Abstract: The trend of more advanced driver-assistance features and the development toward autonomous vehicles enable new possibilities in the area of active safety. With more information available in the vehicle about the surrounding traffic and the road ahead, there is the possibility of improved active-safety systems that make use of this information for stability control in safety-critical maneuvers. Such a system could adaptively make a trade-off between controlling the longitudinal, lateral, and rotational dynamics of the vehicle in such a way that the risk of collision is minimized. To support this development, the main aim of this licentiate thesis is to provide new insights into the optimal behavior for autonomous vehicles in safety-critical situations. The knowledge gained have the potential to be used in future vehicle control systems, which can perform maneuvers at-the-limit of vehicle capabilities.

Stability control of a vehicle in autonomous safety-critical at-the-limit maneuvers is analyzed by the use of optimal control. Since analytical solutions of the studied optimal control problems are intractable, they are discretized and solved numerically. A formulation of an optimization criterion depending on a single interpolation parameter is introduced, which results in a continuous family of optimal coordinated steering and braking patterns. This formulation provides several new insights into the relation between different braking patterns for vehicles in at-the-limit maneuvers. The braking patterns bridge the gap between optimal lane-keeping control and optimal yaw control, and have the potential to be used for future active-safety systems that can adapt the level of braking to the situation at hand. A new illustration named attainable force volumes is introduced, which effectively shows how the trajectory of a vehicle maneuver relates to the attainable forces over the duration of the maneuver. It is shown that the optimal behavior develops on the boundary surface of the attainable force volume. Applied to lane-keeping control, this indicates a set of control principles similar to those analytically obtained for friction-limited particle models in earlier research, but is shown to result in vehicle behavior close to the globally optimal solution also for more complex models and scenarios.