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COORDINATED MODEL PREDICTIVE CONTROL OF ACTIVE TRAILER SAFETY SYSTEMS FOR MULTI-TRAILER ARTICULATED HEAVY VEHICLES

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ABSTRACT

Multi-trailer articulated heavy vehicles (MTAHVs) are widely used in North America and some European countries. However, due to multi-unit structures, larger sizes, and higher center of gravity compared with cars, MTAHVs exhibit poorer low-speed maneuverability and worse high-speed directional stability especially in low-friction road surface condition or emergency driving scenarios like obstacle avoidance. Passive safety systems, e.g., command steering utilized in trailers, may improve the maneuverability at low speeds; however, at high speeds they even exacerbate the lateral stability. Active safety systems categorized as reactive safety systems (RSSs) are not effective for preventing road accidents from happening, because they may only consider the current vehicle states, and not take future states into account. These RSSs, thus, may neither remove nor correct human driver errors during vehicle operations.

Vehicle manufacturers move rapidly toward a new era of autonomous and semi-autonomous driving technologies. Any further development in automated driving systems and, in particular, the automated driving techniques for MTHAVs are critical for increasing the safety of these large vehicles. Most of the studies reported in the literature on predictive safety systems are dedicated to single-unit vehicles, e.g., cars, little attention has been paid to these techniques for MTAHVs. In this study, a coordinated control strategy is proposed, which coordinates the control actions between active trailer steering (ATS) and active trailer differential braking (ATDB) of a MTAHV, i.e., an A-train double, using a model predictive control (MPC) technique. In high-speed evasive maneuvers, the yaw moment is controlled via the ATDB while the lateral tire forces are saturated. In low-speed tightly curved path negotiations, the ATS is executed to reduce the path-following off-tracking of trailers. In emergency operating scenarios, the controller makes full usage of the performance limits of both the safety systems to improve the lateral stability and the maneuverability simultaneously.

The MPC algorithm is designed for determining the control inputs for the ATS and ATDB considering future vehicle states. To this end, an optimization problem with a cost function and constraints is formulated. The solutions of the optimization problem are the optimal control inputs, which make the MTAHV follow the target path with acceptable lateral acceleration. To validate the control strategy, co-simulations are conducted using the MPC controller designed in MATLAB and a MTHAV model generated in TruckSim. Various driving scenarios in the presence of external disturbances and varied road conditions are simulated to examine the robustness of the MPC controller.