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A hierarchical controller design for the motion stability of four in-wheel motor actuated electric vehicles

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Popularization of electrified and intelligent vehicles makes new challenges and opportunities to the traditional vehicle control technologies. The motion stability control of four in-wheel motor actuated electric vehicle is one of the significant problems, hence it is proposed as a benchmark problem at the 62nd IEEE Conference on Decision and Control. In this paper, a hierarchical control scheme is proposed to deal with the associated problems in terms of longitudinal and lateral stability control, respectively. This hierarchical scheme control proposed consists of two levels: the primary control based on nonlinear model predictive control (NMPC) and PID algorithm ensures the accuracy of speed tracking or trajectory tracking; the secondary control optimizes the vehicle's motion stability by tire torque allocation.

In order to deal with the longitudinal motion control problem, the longitudinal kinematics model and four-wheel rotation dynamic model are constructed, and an online estimation algorithm is proposed for the wheel ration rate. Then, a longitudinal dynamics controller is built by using NMPC algorithms, in which the optimal performance indexes comprehensively consider the energy consumption, comfort, and longitudinal stability. Finally, the four wheels' torque outputs are optimized in real time by an online optimization algorithm.

Furthermore, for the lateral stability control, a hierarchical control scheme is developed. At the high level, a PID controller is used to achieve the tracking control of lateral displacement first, meanwhile, a simplified two-degree-of freedom bicycle model is used to represent the system dynamics in terms of the yaw rate and the sideslip angle, and by deducing a linear reference model in the stability domain, and the reference states are generated. Then model predictive controller is proposed to adjust the additional yaw moment torque that realizes the real-time tracking control of reference yaw rate and sideslip angle, and finally, guarantees the lateral stability.

The above proposed controller is validated in the official simulation platform of the Benchmark and the simulation results demonstrate the effectiveness of the proposed control scheme.

Key words: Automotive control; hierarchical design; motion Stability; optimization.

