Enhancing Travel Efficiency in Mixed Traffic Using Control-based and Learning-based Connected and Autonomous Systems

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Inefficient traffic operations have far-reaching consequences in areas beyond transportation, encompassing public health and safety, environmental protection, social equity, and economic prosperity. Congestion, a key symptom of inefficient traffic, leads to increased emissions, accidents, and productivity loss. Therefore, advancements and policies in transportation engineering require careful scrutiny to prevent unintended consequences and capitalize on opportunities for improvement.

Despite significant efforts to enhance traffic operations, human-driven control remains prone to errors such as inattention, impatience, and intoxication. Connected and autonomous vehicles (CAVs) are seen as a potential solution to eliminate human-related inefficiencies.

This dissertation focuses on connectivity and automation, investigating the synergies between these technologies. A deep reinforcement learning strategy is proposed to enable agents to capture proximal and distant information despite dynamic inputs, facilitating learning in rapidly changing traffic. The strategy is applied to alleviate congestion at highway bottlenecks by training a small number of CAVs to cooperatively reduce congestion through deep reinforcement learning.

To address congestion at intersections, the dissertation introduces the fog-based graphic RL (FG-RL) method. This approach allows traffic signals across multiple intersections to form a cooperative coalition, sharing information for signal timing determination. Large-scale traffic signal optimization is computationally inefficient, so the proposed FG-RL approach breaks down networks into smaller fog nodes that function as local centralization points within a decentralized system.

Furthermore, the dissertation explores the use of a small CAV fleet, potentially for shared autonomous mobility services (SAMSs) based on the existing mobility-on-demand (MOD) platform, that can assist with string stable driving in locally congested traffic. These vehicles are dispersed throughout the network to satisfy their own demands, but when encountering high levels of congestion, are routed to interact with HDVs in congestion to aid with alleviating congestion and mitigating emissions.