Safe platoon and intersection coordination of connected and automated vehicles

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Introduction and summary

In recent years, the research interest for connected and automated vehicle (CAV) has grown significantly. Due to the computation and communication capabilities of CAVs, it opens up the potential of new solutions to many challenging traffic coordination problems. In this doctoral thesis work, we consider the platoon formation problem of CAVs in multi-lane road and the intersection coordination problem of CAVs In mixed traffic scenario. The emphasis on both problems is to develop method that guarantee safety while achieving the control and coordination objectives. We utilize constructive barrier feedback for the platoon formation problem due to its design simplicity, and a reachability based model predictive control (MPC) approach for intersection coordination due to its capability that enables planning and ensures safety within one framework.

Safe platoon formulation using constructive barrier feedback

Problem Statement

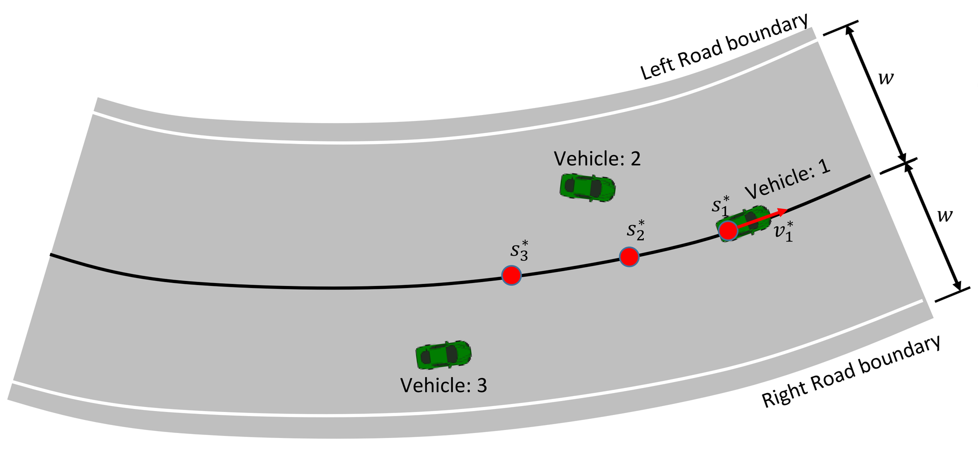


Figure: Platoon formation example of CAVs on curved road.

Consider a multi vehicle platoon formation problem over a generally curved road, developing a control method for CAVs to safely merge into their desired platoon configuration while ensure collision avoidance between vehicles and the road edges.

Proposed method

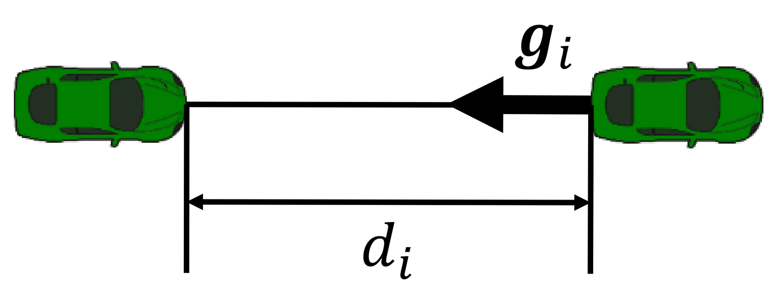
A distributed feedback control based on divergent flow that generates input acceleration and steering on each CAV.

$$u_i = u_i^n + k\boldsymbol{g}_i \frac{\dot{d}_i}{d_i}$$

u_i^n : Nominal control for convergence towards desired platoon formation

$g_i \frac{\dot{d}_i}{d_i}$: Divergent flow for collision avoidance

- Platoon convergence
- Guaranteed collision avoidance
- Bounded feedback control



