Proceedings, Bicycle and Motorcycle Dynamics 2019
Symposium on the Dynamics and Control of Single Track Vehicles,
9–11 September 2019, University of Padova, Italy

Design and implementation of a high-performance, nonlinear MPC-based virtual motorcycle rider

M. Bruschetta*, **E. Picotti***, **A. De Simoi#**, **Y. Chen†**, **A. Beghi***

* Department of Information Engineering
University of Padua
Via 8 Febbraio 1848, 2, 35122 Padova PD, Italy
e-mail: {bruschet, picottie, beghi}@dei.unipd.it

Sinteco Srl
Longarone, Veneto, Italy

† Department of Electrical Engineering
Eindhoven University of Technology
De Zaale, Eindhoven, Netherlands
e-mail: y.chen2@tue.nl

ABSTRACT

Virtual prototyping tools are nowadays widespread among automotive manufacturers. A successful usage of these tools requires a reliable human-like driver/rider. Specifically addressing motorcycles, the design of such controllers, called Virtual Riders (VR), is still a challenging task. In this paper, we first analyze the state of the art of the available control strategies, with specific reference to those base on Model Predictive Control (MPC). We then propose a Nonlinear MPC-based VR for high-performance maneuvers. The internal dynamics is based on the sliding plane model, where the tire lateral forces are computed using Pacejka Magic Formula, and the computed controls are the derivative of the actual bike commands (steering angle, throttle and brake effort). The NMPC problem is solved using an open-source tool (MATMPC), that is devolepd in MATLAB and allows for easy development and tuning. The results are shown in cosimulation with a realistic simulation software (VI-BikeRealTime) on an hairpin turn, reaching over $40deg$ of roll angle and nearly $1g$ of lateral acceleration. Moreover, computational burden is shown to be real-time compatible.

Keywords: Virtual rider, Nonlinear MPC, Real-Time NMPC

1 INTRODUCTION

The development of a high-performance motorcycle rider for virtual prototyping applications is still a challenging task. While modern CAE tools show a high level of reliability in simulating complex dynamics, VR are not yet capable of properly reproducing human-like behaviors.
In the last decades, the virtual rider problem has been largely studied and different control methodologies have been proposed. Getz developed a nonlinear compensator to control a simplified, nonholonomic, non-minimum phase model along a reference path [1]. Sharp implemented a controller based on the optimal control formulation in [2] for a linear motorcycle model, in which the longitudinal and lateral dynamics are decoupled. In [3], the development of a PID controller is described, where a revised version of the Sharp model has been used. The longitudinal and lateral control loops are separated and a gain scheduling based on the the velocity of the motorcycle is applied. More recently, Saccon proposed a sliding plane model, which consists of a rigid body with two ground contact points. The model is used for the design of a virtual rider in three steps [4]. First, the dynamics is inverted for computing state-control trajectory. Then, the solution of the inverse optimal control problem is used to obtain the closed loop dynamics. Finally, a maneuver regulation controller is implemented using the previous results.