicle appears, the system switches to emergency mode instantly.
6. **Emergency Corridor Formation**
   Normal vehicles stop safely and move sideways gradually to clear a path for the emergency vehicle.
7. System Recovery
   Once the emergency vehicle clears the intersection, the system returns to normal traffic operation.

V.   IMPLEMENTATION

The project is implemented using **Python programming language** with **Pygame** for visualization.
Implementation Details:
- Object-Oriented Programming is used for modular design.
- The Vehicle class manages movement, speed control, and rendering.
- The TrafficSignal class controls signal states and timing.
- The SmartTrafficSystem class integrates all modules and manages simulation flow.

Key Features Implemented:
- Smooth acceleration and deceleration
- Lane-wise density calculation
- Emergency vehicle siren and alert panel
- Real-time statistics display
- Collision-free movement

VI.   RESULTS AND DISCUSSION

The system was tested under multiple traffic conditions including low traffic, heavy congestion, and emergency scenarios.

Results Observed:
- Smooth traffic flow with no vehicle overlapping
- Automatic adjustment of signal timings
- Immediate emergency vehicle clearance
- Reduced waiting time for normal vehicles after emergency clearance
- Stable and realistic simulation performance

The results confirm that intelligent signal control combined with emergency priority significantly improves traffic efficiency and safety.

VII.   ADVANTAGES

1. Reduces traffic congestion
2. Ensures fast emergency vehicle response

3. Prevents vehicle collisions
4. Adaptive real-time signal control
5. Cost-effective simulation approach
6. Suitable for smart city deployment

VIII. APPLICATIONS

1. Smart city traffic management
2. Emergency response systems
3. Traffic police training
4. Urban traffic planning
5. Research and academic use

IX. CONCLUSION

The Smart Traffic Navigation System demonstrates an effective and intelligent approach to modern traffic management. By dynamically controlling traffic signals and prioritizing emergency vehicles, the system addresses major shortcomings of traditional traffic systems. The simulation validates that emergency corridors can be created safely without disrupting overall traffic flow.

The project highlights the importance of AI-based traffic control systems in reducing congestion, improving emergency response, and enhancing road safety. The proposed model serves as a strong foundation for real-world intelligent traffic management solutions.

X. FUTURE SCOPE

- Integration with real-time traffic cameras
- YOLO-based vehicle detection
- IoT sensor deployment
- Multi-intersection city simulation
- Machine learning-based traffic prediction
- Government and smart city implementation

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