Simulation Study

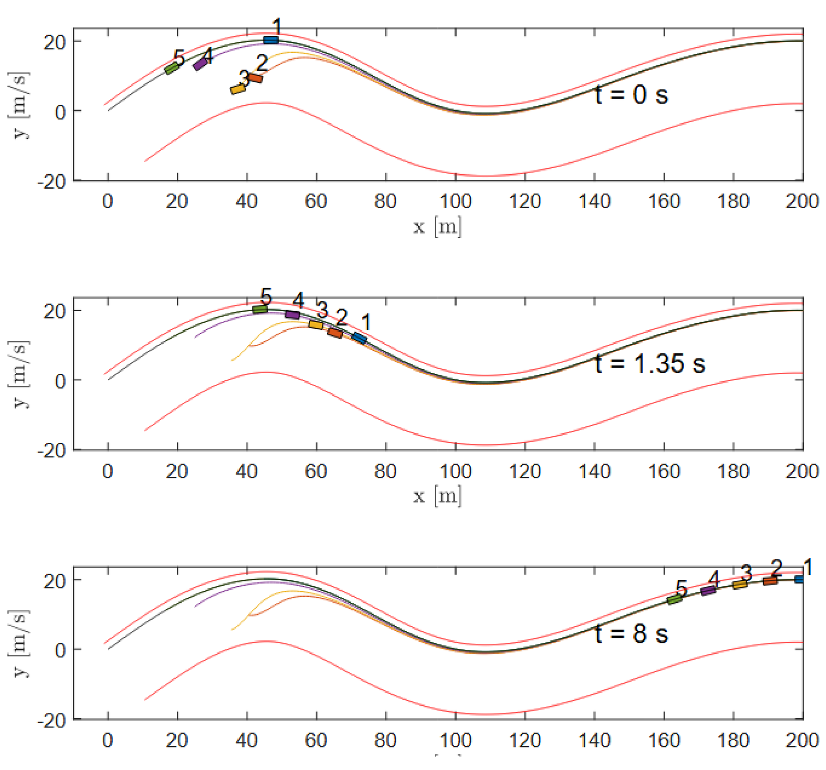


Figure: simulation of 5 vehicle merging on curved road.

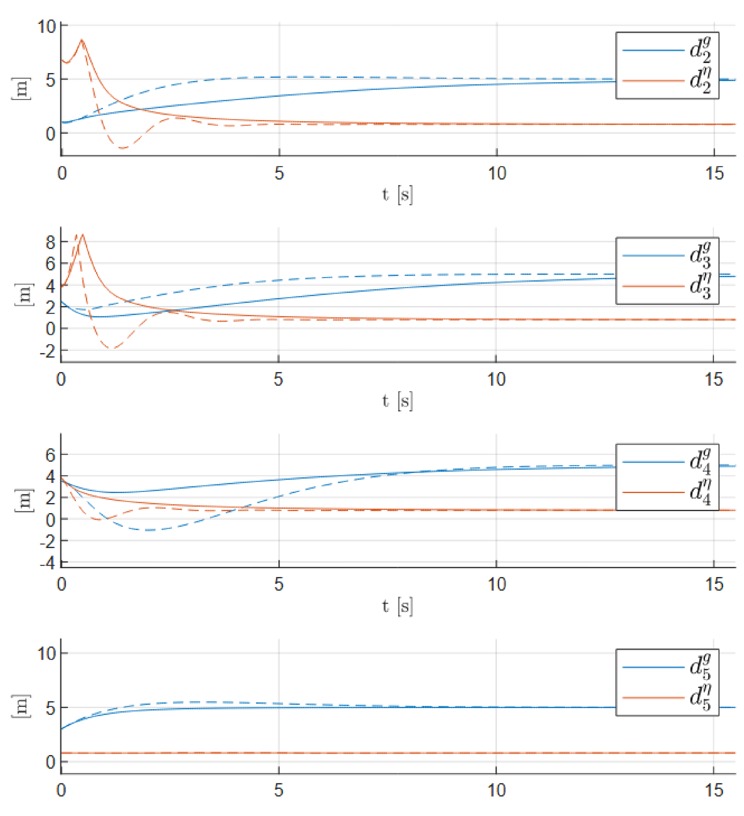


Figure: safety distance for each CAV during the simulation.

The proposed platoon formation control on each CAV enables them to safely converge to their desired platoon configuration. Safety distance is kept positive at all time ensuring collision avoidance

Safe intersection coordination using invariant safe MPC

Problem Statement

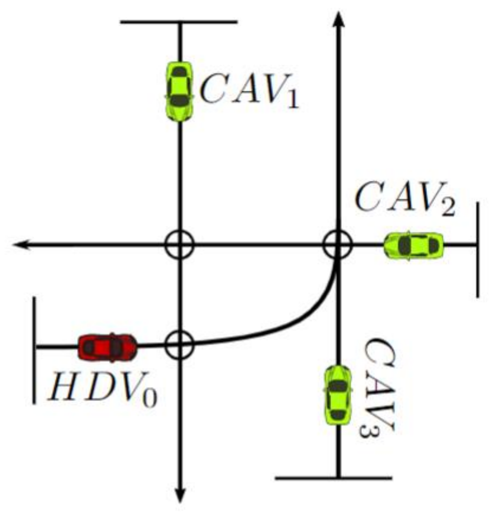


Figure: An example of a general intersection with four vehicles.

Consider any general intersection in mixed traffic with both merging and crossing conflict, develop a coordination strategy for CAVs to traverse through the interaction efficiently with guaranteed safety at all times.

