Cooperative Network Traffic Management in a Miniature Urban Environment

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Connected and automated vehicles (CAVs) can significantly improve the operational efficiency in urban traffic networks. Specifically, the coordination among CAVs can mitigate potential conflicts and reduce unnecessary stop-and-go at intersections, thus increasing the throughput of the entire network. As a result, it is of unprecedented importance to understand the system impacts due to the introduction of CAVs and cooperative traffic management for urban networks. However, it is difficult to test and verify such scenarios and strategies in the real world. Simulation studies, albeit cost acceptable, are not able to capture all the information of the network effectively and model the scenario accurately in a reasonable scope.

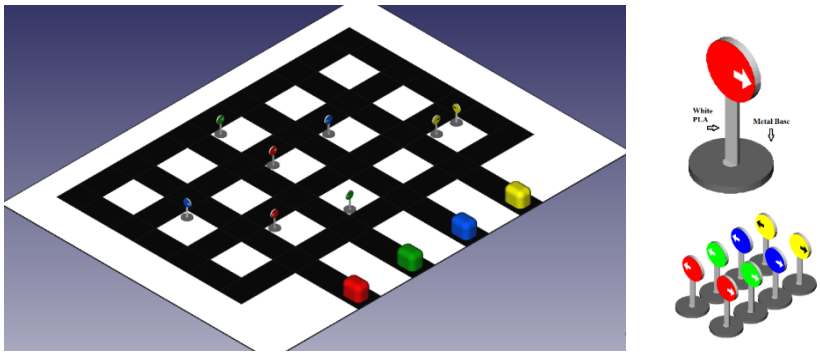
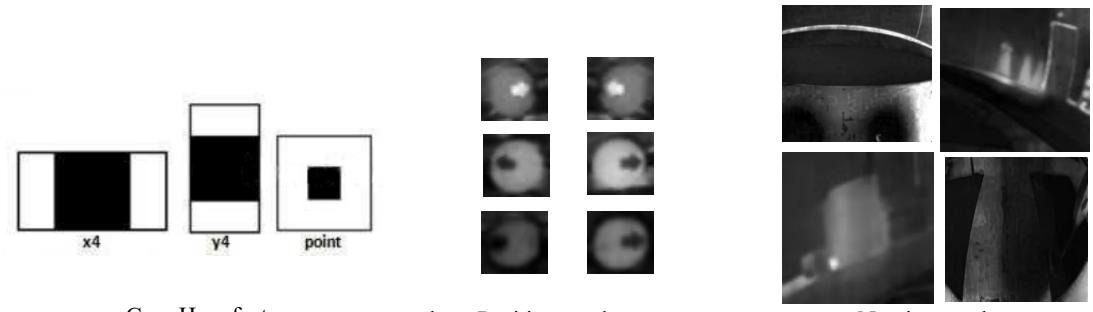


Figure 1. System setup.

To address the problem, we develop a miniature city environment with a group of small-scale CAVs in this research. As shown in Figure 1, the #-shape scenario represents a typical urban traffic network with one-lane track and twelve intersections. During the test, four vehicles (differentiated by different colors, i.e., red, green, blue, and yellow) are able to recognize traffic signs with the associated color at the intersections. Through vehicle-to-vehicle communications, the network management algorithm collects states of all vehicles and controls the access priorities of vehicles.

We first applied a semantic segmentation neural network to extract meaningful regions from the income video stream of the onboard camera. Next, the intersections are recognized by detecting the changing rate of lane width which can be measured from bottom to top of the processed images. Then, the traffic signs are identified based on the saturation and shape which can be realized in a three-step process. The first step is to get the region of interest (ROI) using Haar-like feature-based cascade classifiers (in Figure 2). By transforming the image from RGB to HSV space, the main hue value of the ROI is used in the second step to indicate the color of the traffic sign (in Figure 3). In the last step, the recognized intersection and the traffic sign are matched based on the geometry relations.



a. Core Haar features b. Positive results c. Negtive results

Figure 2. ROI extraction.

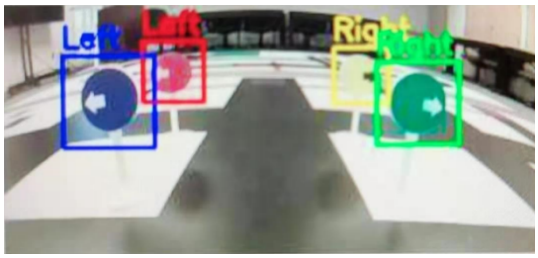


Figure 3. Traffic sign recognition results.

The goal of the proposed cooperative traffic management strategy is to decide the passing sequences of miniature CAVs at each intersection if there are potential conflicts along respective routes. To achieve this goal, we first develop a network localization algorithm that keeps tracking the instantaneous position and travel direction of each individual vehicle (mapped to an 8×11 matrix), and the information is transmitted to the network management module via communications. Then, we develop a centralized reservation-based traffic management strategy, where the link or the intersection can be reserved by only one vehicle at each time step. The reservation matrix (also an 8×11 matrix) is defined to represent the potential occupancies of links and intersections over time for all the vehicles in the network. The workflow of the algorithm is shown in Figure 4.

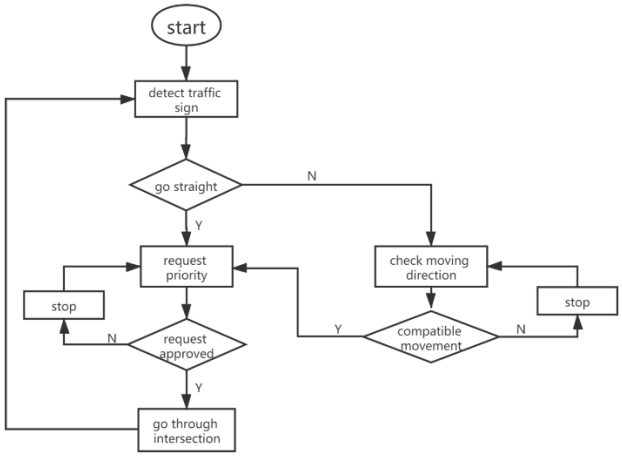


Figure 4. Workflow of network management algorithm.

The preliminary study shows that all the miniature CAVs are able to recognize the respective traffic signs and follow the respective routes as designed. In addition, the proposed cooperative network traffic management system is able to coordinate the operation of all vehicles efficiently to avoid any conflicts and improve network efficiency.