

NLMPC for Real Time Path Following and Collision Avoidance

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ABSTRACT

This paper presents a nonlinear control approach to achieve good performances in vehicle path following and collision avoidance when the vehicle is driving under cruise highway conditions. Nonlinear model predictive control (NLMPC) is adopted to achieve online trajectory control based on a simplified vehicle model. GMRES/Continuation algorithm is used to solve the online optimization problem. Simulations show that the proposed controller is capable of tracking the desired path as well as avoiding the obstacles.

CITATION: Rosolia, U., Braghin, F., Alleyne, A., and Sabbioni, E., "NLMPC for Real Time Path Following and Collision Avoidance," *SAE Int. J. Passeng. Cars – Electron. Electr. Syst.* 8(2):2015, doi:10.4271/2015-01-0313.

INTRODUCTION

Real-time control of autonomous vehicles is an active field of research. The main aspects to take into account are: path following for a non-holonomic vehicle and collision avoidance.

Path following has been widely studied in the literature. A standard formulation is to use a moving coordinate system attached to the path: a Frenet reference frame [1] [2]. The in [1] is preferable, because the moving frame is uniquely determined by the vehicle position and it is not necessary to introduce an additional degree of freedom. Although a singularity problem arises when the lateral vehicle displacement coincides with the curvature radius of the path. This situation is not relevant in our application: a highway curvature radius is at least an order of magnitude larger than the admissible lateral displacement.

Collision avoidance has been thoroughly studied in the past twenty years and many solutions were proposed. Early work in this field used potential functions and online searching [3] [4]. These methods do not take into account the dynamics of the system and the planning phase is independent on the model. To remove these weak points in the planning process, some extensions have been proposed in [2] [5] [6]. However, some fundamental problems concerning local minima and grid discretization are still present [2] [7]. In this paper a model predictive controller (MPC) is presented that successfully overcomes these problems [7] [8]: in fact, in this control approach an optimal control problem is solved over a finite time moving window. Unfortunately, nonlinear model predictive control (NLMPC) is still an open research field and there is an exiguous number of techniques

to find a numerical solution [9]. Among those available, an explicit technique, the MGRES/Continuation, has been chosen: since, conversely to implicit solvers, it uses forward steps to compute the solution and no iteration is required. Therefore, the computational time is fixed which is a key feature in real-time applications [11].

Recently, predictive steering control for path following has been studied and efficiently solved in real time [12] [13] [14]. But this control logic requires a collision-free reference trajectory, which must be computed on-line and could lead to unfeasible real time implementations. Thus to overcome this issue, the authors in [15] [16] have proposed a two level hierarchical control scheme composed of a higher level NLMPC trajectory planner and a lower level NLMPC trajectory follower. In [15] the authors use a simple nonlinear system for the planning phase, but the longitudinal velocity of the simplified system is fixed and the obstacles are modelled using potential functions. In [16] a single track vehicle model (STVM) in spatial coordinates is used for the higher level controller. In [11] the same spatial approach is applied to a more complex model and the optimization is performed on a single layer NLMPC. However, in [11] [16] the obstacle is treated as a boundary on the state. Namely, the vision algorithm has to decide if the obstacle should be overtaken to the left or to the right. This approach, in cruise highway conditions, limits performances. For instance, when the vehicle is leaving a curve, the controller has to decide from which side to avoid the obstacle based on the lateral velocity, on the position and on the gradient of the steering. Furthermore, for cruise driving, speed should be kept constant except during an overtake when the controller should accelerate gently to rapidly complete the maneuver as a