Proposed method

A distributed invariant safe MPC based on reachability that generates both passing order and input acceleration on each CAV.

$$\min \sum_{k=1}^{N} g_{i,k}(u_{i,k}, x_{i,k})$$

$$x_{i,k+1} = f_i(x_{i,k}, u_{i,k})$$

$$x_{i,0} = x_i(0)$$

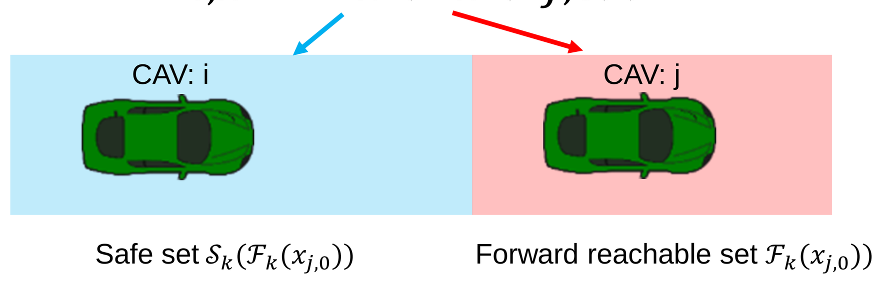
$$u_{i,k} \in \mathcal{U}$$

$$\text{Safety}\begin{cases} x_{i,k} \in \mathcal{S}_k(\mathcal{F}_k(x_{j,0})) \\ x_{i,N} \in \mathcal{S}_N(\mathcal{F}_N(x_{j,0})) \end{cases}$$

- Recursive feasibility and safety

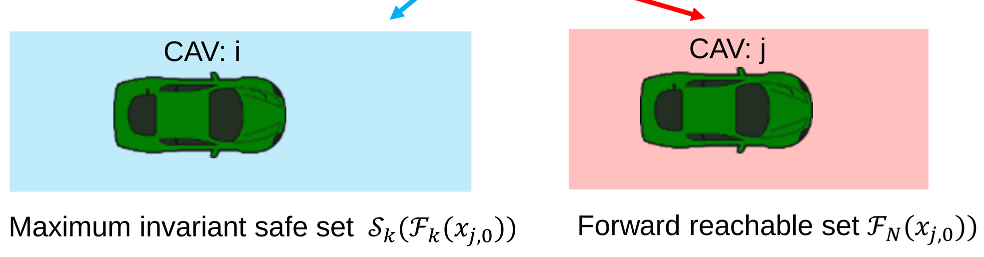
Ensure safety at time k

$$x_{i,k} \in \mathcal{S}_k(\mathcal{F}_k(x_{j,0}))$$



Ensure safety from time N onward

$$x_{i,k} \in \mathcal{S}_N(\mathcal{F}_N(x_{j,0}))$$



Simulation Study

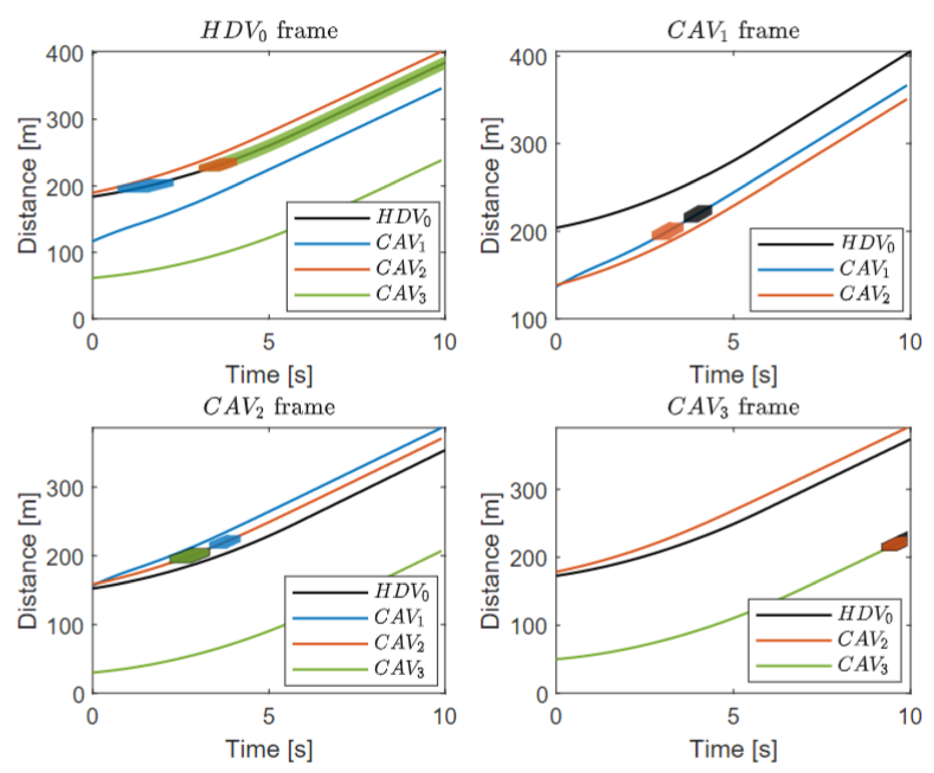


Figure: Simulation result of 4 vehicles with one HDV, the color shaded areas indicate safety region for the corresponding vehicles.

The invariant safe MPC on each CAV enables them to safely traverse the intersection under the presence of an aggressive HDV. Minimum safety distance is maintained as an indication of the invariant safety property of the proposed method

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