CENTRALESUPELEC

SECOND YEAR

COURSES CATALOG

Academic year 2020-2021

Edition du22 septembre 2020

TABLE OF CONTENTS

CORE CURRICULUM COURSES

2CC1000 – Automatic control

Instructors: Didier DUMUR
Department: AUTOMATIQUE
Language of instruction: ENGLISH, FRENCH
Campus: CAMPUS DE PARIS - SACLAY, CAMPUS DE RENNES, CAMPUS DE METZ
Workload (HEE): 60
On-site hours (HPE): 36
Quota :

Description

Students should be able to understand the structure and the interactions among existing systems or systems under development, process information and take decisions.
In this direction, they should highlight signals influencing the state of this system (so-called inputs), and signals which enable to characterize this state or which are related to predefined specifications (so-called outputs). Based on the analysis of the control signals and disturbances, the student should determine the structure of the best control law adapted to the problem. He should analyse the features of the system, compare these features to the specified ones, in order to select, design and validate the most adequate control law, first in simulation then on an experimental platform.

Quarter number

ST5

Prerequisites (in terms of CS courses)

Core curriculum "Modelling" (ST2), semester-long course "Convergence, integration, probability" and "partial differential equations", core curriculum "Signal processing" (ST4)

Syllabus

Course overview:

- Introduction (notion of feedback, block diagrams …)
- Open-loop (OL)/Closed-loop (CL) transfer functions, from OL to CL
- Analysis of continuous time feedback systems (stability, rapidity, accuracy)
- Analysis of discrete time feedback systems (representation, stability, rapidity, accuracy)

- Design of continuous time controllers (feedforward, proportional, phase-lead, PI and PID) – Cascaded structure
- Continuous time to discrete time transformation of controllers
- Reminder about continuous time/discrete time state space representation, continuous time to discrete time transformation
- Controllability, observability, canonical form
- State feedback control
- Observer design

Workclasses description:

- Modelling, stability analysis, accuracy study, proportional control. Water level control of a steam generator
- Design of continuous-time controllers (Phase-lead, PI/PID) and transformation to discrete-time controllers. Application to the regulation of the mean arterial pressure during surgery.
- State feedback control and observers design. Application to the attitude control of an aircraft.

Class components (lecture, labs, etc.)
18h lectures, 9h workclasses and 6h lab works

Grading
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 work classes and lab work, possible penalty.

Course support, bibliography
Handouts:

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

Bibliography:

1. J.J. D’Azzo & C.H. Houpis - "Linear Control System. Analysis and Design" - 3e ed., Mc Graw-Hill, 1988.
2. 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.
3. J.B. Deluche - "Automatique. De la théorie aux applications industrielles. Tome 2 : Systèmes continus" - Edipol, 2000.
4. J.M. Flaus - "La régulation industrielle" - Hermès, 1994.

5. G.F. Franklin, J.D. Powell, A. Emami-Naeini - "Feedback Control of Dynamic Systems" - 7° ed., Ed. Pearson Publishing Company, 2014.
6. B. Friedland - "Control system design" – Mc Graw-Hill, 1986.
7. Ph. de Larminat - "Automatique. Commande des systèmes linéaires" - Hermès, 1996.
8. L. Maret - " Régulation automatique" - Presses Polytechniques Romandes, 1987.
9. K. Ogata - "Modern Control Engineering" - 5e éd., Ed. Pearson Education International, 2009.
10. A. Rachid - "Systèmes de régulation" - Masson 1996.
11. M. Zelazny, F. Giri et T. Bennani - "Systèmes asservis : commande et régulation" - Eyrolles, 1993.

Resources

- **Teaching staff:**

- Lectures Paris-Saclay campus: Antoine Chaillet, Didier Dumur, Emmanuel Godoy, Maria Makarova, Cristina Maniu, Houria Siguerdidjane, Sihem Tebbani, Cristina Vlad
- Workclasses Paris-Saclay campus: Antoine Chaillet, Didier Dumur, Emmanuel Godoy, Maria Makarov, Cristina Maniu, Houria Siguerdidjane, Sihem Tebbani, Cristina Vlad, Sorin Olaru, Pedro Rodriguez, Guillaume Sandou, Giorgio Valmorbida, Rémi Azouit, Stéphane Font, Jacques Antoine, Bruno Lorcet, Jing Dai, Emmanuel Odic, Maxime Pouilly-Cathelain
- Lectures Rennes campus: Romain Bourdais
- Workclasses Rennes campus: Stanislav Aranovskiy, Hervé Guéguen, Marie-Anne Lefebvre, Nabil Sadou, Romain Boudais
- Lectures Metz campus: Jean-Luc Colette

- Maximum enrollment Workclasses: 25 students

- Equipment-specific classrooms: capacity of 50 students per half day, Lab work partly in the Control Department (4 rooms with 5 experimental platforms each), partly in the Energy Department

- Software: Matlab (during Lab work)

Learning outcomes covered on the course

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

1. Model the behaviour of a linear system by means of a time domain or frequency domain representation:

2. Choose an adequate behavioural model (transfer function, state space representation …)
3. Identify the model parameters based on experimental data and/or a priori knowledge
4. Validate the quality of the model

2. Analyse the time and frequency domain behaviour of a system and the effects of feedback

3. Choose and design controllers, in continuous and discrete-time, by means of transfer function or state feedback form, in order to fulfil temporal and/or frequency specifications

- Analyse the features of the initial system and compare them with the specifications
- Choose the most adequate controller structure and design its parameters
- Validate the designed control law and analyse the results

4. Use a simulation software to implement theoretical developments and validate control laws (through lab works)

5. Master scientific and technical communication (through reports during lab works)

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

- "Model the behaviour of a linear 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", milestone 2
- "Analyse the time and 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", milestone 1
- "Choose and design controllers, in continuous and discrete-time, by means of transfer function or state feedback form (in this case with the additional design of an observer if necessary), in order to fulfil temporal and/or frequency specifications" is included in the skill C1.4 "Specify, design, implement and validate all or part of a complex system", milestone 2
- "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", milestone 1

Evaluation of the learning outcomes
The three first learning outcomes 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 fourth learning outcome 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.

Similarly, the fifth learning outcome will be more specifically assessed through the report following the lab work sessions.

