A Small-scale Connected and Automated Vehicle Platform for Freeway Driving Scenario with Parking Consideration

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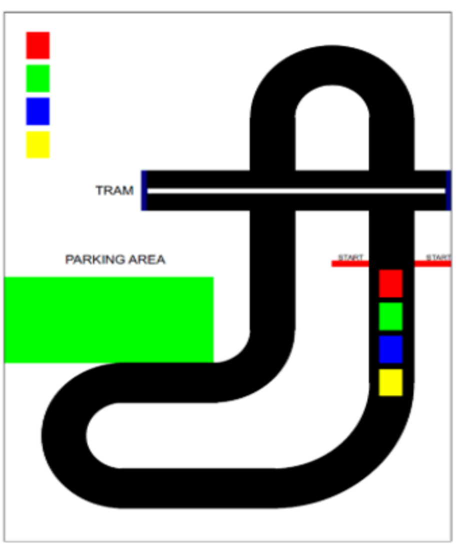
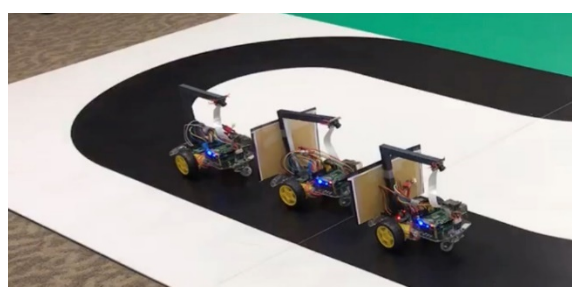
Connectivity and automation are expected to bring a deep transformation into the automotive industry and transportation networks. Towards this end, researchers and engineers are increasingly aware that cooperative automated driving (CAD) can potentially reshape our future transportation systems. To better understand the potential impacts of these emerging technologies, the following questions need to be answered: Are Connected and Automated Vehicles (CAVs) capable of improving the network capacities? Can they deliver the anticipated promises for less congestion, safer, and greener mobility? To investigate these questions, a miniature cooperative automated driving testbed is an ideal platform. Compared with the pure simulation environment, the small-scale automated vehicles equipped with sensors can better reflect the real vehicles' dynamics and provide more realistic sensing information. Compared with the real vehicle and infrastructure testbed, the miniature testbed is more cost-effective without any safety risks.

In this project, a fleet of small-scale connected and automated vehicles (CAVs) equipped with multiple sensors and communication devices are developed and tested on a miniature testbed (set up with a 4m× 3m PVC board as shown in Figure 1) to mimic the freeway driving scenario with parking consideration. The objective of the project is to investigate how the cooperative maneuvers of small-scale CAVs can improve the operation efficiency in a typical freeway scenario. During the test, the miniature CAVs are designed to drive as a platoon and respond cooperatively to the tram. At the end, they can park in the desired space (printed in green ink) in a predefined sequence without any collision with each other.



a. Freeway and parking



b. Vehicle Fleet

Figure 1. System setup.

The small-scale CAV is equipped with Raspberry Pi 4 as the onboard computer which provides enough computational power to process the video stream from the HD camera at an acceptable frame rate while running other functions (e.g., communications and control) in a timely manner. Also, the general-purpose input/output (GPIO) makes it easy to connect different modules, such as sensors and actuators, into the system. The onboard sensors include infrared speed encoder, TOF LiDAR, and HD fish-eye camera. The Robot Operating System (ROS) is then applied as the vehicle software backbone. Through the ROS nodes, the distributed control strategy can be realized, where each node may be a sensor, computation module, or actuator. By broadcasting or subscribing to the specific messages, these nodes are able to transmit the information as designed.

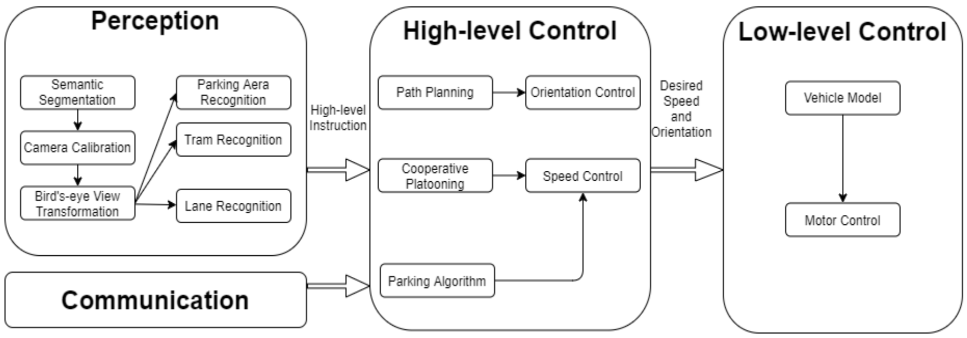


Figure 2. System architecture.

Figure 2 shows the architecture of the entire system, including four major modules: *perception*, *communication*, *high-level control* and *low-level control*. The miniature CAVs need to understand the environment, operate in a platoon, slow down cooperatively when traversing the tram, always remain on the track, and enter the parking area orderly. To fulfill these tasks, our team trained a deep neural network (DNN) for semantic segmentation (see Figure 3), which can provide a prediction label for each pixel on the input images. After the post-processing (such as image undistortion), the useful information is transmitted to the high-level control (decision-making) module.

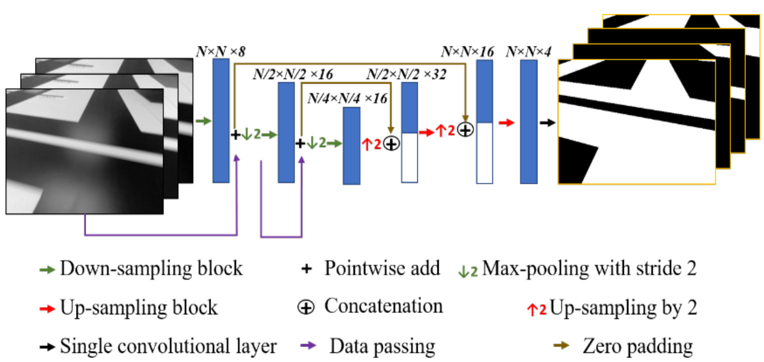


Figure 3. Semantic segmentation.

The controls of the miniature CAVs are realized from two dimensions. Longitudinally, the "cooperative platooning" function schedules linear speed for the vehicles. Laterally, the "path planning" function determines the rotational speed for the vehicles.

The preliminary test shows that, with communication, a group of 4 miniature CAVs are able to travel (in a platoon) along the freeway track and park themselves efficiently without any crashing.