Model Predictive Control

Dates and time

22-04-2024
06-05-2024
13-05-2024
27-05-2024
from 10:15 – 12:30

Course location

Cursus- en vergadercentrum Domstad, Utrecht

ECTS

3 ECTS if the homework is completed successfully.
1 ECTS for auditing the entire course

Lecturers

Dr. M. Lazar, Eindhoven University of Technology, EE
Dr. Chanfreut Palacio, Eindhoven University of Technology, ME

Objective

The course will teach Model Predictive Control (MPC) theory, design methods and implementation in Matlab at the level of PhD or PostDoc researchers. The objective of the course is to provide participants with fundamental and practical knowledge of the MPC field, enabling them to conduct research in the MPC field or to apply MPC controllers to specific application domains.

MPC relies on three main building blocks:

(i) multi-step prediction models,
(ii) cost function and constraints, and
(iii) dynamic (receding horizon) optimization.

At each time instant, an MPC controller predicts the future behavior of the system over a finite time horizon, and computes a sequence of control inputs by solving a constrained optimization problem based on measured data. However, it applies only the first input of this sequence to the system, and the process is repeated again at the next time instant. We will teach all the aspects necessary for mastering the building blocks of MPC mainly for discrete-time linear and nonlinear systems, along with systematic methods for guaranteeing asymptotic stability and recursive feasibility, and ensuring robustness.

The course will be split into two parts: the first part will focus on centralized MPC of standalone / isolated systems; the second part will focus on distributed MPC of multi-agent/interconnected systems. The second part will be built on the knowledge acquired in the first part of the course and will teach specific methods for dealing with the challenges of distributed MPC. Throughout the course, examples will be given/worked out from various application domains, e.g., adaptive cruise control, aerospace, motion control, distributed control of microgrids, distributed control of water networks, etc.

Contents

Lecture 1: INTRODUCTION & LINEAR MODEL PREDICTIVE CONTROL (MPC).
-Principles of MPC, introduction to MPC books and toolboxes used in the course.
-Building blocks of linear MPC, stability and recursive feasibility, tube-based robust linear MPC.

Lecture 2: NONLINEAR MODEL PREDICTIVE CONTROL.
- Stability and recursive feasibility of nonlinear MPC.
- Data-driven nonlinear MPC.
- Computationally efficient nonlinear MPC formulations.

Lecture 3: DISTRIBUTED MODEL PREDICTIVE CONTROL (DMPC)
- From centralized to distributed control, examples of applications.
- Advantages and challenges of DMPC.
- Overview of DMPC schemes: commonalities and differences (control architectures, cooperative/non-cooperative approaches, theoretical properties).

Lecture 4: COORDINATING MULTIPLE DMPC AGENTS
- Communication-based and cooperation-based DMPC algorithms.
- DMPC via dual decomposition and ADMM.
- Robust DMPC.
- Examples of implementation in Matlab.
- Other topics in DMPC: plug-and-play, reconfigurable control structures, time-varying partitioning.

Course materials

A full set of lecture notes and some tutorial material will be made available on the DISC course platform. Several books specializing in different MPC topics will be recommended.

Prerequisites

Following the MPC course will require some background knowledge in convex optimization, discrete-time state-space systems, Lyapunov functions, linear matrix inequalities, set-theoretic concepts (invariant sets and controllable sets). Experience with basic Matlab programming and simulating dynamical systems in Matlab is recommended. However, the course will also contain tutorial material about the above-mentioned subjects and will allow less familiar participants to catch up during the course.

Homework assignments

Two homework sets will be distributed via the course website. Homework is graded on a scale from 1 to 10. Homework sets will include both theoretical, open exercises and Matlab programming assignments, i.e., students will have to submit a report and software files in a zip archive. Missing sets receive the grade 1. The final grade for the course is a weighted average of the grades for the homework sets.