A Comprehensive Review of Adaptive and Intelligent Dynamic Traffic Light Control System

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Abstract. Traffic congestion at urban intersections remains a persistent issue, largely due to fixed-time signal plans that cannot respond to changing traffic demand. This paper reviews recent progress in adaptive and intelligent dynamic traffic light control, with emphasis on sensor-based, vision-based, and reinforcement learning (RL)–driven techniques. The strengths and shortcomings of each category are discussed through comparative analysis of key studies.
Building on these findings, an adaptive hybrid model is introduced that fuses real-time video input and IoT sensor data. The framework employs YOLO-based vehicle detection integrated with a Deep Q-Learning controller in the SUMO simulation environment to adjust signal phases dynamically. The system aims to shorten queues, reduce waiting times, and provide prompt clearance for emergency vehicles. Comparative evaluations indicate a gradual shift from traditional sensor systems toward hybrid AI-driven solutions, offering greater adaptability, scalability, and responsiveness. The study concludes by outlining current research gaps and suggesting directions for future development of intelligent traffic management systems.

Keywords: Dynamic Traffic Control, Reinforcement Learning, YOLO, SUMO, IoT, Smart Cities

1 Introduction

The rapid pace of urban growth and the rising number of vehicles on city roads have intensified the challenges of traffic regulation. In many regions, especially in developing countries, traffic signal systems still rely on pre-timed cycles that cannot adjust to varying traffic volumes. As a result, intersections often experience congestion, prolonged waiting times, unnecessary fuel consumption, and higher emissions [1,2].

Conventional approaches to traffic control—such as manual supervision, fixed-time scheduling, and sensor-triggered actuation—are limited by their poor adaptability and high maintenance demands when deployed at scale [1]. To overcome these limitations, researchers have turned toward *intelligent transportation systems* (ITS) that combine sensing devices, computer vision, and machine learning to optimize traffic flow in real time [4,5].