Lane-free multi-agent reinforcement learning-based control of mixed autonomy traffic

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Center Name: Pacific Northwest Transportation Consortium (PacTrans)

Research Priority: Improving the Mobility of People and Goods

Principal Investigator(s): Jia Li (WSU)

Project Partners: N/A

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Project Start and End Date: 8/16/2023 – 8/15/2025

Project Description: The rapid advancement of Automated Vehicle (AV) technology is reshaping the transportation landscape, ushering in new possibilities for the design and operation of future transportation systems. Much of the current literature has a strong focus on the development of AV behaviors within multilane mixed autonomy environments, typically assuming the continued use of fixed lanes, as is common practice today.

In this research, we are exploring a groundbreaking concept: lane-free mixed autonomy traffic control. This innovative approach envisions a traffic system where vehicles are not confined to fixed lanes for their longitudinal movements but can instead utilize the roadway space freely. The underlying idea is that by enabling seamless information exchange between automated vehicles and infrastructure, we can optimize road capacity utilization. While this paradigm is still in its early stages and remains experimental, recent studies have indicated its potential benefits in alleviating congestion and improving traffic efficiency through advanced simulations.

This research aims to contribute to this emerging field by designing a multi-agent reinforcement learning (RL) framework tailored for lane-free AV control within mixed autonomy environments so that transportation system efficiency and fuel consumption are optimized.

US DOT Priorities: This project will deepen the understanding of how vehicle automation can improve the utilization of existing road infrastructures and traffic flow consisting of heterogeneous agents. Our project represents a pioneering approach to addressing USDOT priorities in safety, equity, and sustainability through the implementation of innovative control systems for mixed autonomy traffic. By developing advanced autonomous control algorithms, we aim to enhance safety by minimizing the risks associated with interactions between autonomous and human-driven vehicles. Furthermore, our solution is designed to prioritize equity by ensuring fair road capacity assignment for all road users, regardless of equipped vehicle technologies or socioeconomic status. Additionally, our approach contributes to sustainability efforts by optimizing traffic flow, reducing congestion, and minimizing emissions, thereby fostering a more environmentally friendly transportation ecosystem.

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Outputs: This research will lead to the following outputs: 1) a new methodological framework to control autonomous vehicles in lane-free environment; 2) microsimulation model of lane-free mixed autonomy traffic flow; 3) simulation data generated from extensive experiments with the microsimulation model, including vehicle trajectories and macroscopic traffic variables; 4) analysis of the simulation results and policy implications.

Outcomes/Impacts: Our project aims to improve freeway operations for mixed autonomy traffic by exploring the lane-free concept, which can be implemented through dynamic lane use policies and variable speed limits. Through the advanced control systems, we'll dynamically allocate road space to driving agents based on traffic conditions and vehicle autonomy levels, thus enhancing safety and reducing congestion. Overall, the control strategy will adapt to changing traffic patterns and environmental factors, optimizing the safety, equity, and sustainability of mixed traffic flow.

Final Research Report: *will be provided upon completion of the project*