

Software Requirements Specification

Smart Traffic Signal Automation System

1. Introduction

This project develops an intelligent traffic signal control system for managing traffic at four-way intersections. The system simulates an intersection where two 2-way roads cross, creating four traffic approach sides, each equipped with a traffic signal and camera.

Unlike traditional fixed-timing signals, our system uses real-time camera feeds and computer vision to analyze traffic conditions and dynamically adjust signal timings. The system counts vehicles, detects emergency vehicles, monitors traffic violations, and stores data in a MySQL database for traffic management authorities.

Key Objectives:

- Reduce traffic congestion through intelligent signal timing
- Prioritize emergency vehicles for faster response times
- Detect and log traffic violations for enforcement
- Provide manual control capability for traffic authorities
- Ensure fail-safe operation during system failures

2. Functional Requirements

2.1 Traffic Signal Control

Sequential Operation: Signals operate in a round-robin sequence (Side 1→2→3→4) with default 30-second green phase and 3-5 second yellow transition.

Dynamic Timing Adjustment: The system analyzes real-time traffic density and adjusts green signal duration between 15-60 seconds:

- Heavy traffic sides receive extended green time (40-60 sec)
- Light traffic sides receive reduced time (15-25 sec)
- Early phase switching when traffic clears quickly

Low Traffic Mode: During low-traffic periods (nighttime), cycle duration automatically reduces to 10-15 seconds per side for improved efficiency.

2.2 Vehicle Detection and Monitoring

- Cameras capture images every 2-5 seconds from each approach
- Computer vision algorithms detect and count vehicles by type (cars, trucks, motorcycles, buses)

- Each vehicle assigned unique ID for tracking
- Real-time traffic density calculation for each side
- Vehicle tracking through intersection for violation detection

2.3 Emergency Vehicle Priority

The system detects emergency vehicles (ambulances, fire trucks, police vehicles) using visual identification. Upon detection:

- Immediate green signal activation for that approach
- Signal remains green until emergency vehicle clears intersection
- Automatic resumption of normal sequence afterward
- Event logged with timestamp and details

2.4 Traffic Violation Detection

Wrong-Way Detection: System monitors vehicle movement direction and logs violations including vehicle ID, timestamp, and location in dedicated database table.

Overspeeding Detection: System tracks vehicle speeds with configurable limits by vehicle type. Violations logged with vehicle ID, recorded speed, timestamp, and location.

All violation data accessible to authorized traffic management personnel for enforcement action.

2.5 Database Management

MySQL database stores:

- Vehicle counts per side with timestamps
- Traffic flow patterns for analysis
- Violation records (separate tables for wrong-way and overspeeding)
- Signal change events and timestamps
- Emergency vehicle events
- System mode changes
- Manual control actions with user IDs

2.6 Manual Override System

Authorized traffic management personnel can:

- Manually control individual or all signals (red/yellow/green)
- Override automatic operation (except fail-safe mode)
- Return to automatic mode at any time

Security Features:

- Username/password authentication required
- All manual actions logged with user ID and timestamp
- Session timeout after 15 minutes of inactivity

- Multiple permission levels (view-only, partial control, full control)

2.7 Fail-Safe Mechanism

System continuously monitors its operational health. On detecting critical failures (camera malfunction, processing errors, communication failures):

- Automatic activation of fail-safe mode within 3 seconds
- Fixed-time operation: 30 seconds per side in sequential order
- Continues until system functionality restored
- Entry/exit events logged with details

2.8 Simulation Environment

The simulation provides:

- Realistic four-way intersection visualization
- Vehicle movement with varying speeds and traffic scenarios
- Real-time signal status display (Red/Yellow/Green)
- Camera view representation for each side
- Traffic counts and system status dashboard

3. Non-Functional Requirements

3.1 Performance Requirements

- **Real-time Processing:** Signal decisions within 2 seconds of detecting traffic changes
- **Emergency Response:** Emergency vehicle detection triggers signal change within 1 second
- **Manual Control:** Commands execute within 0.5 seconds
- **Detection Accuracy:** Minimum 95% vehicle detection accuracy
- **Throughput:** Process 100+ vehicles per minute across all sides
- **Database Operations:** Non-blocking, ensuring signal control remains unaffected

3.2 Reliability and Availability

- **Uptime Target:** 99.9% system availability
- **Fault Tolerance:** Graceful degradation with component failures (e.g., single camera failure)
- **Fail-Safe Activation:** Within 3 seconds of critical failure
- **System Restart:** Complete recovery within 30 seconds
- **Data Integrity:** Atomic database transactions, daily backups, zero violation data loss

3.3 Security

- Authentication required for manual control access

- Session timeout: 15 minutes
- Failed login limit: 3 attempts with temporary lockout
- Encrypted database connections
- Audit logs for all critical operations and data access
- Administrative privileges required for configuration changes

3.4 Safety Requirements

- Never display conflicting green signals simultaneously
- Adequate yellow signal duration per safety standards
- Safe traffic flow during emergency vehicle priority
- Emergency stop function for traffic management personnel
- Fail-safe mode maintains safe operations under all conditions

4. Technology Requirements

- **Programming Language:** Python (backend, simulation, image processing)
- **Database:** MySQL 5.7+
- **Computer Vision:** OpenCV library
- **RAM:** Minimum 4 GB (8 GB recommended)

5. Success Criteria

The project will be considered successful when:

- All functional requirements implemented and tested successfully
- Vehicle detection achieves $\geq 95\%$ accuracy across various scenarios
- Emergency vehicle detection operates with 100% reliability in testing
- Violation detection and logging functions correctly with zero data loss
- Manual override system responsive and secure
- Fail-safe mode activates reliably during simulated system failures
- All performance requirements met (response times, throughput)
- Database operations efficient with maintained data integrity
- Complete system documentation provided