The subtle art of testing algorithms in an autonomous vehicle

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Description

As the reality of autonomous vehicles come closer it becomes more and more important to understand how the "theoretical algorithms" have to take into account the actual problems encountered in a real vehicle, both regarding implementation problems and errors from sensor measurements, noise and robustness. To accuire this knowledge, a project was started which aims to take a "theoretical" overtaking algorithm all the way from the theoretical work to real-life implementaiton.

Background & Motivation

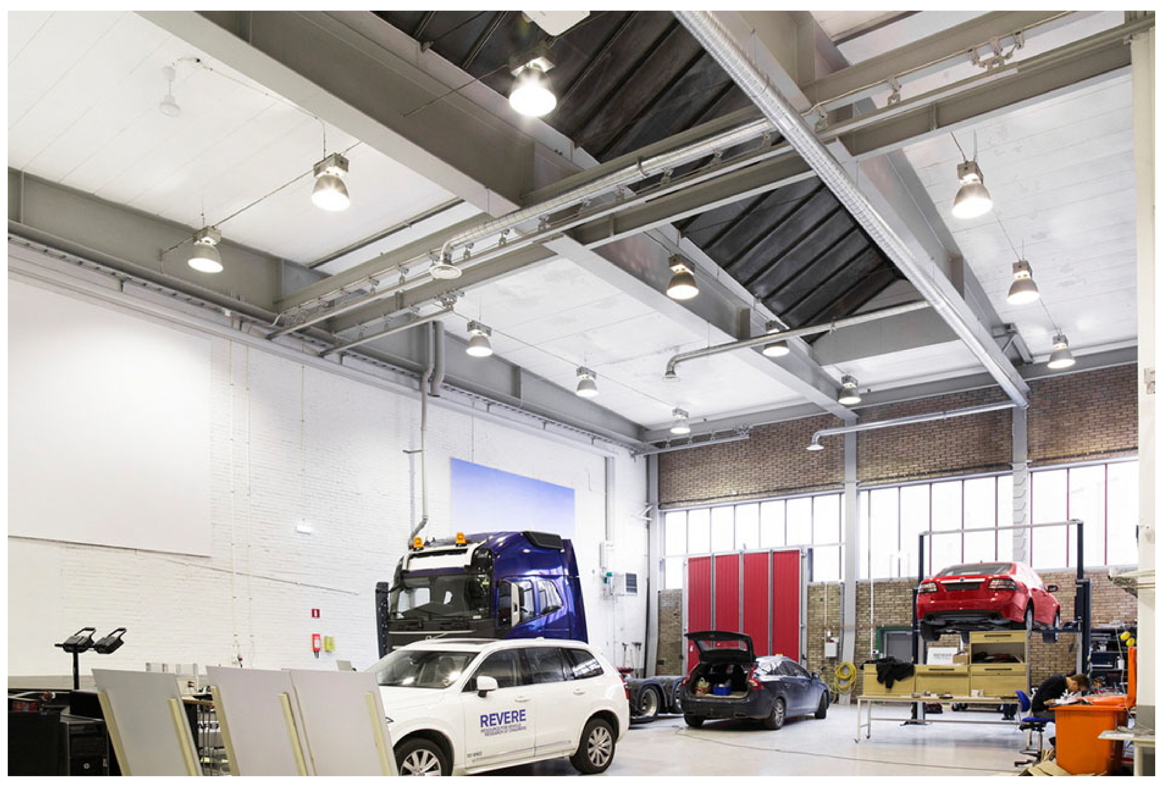


Figure 1: ReVeRe at Lindholmen.

The motivation of this project is twofold. The first is to get some real data from running tests in a real vehicle which can be analyzed and published. The second part is to understand what is needed of new algorithms in order for them to actually be useful in practice, i.e, when implemented in an autonomous vehicle and not just run in simulation. The recources available for doing the testing (which is scheduled in march) is the ReVeRe lab at Chalmers, Lindholmen which has both an autonomous truck and an autonomous car. The actual testing will be performed at the Asta Zero test track.

