Distributed Control of Heavy-Duty Vehicle Platoon Maneuvers in Traffic

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Description

The research focus of this project is on the design of efficient and scalable distributed control and planning algorithms for automated transport systems, with application to heavy-duty vehicle (HDV) platoon coordination. A distributed architecture is often imposed on practical control systems, because a central decision maker with access to all plant information might be very complex and not possible to implement due to communication or computation constraints, or because of the demand for autonomy of the subsystems. The layered control systems architecture with vehicle-to-vehicle and vehicle-to-infrastructure communication over multiple timescales offers a good framework for achieving distributed control and decentralized decision making for automated transport systems. Event-based control and estimation for multi-agent systems is also an important part of heavy duty vehicle platoon coordination, due to the ad-hoc nature of the inter-vehicle communication.

Background & Motivation

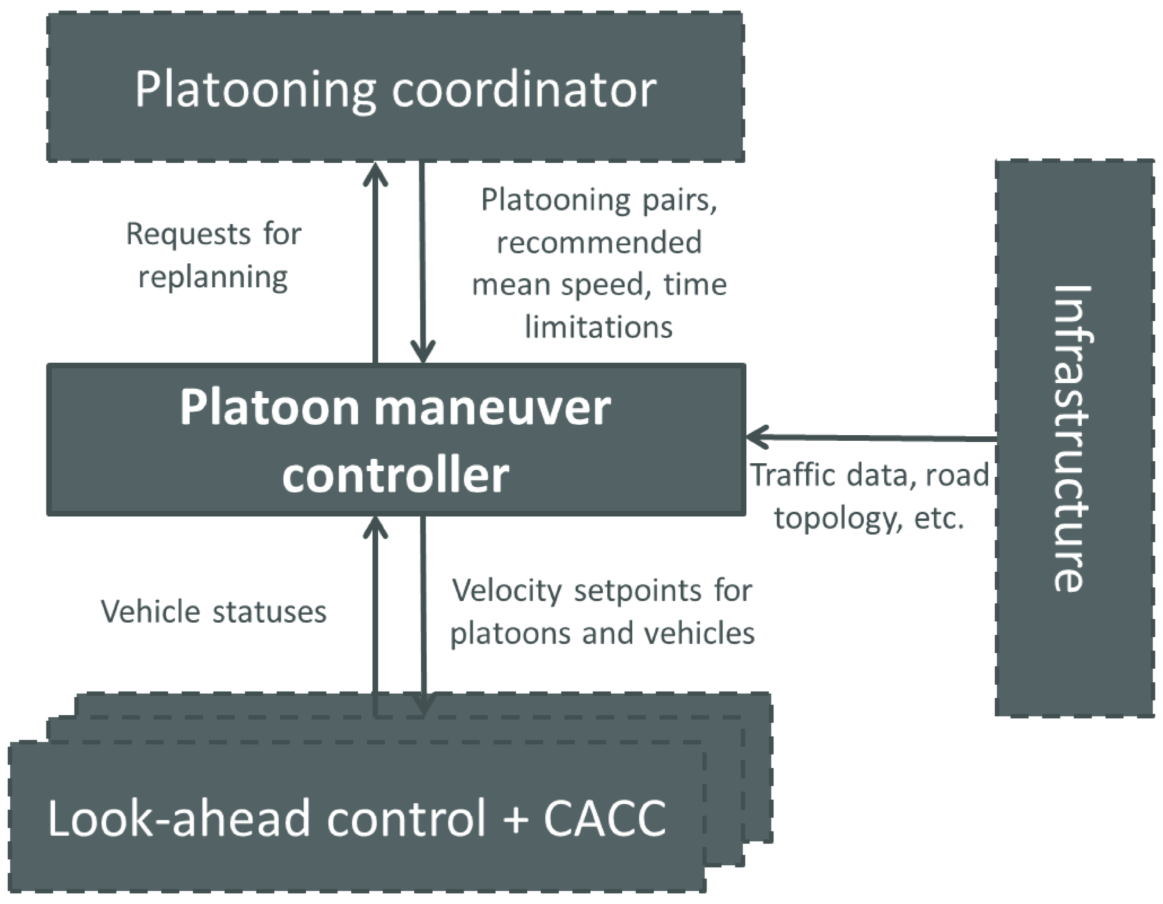

Figure 1: Preliminary architecture - Between the centralized platooning coordinator and vehicle and platoon controllers.

