Master thesis: Energy optimization in traffic situations

Purpose
The aim of the master thesis is to use energy based reasoning in traffic situations to decide upon a tactical driving plan.

Background
There is a trend in the automotive industry towards increased automated driving. The driving should be energy efficient and within safety margins. A first step is to model the behaviour of other vehicles, since it is central to find a tactical plan based on predictions.

Examples of scenarios are the lane change and the ramp merge. Consider, e.g. the scenario depicted in the figure below, where vehicle M adjusts its speed and makes a lane change onto the highway, where vehicle H has increased its gap to vehicle P to facilitate the merge. There are other possible outcomes of this scenario and a decision has to be taken by vehicle M (and continuously retaken) which of the feasible outcomes should be the aim. The analysis becomes slightly depending on which of H, M and P is the ego vehicle, i.e. the vehicle being controlled.

Figure: One of four safe possible ramp merge outcomes of M relative to H and P.

The navigation task implies what conditions need to be fulfilled. A condition to be fulfilled is, for example, having enough space to make a lane change. In order to fulfil this condition, acceleration or deceleration is typically necessary.

More example situations can be constructed, e.g. approaching a slower vehicle from behind, cut-ins, idling slowly in multi-lane queues, or lane change. The traffic situation may prohibit the most energy efficient driving on a given route, which is only possible when there is no traffic. For example, the most energy efficient lane change before an exit is the one that does not require high variations in acceleration profile. However, in a dense traffic situation, it may be necessary to accelerate or decelerate considerably. It has been noticed that professional drivers, when for some time have been blocked by other traffic, reduce speed considerably to force other road users to yield, and catch the last chance to make a lane change before an exit.

A safe and feasible path and speed trajectory that leads the smallest optimization cost (e.g. fuel consumption, deviation from reference trajectories, distance to desired exit, driver discomfort, and constraint violation) could be a valid choice of optimization objective. For a specific scenario, a set of different trajectories may need to be evaluated, e.g. moving to another other lane or staying on your own lane by following the leading vehicle.

Master thesis: Energy optimization in traffic situations
09 November 2017
Expected results

- A simulation setup where expert decisions are made by model predictive control (MPC).
- A decision algorithm where several MPC decisions are weighted to decide the optimal planned path and velocity.
- Investigation on how reinforcement learning (RL) can be used to mimic the decisions of the expert MPC, but with a considerably lower computational effort compared to the MPC.

Delimitations

The type of road considered is a highway, without the option of having oncoming vehicles. It is assumed that dynamic objects are fully known by sensor data fusion, for example based on a collective perception system. It is also assumed that torque or acceleration demand of the ego vehicle can be actuated. It is sufficient to model the vehicle as a point mass, without considering whether it is conventional, electric or hybrid vehicle.

Proposed work plan

- Analyse a unified optimization problem by setting up a set of navigational tasks as use cases that can be relevant.
- Develop an expert MPC for planning lateral and longitudinal motion of the ego vehicle.
- Model behaviour of surrounding vehicles, either by using similarly configured MPC as for the ego vehicle, or by simple driving decisions.
- Build a simulator for interaction with surrounding traffic, starting e.g. with a straight road.
- Design a framework to run multiple MPCs at a decision point, and select the optimal decision.
- Investigate the computation time of MPC and propose RL that can be used to decrease the computational effort.
- Present the result in a pedagogical way half ways and at the end of the period.

Start date and requirements

- The thesis work is planned to start in the second half of January 2018.
- Duration 30 ECTS.
- The thesis will be performed together with Volvo Group.
- We are searching for two students with competence and interest in optimization, control, algorithm development. Knowledge in Reinforcement learning is especially appreciated.

Contact persons

- Martin Sanfridson: martin.sanfridson@volvo.com
- Nikolce Murgovski: nikolce.murgovski@chalmers.se