2CC2000 – System modeling

Instructors: Marija JANKOVIC
Department: SCIENCES ENTREPRISE
Language of instruction: FRENCH, ENGLISH
Campus: CAMPUS DE PARIS - SACLAY, CAMPUS DE METZ, CAMPUS DE RENNES
Workload (HEE): 10
On-site hours (HPE): 6
Quota :

Description

The aim of this class is to raise awareness of students for System modelling theories, process and techniques; in particular in the case of complex systems. Future development challenges need to be supported by the capabilities of engineers to identify factors underpinning a system, to represent them in a formal way to predict system's future behaviour; as well as to understand the use of results and sensitivity analysis in the implementation phase. Through different case studies, the students will be introduced to system modelling (the need for multidisciplinary approaches, issues and challenges in system modelling, etc.)

Quarter number

ST5

Prerequisites (in terms of CS courses)

"Modelling" cours (ST2)

Syllabus

The two sessions will be organised as following:

1. Invited introductory conference that will though a case study illustrate the needs and challenges of system modelling
2. Introduction to the key notions for system modelling (using a industrial illustration or case study)

Class components (lecture, labs, etc.)

Case studies

Grading

Presence mandatory

Course support, bibliography

Recommended text books :

- “A practical guide to SysML: the system modeling language”, Friedenthal & Steiner
- « Model-Based Systems Engineering with OPM and SysML », Dori, Dov, (2016).
- « Structural complexity management », Lindemann, Maurer and Braun, (2009).
- « The limits to growth », Donella Meadows, Dennis Meadows, Jorgen Rangers, Wiliam Behrens III

Learning outcomes covered on the course

At the end of this class, students will raise awareness for :

- Systems thinking and system approaches to solve engineering problems
- Needs and advantages of multidisciplinary approaches for complex system design
- Key points for system modelling such as system perimeter definition, system interfaces definition and management, etc.

Description of the skills acquired at the end of the course

C1.1 Examine problems in their entirety and beyond their immediate parameters. Identify, formulate and analyse the scientific, economic and human dimensions of a problem

C1.5 Bring together broad scientific and technical concepts in a core structure contained within the framework of an interdisciplinary approach.

C9.2 Identify, within a given structure, the scope of liability as well as socio-ethical and environmental responsibilities.

2CC3000 – Optimization

Instructors: Jean-Christophe PESQUET
Department: MATHÉMATIQUES
Language of instruction: FRENCH, ENGLISH
Campus: CAMPUS DE METZ, CAMPUS DE RENNES, CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 36
Quota :

Description

This course will explore various fundamental notions of both continuous and discrete optimization.

The following topics will be addressed and implemented: formulation of optimization problems, existence conditions for global and local minimizers, convexity, duality, Lagrange multipliers, first-order methods, linear programming, integer linear programming, branch and bound approaches, preliminary stochastic optimization concepts.

Quarter number

ST7

Prerequisites (in terms of CS courses)

Basics in functional analysis, differential calculus, and probability (convergence, integration and probability course), knowledge of a programming environment

Syllabus

1. Optimization basics

    1.1 Introductory notions
    1.2 Existence of minimizers
    1.3 Convexity
    1.4 Duality

2. Linear programming

3. Integer linear programming

4. More advanced notions in continuous optimization

    4.1 Lagrange multipliers method
    4.2 Some iterative algorithms

5. Stochastic Optimization

Class components (lecture, labs, etc.)
This course combines lectures and exercise/practical classes.
This represents 22,5 hours of lectures, 10.5 of exercise classes, and 1.5 hour of final exam.

Grading
The grading will be based on a continuous evaluation process and the final written exam. In case of a justified absence to intermediary examinations, the grades of the latters are replaced by the grade of the final examination.

Course support, bibliography

D. P. Bertsekas, Nonlinear Programming, 3rd Edition. Athena Scientific, 2016. ISBN:978-1-886529-05-2

H.H. Bauschke and P. L. Combettes, Convex Analysis and Monotone Operator Theory in Hilbert Spaces, 2nd Edition. Springer, 2017. ISBN: 978-3-319-48311-5

Resources
Software equired: MATLAB, Python,...

Learning outcomes covered on the course
Upon completion of this course, the students will be able to :
address a wide range of concrete optimization problems arising either in a scientific or industrial context.
Formulate the problem in a suitable manner, to handle it numerically by using existing methods,
validate and interpret the solution with regards to the initial problem.

Description of the skills acquired at the end of the course
Intermediary level skills in optimization

SEMESTER LONG COURSES

2SL1000 – Economics

Instructors: Pascal DA COSTA
Department: SCIENCES ENTREPRISE
Language of instruction: ENGLISH, FRENCH
Campus: CAMPUS DE PARIS - SACLAY, CAMPUS DE RENNES, CAMPUS DE METZ
Workload (HEE): 40
On-site hours (HPE): 24
Quota :

Description

You have probably already read the economic press and heard about economic variables and concepts (drivers of growth, inflation-unemployment relationship, types of competition, European Central Bank and other economic institutions): it is now time to clearly define all this and finally grasp the complexity of economic debates. In doing so, you will all meet, at least once in your schooling, the opinion of economists on the major problems and debates that affect our society.
The main goal of the class of economics is to provide the basic concepts required to understand and analyze the economic environment. Each topic will be covered with real facts and real, historical and recent statistics, and then explained with the theories of economics (you will see that the theoretical controversies are quite common in economics).

Quarter number

ECT5

Prerequisites (in terms of CS courses)

None

Syllabus

1- History of economic thought: Mathematical modeling of economic facts. Validation by econometrics.

2- Microeconomics: Markets structures and regulations. Market failures. Positive and negative externalities: innovation and pollution. Natural monopoly. Price discrimination. Asymmetric information. Games theory.

3- Monetary economics: From the economy of debt to the economy of financial markets. The role of money. The role of the Central Bank and commercial banks in the financing of the economy.

4- Fluctuations and economic policies: Monetary policy, Fiscal policy. Unemployment.

5- International economics and globalization: International trade: regulation of world trade, theories of international trade. International finance: exchange rate, balance of payments, international monetary and financial systems (the model IS-without LM in open economy).

6- Economics of growth, innovations, inequality. Economics of the sustainable development.

Class components (lecture, labs, etc.)
12 hours of conferences
10 hours of tutorials
2 hours of exams

or Integrated classes (lectures + tutorials) (limited places)

Courses in French or English (to be chosen by the student).

Grading
1 Online quiz: 10% of the final score 1 Question for Reflection online: 10% of the final grade 1 Final exam (FE): with doc. 2h00 : 80% of the final score : 1 exercise + 1 reflection question Note = Max (0.1.Quizz + 0.1.Question + 0.8.FE, FE) In case of a justified absence to one of the intermediary examinations, the grade of this latter is replaced by the grade of the final examination.

