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CONNECTED AUTOMATED VEHICLES AND ITS, VEHICLE DYNAMICS AND CONTROL, VISION AND SENSORS

Internal Model-Based Robust Path-Following Control for Autonomous Vehicles

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Abstract

The paper presents a new internal model control (IMC) based control technique for lateral trajectory tracking of autonomous vehicles. The controller's proposed structure employs a robust, fault-tolerant nonlinear internal servo control with optimal reference generation concerning vehicle yaw stability and physical limitations. The presented inscription of the reference generation creates a convex optimization task that can be used in real-time applications. Improvements in yaw-rate stability of vehicle motion control are first shown through simulation results performed in a Simulink environment. The controller structure was also implemented in a real-time model and was examined in a Mercedes C-Class vehicle. In this article, the simulation results and the real-time measurements are presented. The results show that the proposed controller has high efficiency in disturbance rejection and lower sensitivity towards parameter changes compared to a model predictive control (MPC) structure.

Keywords Path-tracking control · Robust control · Convex optimization · Autonomous vehicles · Nonlinear control

1 Introduction

One of the main reasons for developing autonomous vehicles is that these vehicles can increase safety in transportation. The safety of autonomous vehicles should be measured in handling a wide range of vehicle operating conditions (load, speed, tire friction) and disturbances. As the first step towards autonomy, driving assistant systems were developed to support inexperienced drivers and increase safety and stability. For longitudinal and lateral control, PID and LQR control is used to increase the stability of human-driven vehicles (Tavan et al., 2015). The linear matrix inequality (LMI) method is used for a robust driver assistant control improving chassis stability (Dahmani et al., 2015).

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The recent emerging technologies have several challenges concerning autonomous technology (Paden et al., 2016). The algorithms should provide a real-time solution that can be evaluated on the test platform to gain reliability. The convexity of the problem space has to be provided to ensure unicity, and the parameters making these algorithms intuitive and scenario-specific should be eliminated.

An improved structure of the pure pursuit method adjusts the look-ahead point and solves the cutting-edge problem (Ahn et al., 2021). This method is good in handling the question of the distance of the look-ahead point, but the vehicle dynamics and limitations are not considered. A comprehensive list of trajectory tracking controllers that are not using optimization and have short runtime can be found in the literature (Calzolari et al., 2017). Still, these methods cannot handle nonlinearities such as tire saturation or actuator limitations. A sliding-mode controller is presented for the lateral control (Tagne et al., 2013). This method is robust in handling nonlinearities. However, it has many intuitive parameters in the control rule and in solving the chattering problem.

Model predictive control (MPC) is an effective structure for longitudinal-lateral control, but in the most cases, it uses a linear model (Lin et al., 2019). A lane change