

# Mechanical Engineering Doctoral Defense

## Vehicle Stability Regions: Estimation, Analysis, and Control


School for Engineering of Matter, Transport and Energy

**Yiwen Huang**

Advisor: Yan Chen

### Abstract

A well-developed vehicle stability analysis and control algorithm, as the fundamental of automated driving technologies, greatly enhances the driving safety of AGVs. Towards developing a complete and safety-guaranteed vehicle lateral stability control algorithm, this dissertation presents a series of contributions, mainly including but are not limited to, the development of vehicle stability analyses and safety-guaranteed control methods based on the estimation of lateral stability regions. First, a new method is proposed to estimate and analyze the vehicle lateral stability region, which provides a direct and intuitive demonstration for the stability control of ground vehicles. As the collections of all the locally stable operation points, the estimated stability regions are conservative. Such conservativeness is especially important for characterizing the stability features of highly/fully automated ground vehicles. The impacts of vehicle lateral load transfer, longitudinal velocity, tire-road friction coefficient, and steering angle on the estimated stability regions are presented and discussed. Second, to analyze the vehicle stability based on the estimated regions, two features of the stability regions are studied. First, a shifting vector is formulated to explicitly describe the shifting feature of the lateral stability regions, so that the shiftable regions are not necessarily re-estimated for a changing steering angle input. Second, dynamic margins of the stability regions are formulated and applied to avoid the penetration of vehicle state trajectory with respect to the stability region boundaries. Third, aiming at keeping the vehicle states (lateral velocity and yaw rate) always in the shiftable vehicle stability regions, multiple novel vehicle lateral stability control methods are presented. Based on different vehicle control configurations (combinations between active front-wheel steering, active rear-wheel steering, and direct yaw moment control), two dynamic sliding mode controllers (SMC) are designed. To better guarantee the vehicle stability without the chattering issues in SMC, a non-overshooting model predictive control is proposed and applied. With less computational requirements and more concise formulations, time-varying control-dependent invariant sets and time-varying control-dependent barrier functions are proposed and adopted in a guaranteed vehicle stability control problem.



April 12, 2021; 3 PM;

Zoom Link: <https://asu.zoom.us/j/82211004663>