Course support, bibliography
Teaching Material and Textbooks:
- Course reader

- Begg, Fischer, Dornbusch (2002) Macroéconomie, Dunod.
- Begg, Fischer, Dornbusch (2002) Microéconomie, Dunod.
- Blanchard, Cohen (2002) Macroéconomie, Pearson Education.
- Burda, Wyplosz (1998) Macroéconomie : une perspective européenne, Boeck Université.
- da Costa (2013) Etats-Unis, Europe, Chine : des Etats au coeur des crises économiques et financières mondiales, l'Harmattan.
- Mucchielli, Mayer (2005) Economie internationale, Dalloz.
- Picard (1992) Eléments de microéconomie, Montchrestien.
- Stiglitz (2000) Principes d'économie moderne, De Boeck Université.

Resources
Teaching team led by **Pascal da Costa**.

Courses in French or English (220 students maximum).

Size of the tutorials: 35 students
Size of the integrated classes (lectures + tutorials): 50 students. 3 integrated classes available.

Learning outcomes covered on the course
- know recent economic theories, their purpose and their limits;
- know the processes to generate knowledge in economic analysis, in the fields of competition, growth financing, currency, economic policies, and international trade;
- develop and implement simple mathematical models in micro and macroeconomics
- write a text comment

Description of the skills acquired at the end of the course
C1.1 Examine a problem in full breadth and depth, within and beyond its immediate parameters, thus understanding it as a whole. This whole weaves the scientific, economic and social dimensions of the problem.

C2.1 Thoroughly master a domain or discipline based on the fundamental sciences or the engineering sciences.

C4.1 Think in client terms, identify and analyse customer needs, the constraints of other stakeholders as well as include societal challenges.

C9.4 Demonstrate rigour and critical thinking in approaching problems from all angles, scientific, human and economic.

2SL1100 – Climate science and climate change issues

Instructors: Pascal DA COSTA
Department: SCIENCES ENTREPRISE
Language of instruction: FRENCH, ENGLISH
Campus: CAMPUS DE PARIS - SACLAY, CAMPUS DE METZ, CAMPUS DE RENNES
Workload (HEE): 10
On-site hours (HPE): 6
Quota :

Description

The objective of the "Climate Sciences and Climate Change Issues" course is to provide the scientific basis for understanding the issues and challenges of current climate change.
The aim is to situate it in the more general context of past climate change, to present the main mechanisms involved, and to introduce the modelling tools and strategies used to try to simulate possible futures.

Quarter number

ST5

Prerequisites (in terms of CS courses)

No prerequisites.

Syllabus

- observation of natural climate variability and its phenomenology: forcings, feedbacks, threshold effects, flip-flops, and hysteresis.
- the main physical and chemical principles: the greenhouse effect (radiation), energy and water transport (fluid mechanics, heat transfer, thermodynamics), the carbon cycle.
- numerical simulations of the climate.
- anthropogenic impact factors: greenhouse gas emissions, aerosols, land use, and future scenarios.

Class components (lecture, labs, etc.)

Lectures: 6 hours

Grading

Online Quiz (not mandatory)

Course support, bibliography

- Course slideshow
- About climate change: the IPCC reports (including "summaries for policymakers"): https://www.ipcc.ch/languages-2/FRENCH/publications/
- About climate and related research: see the IPSL links: https://www.ipsl.fr/Pour-tous

Resources

Teaching Team (IPCC): Valerie Masson-Delmotte, Masa Kageyama, Didier Paillard.

Responsible of the course: Didier Paillard.

Lectures in French and English (only one occurrence of the course in English).

Learning outcomes covered on the course

At the end of this teaching, the student will be able to :

- anchor the questions relating to climate change currently under way in the familiar physical principles of engineering (thermodynamics, fluid mechanics...).
- understand the orders of magnitude for energy, the natural carbon cycle and their anthropogenic disturbances.
- implement the notions of feedback, threshold, hysteresis, complex system, in the context of the functioning of planet Earth.

Description of the skills acquired at the end of the course

C1.1 Examine a problem in full breadth and depth, within and beyond its immediate parameters, thus understanding it as a whole. This whole weaves the scientific, economic and social dimensions of the problem.
C2.1 Thoroughly master a domain or discipline based on the fundamental sciences or the engineering sciences.
C9.4 Demonstrate rigour and critical thinking in approaching problems from all angles, scientific, human and economic.

2SL2000 – Law

Instructors: Valérie FERAY
Department: SCIENCES ENTREPRISE
Language of instruction: ENGLISH, FRENCH
Campus: CAMPUS DE METZ, CAMPUS DE PARIS - SACLAY, CAMPUS DE RENNES
Workload (HEE): 20
On-site hours (HPE): 12
Quota :

Description

12. General introduction to law and its role in society
13. Contract law, civil liability
14. Fundamentals of Intellectual Property Law (patents, trademarks, designs, copyright for software protection)

Quarter number

ST5

Prerequisites (in terms of CS courses)

None

Syllabus

Topics of the lectures :

- Introduction to law
- Patent, trademark and design law
- Software protection
- Contract law, civil liability

Class components (lecture, labs, etc.)

Lectures (3 * 1:30); Conference (1*1:30); Tutorials (3 * 1:30), Final Exam (1*1:30)

Grading

Final exam (100% of final mark): Multiple choice questions without documents

Course support, bibliography

Traité de droit de la Propriété Industrielle, Tomes 1 et 2. Jérôme Passa

Resources

• Teaching staff (instructor(s) names):
Valérie FERAY (main lecturer - Founder and managing partner - IPSILON), Grégoire DESROUSSEAUX (speaker and teaching assistant - attorney-at-law), Ghislain DEMONDA (speaker and teaching assistant - Patent engineer - IPSILON).

• Software, number of licenses required: N/A

• Equipment-specific classrooms (specify the department and room capacity): No

Learning outcomes covered on the course
Have a legal basis in the fundamental law aspects which the engineers and entrepreneurs can face, in order to give them good reflex in sensitive situations

Description of the skills acquired at the end of the course
C 1.1 - Examine a problem in full breadth and depth, within and beyond its immediate parameters, thus understanding it as a whole. This whole weaves the scientific, economic and social dimensions of the problem.
C.2.3 - Rapidly identify and acquire the new knowledg and skills necessary in applicable domains, be they technical, economic or others.
C 3.1 - Be proactive and involved.
C 4.1 - Think in client terms, identify and analyse customer needs, the constraints of other stakeholders as well as include societal challenges.
C 9.4 - Demonstrate rigour and critical thinking in approaching problems from all angles, be they scientific, social or economic.

