Advanced Control Systems

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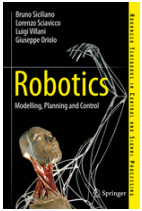
DI INNOVAZIONE

Advanced Control Systems

- Master degree: Computer Engineering for Robotics and Smart Industry
- Year | Semester: 2° | I
- ECTS (theory | lab): 6 (4 | 2)
- Prerequisites: Robotics (Master) and Controlli Automatici (Bachelor)
- Classes (2024/2025)
  - Wednesday 10.30–13.30 (room T.06)
  - Monday 14.30–16.30 (room T.06)
- Communications, slides, etc. via Moodle
- No recording, No streaming

Advanced Control Systems

Lectures are based on the textbook



B. Siciliano, L. Sciavicco, L. Villani, G. Oriolo, *Robotics: Modelling, Planning and Control*, 3rd Edition, Springer, 2009

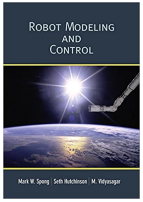
Several pictures from this book have been copied and pasted here

The pdf's of the slides will be uploaded on the course webpage within encrypted .zip files.

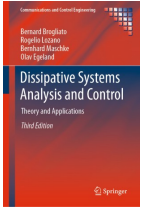
The password is **ACS24_5**

Advanced Control Systems

Further readings



M.W. Spong, S. Hutchinson, M. Vidyasagar, *Robot modeling and control*, John Wiley & Sons, Second edition, 2020



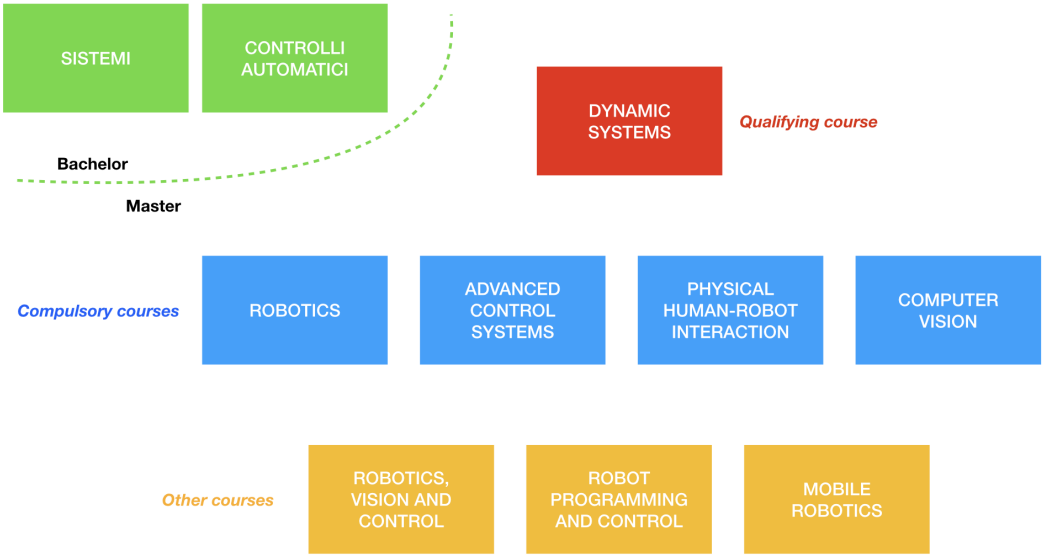
B. Brogliato, R. Lozano, B. Maschke, O. Egeland, *Dissipative Systems Analysis and Control: Theory and Applications*, 3rd Edition, Springer, 2020

General Info

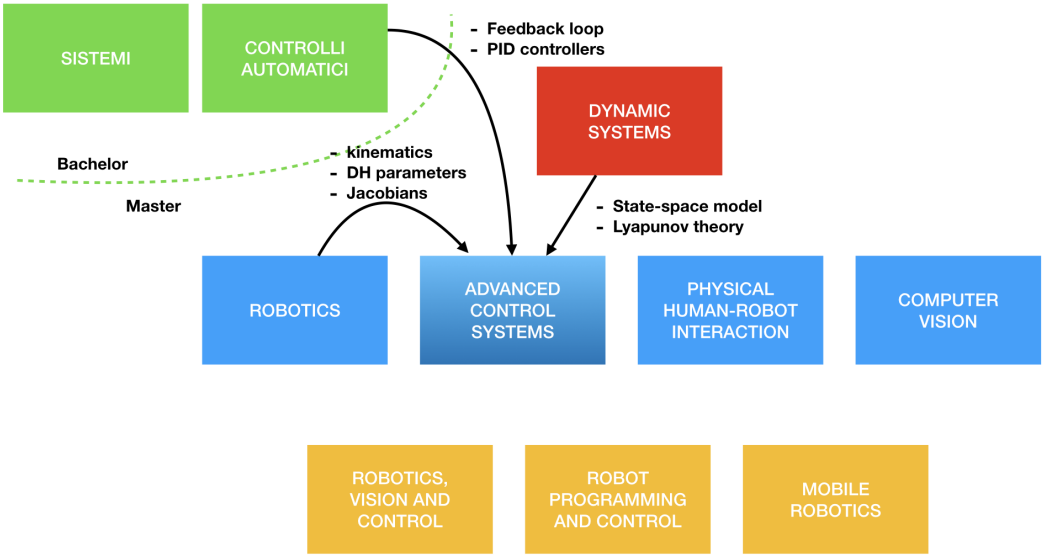
Advanced Control Systems is a compulsory course for the *Robotics systems* path

