2CC1005 – Control theory - DUAL

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Department: DÉPARTEMENT AUTOMATIQUE
Language of instruction: FRANCAIS
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 36,00

Description

The physical systems generally rely on the fundamental concept of a feedback loop, allowing them to be controlled and giving them a behavior that is as insensitive as possible to environmental disturbances. The general objective of this course is to provide students with the concepts and skills enabling them to understand the structure and interactions within existing dynamic systems or along with their design. They will also be able to process information, design a control law to meet specifications, and analyze its performance and robustness. To achieve this, the students must first be able to define a model (or a set of models), highlighting the variables influencing the state of this system (inputs), the measures allowing access to this state, and variables to which the specifications relate (outputs), as well as the relationships between these variables. Then, in a second step, and from the analysis of the inputs that can be controlled (commands) or those that are undergone (disturbances), students will have to design a control law in order to ensure the expected performances. The last step in this course will concern the analysis of the robustness of the determined control law.

Prerequisites (in terms of CS courses)

Core curriculum “Modelling” (ST2), semester-long course “Convergence, integration, probability" and "partial differential equations”

Syllabus

Course overview:

1. Introduction

    a. Interest of the closed loop, key notions of control, disturbance rejection
    b. Classical frequency approach vs more current and generic

temporal approach
c. Application examples
d. General theorems: intrinsic limitations of the ideal loop (needs to formalize, trade-off to be made)

2. State-space representation

a. Reminders
b. Properties (controllability, observability)
c. Linearized / nonlinear links - implementation of the control law on the nonlinear model

3. State feedback control law design

a. Control by pole placement in the monovariable case, reference tracking and accuracy
b. Linear Quadratic controller (LQ control)
c. Case of measurable disturbances (disturbance rejection)
d. LQ control with integral action

4. Estimated state feedback control

a. Observer by pole placement
b. Kalman filter (LQ control duality)
c. Linear Quadratic Gaussian controller (LQG) – Separation theorem

5. Performance and robustness analysis of a control law

a. Reminders: links with the transfer function
b. Equivalent controller for the LQ and LQG controllers.
c. Small gain theorem
d. Definition of multivariable stability margins.
e. Special case of monovariable stability margins
f. Special case of the LQ and LQG controllers. Loop Transfert Recovery (LTR)
g. Special case of margins for classical frequential controllers (e.g. phase-lead, PI and PID)

6. Industrial conference: open and current issues and problems of control in industry

Class components (lecture, labs, etc.)
15h lectures, 10.5h workclasses, 6h lab works, 1.5h industrial lectures.

All courses are given in French.

Grading

Knowledge assessment:

- Lab works are mandatory activities
- Report of lab work & final written exam (3h) with calculator, handouts and personal notes authorized.
- Notation: lab work: 25%, final exam: 75%, attendance checked during workclasses and lab work, possible penalty.

Skills assessment:

– The C1 and C2 skills will be evaluated by means of the lab work and final exam. The text of these activities will clearly highlight the sections and questions related to each of these competencies.
– The C2.4 skill will be more specifically evaluated during the lab work activities.
– All the tasks for validating these two competencies will be explained by the teaching staff at the beginning of the first lecture.

Course support, bibliography
Handouts:

- Handout “Control theory” in French
- Control theory glossary French-English and English-French
- Slides shown during the lectures

Bibliography:

- J.J. D’Azzo & C.H. Houpis - "Linear Control System. Analysis and Design" - 3e éd., Mc Graw-Hill, 1988.
- P. Borne, G. Dauphin-Tanguy, J.-P. Richard, F. Rotella et I. Zambettakis - "Analyse et régulation des processus industriels. Tome 1. Régulation continue, Tome 2. Régulation numérique" - Éditions Technip, 1993.
- J.B. Deluche - "Automatique. De la théorie aux applications industrielles. Tome 2 : Systèmes continus" - Edipol, 2000.
- J.M. Flaus - "La régulation industrielle" - Hermès, 1994.
- G.F. Franklin, J.D. Powell, A. Emami-Naeini - "Feedback Control of Dynamic Systems" - 7° ed., Ed. Pearson Publishing Company, 2014.
- B. Friedland - "Control system design" – Mc Graw-Hill, 1986.
- Ph. de Larminat - "Automatique. Commande des systèmes linéaires" - Hermès, 1996.

