Master's Department of Engineering Sciences

MSc in Automation Engineering and Robotics

Name of the unit: Robust Control

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Course code: MU5RBR30-ROB
Student workload: 12 h of lectures, 8 h of tutorials, 8 h of labs
Credits: 3 ECTS
Specialization tracks: ☒ ROBOT (elective) ☐ SI ☐ MeDH
Semester offered: ☐ S1 ☐ S2 ☒ S3 ☐ S4
Language of instruction: ☐ French ☒ English
Targeted audience: ☒ Engineering Sciences students ☒ Other (specify): ENSAM
Localization : ☐ PMC Campus ☐ Other (specify):

Course Overview

In control theory, robust-control methodologies aim to design a controller that guarantees robust stability and performance when the controlled process has nonlinear dynamics or is subject to parameter variations or external disturbances. This question is often formulated as an optimization problem. The objective of this course unit is to provide an overview of robust-control methodologies for linear systems with parametric uncertainty and disturbances, using the H framework.

Keywords: System interconnections, closed-loop systems, H norm, singular values, modeling of uncertain systems, small-gain theorem, standard H problem, loop shaping, weighting functions.

Prerequisites

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

- Classical control theory and state-space representation

Intended Learning Outcomes

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

1. Calculate the singular values of a transfer matrix.
2. Calculate the norms of a vector, matrix, signal and system.
3. Understand and apply the small-gain theorem.
4. Model a closed-loop system with disturbance inputs.
5. Understand the principle of frequency separation for closed-loop disturbance rejection.
6. Model uncertainties.
7. Analyze the stability of uncertain linear systems.
8. Define the standard H problem from a set of specifications.
9. Model an augmented system with weighting functions.
10. Define and calculate weighting functions.
11. Calculate a standard H controller.

Indicative Teaching Sequence and Methods

Week	C/TD/TP*	Content	Preparation	Learn. outc.
S1	C1	Part 1: Introduction to robust control 1.1 - Modern robust-control theory: an introduction 1.2 - Fundamentals of robust control 1.2.1 - Modeling and analysis of linear systems (Laplace transform, transfer function, state-space representation, controllability, observability) 1.2.2 - System interconnections (sum, product, linear fractional transformation) 1.2.3 - Closed-loop system configurations (feedback loops, pre-compensator, post-compensator, etc.) 1.2.4 - Characteristic functions (open-loop transfer functions, sensitivity function, complementary sensitivity function, etc.)		
S2	C2	Part 2: Mathematical tools 2.1 - Norms of matrices, signals and systems 2.2 - Singular values 2.3 - Calculation of the H norm 2.4 - Linear matrix inequalities		AAV1, AAV2
S2	TD1	Exercises on C1 and C2		
S3	C3	Part 3: Modeling disturbances and uncertainties 3.1 - Disturbance modeling and frequency-separation concepts for disturbance rejection 3.2 - Uncertainty modeling (additive representation, multiplicative representation, etc.) 3.3 - Robust stability (small-gain theorem) 3.4 - Passivity		AAV3, AAV4, AAV5, AAV6
S3	TD2	Exercises on C3		
S4	C4	Part 4: H control 4.1 - Standard H problem 4.2 - General synthesis and augmented scheme 4.3 - Solving the H problem		AAV7, AAV8, AAV9
S4	TD3	Exercises on C4		
S5	C5	Part 5: Loop shaping and H controller synthesis. 5.1 - Loop shaping 5.2 - Selection of weighting functions 5.3 - Example: control of a second-order system.		AAV10, AAV11
S5	TD4	Exercises on C5		
S6	C6	Part 6: LMI techniques for H synthesis. 6.1 - LMI techniques for H synthesis. 6.2 - Application example		
S7	TP$_{part1}$			AAV1-AAV11
S8	TP$_{part2}$			AAV1-AAV11

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

Indicative Assessment of Intended Learning Outcomes (1st session)

Week	Individ./group	In-person/remote	Type of exam	Evaluated outcomes	Scale %
S9	Individual	In-person	Written exam	AAV1-AAV11	70 %
S10	Group	In-person	TP	AAV1-AAV11	30 %

2nde session of exam

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

Bibliographic references

- 1. G. Duc and S. Font, Commande H et -analyse, Hermes Science Publications, Paris, 1999.
- 2. Doyle john, bruce francis and allen tannenbaum. feedback control theory. ISBN-10 : 0023300116, 1991.
- 3. K. Zhou, J. C. Doyle, and K. Glover, Robust and Optimal Control, Prentice-Hall, 1996.

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