2SL3000 – Philosophy

Instructors: Cynthia COLMELLERE
Department: SCIENCES HUMAINES ET SOCIALES
Language of instruction: ENGLISH, FRENCH
Campus: CAMPUS DE METZ, CAMPUS DE PARIS - SACLAY, CAMPUS DE RENNES
Workload (HEE): 30
On-site hours (HPE): 18
Quota :

Description

This course is an introduction to philosophy. It is structured around different branches of philosophy, in particular moral and political philosophy and the philosophy of science.
This teaching has four objectives.
1. Introduce the discipline through its history, the major questions it addresses and the types of answers it offers,
2. Understand and question the scientific approach based on knowledge in the philosophy of science and epistemology,
3. Initiate and deepen a reflection on scientific and technological progress with social progress.
4. Based on fundamentals in moral and political philosophy, propose resources for reflection on professional (engineering ethics) and personal ethics.
Specialists give the courses in the form of conferences: Mathias Girel (ENS Ulm), Etienne Klein (CEA)
The examples and situations are taken from different fields related to the social issues covered in the curriculum from the first year onwards. These examples could be linked to scientific, technological, political and social news. This variety of situations, and contexts is intended to facilitate the understanding and use of the concepts studied.
Each part includes a theoretical basis and developments based on examples from the history of science and technology and political and social history.
Main concepts covered

5. Truth, scientific evidence
6. Knowledge, ignorance
7. Technological progress/social progress
8. Power, democracy, responsibility
9. Ethics

Quarter number
ST7

Prerequisites (in terms of CS courses)
none

Syllabus
Each class session lasts 1h30, the sessions are grouped into 3h sessions
Partie 1 : introduction 3h
The issues addressed in this course.

- Why philosophy ?
- Philosophy and astonishment
- Philosophy as a way of life
- What do philosophers do?

Part 2: Philosophy of science 6h (3h+3h+3h)
This part of the course philosophically questions the most contemporary scientific knowledge,
This part of the course questions the most contemporary scientific knowledge to adress these issues :

- Information,
- Knowledge
- Truth
- Ignorance

Based on the research in the field of from physics (Einstein's work) and its implications, the course will address the issues of :

- Time
- The effectiveness of mathematics in physics
- Scientific and technical progress / social progress

Class components (lecture, labs, etc.)
This course takes the form of conferences.

Grading
The evaluation is an individual work (essay), duration: 3H

Course support, bibliography
Each speaker will send a bibliography relating to his or her part of the course.

2SL4000 – Sociology of organizations

Instructors: Cynthia COLMELLERE
Department: SCIENCES HUMAINES ET SOCIALES
Language of instruction: FRENCH, ENGLISH
Campus: CAMPUS DE PARIS - SACLAY, CAMPUS DE RENNES, CAMPUS DE METZ
Workload (HEE): 20
On-site hours (HPE): 12
Quota :

Description

This course is an introduction to the sociology of organizations. This part of sociology studies individual and collective behaviors within constituted human groups: organizations.
This course provides theoretical and methodological knowledge in organizational sociology and psychosociology for use in real contexts of problem-solving and change. This course covers the main phenomena in organizations: decisions, strategies, power, negotiations, conflict... It also helps to understand dysfunctions and deviance phenomena in organizations. A typology of the forms and modes of functioning of organizations allows students to address some common problem situations.

Quarter number

SG6

Prerequisites (in terms of CS courses)

Economic, business administration, business games

Syllabus

1. Session 1: Introduction, 3-hour course
- Presentation of the course and its objectives.
- Introduction to sociology (concepts, methods, foundations, scientificity).
- The notions of organization, institution, organized group.
- The founding works of the sociology of organizations: F. W Taylor (doctrine, scientific organization of work (OST); H. Ford (Fordism), Toyotism
- Doctrines of work organization, the rationalization of work, from the industrial revolution to the most recent developments of capitalism (dematerialization of work, platforms),
- The notion of work, the individual at work (subjective dimensions and socialisations at work)

Each notion is approached from a theoretical point of view and from examples (situations, investigations) in various formats (including film extracts).

2. Session 2: Formal/informal, course 1h30 and TD 1h30

Course 1h30

- Standards and rules in organizations, respect, adaptations, bypasses (work of JD Reynaud)
- Theories of motivation (Maslow and Herzberg) and their limits
- The bureaucratization of organizations: Work of Henri Fayol, Max Weber, David Graeber, G. Chamayou

Each notion is approached from a theoretical point of view and from examples (situations, investigations) in various formats (including film extracts).

TD (1h30) : case study

3. Session 3: Power and authority, course 1h30 and TD 1h30

Course 1h30

- Concepts of power, authority, legitimacy, domination. Work (M. Weber, M. Crozier, S. Milgram)
- Introduction and practice of strategic and systemic analysis of organizations
- Criticisms of strategic analysis of organizations and proposals: new approaches to the analysis of human and social dynamics in organizations.

TD (1h30) Case study

Course sequence, organization of the course (sequencing CM, TD, EL/TP...) :

This course is subject to a different time schedule and modalities depending on the students (yes/no), if yes description of the system: no

This teaching consists of courses and TDs. It combines theoretical contributions, exercises, case studies, simulations... Examples and practical cases are taken from different fields: companies and industries, institutions (political, educational), associations. This variety of situations and contexts is intended to facilitate the implementation of the proposed concepts and methods.

Class components (lecture, labs, etc.)

This teaching consists of courses and TDs. It combines theoretical contributions, exercises, case studies, simulations... Examples and practical cases are taken from different fields: companies and industries, institutions (political, educational), associations. This variety of situations and contexts is intended to facilitate the implementation of the proposed concepts and methods.

The course is given in French but reference texts (from a textbook) are given in English.

A Td is offered in English in its entirety on the Gif campus, On the Rennes and Metz campuses, one of the two Td's is given in French but the interaction with the teacher can be in English.

