SHAKE THE FUTURE.

CENTRALE NANTES

MASTER OF SCIENCE, TECHNOLOGY AND HEALTH

CONTROL AND ROBOTICS

CONTROL SYSTEMS

YEAR 2

PROGRAMME SUPERVISORS:
MALEK GHANES, OLIVIER-HENRI ROUX

CONTROL AND ROBOTICS – CONTROL SYSTEMS

YEAR 2 - AUTUMN SEMESTER

ROBUST AND OPTIMAL CONTROL

CONTROL AND ROBOTICS – CONTROL SYSTEMS
YEAR 2 - AUTUMN SEMESTER

LEAD PROFESSOR: Bogdan MARINESCU

Objectives

At the end of the course the students will be able to:

- Analyse and control complex systems with multi-inputs / multi-outputs and state variables
- Apply techniques to ensure optimal performance and the robustness required in industrial specifications:
  - robust stability, robust reference tracking, robust disturbance rejection,
  - oscillation damping, compensation of the effect of data transmission delays

Course contents

- Optimal control
  - Linear quadratic (LQ and LQG) control
  - Optimal state estimation and separation principle
  - H2, H8 control - robustness
  - Lyapunov and Riccati equations / Linear Matrix Inequalities (LMI)
- Predictive control
- Control methodology for optimal and robust MIMO linear control:
  - solution of the regulator problem with internal stability,
  - specification to ensure robust asymptotic tracking and disturbance rejection,
  - proposition of weight matrices of ARE to obtain robust stability

Course material

Optimal control:

- F.L. Lewis, V.L. Syrmos, Optimal Control, 2nd edition 1995 Wiley.
- J.M. Dion, D. Popescu, Commande optimale - conceptions optimisées des systèmes, Diderot 1996
- S. Boyd, L. El Ghaoui, E. Feron, V. Balakrishnan (1994): Linear Matrix Inequalities in Systems and Control Theory. SIAM.

H2, H8, LQ, Model reduction:

- S. Skogestad, I. Postlethwaite, Multivariable Feedback Control - Analysis and Design, Wiley 2005.
- K. Zhou, J.C. Doyle, K. Glover, Robust and Optimal Control, Prentice-Hall 1996.
- K. Zhou, J.C. Doyle, Essential of Robust Control, Prentice Hall 1998.

Predictive control:

- P. Boucher, D. Dumur, La commande prédictive - avancées et perspectives, Hermes-Lavoisier 2006
- Bemporad, M. Morari (1999): Robust model predictive control: A survey. Robustness in Identification and Control, Springer London, 207-226.

Control Methodology for Linear Systems:

- W.M. Wonham, Linear Multivariable Control: A Geometric Approach Springer Verlag, 1985
- Ph. de Larminat, Contrôle d'état standard, Hermes 2000.

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	**EXAM**
English	**4**	**18 hrs**	**4 hrs**	**8 hrs**	**0 hrs**	**2 hrs**

OBSERVATION AND DIAGNOSTIC

CONTROL AND ROBOTICS – CONTROL SYSTEMS
YEAR 2 - AUTUMN SEMESTER

LEAD PROFESSOR: Malek GHANES

Objectives

Measuring state by physical sensors of a given system may fail because sometimes measurements are impossible and sometimes, possible, but too expensive. That is why estimating the state of a system by means of software sensors (observers) is an important issue. The first part of this course investigates several methods of observer design for nonlinear systems.

Moreover, faults in sensors, actuators or process components may deteriorate overall system performance and could cause serious damage.
From this point of view, the second part of this course will provide some basic definitions and different existing methods of diagnosis. Then, the diagnosis problem will be mainly investigated by using observers (studied in the first part) in the case of fault estimation (simultaneous state and parameter estimation). Finally, fault tolerant control problem is briefly studied.

Examples and labs will illustrate the validity of these two parts in the framework of academic and real applications.

Course contents

Part 1 - Introduction to Observation and Diagnosis Problems

Part 2 - Observation:
- Observability study
- Estimation of the internal states of the system (observer-based or software sensors)
- Parameter identification/estimation (observer-based or left invertibility)
- Simultaneous State and Parameter estimation, i.e. Adaptive Observation
- Estimation of unmeasured perturbations

Part 3 - Diagnosis:
- Fault Detection and Isolation Problems
- Fault Tolerant Control

Course material

Observation:

- R. Hermann and A.J. Krener, Nonlinear controllability and observability, IEEE Trans. Automatic Control, 22:728–740, 1977.
- R.E. Kalman and R.S. Bucy. New results in linear filtering and prediction, theory. J. Basic Eng., 83:95–108, 1961.
- G. Besançon (Ed.). Nonlinear Observers and Applications. LNCIS, Vol. 363. Berlin, Springer-Verlag, 2007.
- M. Ghanes, JP. Barbot, L. Fridman and A. Levant, A novel differentiator: A compromise between super twisting and linear algorithms, IEEE CDC, 2017.