- Robotics, 1° year, 6 ECTS
- Computer vision, 1° year, 6 ECTS
- Advanced Control Systems, 2° year, 6 ECTS
- Physical Human-Robot Interaction, 2° year, 6 ECTS

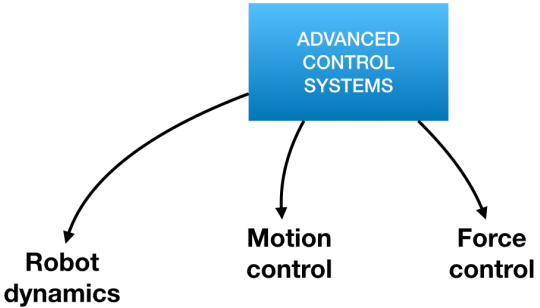
Robotics path



Robotics path – Prerequisites



Robotics path – Topics



Chapters 7, 8, 9 Siciliano et al.

Robotics path – Topics

Robot dynamics

Compute the dynamic model $\dot{x} = f(x, u)$ of robotic manipulators

- direct and inverse dynamics
- Euler-Lagrange formulation and Newton-Euler formulation
- properties of the dynamic model
- identification of dynamic parameters

Motion control

Design of feedback laws for controlling the robot moving in free motion

- PD controller with gravity compensation
- feedback linearization and input-output decoupling
- adaptive (and robust) control

Robotics path – Topics

Force control

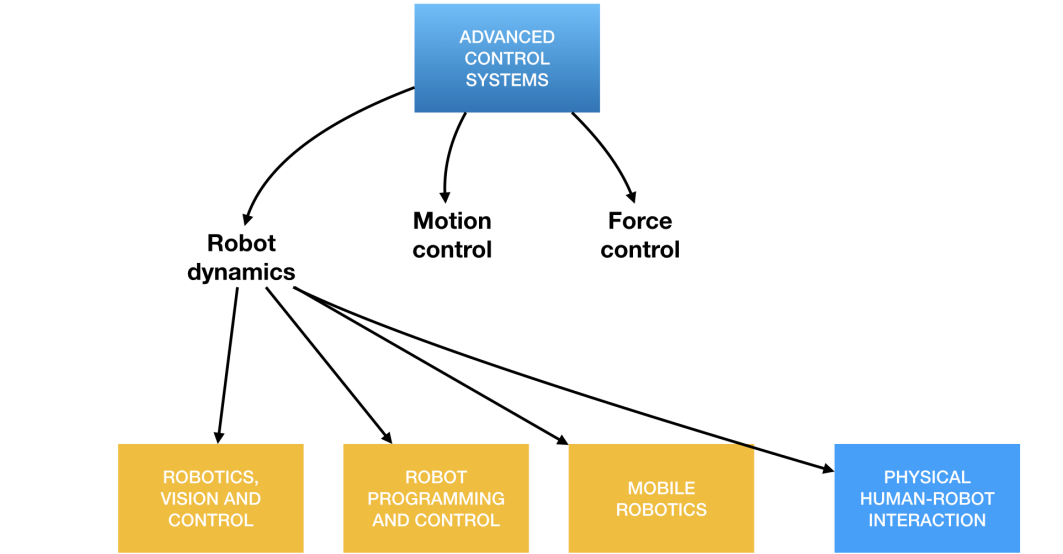
Design of feedback laws for controlling the robot interacting with the environment

- compliance control
- impedance control
- hybrid force/velocity control

Other topics (if there is time)

- flexible joints
- inclusion of geometric constraints
- design of disturbance observers
- design of estimators for the unknown environment
- fault detection

