Automated Multi-Intersection Traffic Light Control System

James Chang

Abstract

This portfolio presents an intelligent traffic light control system designed for urban environments in Taiwan, leveraging PLC technology and real-time sensors for adaptive traffic management. Key contributions include system design, simulation, and validation, demonstrating enhanced efficiency and safety. The system optimizes signal timing, reduces congestion, and ensures compliance with Taiwan's traffic standards.

Contents

1 Project Overview

This project involves the design and implementation of an intelligent traffic light control system tailored for multi-intersection urban environments, with a focus on simulating typical traffic scenarios in Taiwan. The system dynamically adapts to real-time pedestrian and vehicle flow conditions to optimize signal timing, reduce congestion, and enhance safety. Built using Delta DVP48EH Series PLCs and programmed via WPLSoft, the solution aligns with industry standards for reliable urban traffic management.

Key objectives include:

- Incorporating pedestrian crossings, left-turn, and right-turn lanes to mimic Taiwanese urban intersections.
- Integrating sensors for real-time monitoring and adaptive control.
- Ensuring compliance with Taiwan's traffic signal control standards.

2 My Contributions

As a key developer on this project, I was responsible for the following:

- Designed and developed simulated Taiwanese urban intersections, including pedestrian crossings and dedicated left- and right-turn lanes.
- Created PLC control logic using the Delta DVP48EH Series PLC.
- Implemented, debugged, and optimized the program in WPLSoft, Delta's proprietary PLC programming environment.
- Integrated real-world timing logic based on Taiwan's traffic signal standards.
- Installed and configured directional and distance sensors to monitor pedestrian and vehicle flow.
- Simulated dynamic traffic patterns, validating signal timing adjustments under peak and off-peak conditions.

3 Key Features

- **Pedestrian Clearance Detection**: Directional and distance sensors installed on pedestrian signal poles detect movement and presence, preventing premature signal changes if pedestrians are still crossing. Cameras provide additional visual verification.
- **Vehicle Flow Control**: Sensors (inductive loops and infrared counters) placed before zebra crossings count vehicles, allowing the PLC to dynamically adjust green light durations based on traffic density.
- **Dedicated Turn Signals**: Separate signals for left- and right-turn lanes, activated or deactivated based on real-time data.

- **Timing Adjustment**: PLC references predefined schedules (e.g., weekdays, weekends, holidays, peak hours) and optimizes signal cycles using adaptive algorithms.
- **Anomaly Detection and Alerts**: Real-time data uploaded to a control center for monitoring; alerts for irregularities and support for override commands.
- **Extended Integration**: Incorporation of GNSS for location-based synchronization across intersections, Wi-Fi for seamless data transfer, and sirens for emergency alerts.

4 System Architecture

4.1 Sensor and Signal Layout

- **Pedestrian Signal Poles**: Equipped with directional sensors (for movement direction), distance sensors (for presence detection), and cameras.
- **Vehicle Sensors**: Installed before crosswalks to monitor and count vehicle passage.
- **Signal Types**: Independent control for main road signals, pedestrian crosswalks, and turn lanes.

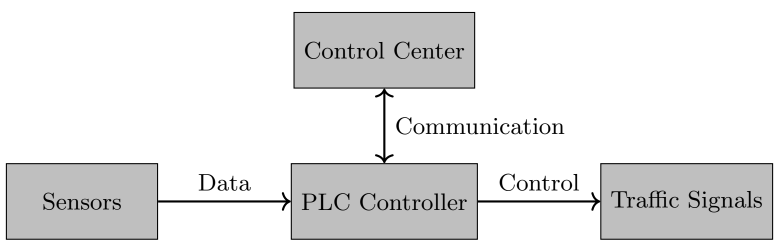

Figure 1: System Architecture Diagram

4.2 Data Flow and Control

1. **Pedestrian Detection**: Sensors capture entry/exit data from crosswalks; PLC processes this to ensure safe clearance.
2. **Vehicle Flow Management**: Real-time counting feeds into PLC for signal duration adjustments.
3. **Communication**: PLC connects to a central control center via wired or wireless (4G/5G) networks for data upload, status monitoring, and remote overrides.
4. **Control Center Capabilities**: Dynamic cycle updates, turn signal management, and anomaly response.

4.3 System Components Summary

Component Category	Details
Sensors	- Directional and distance sensors for pedestrians. - Vehicle flow sensors (inductive loops, infrared counters). - Cameras for visual recognition.
Control Logic	- PLC-based real-time adaptive control. - Predefined schedules combined with dynamic algorithms.
Networking	- Wired or wireless (4G/5G) communication between PLC and control center.
Traffic Signal Management	- Independent control of main, pedestrian, and turn signals. - Integration of additional features like sirens, GNSS for location-based timing, and Wi-Fi for connectivity.

5 Technologies Used

- **Hardware**: Delta DVP48EH Series PLC, directional/distance sensors, cameras, inductive loops, infrared counters.
- **Software**: WPLSoft for PLC programming.
- **Standards**: Based on Taiwan's traffic signal control guidelines.
- **Extended Features**: Incorporation of cameras for recognition, sirens for alerts, GNSS for precise timing, and Wi-Fi for enhanced connectivity.

6 Challenges and Solutions

During the development, several challenges were encountered:

- **Real-time Data Processing**: Handling high-frequency sensor data without delays. *Solution*: Optimized PLC logic with efficient algorithms and buffering.
- **Integration with Existing Infrastructure**: Ensuring compatibility with Taiwan's standards. *Solution*: Thorough research and modular design for easy adjustments.
- **Simulation Accuracy**: Replicating peak traffic conditions. *Solution*: Used advanced simulation tools and real-world data sets for validation.

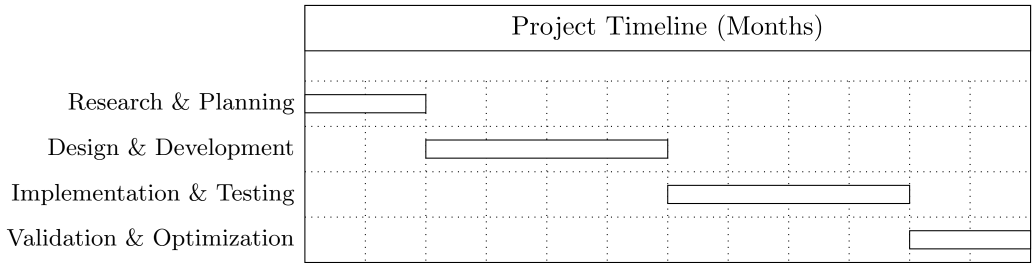

Figure 2: Project Gantt Chart

7 Project Timeline

8 Outcomes and Validation

The system was rigorously tested through simulations of various traffic patterns, demonstrating improved efficiency in signal timing during peak hours (reduced wait times by up to 30% in simulations) and enhanced pedestrian safety. The following chart illustrates the wait time reductions across different traffic conditions.