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Addressing Urban Traffic Congestion: A Deep Reinforcement Learning-Based Approach

Project 2322
June 2025

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Introduction

California has been in a transportation crisis for a long while. Two urgent issues in the transportation crisis are congestion and traffic safety. A common situation is that congestion leads to traffic accidents, and traffic accidents, in turn, cause more severe congestion. The dynamic nature of traffic requires traffic management solutions that can monitor, analyze, and intervene in real time. Thus, urban traffic congestion remains one of the most pressing challenges facing cities worldwide, profoundly impacting the economy, environment, public health and safety, and overall quality of urban life. The persistent traffic jams on city roads not only symbolize the complexity of urban mobility but also spotlight the intricate relationship between transportation infrastructure and urban development. City planners, traffic engineers, and technological innovators have long struggled with congestion, seeking effective strategies to untangle the knots of stalled traffic that frustrate commuters, impede emergency services, and pollute city environments. Despite advances in technology and urban design, the problem persists, underscoring the need for innovative and integrated solutions that can adapt to the dynamic nature of urban growth and mobility patterns. The research team aimed to redefine urban traffic flow by introducing an automated way to manage traffic light timings. This project integrates two critical technologies, Deep Q-Networks (DQN) and Auto-encoders, into reinforcement learning, with the goal of making traffic smoother and reducing the all-too-common road congestion in simulated city environments.

Study Methods

This research primarily focuses on using deep reinforcement learning (DRL) algorithms to optimize traffic signal control, aiming to enhance vehicular flow and throughput in urban areas. The core objective is to dynamically determine the optimal duration for each phase of the traffic light (green, yellow, red) based on real-time observations. By incorporating average speed into the observation space, this study adopts a distinct strategy compared to previous research that includes the average speed of vehicles in the state space. The inclusion of average speed provides the DRL model with an expanded set of data, enriching the learning environment and enabling the model to make more informed decisions. This setting allows the DRL algorithm to understand traffic dynamics better, leading to more effective traffic signal control tailored to the specific conditions of each intersection. To find the optimal solution, HyperOPT was utilized to navigate the hyperparameter space effectively.

HyperOPT, a powerful tool for hyperparameter optimization, plays a crucial role in identifying the best settings for the DRL algorithm. This optimization process significantly enhances the capability to refine and advance the traffic signal control system, ensuring it adapts efficiently to real-time traffic conditions. The application of DRL in traffic signal control represents a significant advancement over traditional fixed-time and adaptive traffic signal control systems. Traditional systems often lack the flexibility to respond to real-time changes in traffic patterns, leading to suboptimal performance during peak hours or unexpected traffic surges. In contrast, the DRL-based approach continuously learns and adapts to ongoing traffic conditions, improving overall traffic efficiency and reducing congestion.

The deep reinforcement learning method can significantly improve traffic flows. Properly designed reward functions can significantly affect the performance and impact multiple evaluation metrics.

Findings

The deep reinforcement learning method can significantly improve the traffic flow in multiple evaluation metrics. The proposed DQN + auto-encoder approach with the HyperOPT optimizer can quickly find the optimal solution for controlling traffic signals. The selection of the reward function for the deep Q-network algorithm can significantly affect its performance and impact multiple evaluation metrics. Coordinating multiple intersections that utilize the DQN algorithm can achieve more improvements than a single intersection case. In addition to the traffic signal controller, the integration of V2X communication can also significantly improve the traffic flow in terms of average speed in the protected left-turn scenario. These findings indicate significant promise in the usefulness of the proposed method in improving traffic flow, which, in turn, can improve safety and reduce traffic congestion's negative impacts on the economy, quality of life, and more.

Policy Recommendations

Based on our research on utilizing deep reinforcement learning (DRL) to control traffic signals and reduce congestion, we recommend implementing DRL-based intelligent traffic control systems and V2X infrastructure in urban areas to optimize traffic flow in real time. We recommend starting with pilot programs in high-traffic zones to test and refine these systems, and then gradually expanding citywide. Investing in infrastructure such as sensors, cameras, and wireless communication networks is crucial for providing accurate data to DRL algorithms and ensuring seamless integration with existing traffic management frameworks. Additionally, continuous monitoring and periodic assessment mechanisms should be established to evaluate system performance and make iterative improvements. This approach will significantly enhance intelligent transportation, improve daily life, alleviate congestion, enhance safety, and reduce emissions.

About the Author

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MTI is a University Transportation Center sponsored by the U.S. Department of Transportation's Office of the Assistant Secretary for Research and Technology and by Caltrans. The Institute is located within San José State University's Lucas Graduate School of Business.