Research Goal & Question

The goal of this particular research is trifold. The first, and most direct goal is simply to implement and test the overtaking algorithm developed in [1]. This has in part already been done in [2]. The second goal is to develop a simulation platform on which tests can be run to discover new research questions in form of interesting scenarios and problems related to the algorithm. Lastly, this project is supposed to work as a start up to not only get familiar with the mathematical machinery needed for decision making but also to understand what it takes to do the implementation in a real vehicle. The idea is that this start up will be very helpful for future research.

Methods & Preliminary Results

The main focus of the project is the trajectory planner. There are several different ways of implementing this planner as an optimization problem. The most obvious way is to sample in time. However, this will yield not only a non-convex but a mixed integer problem. The integer constraints (and the non-convexity) occurs when modelling the leading vehicles critical zone (see Figure 1). The critical zone can in fact be modeled as a convex constraint if one sample in space instead of time. Except for the critical zone constraints there are also bounds on the vehicle states (such as longitudinal and lateral velocity and slip) and control signals (such as lateral acceleration). Here, only the space formulation and its results are presented. As can be seen this problem is also non-convex (since we divide by the longitudinal velocity $\dot{\tilde{x}}$). But this is not an integer problem and can thus be linearized using standard methods.

$$\min_{\hat{\mathbf{u}}_{\mathrm{E}}(\tilde{x})} \tilde{J}(\hat{\mathbf{x}}_{\mathrm{E}}(\tilde{x}), \hat{\mathbf{u}}_{\mathrm{E}}(\tilde{x}))$$

subject to

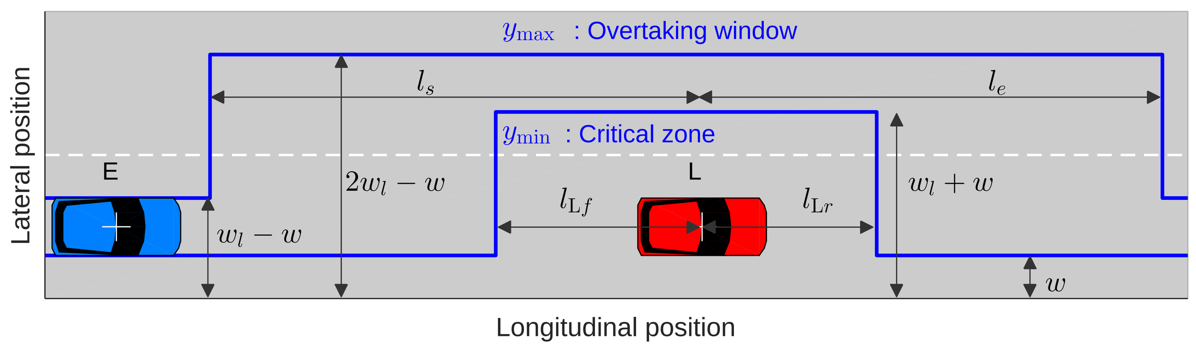
$$\dot{\hat{\mathbf{x}}}_{\mathrm{E}}(\tilde{x}) = A\hat{\mathbf{x}}_{\mathrm{E}}(\tilde{x}) + B\hat{\mathbf{u}}_{\mathrm{E}}(\tilde{x})$$