Diagnosis:

- R. Isermann, Fault-diagnosis applications: model-based condition monitoring: actuators, drives, machinery, plants, sensors, and fault-tolerant systems. Springer Science & Business Media, 2011.

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	**EXAM**
English	**4**	**16 hrs**	**6 hrs**	**8 hrs**	**0 hrs**	**2 hrs**

OPTIMIZATION

CONTROL AND ROBOTICS – CONTROL SYSTEMS
YEAR 2 - AUTUMN SEMESTER

LEAD PROFESSOR: Ina TARALOVA

Objectives

Optimization is transversal to all engineering fields, and far beyond; it is about finding the best (i.e. optimal) solution, according to given /predefined/ criteria. In the field of control, it refers to identification and estimation problems, trajectory planning, control policies and controller design, denoising etc.

The aim of the course is to get acquainted with iterative optimization methods in one dimensional and multidimensional cases, linear or nonlinear, with or without constraints. Students will be given further analytical tools for the formulation and solution of functional optimization, with applications to benchmark problems in control theory.

Course contents

- Introduction, definitions, examples of optimization problems
- Linear case, simplex method
- Monovariable optimization: Newton's method, golden section, Fibonacci's method, quadratic approximation, "economic" methods, minimax problems
- Multivariable optimization: Heuristical methods, Gradient method, Conjugate gradients, Quasi-Newton
- Constrained optimization: Primal and dual methods, Lagrangian function
- Functional optimization: Euler-Lagrange equations, Brachistochrone problem (optimal trajectory)
- Isoparametric optimization: Dido's problem
- Pontryagin's Maximum Principle
- Applications:
  - Minimum time problem: car-parking problem, linearized pendulum stabilization
  - Minimum fuel control problem: moon lander

Course material

- D.Bertsekas, Nonlinear Programming, Athena Scientific.
- P. Borne, Commande et optimisation des processus, Ed. Technip.1961.

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	EXAM
English	4	20 hrs	6 hrs	4 hrs	0 hrs	2 hrs

GENERALIZED AND TIME-VARYING SYSTEMS

CONTROL AND ROBOTICS – CONTROL SYSTEMS
YEAR 2 - AUTUMN SEMESTER

LEAD PROFESSOR: Guy LEBRET / Bogdan MARINESCU

Objectives

System coefficients may vary with time. This is often the case in industry and leads to difficulties in analysis and control of such systems, called time-varying or non-stationary systems. Dynamic systems are often modelled by transfer matrices (in the linear case), state-space realizations, etc. These representations relay on an a priori definition/choice of the input and output variables (controls and measures) which are not appropriate in many cases.

This course provides analysis and control solutions for time-varying systems in an intrinsic approach which considers the system close to its analytic modeling. It is thus close to physics and unifies several engineering fields. Those methods rely on simple algebraic computations, being thus easy to implement in practice. Many of them have already been used to solve industrial problems and will be used as examples in the class.

Course contents

- Time-varying systems; motivating examples
- Intrinsic structural analysis (poles, zeros, stability, controllability, observability)
- Pole placement for linear time-varying systems
- Extensions to the case of nonlinear systems
- Control by linearization around trajectories
- Industrial applications

Course material

- H. Bourlès and B. Marinescu (2010) Linear Time-Varying Systems: Algebraic-Analytic Approach, (2011) Springer-Verlag, New York.
- Kailath, T. (1980) Linear systems, Prentice-Hall, Englewood Cliff, N.J.

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	EXAM
English	4	14 hrs	8 hrs	8 hrs	0 hrs	2 hrs

COMPLEX SYSTEMS

CONTROL AND ROBOTICS – CONTROL SYSTEMS
YEAR 2 - AUTUMN SEMESTER

LEAD PROFESSOR: Ina TARALOVA

Objectives

The aim of this course is to for students to become acquainted with complex system dynamics: delayed, hybrid and chaotic systems, from analysis to design: stability, controllability, identifiability, synchronization, and applications.

Hybrid complex systems or those involving delays are used in many fields, for example in biology, economics, mechanical or electrical engineering. Basically, delays appear when different agents interact and exchange goods or information, and the delays are associated with their transport.

Classical examples of hybrid systems are encountered in sampled-data control systems that combine both continuous-time plants and discrete-time control algorithms, and in electronics, where components (diodes, transistors, on/off switches) induce sudden changes in the systems dynamics. The same systems for particular parameters could exhibit also more complex, chaotic behavior, encountered as well in other engineering fields implying particular non-linearities: robotics, control, chemical engineering, process modelling, optimisation, random number generators design, etc.