There has been a lot of research on HDV platooning [2], mostly on controlling already formed platoons and centralized platooning coordination. Since HDV platoons will need to be formed, merged and split all while driving on the road, there is a need for an intermediate control layer between the high-level centralized coordinator and low-level vehicle and platoon control, that will govern platoon maneuvers while taking into account all available data obtained from the infrastructure. It is at this level that we attempt to cancel out the effects of disturbances that are not considered at higher level control, to ensure platoon rendezvous proceeds as planned by the platooning coordinator, as well as give a better prediction of when the platoon will be formed. This reduces the need for the costly replanning, by handling local disturbances at the local level in a decentralized manner. Since attempting to form a platoon entails higher fuel consumption during the catch-up and merging phase, which we hope to offset by fuel savings during the time the vehicles drive in a platoon. It is therefore important to have a good prediction of when the platoon merging will be completed, so as to be able to calculate predicted fuel savings and make a better informed decision on whether to attempt to form a platoon at all.

Methods & Preliminary Results

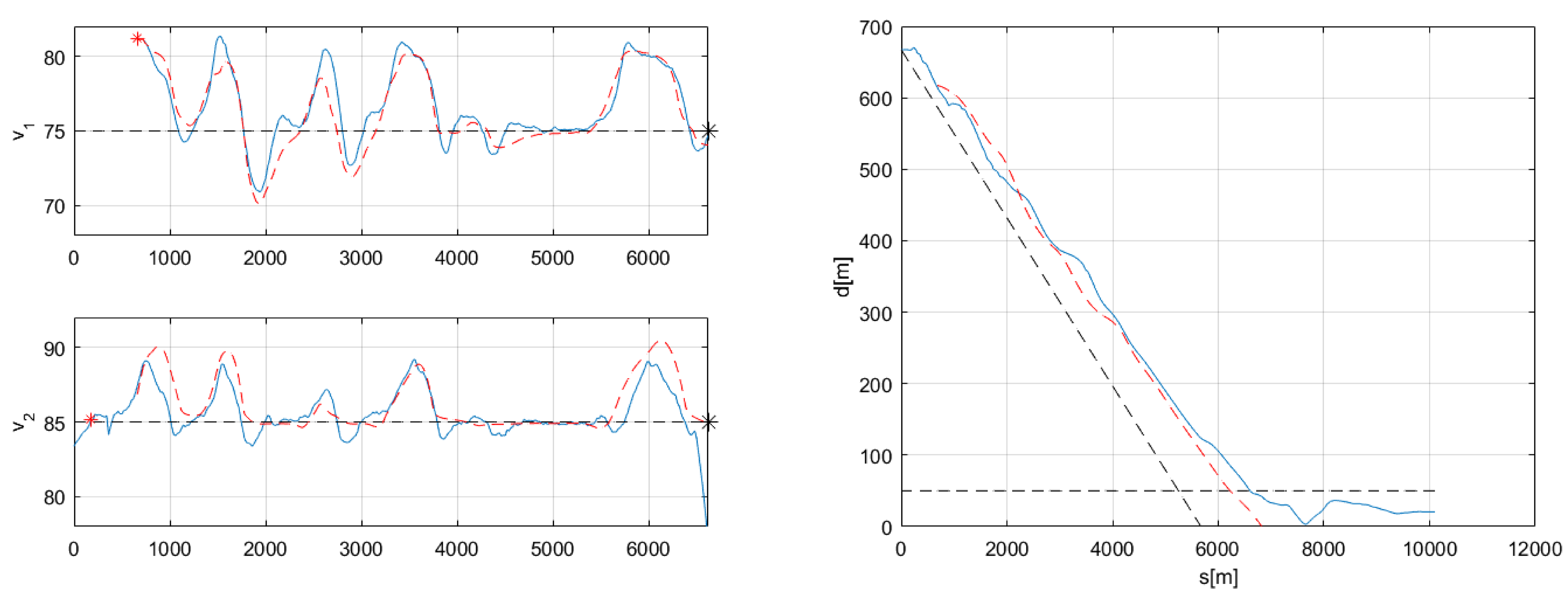

Figure 3: Truck velocities and the distance between them.