Grading

The proposed evaluation methods are: An individual evaluation: 3-hour table-top exam, without documents, course questions, and case study. 100 % final score

Course support, bibliography

Amblard, H., Bernoux, P., Herreros, G., Livian, Y.-F., Les nouvelles approches de la sociologie des organisations, Paris, Seuil, 2007 (3ème édition augmentée).
Ballé C., La sociologie des organisations, Bidet, A., Borzeix, A. Pillon, T., Rot, G. et F. Vatin (coordinateurs) (2006). Sociologie du travail et activité, Toulouse : Octarès Editions, 2006.
Chamayou G. La société ingouvernable. Une généalogie du libéralisme autoritaire, Paris, La Fabrique, 2018
Crozier M., Le phénomène bureaucratique, Paris, Seuil, 1963
Crozier M., Friedberg E., L'acteur et le système, Paris, Seuil, 1977.
Graeber, D. Bureaucratie. L'utopie des règles, Paris, Les Liens qui libèrent, 2015,
Hely, M., Moulevrier, P., L'économie sociale et solidaire, de l'utopie aux pratiques, Paris, La Dispute, 2013.
Linhart, R. L'établi, Paris, Editions de minuit, 1978.
Seris, J.-P., Qu'est-ce que la division du travail, Paris, Vrin, 1994.
Stroobants, M., Sociologie du travail, Paris, Amand Colin, 2010 (3ème édition).
Terkel S., Working, Histoires orales du travail aux Etats-Unis, Paris, Editions Amsterdam, 2005 (1st Edition 1972, 1974)
Weber M., L'Éthique protestante et l'esprit du capitalisme, Paris, Plon, 1964.
Weber M., Économie et Société, Paris, Plon, 1971
Weber M., La domination, Paris, La Découverte, coll. « Politique & sociétés », 2013, édition critique française établie par Yves Sintomer, traduction française par Isabelle Kalinowski

Resources

- Teaching team (names of the teachers of the lectures): Cynthia Colmellere
- Size of the TDs (default 35 students): 40

Learning outcomes covered on the course

- Acquire methods and practices of reasoning to explain behaviors in reference to interests, strategies, values, and experiences
- Acquire a way of thinking about problems in organizations that avoids explanations limited to personality or individual psychological characteristics.
- Understand failures and successes in change processes in organizations.
- Understand the systemic complexity in organizations (companies, institutions, administrations) by taking into account the human and social dimensions and the context.
- Understand the strength of the logic of actors at the individual and collective level

Description of the skills acquired at the end of the course

- analysing problems in organizations avoiding explanations limited to personality or individual psychological characteristics.
- analysing failures and successes in change processes in organizations.

2SL5000 – "Engineering Skills" Workshops

Instructors: Philippe MOUSTARD, Christophe LAUX
Department: LEADERSHIP ET MÉTIERS DE L'INGÉNIEUR
Language of instruction: FRENCH
Campus: CAMPUS DE METZ, CAMPUS DE RENNES, CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 21
Quota :

Description
This course is the continuation of 1SL5000. The objective is to continue exploring and developing the skills expected from a CentraleSupelec engineer: teamwork, project management, communication, complex problem solving, creativity, leadership, ethics, multicultural awareness.

Quarter number
ST5, SG6, ST7 and SG8

Prerequisites (in terms of CS courses)
It is highly recommended to have taken the 1SL500 course.
Because the workshops are held in French and are highly interactive, a good command of spoken French is recommended. Homework and reports may be written in English.

Syllabus
Key skills of the engineer:
- teamwork: organize, decide, lead in a team; different roles of team members; influence of the personality on the performance of the team
- oral communication: develop impactful oral communication, speak in public, structure a synthesis, build a presentation
- approach to solving complex problems:analyze the issues, make robust assumtions, use relevant orders of magnitude, manage risk and uncertainty
- creativity: understand group creativity methods
- leadership and self-knowledge
- multicultural: open to others, understand how to adjust to a different environment
- ethics: act ethically, understand the consequences of one's choices

API 8: Ethics
API 9: Leadership
API 10: Multicultural awareness

API 11: Project Coaching
API 12: Project Coaching
API 13: Project Coaching

Class components (lecture, labs, etc.)
- Case studies in groups
- Practical applications
- High student participation
- Application of the skills seen in the workshops to a real project
- Homework

Grading
Attendance at the workshops is mandatory because any absence penalizes the learning of the student and handicaps the group.
The participation of each student during the workshops is graded because it is a necessary condition for learning skills.
Individual or team work requested during workshops or between workshops is graded. The respect of the deadlines intervenes in the evaluation.
The team work gives rise to a collective grade for the team (except in the obvious case of withdrawal of the team).
The individual essays are given full credit if they are turned in on time and show sufficient quality of the personal reflection, without judgment on the opinions expressed when they are argumented.
Mini-quizzes may be given at the beginning of some of the workshop, on the content of previous workshops,. The quizzes are then graded.

The grade of each semester will be based on:
- Productions in the group work
- Individual and team homework (TIA)
- Quality of individual participation
- Result of the mini-quizz if any
An unjustified absence (ABI) leads to a penalty of 2 points per half-day of absence

Resources
Workshops in groups of 30 to 40 students, led by two professors
Practical engineering cases
Films and videos
Exchanges with other students and invited professionals
Conferences
Close link between the workshops and the second year team project of S8

Learning outcomes covered on the course

At the end of this course, the student will have understood the basics of:

- teamwork
- oral scientific communication
- problem solving
- creativity techniques
- leadership
- working in a multicultural environment
- ethics in engineering

Description of the skills acquired at the end of the course

At the end of the course, the student will have continued to progress in the following skills:

- solving complex problems (C1)
- be proactive, take initiatives, propose new solutions (C3)
- think customer and know how to identify the value brought (C4)
- familiarization with intercultural (C5)
- know how to convince (C7)
- lead a project and work in a team (C8)
- act ethically (C9)

2SL7000 – Professional Practice Workshops

Instructors: Philippe MOUSTARD, Christophe LAUX
Department: LEADERSHIP ET MÉTIERS DE L'INGÉNIEUR
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY, CAMPUS DE METZ, CAMPUS DE RENNES
Workload (HEE): 20
On-site hours (HPE): 7
Quota :

Description
This course aims to continue supporting students in the discovery of the engineering profession and in the construction of their professional project

Quarter number
ST5, SG6, ST7, and SG8

Prerequisites (in terms of CS courses)
have completed the placement
The workshops are held in French. Footnotes or summary notes may be written in English.

Syllabus
This course includes:
- half a day to share experience on the blue-collar internship
- a mid-year workshop
- two individual meetings with the professors
- round tables with company representatives

Class components (lecture, labs, etc.)
- group work
- experience sharing and report on the blue-collar internship
- one-on-one meetings with one of the professors
- exchanges with company representatives

Grading
Active attendance at the workshops and one-on-one meetings is mandatory.
The course is graded as "pass or fail".