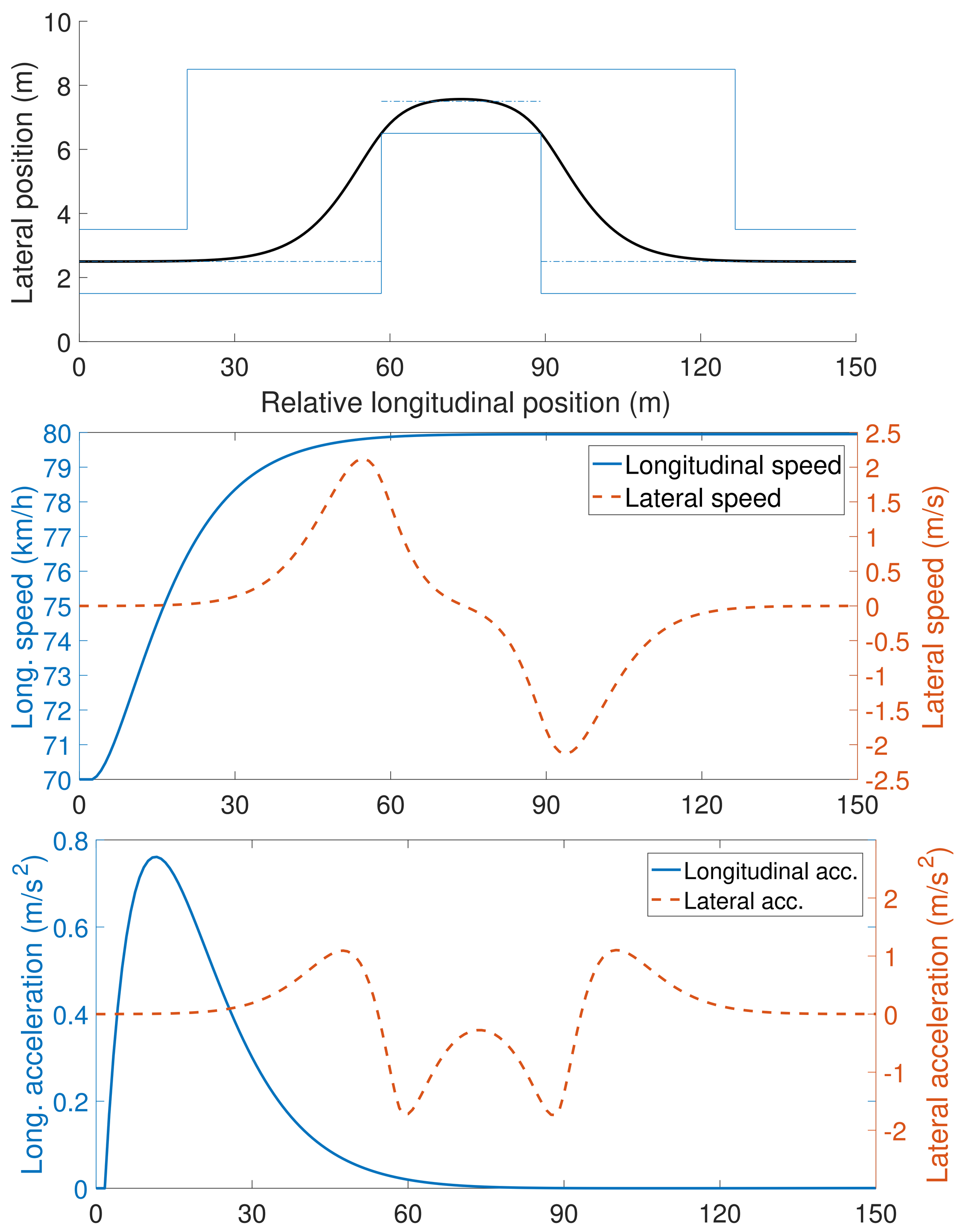
$$\hat{\mathbf{x}}_{\mathrm{E}}(\tilde{x}) \in [\hat{\mathbf{x}}_{\min}(\tilde{x}), \hat{\mathbf{x}}_{\max}(\tilde{x})]$$

$$\hat{\mathbf{u}}_{\mathrm{E}}(\tilde{x}) \in [\mathbf{u}_{\min}(\tilde{x}), \mathbf{u}_{\max}(\tilde{x})]\frac{1}{\dot{\tilde{x}}(\tilde{x})}$$

$$y'_{\mathrm{E}}(\tilde{x}) \in [s_{\min}, s_{\max}]\left(1 + \frac{v_L}{\dot{\tilde{x}}(\tilde{x})}\right)$$

