UNIVERSITÀ DI PARMA

Dipartimento di Ingegneria dei Sistemi e delle Tecnologie Industriali - DISTI
Department of Engineering for Industrial Systems and Technologies (DEIST)

PhD course

"Optimization tools for Predictive Control in Engineering Applications"

Lecturer: Costanza Saletti, PhD (University of Parma)

Credits: 2 CFU – 14 hours

Schedule:

- Tuesday 15/10/2024, 14:00-17:00
- Wednesday 16/10/2024, 14:00-18:00
- Tuesday 22/10/2024, 14:00-17:00
- Wednesday 23/10/2024, 14:00-18:00

The course is delivered **online** on Teams in **English**.

It is recommended to register by filling the following form (deadline: 11/10/2024): https://forms.office.com/e/EJtim3mPvz

For additional information, please contact the lecturer at costanza.saletti@unipr.it

Course content

The growing complexity of systems in different engineering fields requires advanced tools based on optimization that can outsmart traditional control strategies. For instance, in the context of the sustainable energy transition, modern energy systems are characterized by the integration of different energy conversion and storage units, as well as by a significant penetration of non-programmable renewable sources. In presence of highly variable boundary conditions, rule-based control methods lead to non-effective system management. Moreover, in the automotive field, the recent spread of hybrid and electric engines imposed the use of advanced controllers to assist powertrain management. Additionally, the same necessity arose in chemical and industrial processes, where products are required to have specific quality constraints and detailed knowledge and control over such processes are paramount.

In this framework, the course aims to provide the knowledge and skills for the design and implementation of advanced optimization and control strategies for decision-making in industrial engineering applications. Firstly, the course will deal with the theoretical background of optimization problems, presenting the concept, problem classification and available algorithms and solvers. Then, traditional and advanced control strategies will be described, with a specific focus on Model Predictive Control (MPC), a well-established technique for multivariable systems subject to constraints. Finally, a methodology for verifying and comparing control strategies through system models, namely Model-in-the-Loop, will be provided.

During the course, several examples and practical applications (with particular emphasis, but not exclusively, on contexts typical of industrial engineering, e.g. energy systems) will be proposed: students will employ MATLAB® code to develop optimization algorithms for selected case studies and the Simulink® environment to create a model and apply Model Predictive Control.

Learning objectives

During the course, the student will acquire:

1) specific knowledge related to optimization problems, optimization algorithms and potential applications in engineering fields;
2) specific knowledge related to conventional and advanced control techniques, with particular focus on Model Predictive Control for decision-making and management of complex engineering applications;
3) the skill to write an optimization problem, select an appropriate optimization algorithm and solve it in a computational environment;
4) the ability to design and implement conventional and advanced control solutions for industrial engineering problems and to test them on a dynamic model in MATLAB®/Simulink®.

Teaching methods

Learning activities will be developed in the form of frontal lectures and practical exercises. Students are required to download MATLAB® with the following additional packages: Control System Toolbox, Global Optimization Toolbox, Model Predictive Control Toolbox, Optimization Toolbox, Simulink, System Identification Toolbox.

Prerequisites

Students should have a basic experience with the MATLAB® programming environment.

Full programme

1) Introduction to optimization and control methods in industrial engineering domains.
2) Optimization algorithms:
    - Linear Programming (LP): mathematical formulation and simple 2D numerical example, linearization or piece-wise linearization, application example (performance curve of a pump, which is typically nonlinear).
    - Mixed Integer Linear Programming (MILP): mathematical formulation and simple 2D numerical example.
    - Dynamic Programming (DP): mathematical formulation, discrete solution algorithm.
    - Heuristics: Genetic Algorithm and Particle Swarm Optimization.
    - **Exercises**: solution of linear and dynamic optimization problems in MATLAB®.
3) Control strategies:
    - Traditional feedback and feedforward control.
    - Model Predictive Control: concept, theoretical formulation, set-point tracking and economic MPC.
    - Applications.
4) Model-in-the-Loop verification of control strategies:
    - Modeling: simulation models vs control models.
    - Use of Simulink® for modeling.
    - **Final exercise**: Model-in-the-Loop application of MPC in Simulink