To receive a passing grade for the APPs of semester 7, the following conditions must be all met: - attend the collective workshops, turn in internship report by the deadline, prepare and attend the one-on-one meeting - attend 2 round tables .

A final report on the professional project may be required.

Resources

Workshops in groups of 30 to 40 students, led by two professors

2SL8000 – Project S7

Instructors: Laurent BOURGOIS
Department: ENERGÉTIQUE
Language of instruction: ENGLISH, FRENCH
Campus: CAMPUS DE RENNES, CAMPUS DE PARIS - SACLAY, CAMPUS DE METZ
Workload (HEE): 60
On-site hours (HPE): 36
Quota :

Description

A project is a collective working modality used to address complex and open problems. Its effectiveness depends on the individual skills of each individual and the operating practices of the team; the objective being to achieve a final product for a sponsor, in a given time. The projects proposed in engineering training allow the learning of this modality through increasingly complex scenarios. Projects must lead to an ambitious achievement, which could not be achieved by doing what we already know how to do.

Quarter number

ST5 and SG6

Prerequisites (in terms of CS courses)

Project management, API workshop

Syllabus

Projects follow the usual phases of a project:
* Define and frame the project
* Structure the actions
* Define roles and responsibilities
* Measure progress and conduct feedback loops
* Develop technical and organizational skills
* Communicate your achievements
* Capitalize on the experience gained

Class components (lecture, labs, etc.)

As the project progresses, there are many and varied interactions with the project environment. It is based on individual and collective actions. There will be (1) collective times at the level of the cluster for the transmission of good practices and knowledge, (2) personal work to be defined within the group, (3) collective work to align and manage the project group. The supervisors will monitor the project regularly to ensure that no blockages appear and to validate the steps taken.

Grading

Although there is no evaluation for this optional S7 project, coaches will be attentive to the ongoing participation during the year, the quality of the written report and the oral presentations made during the project. These contributions will be viewed from four different angles:
* the taking of initiatives or even risks
* the relevance of the proposed solutions
* the ability to convince on the substance of the subject and to build trust
* the team's operation in project mode

Resources

Projects are conducted in groups. Each project is linked to a Pole where projects of the same nature are grouped together. The divisions provide supervisory resources and software and hardware resources. Students can apply to join a specific cluster or project, they can also propose to conduct a personal project with a team that will be hosted in a cluster. The cluster managers choose the most motivated students. There is no earmarking or credit recognition for this optional S7 project.

Learning outcomes covered on the course

At the end of this teaching, the student will be able to:
* summarize personal action within a project
* produce a high value-added deliverable in conjunction with various stakeholders
* organize a team to produce an original, valuable solution to a complex problem
* anticipate the human, social and environmental consequences of its actions, and determine the scope of your responsibilities
* prepare clear and rigorous communication about the project's achievements and operation

Description of the skills acquired at the end of the course

Milestones will be achieved in the following competencies:
* C3 – Act, undertake, innovate in a scientific and technological environment
* C4.2 – Identify the value provided by a solution for a customer, the market. Know how to identify opportunities, good business opportunities and seize them

* C7.2 – Convince by working on the relationship with the other. Understand the needs and expectations of your interlocutors. Take this into account in an evolutionary way. Encourage interaction. Creating a climate of trust
* C8.3 – Use the expertise of others and push your own limits. Identify and exploit wealth and talent

2SL8100 –Project S8

Instructors: Laurent BOURGOIS
Department: ENERGÉTIQUE
Language of instruction: FRENCH, ENGLISH
Campus: CAMPUS DE METZ, CAMPUS DE RENNES, CAMPUS DE PARIS - SACLAY
Workload (HEE): 200
On-site hours (HPE): 96
Quota :

Description

A project is a collective working modality used to address complex and open problems. Its effectiveness depends on the individual skills of each individual and the operating practices of the team; the objective being to achieve a final product for a sponsor, in a given time. The projects proposed in engineering training allow the learning of this modality through increasingly complex scenarios. Projects must lead to an ambitious achievement, which could not be achieved by doing what we already know how to do.

Quarter number

ST7 and SG8

Prerequisites (in terms of CS courses)

Project management, API workshop

Syllabus

Projects follow the usual phases of a project:
* Define and frame the project
* Structure the actions, define roles and responsibilities
* Measure progress and conduct feedback loops
* Develop technical and organizational skills
* Communicate your achievements
* Capitalize on the experience gained

Class components (lecture, labs, etc.)

As the project progresses, there are many and varied interactions with the project environment. It is based on individual and collective actions. There will be (1) collective times at the level of the cluster for the transmission of good practices and knowledge, (2) personal work to be defined within the group, (3) collective work to align and manage the project group. The supervisors will monitor the project regularly to ensure that no blockages appear and to validate the steps taken.

Grading

The evaluation covers the ongoing participation during the year, the quality of the written report and the oral presentations made during the project. These contributions will be viewed from four different angles:
* the taking of initiatives or even risks
* the relevance of the proposed solutions
* the ability to convince on the substance of the subject and to build trust
* the team's operation in project mode

Resources

Projects are conducted in groups. Each project is linked to a "Pôle" where projects of the same nature are grouped together. Each division provides supervisory resources and software and hardware resources. Students can apply to join a specific cluster or project, they can also propose to conduct a personal project with a team that will be hosted in a cluster. All students participate in an online assignment campaign. The cluster managers choose the most motivated students.