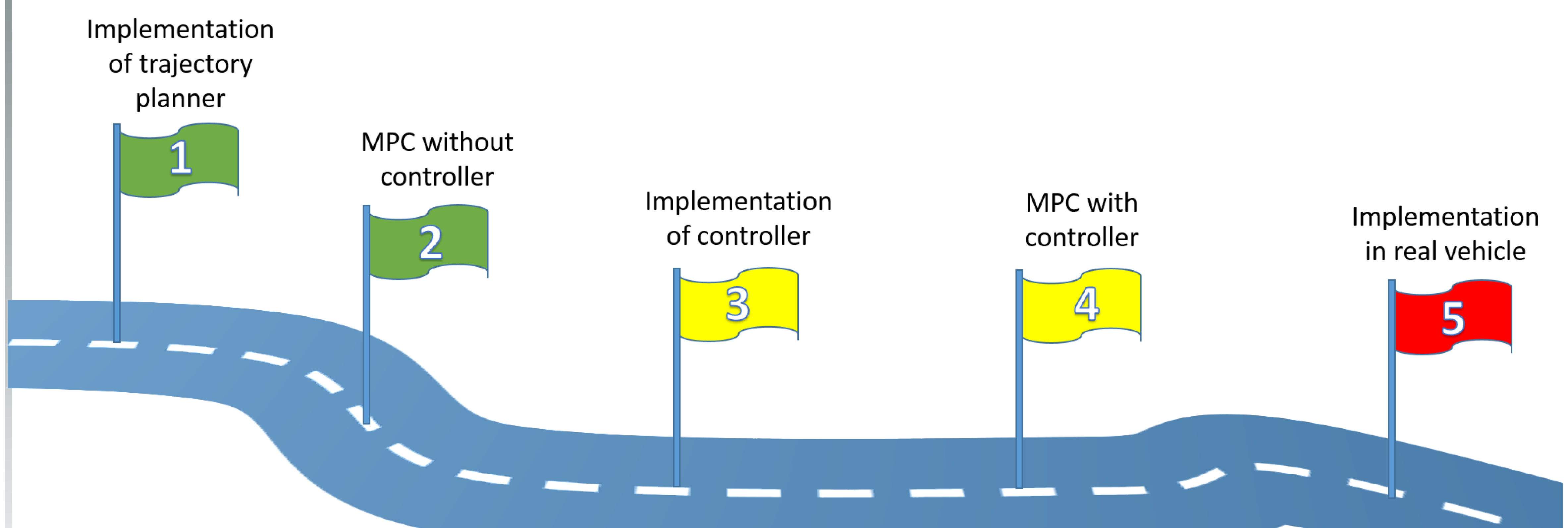
$$\hat{\mathbf{x}}_{\mathrm{E}}(0) = \hat{\mathbf{x}}_{\mathrm{E0}}$$





Roadmap & Milestones

As can be seen in the roadmap below there are essentially five milestones. The first four are done in simulation on PC and the last one is done in a real vehicle. The goal of the different milstones are 1) to generate safe and comfortable overtaking trajectories, 2) To succesfully use the trajectory planner in a model predictive control (MPC) scheme, 3) To implement controllers which can follow trajectories generated in step 1, 4) To include this controller into the MPC model, 5) Implement the environment resulting from steps 1-4 in a real vehicle.



Bibliography

[1] N. Murgovski and J. Søberg, "Predictive cruise control with autonomous overtaking" in *Deicision and control (CDC)*, Osaka, Japan, 2015.

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[3] Boyd, S. Vandenberghe, L,"Convex optimization", Cambridge university press , New york, USA, 2004.