Volvo Group Trucks Technology

Master Thesis proposal:

Safe switching for motion coordination control

Trucks with different trailer combinations can have several motion actuators that can be used for controlling the desired vehicle motions. The number of motion actuators such as steerable axles, mechanical brakes, and auxiliary brakes in combination with available powertrain actuators exceeds the number of controlled motions, so called over-actuation. This allows several feasible solutions to achieve the desired longitudinal, lateral, yaw, and roll motion of each unit within the vehicle combination. A tractor-semitrailer combination with a total of 12 wheels is shown in Fig. 1, which could have individual electrical/mechanical brake/propulsion, input \( u \).

In Fig. 1, Tractor+semitrailer consisting of two units; tractor with an articulation angle \( \theta \).

One way to solve the over-actuation is to use Control Allocation (CA) within the control system. The CA approaches are classified in two main categories: optimization-based and rule-based CA. Control allocation is an approach for coordination when the system has more input signals \( u \in \mathbb{R}^m \) than virtual signals controlled \( v \in \mathbb{R}^k, k < m \). The idea is to map the virtual control input onto \( u \), \( v \mapsto u \).

In the optimization-based approach, one promising optimization method for mapping is the constrained mixed optimization formulation

\[
\begin{align*}
\hat{u} &= \arg \min \| W_u(u_{des} - u) \|_p^p + \gamma \| W_v(Bu - v) \|_p^p \\
\text{subject to} \quad \underline{u} \leq u \leq \bar{u}
\end{align*}
\]

where \( B \) is the control effectiveness matrix dependent on the articulation angles, \( W_u \) and \( W_v \) are diagonal weighting matrices, and \( \gamma \) is scalar weighting parameter to allow different priority between the mapping error \( Bu-v \) compared with error in desired signal error \( u_{des}-u \). When \( p \) is set to 2, the problem becomes a weighted least squares formulation. The numerical solution of the optimization problem here is solved with the active set method. Solving CA for articulated heavy vehicles has been shown in [1], [2].

On the other hand, the rule-based strategies due to the simplicity in implementation are much more prevalent in industry.

The goal of this thesis is to ensure that that the switch to a new controller for motion coordination (rule-based or optimization-based) will not cause any transient instability or performance degradation. Therefore, we want to maintain performance at each switching between controllers (safe switching). Assuming that we have available in the VMM SW different control strategies for the motion coordination, the goal is to ensure that when we switch to a new controller for motion coordination (rule-based or optimization-based) will not cause any transient instability or performance degradation. Therefore, we want to maintain performance at each switching between controllers (called safe switching).

One way to deal with this problem is to use switched Linear Parameter-Varying (LPV) systems. The synthesis of an LPV control can be formulated as a Linear Matrix Inequality (LMI) optimization problem as presented in [3], a discontinuous Lyapunov function consisting of multiple parameter dependent Lyapunov functions is useful for stability analysis and control design of switched LPV systems. The possible transient instability caused by switching among controllers is prevented by selecting suitable switching logics. Other approaches should also be investigated as well and the most suitable should be proposed for this application [4,5].

The thesis work will include control theory, vehicle dynamics and optimization. The work will be carried out at Volvo Group Trucks Technology. The thesis is recommended for one or two students with control analysis profile with good mathematical skills. Thesis start: Jan 2023.

If you find this proposal interesting send your application with CV and grades to:

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References:
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