Learning outcomes covered on the course

At the end of this teaching, the student will be able to:
* summarize personal action within a project
* produce a high value-added deliverable in conjunction with various stakeholders
* organize a team to produce an original, valuable solution to a complex problem
* anticipate the human, social and environmental consequences of its actions, and determine the scope of your responsibilities
* prepare clear and rigorous communication about the project's achievements and operation

Description of the skills acquired at the end of the course

Milestones will be achieved in the following competencies:
* C3 – Act, undertake, innovate in a scientific and technological environment
* C4.2 – Identify the value provided by a solution for a customer, the market. Know how to identify opportunities, good business opportunities and seize them
* C7.2 – Convince by working on the relationship with the other. Understand the needs and expectations of your interlocutors. Take this into account in an evolutionary way. Encourage interaction. Creating a climate of trust
* C8.3 – Use the expertise of others and push your own limits. Identify and exploit wealth and talent

2SL9000 – Sport

Instructors: Stéphane BLONDEL
Department: SPORTS
Language of instruction:
Campus: CAMPUS DE PARIS - SACLAY, CAMPUS DE RENNES, CAMPUS DE METZ
Workload (HEE): 60
On-site hours (HPE): 48
Quota :

Quarter number

S7 and S8

ELECTIVES

2EL0010 – Teaching assistant

Instructors: Jocelyn FIORINA, Charles PAILLARD
Department: MATHÉMATIQUES, PHYSIQUE
Language of instruction: FRENCH, ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :

Quarter number

SG6 and SG8

2EL1110 – Dynamical systems in neuroscience

Instructors: Antoine CHAILLET
Department: AUTOMATIQUE
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : Yes

Description

This course constitutes an introduction to tools for the analysis of dynamical processes involved in brain functioning. Despite their huge complexity, brain functions are indeed based on elementary dynamics, some of which can be apprehended by a mathematical approach. Mastering these techniques is fundamental to progress in our understanding of brain functioning, to optimize instrumentation for brain activity measurements (brain imaging, electrophysiological recordings…), to improve brain-machine interfaces, to build up neuro-inspired computational units, and to understand the mechanisms involved in some brain diseases and thus improve their treatment.

Quarter number

SG6

Prerequisites (in terms of CS courses)

- SG1 : Information systems and programming
- SG1 : Convergence, integration, probability, partial differential equations
- ST2 : Modelling
- ST4 : Signal processing
- ST5 : Control engineering

Syllabus

Chapter 1: Fundamentals in physiology and brain functions (CM: 6h)

This first chapter introduces the physiological bases of neuronal activity. It describes the elementary principles involved in the generation of an action potential and in the communication between neurons (soma, axon, dendrite, synapse, ion channels, rest potential), as well as synaptic plasticity and homeostatic regulation mechanisms. It describes the physical and biological principles that come into play in these behaviors. It finally presents the main brain functions (memory, motor tasks, olfaction, and vision) and their alteration in pathological conditions.

Chapter 2: Measurement and actuation of brain activity (CM: 3h)
This second chapter presents different techniques to measure brain activity, including electrophysiological techniques (patch-clamp, multi-unit recordings, LFP, EEG, MEG) and brain imaging (MRI, 2-photon). It also describes technological ways to influence brain activity, including electrical stimulation and optogenetics.

Chapter 3: Brain-machine interfaces (CM: 4.5h)
This sixth chapter addresses the development of brain-machine interfaces, also known as neuroprostheses. These devices aim at restoring the autonomy of amputated or quadriplegic patients. Their implementation in animals or humans also provides knowledge on the functioning and learning of natural sensory-motor loops. This chapter details the needed elements for such interfaces: neuronal activity recording (whether invasive or not), signal processing, motor control, and sensory feedback from the prosthesis to the brain. It also describes the plasticity mechanisms on which these interfaces can rely to optimize learning.

Chapter 4: Mathematical models of neurons (CM: 3h)
This chapter presents well-known neuron models. It introduces conductance-based models through the famous Hodgkin-Huxley model and underlines its electronic analogy. It then presents simplified models, such as integrate & fire or FitzHug-Nagumo models, as well as simple models of synapses and neuronal plasticity. Numerical simulation of these models is also introduced.

Chapter 5: Analysis of neuron models (CM: 6h, TP: 3h)
This chapter present mathematical tools to study neuronal behavior. It introduces the notion of phase diagram and bifurcation. These notions are first given for one-dimensional systems, and then for planar systems. The chapter establishes a link between these bifurcations and the qualitative behavior of the neuron. A lab session on Matlab-Simulink aims at implementing a conductance-based model of a neuron and to predict its response thanks to the introduced theoretical tools.

Chapter 6: Neuronal populations (CM: 3h, TP: 3h)
This chapter addresses the dynamics of a whole population of neurons or a cerebral structure. It presents simplified models of the activity of a population, such as the Wilson-Cowan model or neural fields. It shows how to predict the behavior of such models by stability or bifurcation analysis. A lab session on Matlab-Simulink will aim at studying the binocular rivalry phenomenon through a simple neuronal population model.

Conference: Example of a start-up creation (1.5h)
A conference by the co-funder and scientific manager of start-up Dreem (Rhythm) concludes this course by presenting recent industrial innovations (non-invasive measurement of brain activity, pattern recognition in electrophysiological data, …) as well as opportunities given by neuroscience for industry and entrepreneurship.

Class components (lecture, labs, etc.)
CM, TD, TP, homework.

Grading
Evaluation will be made based on a written exam without documents (2h) at the end of the course and on the written reports of the two lab sessions. The following weights are envisioned: 60% for the written exam and 20% for each lab session report. Any unjustified absence at the TP will lead to a zero as TP grade. Skills will be evaluated through the lab session reports and the written exam. Skills C1.2 and C1.3 will be deepened during the lab sessions.

Course support, bibliography

- Dynamical Systems in Neuroscience: The Geometry of Excitability and Bursting, Eugene M. Izhikevich, The MIT Press, 2007
- Nonlinear dynamics and Chaos, by Steven Strogatz, Westview Press, 2001
- Mathematical Foundations of Neuroscience, by G. Bard Ermentrout & D. Terman, Springer, 2010
- Theoretical neuroscience, by P. Dayan & L.F. Abbott, The MIT Press, 2005

Resources
A multi-disciplinary teaching team, including researchers in computational neuroscience, a neurosurgeon, a professor in control theory and a start-up creator.

Practical works will be made on computers with Matlab-Simulink.

Learning outcomes covered on the course
At the end of this course, students will have acquired basic neuroscience knowledge to allow interaction with professionals of the field

(neurosurgeons, computational neuroscientists, experimenters). They will know of mathematical tools to model activity of a single neuron or a whole neuronal population, and to predict their dynamical properties both analytically and through simulations. They will also have been made aware of opportunities offered by neuroscience in terms of research, medical and industrial development, and entrepreneurship.

Description of the skills acquired at the end of the course
By the end of this course, students will be able to:

- Understand neuroscience fundamentals, for possible interaction with professionals of the field (neurosurgeons, computational neuroscientists, experimenters)
- Model the activity of a neuron or a whole neuronal population
- Predict their behavior both analytically and numerically.