There are two major external factors that need to be considered when predicting when the platoon merging will occur:

- Influence of road grade
- Influence of traffic conditions

So far, we have looked into how we can use the information about road topology to improve platoon merging distance prediction. The method proposed in [1] uses vehicle speeds predictions obtained using simple neural network models of net propulsive force, that were trained on experiment data. The influence of traffic conditions will be considered in future work.

Research Goal & Question

We are looking to design the control architecture for platoon maneuver control, with focus on controlling platoon rendezvous on the higher tier of the platooning layer. We consider decentralized control over a large geographical area, and communication constraints, stemming from the inherent networked nature of the system, must also be considered.

A big question that remains open is how best to utilise the available traffic data. The influence of local traffic conditions around HDVs needs to be modelled. Also, the problem of getting local traffic conditions from coarse traffic measurements, as well as the problem of predicting the evolution of traffic condition into the future, need to be addressed.

Finally, the designed control needs to be verified in simulations as well as in experiments.

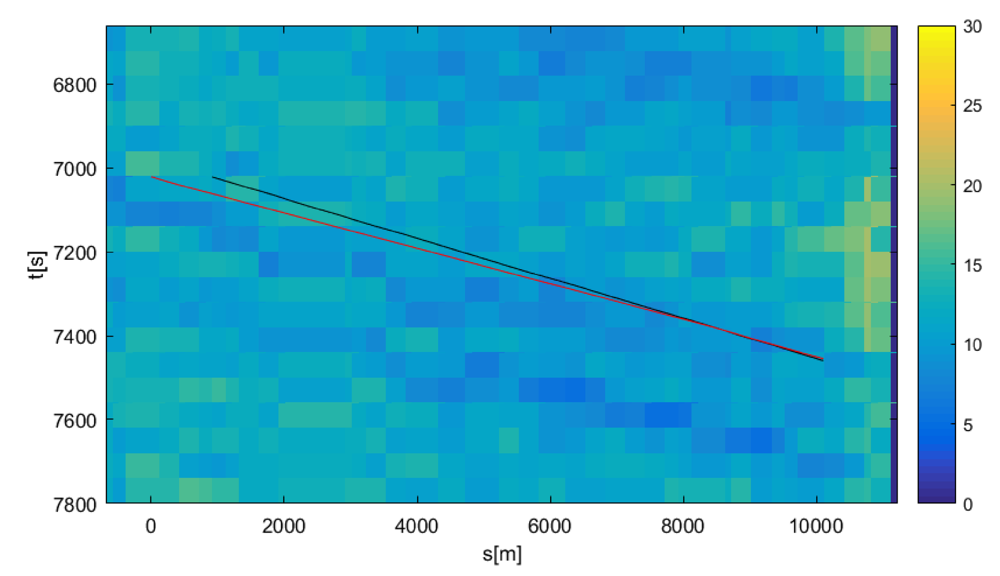

Figure 2: Traffic density and truck trajectories.

Bibliography

[1] M. Čičić, K.-Y. Liang, and K. H. Johansson (2017). “Platoon Merging Distance Prediction using a Neural Network Vehicle Speed Model”. IFAC World Congress, Toulouse, France, July 2017

[2] A. Alam, B. Besselink, V. Turri, J. Mårtensson and K. H. Johansson, “Heavy-Duty Vehicle Platooning for Sustainable Freight Transportation: A Cooperative Method to Enhance Safety and Efficiency“, IEEE Control Systems, vol. 35, no. 6, pp. 34-56, Dec. 2015.