Proposal – Open Invited TRACK at 20th IFAC World Congress
Nonlinear Model Predictive Control
for Mechatronic Systems and Motion Control

Organizers

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Abstract

Over the last years, the development of tailored optimization methods and increased computational power have led to a considerable speed-up of Nonlinear Model Predictive Control (NMPC) algorithms such that feedback sampling rates in the order of 1kHz are feasible nowadays. These advances enable real-world implementation of NMPC algorithms for control and coordination of (multi-agent) mechatronic systems. The proposed open invited track focuses particularly on optimization-based predictive control of nonlinear systems collecting latest improvements on implementation and theory development with respect to mechatronic applications. Amongst others the intended contributions will present novel results on: generalized NMPC formulations combining path-following with force-feedback for robotic manipulators, the issue of stability in path-following NMPC, new updating techniques (real-time iterations and sensitivities) exploiting the geometry of mechatronic control problems, and new distributed NMPC schemes targeting the coordination of multi-agent mechatronic systems. The track specifically aims to bring together researchers from academia and industry. This way, it shall provide a platform for presenting theoretical and application-oriented contributions, and it shall foster new ideas and collaborations regarding the tailored design of NMPC for mechatronic systems and motion control problems.

IFAC Technical Committee for Evaluation

TC 4.2 "Mechatronic Systems"

Detailed Description

From a control point of view, Nonlinear Model Predictive Control (NMPC) is particularly attractive due to its ability to directly incorporate nonlinearities in both dynamics and constraints as well as to account for performance requirements. As is well-known, the main idea of NMPC is easily described by three-step procedure: (I) Obtain an estimate of the current state of the system. (II) Find a control sequence optimizing a predefined performance index over a finite time horizon. (III) Implement the first part of the optimal control sequence. As a result, any NMPC scheme contains the open-loop component of optimizing over a prediction of the system, and closes the control loop by the implementation step. Since the optimization step is computationally demanding, real-world application of NMPC schemes was first conducted in petro-chemical plants, where the dominating time constants are in the order of several minutes up to a few hours.

In contrast to this, mechatronic systems and motion control problems typically require much higher sampling rates in the order of 1kHz and faster. On top, these systems exhibit significant nonlinearities, tight performance specifications and are typically subject to hard state and input constraints. Hence, in this context, NMPC is a promising candidate control strategy. Yet, despite the ongoing progress in algorithmic development, real-world implementation of NMPC algorithms remains challenging. To ensure fast sampling, popular approaches are based on tailored control updates such as real-time iterations, sensitivities, offline precomputation or intermediate updates of components of the underlying system of KKT equations.

Besides the ongoing numerical challenge in NMPC, recent research efforts have focused on deriving NMPC formulations applicable to problems beyond setpoint stabilization and trajectory tracking. Examples of these developments are path-following formulations, in which online trajectory generation on a reduced-order manifold in the workspace (i.e. on the geometric reference path) is combined with the stabilization of this manifold, or distributed NMPC schemes of multi-agent systems as they arise in the context of autonomous and unmanned vehicle operation.

The main intention of the proposed track is to push forward the application of NMPC to mechatronic systems and motion control problems. We invite researchers from leading groups from different countries (Canada, Germany, Portugal, Switzerland, United Kingdom, USA) and industrial companies to share their latest advances regarding tailored NMPC formulations, algorithmic design, and new applications, whereby all contributions shall be of relevance for mechatronic systems. This scope is reflected in the list of foreseen contributions, see below. The invited track encourages both theoretical and application-related contributions. Amongst others, foreseen contributions will discuss timely applications in the areas of airborne energy systems, close human-robot interaction, electrical vehicles and multi-agent systems. As mechatronic systems are widespread in industrial applications, we expect further contributions besides the ones listed below, addressing theory as well as application-oriented recent advances in the field of NMPC of mechatronic systems. The track also aims to provide a platform for discussions between academic and industrial researchers to foster the new ideas, identify issues and challenges for future research, and establish new connections between academia and industry.

Intended Contributions

1. **Title: Nonlinear model predictive path-following force control applied to a lightweight robot**

   Authors: Janine Matschek, Johanna Bethge, Pablo Zometa, and Rolf Findeisen (Otto-von-Guericke Universität Magdeburg, Germany)

2. **Title: Predictive path following of mobile robots without stabilizing constraints**

   Authors: Timm Faulwasser (Karlsruhe Institute of Technology, Germany & École Polytechnique

Fédérale de Lausanne, Switzerland), Karl Worthmann (TU Ilmenau), George K.I. Mann, Raymond G. Gosine, Mohamed Said (University of New Foundland, Canada)

3. **Title: A multiobjective MPC approach for autonomously driven electric vehicles**
   Authors: Kai Schäfer, Sebastian Peitz, Michael Dellnitz (University of Paderborn, Germany), Sina Ober-Blöbaum (University of Oxford, UK), Julian Eckstein, Patrick Friedel, Ulrich Köhler (Hella KGaA Hueck & Co., Germany)
4. **Title: A distributed MPC scheme for coordination of multi-agent systems**
   Authors: Andrea Alessandretti (University of Porto, Portugal), A. Pedro Aguiar (University of Porto, Portugal)
5. **Title: Impact of quantization on consistency of distributed model predictive control in street traffic**
   Authors: Tobias Sprodowski, Jürgen Pannek (University of Bremen, Germany)
6. **Title: Real time nonlinear model predictive controller for a tethered aircraft**
   Authors: Petr Listov, Colin Jones (École Polytechnique Fédérale de Lausanne, Switzerland), Timm Faulwasser(Karlsruhe Institute of Technology, Germany & École Polytechnique Fédérale de Lausanne, Switzerland)
7. **Title: Robust MPC for sampled-data systems**
   Authors: Fernando A.C.C. Fontes (University of Porto, Portugal), Sasa V. Rakovic (Texas A&M University, College Station, USA) and Ilya V. Kolmanovski (University of Michigan, USA).
8. **Title: Optimal control strategies for motor vehicles**
   Authors: Andreas Huber, Matthias Gerdts (University of Armed Forces Munich, Germany)
9. **Title: Numerical experiments with multistep model-predictive control approaches for the tracking control of cars**
   Authors: Matthias Gerdts (University of Armed Forces Munich, Germany)