Control of Sideslip and Yaw Rate in 4-Wheel Steering Cars

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Abstract
A new steering control structure for cars equipped with 4-wheel steering is presented. This control structure is based on a simplified linear model that captures the main features of the lateral dynamics of 4-wheel steering cars at constant speed. The proposed control structure allows for the decomposition of an originally 2-by-2 MIMO control design problem into two SISO control design problems by using individual channel decomposition. The control design can be carried out using classical Bode-plot based techniques and results in very simple sideslip and yaw rate controllers valid for the entire speed operating envelope.

1. The control problem
- Track reference yaw rate (\( \dot{\psi} \)) and sideslip signals (\( \beta \)) with the highest possible closed-loop bandwidth (Desirable: 3 Hz).
- Reject any disturbances in sideslip and yaw rate (i.e. those caused by wind gusts or \( \mu \)-split braking) with highest possible bandwidth.
- Robustness to uncertainties and parameter changes (e.g. tyre stiffness).
- Speed operating envelope: 10–60 m/s.

2 Single-track linear model of 4-wheel steering dynamics

3. Individual channel decomposition (Diagonal controller)

4. Control structure

4. Control design
- Design is carried out in the frequency domain using an improved linear model of the car that includes time delay and actuator dynamics.
- The controller structure allows for the design of two controllers \( \hat{K}_1 \) and \( \hat{K}_2 \) valid for the entire operating envelope.
- The design is based on \( \hat{g}_1 \) and \( \hat{g}_2 \), respectively.
- Bandwidth separation is imposed (BW of Channel 1 << BW of Channel 2) in order to improve cross-channel disturbance rejection.
- Good phase and gain margins are obtained with integral control in order to improve cross-channel disturbance rejection.

5. Simulation results
Using a non-linear two-track model of a Mercedes S Class
- Step reference of 0.04 rad/s in yaw rate. Maintain sideslip at 0 rad
- \( \mu \)-split braking (1-0.2). Initial speed: 40 m/s. Braking: 9 m/s in 4 seconds

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