

M09 PARIS-SACLAY
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Dissipativity in Optimal Control - Turnpikes, Predictive Control, and Uncertainty



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Summary of the course

The optimal control twin breakthroughs, i.e. Pontryagin's maximum principle and Bellman's dynamic programming principle, and the dissipativity notion for open systems conceived by Jan. C. Willems are supporting pillars of systems and control. On this canvas, this course explores the constitutive relations between optimal control and dissipativity.

The week commences with a brief and example-driven introduction into optimal control formulations in continuous time and discrete time and we comment on the challenges that arise from infinite-horizon problems. We then turn towards dissipativity, discussing how optimal control has been at the very core of the concept since its inception. We comment on the surprisingly rich set of systems-and-control problems that admit a dissipativity-based analysis.

After this introduction we explore the turnpike phenomenon in optimal control – the first observations of which can be traced back to John von Neumann and Frank P. Ramsey. We discuss the deep link between dissipativity notions for optimal control problems and the turnpike phenomenon as well as the relation to the optimality system implied by the maximum principle.

Moving from open-loop to feedback considerations, we show how dissipativity helps to analyze the properties of receding-horizon approximations to infinite-horizon problems, i.e., we close the loop with model predictive control. Furthermore, we explore how the dissipativity-based framework can be extended to stochastic problems. Throughout the week our discussions are illustrated with examples from different application domains such as process control, mechanics, thermodynamics, and energy. Moreover, the students will conduct numerical experiments in class. The course concludes with an outlook on open problems and on ongoing research.

Outline

1. Introduction
 - Optimal Control
 - Dissipativity and Optimal Control
 - The Turnpike Phenomenon
2. Turnpike and Dissipativity
 - Detectability and Turnpikes
 - Turnpikes and the Maximum Principle
 - Infinite-horizon optimal control and dissipativity
3. Predictive Control
 - Economic MPC and Dissipativity
 - Stochastic Turnpike and MPC
4. Advanced topics
 - Discounted Optimal Control and turnpike
 - port-Hamiltonian systems and symmetries
5. Summary and Outlook