The above systems are all complex, but exhibit at the same time specific features, since the complexity could be attributed to different sources (combined continuous/discrete dynamics; delays; specific non-linearities), therefore specific methods will be used for the design and evaluation of the performance.

Course contents

Delayed systems

- Examples of time-delay systems.
- Basic control design: Ziegler and Nichols, Smith's predictor, Tsypkin's theorem.
- Models and approaches: Convolution systems, transfers, systems over a ring, 2D systems, realization theory.
- Stability: Exponential, L1, L2, and BIBO-stability, zeros of quasi-polynomials, robust stability, D-partition.
- Stabilization: Static feedback, Robust stabilisation, Prediction and pole placement.
- Examples of control design: Crane control, Logistic system, Cyber-physical system.

Hybrid systems

- Switched and impulsive models – motivations and examples.
- Stability and stabilization of switched and impulsive systems
- LMI implementation of stability / stabilizability criteria
- Structural properties (observability, controllability, minimality) of switched systems with arbitrary switching

Chaotic systems

- Introduction to chaotic systems - definitions, examples
- Analysis of chaotic systems:

- Periodic and aperiodic orbits, chaotic attractors
- Bifurcations and basins of attraction, multi-stability

▪ Synchronization of chaotic systems using observers
▪ Applications: Chaotic maps for encryption, design of pseudo-random number generators

Course material

▪ S.-I. Niculescu (2001): Delay effects on stability. A robust control approach, Springer: Heidelberg, Series:LNCIS, vol. 269.New York.
▪ D. Liberzon (2012). Switching in systems and control. Springer Science & Business Media.
▪ Z. Sun (2006). Switched linear systems: Control and design. Springer Science & Business Media.
▪ T.Kapitaniak (2012). Chaos for Engineers: Theory, Applications, and Control. Springer Science & Business Media.

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	EXAM
English	4	20 hrs	2 hrs	8 hrs	0 hrs	2 hrs

Mathematical Modeling

CONTROL AND ROBOTICS – CONTROL SYSTEMS
YEAR 2 - AUTUMN SEMESTER

LEAD PROFESSOR: Elkhatib IBRAHIM

Objectives

The aim of this course is to present the different types of mathematic models of dynamic systems used for analysis and control. The difference between a model and the system which is represented is demonstrated along with the classes of equivalent models of a given system. Methods to build models and estimate their parameters are given. Particular approaches to quantify uncertainties are discussed.

Course contents

Purposes and classifications of models

- Control/simulation, Linear/nonlinear, Continuous/discrete/hybrid, Time invariant/time-varying
- Deterministic/stochastic, Parametric/non-parametric, Finite/infinite dimension
- State/frequency/transfer/Rosenbrock/Differential-Algebraic Equations (DAE), etc

Classes of equivalence of DAE models

- Intrinsic definition of a system
- linear case: dynamic systems as modules over polynomial rings
- nonlinear case: Lie-Bäcklund transformations, Orbital equivalence, Flatness

Parameterized models and identification

- ARMA, ARMAX, etc
- Parameters' identification

Fuzzy/neuro and bond graphs models

- Uncertainty quantification
- Energy/causality/multi-physics

Course material

- L. Ljung, "Modelling of Dynamic Systems", Prentice Hall, 1994.
- T. Södertström, P. Stoica, "System identification", Prentice Hall, 1989.
- H. Bourlès and B. Marinescu (2010) Linear Time-Varying Systems: Algebraic-Analytic Approach, (2011) Springer-Verlag, New York.

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	EXAM
English	4	16 hrs	6 hrs	8 hrs	0 hrs	2 hrs

PROJECT

CONTROL AND ROBOTICS – CONTROL SYSTEMS
YEAR 2 - AUTUMN SEMESTER

LEAD PROFESSOR: Said MOUSSAOUI

Objectives

The purpose of this project is for the student to apply the theories and techniques studied during the courses, according to his/her career plan. It is, therefore, either a technical project for an industrial application, or an introduction to research to consider a research profession.

Course contents

This project can be either a technical project or an initiation to research: latest developments, proposals, experiments, analysis and prospects etc.
It is an extended individual project (including scientific support, bibliography, scientific study)

Course material

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	EXAM
English	2	0 hrs	0 hrs	0 hrs	0 hrs	0 hrs

Cultural and Communication English

CONTROL AND ROBOTICS – CONTROL SYSTEMS

Year 2 – Autumn Semester

LEAD PROFESSOR: Spencer HAWKRIDGE

Objectives

Team-building and Communicational English:

- Understand the general concepts of team-building
- Build a team-building project
- Understand and nurture the creative process
- Enhance self-belief and self-empowerment

Behavioral skills in an inter-cultural environment:

- Strengthen self-confidence and capacity for interaction
- Develop active listening and reformulation skills
- Develop networking skills

Course contents

Cultural and Communicational English: exercises to explore in practice the areas of culture and communication
Field-related or inter-cultural project (for example, construct content for inter-cultural teambuilding activities; example WIOBOX website etc).

