Chapter 5
Autonomous Vehicle Tracking Based on Non-Linear Model Predictive Control Approach

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ABSTRACT

Autonomous driving vehicles are developing rapidly; however, the control systems for autonomous driving vehicles tracking smoothly in high speed are still challenging. This chapter develops non-linear model predictive control (NMPC) schemes for controlling autonomous driving vehicles tracking on feasible trajectories. The optimal control action for vehicle speed and steering velocity is generated online using NMPC optimizer subject to vehicle dynamic and physical constraints as well as the surrounding obstacles and the environmental side-slipping conditions. NMPC subject to softened state constraints provides a better possibility for the optimizer

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to generate a feasible solution as real-time subject to online dynamic constraints and to maintain the vehicle stability. Different parameters of NMPC are simulated and analysed to see the relationships between the NMPC horizon prediction length and the weighting values. Results show that the NMPC can control the vehicle tracking exactly on different trajectories with minimum tracking errors and with high comfortability.

INTRODUCTION

The rapid and widespread development of advanced technologies on robotics, automation, IT and high-speed communication networks has made the application of autonomous driving vehicles growing constantly and changing the society. Autonomous vehicles have been received considerable attention in recent years and the needs are arising for the mechatronic systems to control the vehicle tracking from any given start points to any given destination points online generated from the global positioning system (GPS) and subject to the vehicle physical constraints.

This book chapter develops a real-time control system for an autonomous ground vehicle directed online from the GPS maps or/and from unmanned aerial vehicles (UAVs) images. This system can be applied for auto traveling on road or off road for unmanned ground vehicles. The system can also be used for auto parking and auto driving vehicles.

Motivation for the use of MPC is its ability to handle the constraints online within its open-loop optimal control problems while many other control techniques are conservative in handling online constraints or even try to avoid activating them, thus, losing the best performance that may be achievable. MPC can make the close loop system operating near its limits and hence, produce much better performance.

However, MPC regulator is designed for online implementation, any infeasible solution of the optimization problems cannot be allowed. To improve the system's stability once some constraints are violated, some kinds of softened constraints or tolerant regions can be developed whereas the output constraints are not strictly imposed and can be violated somewhat during the evolution of the performance.

To deal with the system uncertainties and the model-plant mismatches, robust MPC algorithms can be built accounting for the modelling errors at the controller design. Robust MPC can forecast all possible models in the plant uncertainty set and the optimal actions then can be determined through the min-max optimization.

The reference feasible trajectories can be generated online using solver for ordinary differential equations (ODEs) with the flatness or polynomial equations presented in (Minh V.T, 2013). Algorithms for robust MPC tracking set points are referred in Minh V.T and Hashim F.B (2011), where the system's uncertainties are

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