Multi-vehicle trajectories design during Cooperative Adaptive Cruise Control (CACC) platoon formation

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Abstract

This study aims to design optimal vehicle trajectories of CAVs during CACC platoon formation.

A basic scenario and a destination-based protocol to determine vehicle sequence in the platoon is described.

A space-time lattice based model is formulated to construct vehicle trajectories considering boundary conditions of kinematic limits, car-following safety, and lane changing rules. The objective is to optimize the vehicle sequence and fuel consumption simultaneously.

A two-phase algorithm is proposed to solve this model, where the first phase is a heuristic algorithm that determines vehicle sequence and dynamic programming is adapted in the second phase to optimize fuel consumption based on the determined sequence.

Problem Statement

Two lanes of a freeway segment, where one is the managed lane for CAVs only and another is a normal lane opened to both CAVs and HVS. All CAVs on normal lane are ready to form a platoon on managed lane.

Initialization

Determine the set of all decision variables for all CACC-embedded vehicles

Update the state of all vehicles

Drop the unfeasible states according to the determined sequence and other constraints

Flow chart of vehicle sequence determination

Start from vehicle sequence m

Determine the next vehicle i on managed lane

Determine if vehicle i on managed lane

Yes

No

Yes

No

Yes

All CACC-embedded vehicles passed the feasible lane changing area?

Yes

No

No

Flow chart of fuel consumption optimization

Select optimal states of

Flow chart of vehicle sequence determination

Scenario descriptions:

Five CAVs on normal lane and their locations are $x_i(0) = 20m, x_{i}(0) = 40m, x_{i}(0) = 60m, x_{i}(0) = 80m, x_{i}(0) = 100m$; their destinations are $d_i = 6000m, d_i = 5000d, d_i = 4000d, d_i = 2000md, d_i = 3000m$

The initial speed of those five CAVs are 80 km/h and the safe distance is 15m.

The starting point and the length of the lanes changing area are $x_{L} = 120m and 400m$

The control variable is from $u = (-2 m/s^2, -1m/s^2, 0 m/s^2, 1m/s^2, 2m/s^2)$

The maximum speed is 120km/h and the minimum speed is 60km/h

Conclusions

This study proposed a model to design trajectories of CAVs during CACC platoon formation that yields optimum performance on vehicle sequence, with an objective of minimum total fuel consumption.

Using numerical tests, the proposed model and algorithm has shown its promise in simulating CACC vehicle sequence and fuel consumption with a promising computation efficiency.