Abstract

The ongoing collaborative effort against climate change necessitates innovative solutions within the transportation sector, where the integration of advanced technologies holds promise in reshaping the environmental landscape. Within the array of solutions aimed at mitigating the carbon footprint of the transportation sector, the combination of powertrain electrification and advanced optimal controller emerges as particularly promising avenue.

This thesis presents the development and evaluation of three Adaptive Cruise Control (ACC) solutions designed to enhance energy efficiency, driving comfort, string stability, and safety for both electric and internal combustion engine vehicles.

The first ACC solution is developed for internal combustion engine (ICE) vehicles using a Model Predictive Control (MPC) framework, with the primary objective of minimizing fuel consumption while maintaining safety and driving comfort. More into detail, two MPC are proposed, in the first approach, a strictly quadratic cost is adopted, and fuel consumption is indirectly minimized by adjusting the weights assigned to state tracking and control effort, while in the second approach, a fuel consumption map is explicitly included in the MPC cost function, aiming to directly minimize it. The proposed ICE ACC system is validated through simulation, showing effective reductions in fuel usage while maintaining acceptable levels of vehicle safety and comfort for the two alternatives. Results imply that the first alternative is more suitable for online implementation, due to the more favorable characteristics of the associated optimization problem.

The other two solutions are Cooperative Adaptive Cruise Control (CACC) systems, developed for electric vehicles (EVs), leveraging reinforcement learning (RL) for autonomous decision-making. The first CACC employs RL in a centralized control architecture, enabling global optimization across multiple vehicles to achieve energy savings and improve traffic flow stability. A comparison between the proposed RL-based CACC and a classic linear quadratic (LQ) control is proposed. The second CACC is designed as a decentralized system, where each EV operates with a local RL controller, focusing on real-time decision-making to balance individual energy consumption, comfort, and safety while maintaining string stability in multi-vehicle platoons. Both CACC solutions are evaluated against key performance metrics including energy consumption, passenger comfort, string stability, and safety, demonstrating significant improvements in electric vehicle performance.

Together, these three ACC and CACC systems represent advancements in adaptive cruise control technology, addressing the specific needs of electric and combustion-engine vehicles and contributing to the development of sustainable and efficient transportation systems.