- L. Maret - " Régulation automatique" - Presses Polytechniques Romandes, 1987.
- K. Ogata - "Modern Control Engineering" - 5e éd., Ed. Pearson Education International, 2009.
- A. Rachid - "Systèmes de régulation" - Masson 1996.
- M. Zelazny, F. Giri et T. Bennani - "Systèmes asservis : commande et régulation" - Eyrolles, 1993.

Resources

- Teaching staff: Cristina Vlad
- Lab work in the Control Department
- Software: Matlab (during Lab work)

Learning outcomes covered on the course

After completion of this course, students will be able to:

1. Understand and analyze the interest of a closed-loop control structure

2. Model the behavior of a dynamic system by a time representation (state-state representation) or possibly a frequential one:

    • choose a model (or a set of models) suitable to the control and/or analysis objective (linearization, model reduction, etc.)
    • validate the relevance of the model (or of the set of proposed models)

3. Design control laws based on the state-space representation of the system, if necessary, by the synthesis of an observer.

    • analyze the characteristics of the initial system and compare them to the specifications
    • choose and design the appropriate control law
    • determine an observer allowing to estimate the unmeasured state variables
    • validate in simulation and experimentally the control law and criticize the obtained results
    • analyze the performance and robustness of control law

4. Use simulation software to implement theoretical developments and validate control laws (particularly through experimental work)

5. Master scientific and technical communication (through the report of lab work)

Description of the skills acquired at the end of the course
Validated skills:

- Concerning the skill C1 "Analyze, design and build complex systems with scientific, technological, human and economic components", evaluated in this module:

    * "Model the behaviour of a dynamic system by means of a time domain or frequency domain representation" is included in the skill C1.2 "Use and develop appropriate models, choose the right modelling scale and the relevant simplifying hypotheses to deal with a problem"

    * "Analyse the time and/or frequency domain behaviour of a system and the effects of feedback" is included in the skill C1.1 "Study a problem as a whole and an overall situation. Identify, formulate and analyse a problem in its scientific, economic and human dimensions"

    * "Determine a control law by state feedback (completed if necessary by the synthesis of an observer), in order to satisfy a temporal and/or frequential specification" is included in the skill C1.4 "Specify, design, implement and validate all or part of a complex system"

    * "Validate a control law by means of simulation or experiments and critisize the obtain results" is included in the skills C1.3 "Solve a problem by means of approximation, simulation and experiments"

- Concerning the skill C2 "Develop in-depth skills in an engineering field and in a family of professions", evaluated in this module:

    * "Model the behaviour of a dynamic system" and Analyzing the characteristics of the initial system and comparing them to the specifications" requires an appropriation of the field of application considered together with its constraints, and is therefore part of C2.2 "Importing knowledge from other fields or disciplines" and C2.3 “Identify and independently acquire the required new knowledge and skills”

    * "Analyze the performance and robustness of control laws" is part of C2.4 "Produce data and develop knowledge according to a scientific approach"

    * "Use simulation software to implement theoretical developments and validate control laws (in particular through

experimental work)" is part of C2.4 "Producing data and developing knowledge according to a scientific approach"

- "Master scientific and technical communication (through reports during lab works)" is included in the skill C7.1 "Render complex content intelligible. Structure one's ideas and arguments. Synthesize and see the bigger picture". This skill is not evaluated in this module.

Evaluation of the learning outcomes

Skills C1 and C2 will be evaluated in two different situations:

- Two lab work sessions will enable evaluating all these three learning outcomes, students having a real process to model, analyse and control. In particular, this pedagogical method allows students to experience experimental training and validation of the modelling and design approach

- A final exam will also confront students with a real problem of a process that should be modelled, analysed and controlled. The emphasis will be less on experimental aspects than on the ability to satisfy an industrial problem through its specifications.

The skill C2.4 will be more specifically assessed during the lab work sessions, as well as during personal work (requiring the implementation of the process via a simulation software) between the two lab work sessions.

The skill C7 will not be evaluated, but it will be more specifically handled through the report following the lab work sessions