Robotics path – Follow up



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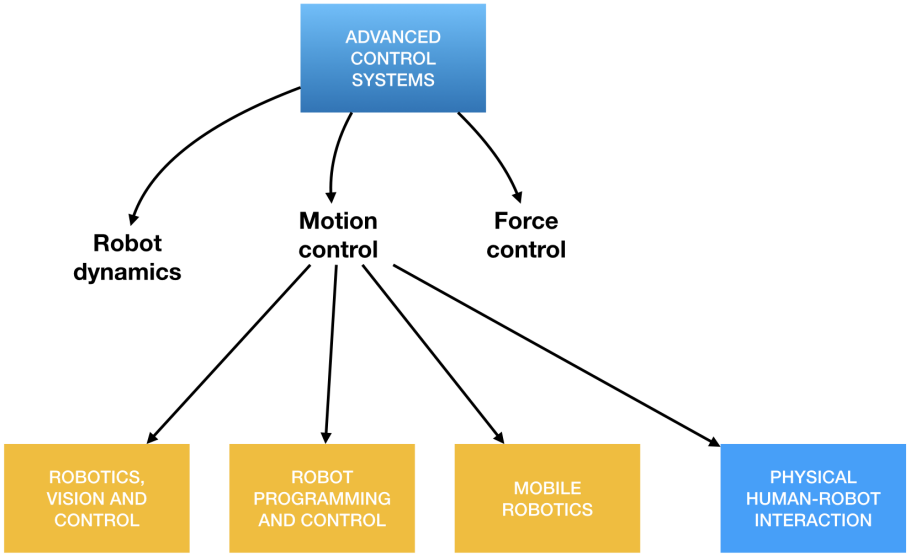
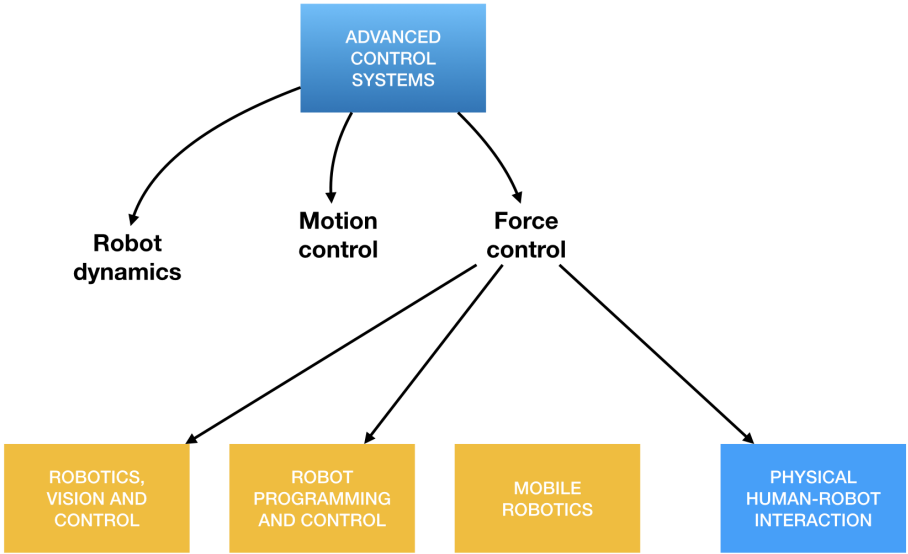


Robotics path – Follow up

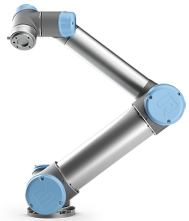


Why are these topics important?

Videos from the Internet

The first three robots are available in the ICE lab.

When needed, I will explain the theory and show you the corresponding Matlab/Simulink implementation using the 6DoF UR robot



Exam

The exam consists of a “course-long” project:

- A 3 DoF manipulator will be assign to all of you

Students have to

- compute the dynamic model using the Lagrangian method
- compute the inverse dynamics using the recursive Newton-Euler method
- compute the linear-in-the-dynamic-parameters model
- implement the architectures to control the motion
- implement the architectures to control the interaction force
- implement ...

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The exam will be only oral and students should prepare a *brief technical report* and describe their work by explaining the simulations and motivating the design choices. The code should also be provided.

Exam

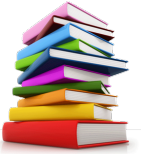
The “course-long” project will consist of several homeworks that will be assigned during the course.

The HWs will be presented by YOU during the course and discussed all together.

I expect all of you will be involved.

Exam

From knowledge to Competence



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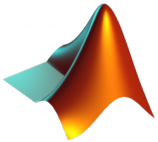

Matlab

- Robotics System Toolbox
- Control System Toolbox

PDF Documentations available on line for both Toolbox

Matlab/Simulink

- simulate the robot dynamics
- implement the control architectures

ROS: Robot Operating Systems

- implement the control architectures on real robots