Master's Department of Engineering Sciences
MSc in Automation Engineering and Robotics

Name of the unit: Robotic Manipulators Control

Lecturer: Mahdi Khoramshahi (mahdi.khoramshahi@isir.upmc.fr)
Course code: MU5RBR10-COM
Student workload: 16 h of lectures, 6 h of tutorials, 8 h of labs
Credits: 3 ECTS
Specialization tracks: ☒ ROBOT ☐ SI ☐ MeDH
Semester offered: ☐ S1 ☐ S2 ☒ S3 ☐ S4
Language of instruction: ☐ French ☒ English
Targeted audience: ☒ Engineering Sciences students ☐ Other (specify):
Localization : ☒ PMC Campus ☐ Other (specify):

Course Overview
This course aims to train students in the principles and practical applications of controlling robotic manipulators, from understanding the dynamics of manipulators to implementing advanced control strategies. The teaching focuses on a comprehensive understanding of system dynamics and control theory for robotic applications.
Keywords: Actuator dynamics, single-joint control, feedforward control, pre-computed torques, joint-space control, task-space control, motion-planning, trajectory interpolation, constrained inverse kinematics, quadratic programming, adaptive control for robotic manipulators, physical interaction, impedance/admitta control, stability of robotic control loops, robotic manipulation.

Prerequisites
Students should have previously acquired the following prerequisites to follow this course:

- Calculus (single and multivariable), Linear Algebra, Differential Equations
- Linear dynamics and control
- Mechanics basics (including dynamics and kinematics)
- Recommended: Nonlinear control, optimal control, adaptive control
- Recommended: Familiarity with ROS and programming in Python

Intended Learning Outcomes
By the end of this course, students will be able to:

1. Understand the dynamics of a single robot joint including dyanmics of a DC motor and transmission effect
2. Understand and apply PD and PID controllers to a single joint
3. Understand and apply trajectory planning and interpolation methods to a single joint
4. Understand and apply feedforeward control to a robotic manipulator
5. Apply and Analyze Decentralized control of a 2d planer robot
6. Understand centralized control of robotic manipulators
7. Understand and apply Lyapunov stability theorem
8. Apply and Analayze centralized control of robotic manipulators
9. Understand Motion control for robotic manipulators,

10. Apply different types of controllers for motion control
11. Understand different approaches for task-space control
12. Understand basic concepts for robotic interaction with the environment and humans

Indicative Teaching Sequence and Methods

Week	C/TD/TP*	Content	Preparation	Learn. outc.
S1	C1	Dynamics of a single robotic joint, Transimission effect		AVV1-2
S2	C2	Set-Point control and decentralized control		AVV3-4
S3	C3 / TD1	Trajectory Planning and Interpolation Methods		AAV5
S4	C4	Feedforward control		AAV6
S5	TP1	Decentralized control of a 2D planar robot		AAV6
S6	C5 / TD2	Joint-space control, Centralized control		AAV8-9
S7	TP2	Centeralized control of 2D Planar robot		AAV10
S8	C6	Motion control, Adaptive control for robotic manipulators		AAV11-12
S9	C7	Task-space control		AAV13-14
S10	C8 / TD3	Interaction Control: imepdance/admittance control		AAV15

* C/TD/TP respectively corresponds to lectures, tutorials and lab sessions.

Sequence of the unit:
The UE is divided into 4 successive sequences:
- Sequence 1: Introduction, single-joint control and trajectory generation (C1/2/3 + TD1 + Quiz1)
- Sequence 2: Feedforward control, Decentralized control (C4 + TP1)
- Sequence 3: Joint-space control, Centralized control (C5 + TD2 + TP2 + Quiz2).
- Sequence 4: Advanced topics in control of manipulators (C6/7/8 + TD3)

Indicative Assessment of Intended Learning Outcomes (1st session)

Week	Individ./group	In-person/remote	Type of exam	Evaluated outcomes	Scale %
S6	Individual	In-person	Quiz	AAV 1-5	5 %
S12	Individual	In-person	Quiz	AAV 6-9	5 %
S6	Group	In-person	TP	AAV 1-10	30 %
S12	Individual	In-person	Written exam	AAV 1-15	60 %

2nde session of exam

Session	Individ./group	In-person/remote	Type of exam	Evaluated outcomes	Scale %

Bibliographic references

- Spong, Mark W., Seth Hutchinson, and Mathukumalli Vidyasagar. Robot modeling and control. John Wiley Sons, 2020.
- Kelly, Rafael, Victor Santibáñez, and Antonio Loría. Control of robot manipulators in joint space. Vol. 693. London: Springer, 2005.
- Chung, Wan Kyun, Li-Chen Fu, and Torsten Kröger. "Motion control." Springer handbook of robotics (2016): 163-194.

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