2EL6150 – Model-based predictive control

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Department: CAMPUS DE RENNES
Language of instruction: ANGLAIS
Campus: CAMPUS DE RENNES
Workload (HEE): 60
On-site hours (HPE): 35,00
Elective Category : Engineering Sciences
Advanced level : Yes

Description

Model Predictive Control (MPC) is the advanced control technic the most used for engineering systems. Its industrial use is booming because it optimizes the operation of an industrial process, its energy efficiency while integrating operating constraints. However, it is still the subject of a large number of scientific publications, even if the last concerns of the scientific community remain very theoretical.

This course presents the main principles of the predictive control in a precise, readable and intuitive mathematical formalism and which is not reserved for the automation engineers - *The predictive control will be treated in depth and in all the aspects of the automatic in the mention of 3rd year "Control Engineering"* - After an introduction to the basic concepts of the MPC, this course is built around many case studies, where they will be applied both in simulation and in practice for different industrial processes. In this course, it is therefore a question of providing decision and control tools that exploit a model of the system in order to improve its efficiency. Expectations in terms of efficiency are translated into a mathematical multicriteria that must be minimized. The model can be derived from a mathematical representation of the considered system, in which case conventional methods (deterministic, linear programming for example, or explicit resolution) of optimization can be used. The optimization process can also use a simulator of the studied system, which must then use heuristic techniques.

The applications will focus on energy management in an eco-district and the exploitation of such techniques for the sizing of energy production or storage systems.

Quarter number

SG8

Prerequisites (in terms of CS courses)
Control Science Course
Optimisation Course

Syllabus

An Introduction to Model Predictive Control (6h lecture, 6h de TD, 9h of Laboratory Work, including 1 hour of exam)

- Basis concepts
    - Prediction model
    - Receding horizon principle
    - Specifications and mathematical translation of objectives
    - Optimization problem solving and closed-loop behavior
    - Tuning
    - Explicit and Implicit solving
- Economic MPC
- Constraints Integration

Case Study 1**:** Energy management in Residential Houses (1h lecture, 4h laboratory work, 9h Homework, 1 hour of exam)**.** Group work of 3/5 students. This first case study aims at integrating a set of complex heterogeneous systems into an energy manager.

- Data analysis and bibliographic analysis
- Design of a power management system, integrating energy and power constraints
- Integration of mixed processes: continuous and with decision variables
- Development of a performance evaluation simulator
- Written exam

Case Study 2**:** Dimensioning and predictive management of a solar production and an electrical storage for the energy independence of an isolated site (1h lecture, 5h laboratory work, 18h homework, 1 oral presentation of the results). This second case study incorporates an economic dimension coupled with risk-taking in the management of uncertainties.

- Data analysis and bibliographic analysis
- Integration of uncertainty (weather phenomena, random consumption)
- Compromise search: investment in infrastructure and strong active management capability
- Return on investment calculation

- Assessment of the comforts (satisfaction of the requests)
- Risk analysis
- Team Challenge - Presentation and Peer Review

Class components (lecture, labs, etc.)

This module is built on very few theoretical courses. Practical work is at the heart of this module, which combines both model experiments (industrial wind tunnel) and technical-economic studies where theoretical content is used as a basis for decision-making.

Grading

Written exam of part 1 (0.25) Written exam of part 2 (0.25)Oral presentation of part 3 (0.5)

Course support, bibliography

- Model-based Predictive Control – A practical approach, J.A. Rossiter, CRC Press, 2003
- Model Predictive Control: Theory and Design, J. Rawlings and D. Mayne, Nob Hill Pub, 2009
- Model Predictive Control, E. Camacho and A. Bordons, Springer-Verlag London, 2007

Resources

- Teaching staff (instructor(s) names): Romain Bourdais, Pierre Haessig
- Maximum enrollment (default 35 students): 25 students
- Software, number of licenses required: Matlab/Simulink/Optimization Toolbox
- Equipment-specific classrooms: 25 students, Model Wind tunnel (available on Rennes Campus)

Learning outcomes covered on the course

At the end of this course, the student will be able to

- Specify the technical and economic stakes of the control-command problem under a Model Predictive Control formalism:
    - Choose an optimization criterion
    - Integrate operating and usage constraints
- Choose and use an appropriate optimization tool to solve the predictive control problem under consideration.

- Tune the parameters adapted to the situation and argue about these choices through simulation.
- Master scientific and technical communication (during reports or oral presentations).

Description of the skills acquired at the end of the course

- "Specifying the stakes of the control-command problem under a predictive command formalism" is part of C1.1 "Examine a problem in full breadth and depth, within and beyond its immediate parameters, thus understanding it as a whole. This whole weaves the scientific, economic and social dimensions of the problem.".
- "Choosing and using a suitable optimization tool for solving the predictive control problem under consideration" is part of C1.2 "Select, use and develop modelling scales, allowing for appropriate simplifying hypotheses to be formulated and applied towards tackling a problem".
- Select and use an optimization tool to solve the predictive control problem under consideration" is part of C2.3 "Independently identify and acquire new knowledge and skills needed"