Control of flows and heat transfers

Course proposal – Master of Science in Aeronautics and Space

10 h

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Language: This course may be given in English depending on the audience.

Optimization is at the center of many scientific and/or societal issues (understanding and modeling of complex physical phenomena, improvement of system performance, reduction of noise or pollution, machine learning, ...). The objective of this course is to present the concepts and tools (mainly numerical) necessary to approach in a modern way the control of flows and heat transfers. First, we will introduce the optimal control methods by showing the diversity of problems that can be solved in this framework. We will then present the essential elements of analysis and control of linear systems (LQR and LQG methods). We will illustrate these different methods on examples from fluid mechanics and thermal transfers.

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1/ Introduction.

2/ Optimal control (open-loop).

- 2.1/ Constrained optimization in finite dimension for time independent systems.
- 2.2/ Gradient methods based on sensitivities.
- 2.3/ Variational formulation.
- 2.4/ Gradient methods based on adjoint equations.
- 2.5/ Constrained optimization in finite dimension for time dependent systems.
  - 2.5.1/ Illustration: Optimal Energy Growth.
  - 2.5.2/ Illustration: Terminal Time Control by Unsteady Forcing.
- 2.6/ Constrained optimization of a space-time system by adjoint methods.
  - 2.6.1/ Illustration: Determination of the adjoint Navier-Stokes equations.
- 2.7/ Introduction to variational data assimilation.

3/ Analysis of linear systems.

- 3.1/ State space representation of dynamical systems.
- 3.2/ Linear state representation.
  - 3.2.1/ Illustration: Orr-Sommerfeld/Squire system.
- 3.3/ Commandability and observability.

3.4/ Balanced representation.

4/ Closed-loop linear control with full information.

4.1/ Linear Quadratic Control (LQR). Riccati equations.

4.1.1/ Illustration: Control of a stable non-normal linear system modeling a transient energy growth.

4.1.2/ Illustration: Control of the heat equation.

5/ Linear closed-loop control with state estimation.

5.1/ Reminder on stochastic processes.

5.2/ Estimation and Kalman filter.

5.3/ Linear Gaussian control (LQG). Principle of separation.

Notions can be illustrated using reduced-order models. Model reduction techniques are covered in the course "Model reduction for fluid mechanics and heat transfer".



From flow control to biomimetism. After Franck Fish.

Calendrier

Date, horaire	Salle
Mardi 13 Octobre 17h30-19h30	B134 ENSMA
Mercredi 14 Octobre 17h30-19h30	B139 ENSMA
Mercredi 21 Octobre 17h30-19h30	B139 ENSMA
Vendredi 23 Octobre 17h30-19h30	B139 ENSMA
Mercredi 04 Novembre 17h30-19h30	B139 ENSMA