

Stability of Soft Constrained Finite Horizon Model Predictive Control

M. Askari, M. Moghavvemi, Haider A. F. Almurib, *Senior Member, IEEE*, Ahmed M. A. Haidar, *Senior Member, IEEE*

Abstract -- This article addresses the stability of soft-constrained model predictive control. It is shown that the infinite horizon soft-constrained model predictive control problem can be solved as a finite horizon soft-constrained model predictive control problem if the prediction horizon is greater than an upper-bound. The contribution of this paper is a procedure to compute the prediction horizon upper bound which guarantees the stability. The proposed technique is verified using two simulation example. The second example (inverted pendulum) is verified through practical implementation.

Index Terms-- Model predictive control, Soft constrained, finite horizon, infinite horizon

I. INTRODUCTION

Model predictive control (MPC) is a control strategy that has been widely accepted in the industrial process control community and implemented successfully in many commercial applications. The incorporation of the constraints in the problem formulation is the main advantage of MPC [1-6]. Constraints are classified in two categories: hard constraints and soft constraints. Hard constraints can lead to feasibility problems, this means that the controller cannot lead the states from initial condition to set-point without any hard constraint violation. Feasibility problems may occur when a disturbance drives the system into a state for which no admissible input exists under the given constraints [7]. The controller will then fail to produce a control input, which is obviously an unacceptable behavior for a control system.

Infeasibility problem may also occur due to some initializing states or modeling errors. The general method for solving the infeasibility problem is to soften the constraints, by adding slack variables to the optimization problem [8].

Prediction horizon is an important parameter of predictive control which affects stability, computational complexity,

optimality and feasibility of MPC. A MPC scheme is infinite-horizon optimal, if the resulting control sequence minimizes a cost function over an infinite prediction horizon. Nevertheless, the difficulty of using an infinite horizon is the infinite decision variables to choose, which causes high computational load.

MPC is the most widely used method for modern control and a great deal of literature has been produced. A robust MPC scheme using neural network-based optimization was proposed in [9] to stabilize a physically constrained mobile robot. According to [9], the MPC optimization can be formulated as a convex nonlinear minimization problem and a primal-dual neural network is adopted to solve this optimization problem over a finite receding horizon. Another robust MPC method has been developed for constrained nonlinear systems with control constraints and external disturbances [10]. In this method, the control signal is obtained by optimizing an objective function consisting of an integral non-squared stage cost and a non-squared terminal cost. To deal with the persistent disturbance, the authors in [11] introduced the notion of input-to-state stability of discrete-time singular system. Here, the optimal control can be obtained by solving a quasi-min-max optimal problem of a finite horizon cost function. A predictive speed controller based on finite control set MPC proposed by [12] for electric drives. The performance of this method is achieved by using proper weighting of the speed errors along with the current errors in the cost function. Authors in [13] addressed the problem of feedback control with a constrained number of active inputs by using a quadratic MPC strategy that guarantees sparsity. In such approach, the combinatorial optimization problem was transformed into an equivalent optimization problem that does not consider relaxation in the cardinality constraints. The idea of control Lyapunov functions for continuous-time nonlinear systems has been utilized in [14], to compute the terminal regions and terminal control laws with some free-parameters in the dual-mode nonlinear MPC. A performance comparison is presented in [15] between three well-known stochastic MPC approaches, namely, multi-scenario, tree-based, and chance-constrained MPC. The advantages and disadvantages of these approaches are extensively discussed and analyzed, for deriving valid criteria of selecting an appropriate stochastic predictive controller.

In the aforementioned review, there are numerous approaches developed under MPC umbrella. However, not many of these approaches have a specific focus on both linear

M. Askari is with the Academic Center for Education Culture and Research, IUT Branch, Isfahan, Iran (email: m_askari@acecr.ac.ir)

Mahmoud Moghavvemi is with the Center of Research in Applied Electronics (CRAE), Department of Electrical Engineering, Faculty of Engineering University of Malaya and also with the University Science and Culture, Tehran Iran (e-mail: mahmoud@um.edu.my)

Haider Abbas Mohamed is with the Electrical and Electronic Engineering, Faculty of Engineering University of Nottingham, Kuala Lumpur, Malaysia (email: haider.abbas@nottingham.edu.my)

Ahmed M. A. Haidar is with the Department of Electrical and Electronic Engineering, University Malaysia Sarawak, Malaysia (email: ahahmed@unimas.my), and also with the School of Mechanical and Electrical Engineering, University of Southern Queensland, Australia (email: Ahmed.Haidar@usq.edu.au)