

Abstract

The transition towards automated driving has the potential to significantly improve road safety, particularly during emergency manoeuvres or under adverse environmental conditions. In such scenarios, vehicle stability plays a central role, and the responsibility for maintaining safe operation is progressively transferred from the human driver to automated control and decision-making algorithms. This work addresses the problem of stability in automated vehicles by explicitly accounting for nonlinear vehicle dynamics and physical stability limits within planning and control frameworks. Both longitudinal and lateral motion domains are investigated, considering Cooperative Adaptive Cruise Control (CACC) for platooning and Automatic Lane Change (ALC) manoeuvres as representative use cases. Heavy-duty vehicles are analysed in the context of platooning, while passenger cars are considered for lateral manoeuvres. For longitudinal dynamics, a simulation-based CACC framework is developed using simplified vehicle models that explicitly include actuator saturation and tyre-road friction limits. String stability, safety, comfort, and energy efficiency are jointly analysed through offline-generated performance maps based on Linear Quadratic Regulator tuning. For lateral dynamics, nonlinear vehicle stability is investigated using phase-plane analysis and bifurcation theory, enabling the identification of practical stability boundaries and critical operating conditions as functions of speed, friction, road slope, and longitudinal acceleration. These limits are embedded into a stability-aware planning strategy for automatic lane change manoeuvres. An automated driving architecture based on Linear Time-Varying Model Predictive Control is proposed for combined path and velocity tracking, explicitly incorporating stability-related constraints while retaining computational efficiency. In parallel, human driver behaviour is analysed through Driver-in-the-Loop experiments and parametric driver modelling, providing a benchmark for automated control strategies. Overall, this work demonstrates that embedding nonlinear vehicle stability limits

into planning and control enables safer and more reliable automated driving across a wide range of operating conditions.