# Research
# Report Summary

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## Investigating the Effects of Cooperative Driving for CAVs in Different Driving Scenarios Using Multi-Driver Simulator Experiments

This study aims to investigate the effects of cooperative driving for two driving scenarios: non-signalized intersection (Fig 1) and freeway off-ramp. Multi-driver-in-the-loop co-simulation used for this research.

Three tasks were investigated: (1) developing cooperative driving strategies (CDS) for non-signalized intersections in a mixed traffic environment; (2) proposing human-machine-interfaces (HMI) for non-signalized intersection cooperative driving; (3) training a multi-agent reinforcement learning decision-making model for cooperative diverging at freeway off-ramp.

To deal with the research gap, this study developed a multi-driver-in-the-loop co-simulation platform. It is a high fidelity and customizable simulation platform, and it create a simulation environment that enables the interaction between multiple subject vehicles.

For task 1, an efficiency-oriented CDS was developed for mixed traffic cases, and tested on different CV and CAV market penetration rates. The experiment results showed that the proposed CDS reduced up to 53.8%, 66.4%, and 73.7% of travel time in CV-HDV (human-driven vehicle), CV-CAV, and CAV environments, respectively (Fig 2).

For task 2, a driver-centered CDS was developed by modifying the algorithm in task 1, and then three different cooperative driving HMIs were evaluated by simulators (Fig 3). The results suggest a graphic-based HMI is better at displaying minor speed change requirements to the drivers, and it can guide the drivers

Fig 1. Study location

Fig 2. Travel time reduction for different CV/CAV MPR

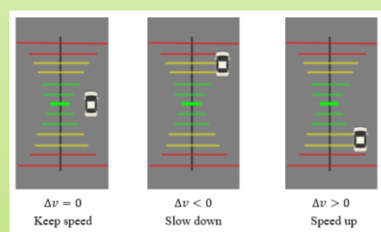



Fig 3. HMI for cooperative driving

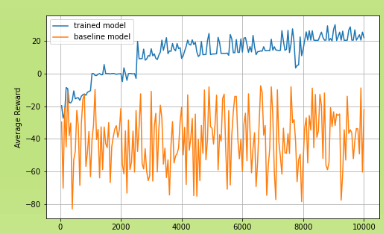
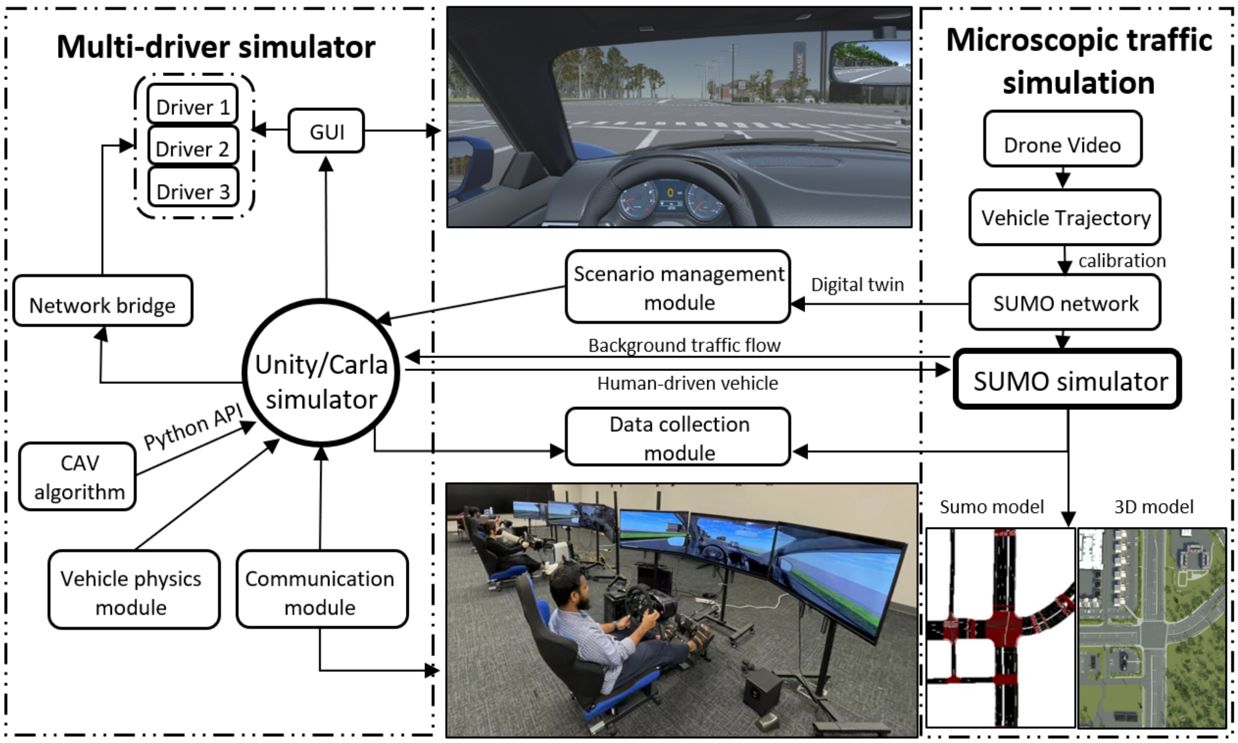



Fig 4. Reward curves of trained model and baseline model

approaching an intersection with better precision.

For task 3, a multi-agent deep-Q network (MADQN) was trained for decision-making on freeway off-ramp diverging driving scenarios. The trained model significantly outperformed the baseline model in terms of efficiency and safety while ensuring decent successful diverging rate (Fig 4).

**UCF SST Multi-driver-in-the-loop Co-simulation Platform**




**Outcomes**

The results show the cooperative driving strategy can significantly reduce travel time and conflict at non-signalized intersections, and performance improves with the increase of CV/CAV MPR environment. With a graphic HMI, the drivers are following the driving suggestions more closely and yields better performance.

Deep reinforcement learning generates better driving decisions at off-ramp diverging area and produce smooth diverging behaviors.

**Impacts**

The implementation of cooperative driving strategy improves traffic efficiency and safety by suggesting optimal real-time driving decisions to the CV/CAV drivers, and it reduces travel time and conflicts at multiple driving scenarios.

The design of HMI for cooperative driving worth investigation, and appropriate graphic design improves driving performance.

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