Course material

Written and televised press, information and digital tools, general documents business environment and company strategies.
Internet conferences (Ted Talks, etc.), our own educational materials on Hippocampus (Moodle).

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	EXAM
English	4	0 hrs	32 hrs	0 hrs	0 hrs	0 hrs

French Language

CONTROL AND ROBOTICS – CONTROL SYSTEMS

Year 2 – Autumn Semester

LEAD PROFESSOR: Silvia ERTL

Objectives

The objective is to familiarize the learner with the French language and French culture through an entertaining task-based communicative language teaching, focused on speaking combined with:

- Phonetics
- Self-correcting exercises on our learning platform
- Learning Lab activities
- Project work
- Tutoring

Course objectives include the acquisition and reinforcement of vocabulary, syntax, and pronunciation by both traditional means and through the use of digital resources. Students will learn general French, develop language skills of oral and written comprehension and expression.

After completing this course (32 hours + personal work), the students will be able to communicate in spoken and written French, in a simple, but clear manner, on familiar topics in the context of study, hobbies etc. Another important goal of this course is to introduce the student to French culture.

At the end of the course (2 semesters), complete beginners can achieve an A1 level and some aspects of the A2 of The Common European Framework of Reference for Languages. More advanced students may aim for B1/B2 levels. Those who already completed the first year of the French course will be prepared for working in a French business environment.

Course contents

Two different tracks are proposed: track 1 for students newly arrived at Centrale Nantes and track 2 for students who have completed the first year of the French course.

Track 1:
Full range of practical communication language exercises: reading comprehension, listening comprehension, written expression, oral expression.
Learners will be able to use the foreign language in a simple way for the following purposes:

1. Giving and obtaining factual information:
- personal information (e.g. name, address, place of origin, date of birth, education, occupation)
- non-personal information (e.g. about places and how to get there, time of day, various facilities and services, rules and regulations, opening hours, where and what to eat, etc.)

2. Establishing and maintaining social and professional contacts, particularly:
- meeting people and making acquaintances
- extending invitations and reacting to being invited

- proposing/arranging a course of action
- exchanging information, views, feelings, wishes, concerning matters of common interest, particularly those relating to personal life and circumstances, living conditions and environment, educational/occupational activities and interests, leisure activities and social life

3. Carrying out certain transactions:

- making arrangements (planning, tickets, reservations, etc.) for travel, accommodation, appointments, leisure activities
- making purchases
- ordering food and drink

Track 2:
This track follows on directly from the first-year French course, developing and completing the concepts studied thus far. The main themes are: housing, health and work. These topics will help prepare students for their future work environment. For example, housing is explored in the form of a search for accommodation upon arrival in a new city.

Course material

Preparation manuals, our own tailor-made documents, written and televised press, internet, general civilization documents, digital tools, our own educational materials on Hippocampus (Moodle).

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	**EXAM**
French	4	0 hrs	32 hrs	0 hrs	0 hrs	0 hrs

YEAR 2 - SPRING SEMESTER

Master Thesis / Internship

Master Thesis / Internship

CONTROL AND ROBOTICS – CONTROL SYSTEMS
YEAR 2 - Spring Semester

LEAD PROFESSOR: Franck PLESTAN

Objectives

- Be exposed to and adapt to an industrial or research environment
- Put in practice the scientific and technical skills acquired in the previous semesters
- Strengthen interpersonal and communication skills
- Be part of or manage a project
- Organize tasks, analyze results and build deliverables

Course contents

Students should be pro-active and career-oriented in the search for their thesis/internship. The topics are validated by the program supervisor to ensure an adequate Master level. The thesis/internship is evaluated through the submission of a written report and an oral defense.

Course material

- Turabian Kate Larimore, Booth Wayne Clayton, Colomb Gregory G., Williams Joseph M., & University of Chicago press. (2013). A manual for writers of research papers, theses, and dissertations: Chicago style for students and researchers (8th edition.). Chicago (Ill.) London: University of Chicago Press.
- Bui Yvonne N. How to Write a Master's Thesis. 2nd ed. Thousand Oaks, Calif: Sage, 2014.
- Evans David G., Gruba Paul, et Zobel Justin. How to Write a Better Thesis. 3rd edition. Carlton South, Vic: Melbourne University Press, 2011.

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	**EXAM**
English	30	0 hrs	0 hrs	0 hrs	0 hrs	0 hrs