This course will thus be an opportunity to deepen skills:

- C1.2: "Use and develop adequate models, choose the right modeling scale and the right simplifying assumptions to treat a problem": Jalon 3
- C1.3: "Solve a problem by employing approximation, simulation and experiments": Jalon 2A
- C1.5: "Use a wide scientific and technical background in the context of a transdisciplinary approach"
- C2.2: "Transpose to other fields, generalize knowledge"
- C2.3: "Quickly identify and acquire new knowledge and skills in relevant domains (technical, economical or other)".

2EL1120 – Interactive Robotic Systems

Instructors: Maria MAKAROV
Department: AUTOMATIQUE
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : Yes

Description

Industrial and service robotics currently undergo deep changes with the development of **collaborative robots designed to interact physically with humans**, and to share the same workspace or the same task. Collaborative robots are key elements both in **factories of the future** or in **assistance** tasks. Human-robot interaction is therefore an active research and development domain in robotics. It requires a **multidisciplinary** approach to design safe and efficient advanced systems.

Subjects covered by this course will allow the students to understand the main issues of interactive robotics and the technical aspects associated to these **complex systems in interaction with humans or their environment**. The course aims at exposing the context, the fundamental methodological tools and the current research and development subjects related to interactive robotic manipulators.

Quarter number

SG8

Prerequisites (in terms of CS courses)

15. Automatic Control (ST5)
16. Basic knowledge in rigid body mechanics to acquire by self-study if needed

Syllabus

- Introduction, brief historical perspective, industrial and research context

- Basics of modeling in robotics (geometric & kinematic models)
- Dynamic modeling (rigid and elastic body), identification and control of robots
- Force-feedback tele-operation
- Collaborative robotics
- Introduction to ROS (Robot Operating System)

Class components (lecture, labs, etc.)
Lectures, during which the presented concepts will be abundantly illustrated by examples, will be complemented with tutorial sessions on computers (in groups of two or three) to apply the theoretical concepts on practical case studies. The tutorials will require preparatory personal work outside class.

10. **Tutorial #1 and Tutorial #2 :** illustration of robot modeling using Matlab/Simulink or python
11. **Tutorial #3 and Tutorial #4:** introduction to ROS (Robot Operating Software) and application to robot manipulators

Class components:

- Lectures : 21h
- Tutorials on computers : 12h
- Final evaluation (quizz) : 2h

Grading
Continuous evaluation: Written report following the tutorials with functional and commented programs [50% of overall grade]; Final evaluation: written quizz with documents (2h) [50% of overall grade]. Attendance checked during tutorials, possible penalty on the written report grade. An unjustified absence during a tutorial automatically leads to grade 0 for the said tutorial.

Course support, bibliography

- **Handouts :** Slides shown during the lectures

- **References :** W. Khalil, E. Dombre, “Modeling, Identification and Control of Robots”, Butterworth-Heinemann, 2004.

Resources

- **Teaching staff (instructor(s) names):** Maria Makarov, Mathieu Grossard (CEA LIST Laboratoire de Robotique Interactive), Franck Geffard (CEA LIST Laboratoire de Robotique Interactive), Xavier Lamy (CEA LIST Laboratoire de Robotique Interactive), Alex Caldas (ESME Sudria)

- **Maximum enrollment:** tutorial groups of max 18 students

- **Software**, number of licenses required:

  - Matlab/Simulink, campus license (unlimited)
  - python (free)
  - ROS (free; virtual machine provided with Ubuntu and ROS installed)

Learning outcomes covered on the course
After completion of this course, students will be able to:

- Describe the current context (through technical, applicative and economic issues) of interactive robotics seen as a multidisciplinary field related to the interaction between human and robot and between robot and environment. Describe the main hardware and software components of an industrial robotic system.
- Establish the classical models of a robot manipulator: geometric, kinematic, dynamic models.
- Select the appropriate control architecture depending on the target application and determine its tuning parameters in order to satisfy the performance-robustness trade-off.
- Model a robot manipulator in contact with a human or a passive environment; determine the stability conditions of the global feedback-controlled system (teleoperation or collaboration cases).
- Use specialised software (Matlab/Simulink or python, ROS) to build and simulate models of robot manipulators as dynamical systems.
- Master scientific and technical communication (through reports on the tutorials).

Description of the skills acquired at the end of the course

- “Establish the classical models of a robot manipulator: geometric, kinematic, dynamic models” and “Model a robot manipulator in contact with a human or a passive environment” is included in the skill **C1.2 “Select, use and develop modelling scales, allowing for appropriate simplifying hypotheses to be formulated and applied towards tackling a problem” – milestone 3.**

- “Select the appropriate control architecture depending on the target application and determine its tuning parameters in order to satisfy the performance-robustness trade-off” and “determine the stability conditions of the global feedback-controlled system (teleoperation or collaboration cases)” is included in the skill **C1.1 "Examine a problem in full breadth and depth, within and beyond its immediate parameters, thus understanding it as a whole. This whole weaves the scientific, economic and social dimensions of the problem"** and in **C1.4 “Design, detail and corroborate a whole or part of a complex system” – milestone 2.**

- “Use specialised software to build and simulate models of robot manipulators as dynamical systems” is included in the skill **C6.1 “Identify and use the necessary software for one’s work” – milestone 1** and **C1.3 "Apply problem-solving through approximation, simulation and experimentation " – milestone 3B**

- "Master scientific and technical communication (through reports on tutorials)" is included in the skill **C7.1 "Render complex content intelligible. Structure one’s ideas and arguments. Synthesize and see the bigger picture" – milestone 1**

2EL1130 – Dynamical Multi-Agent Systems. Application to drones formation control

Instructors: Cristina MANIU
Department: AUTOMATIQUE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : Yes

Description

Numerous applications involve formation of several autonomous systems, capable of cooperation in a specific environment and of reconfiguration for the mission achievement. In particular, formation flying (Unmanned Aerial Vehicles - UAVs, satellites, etc.), car traffic control or pedestrians behavior in a crowd highlight the notion of a dynamic Multi-Agent System (MAS).

In the context of rescue missions (large-scale fire extinguishing missions, search for avalanche victims or black boxes in a large environment, etc.), the coordination and the control of a fleet of vehicles becomes key elements. These multi-agent missions relay on several MAS concepts such as tasks assignment, trajectory/path planning, and induce control problems in real time under constraints etc. The topics covered in this course will allow students to understand the basic concepts and challenges related to dynamic multi-agent systems via several experimentations on UAVs formations.

Experiments on Parrot UAVs (Mambo, Bebop) and on the Robotarium platform are planned as part of this course.

Quarter number

SG8

Prerequisites (in terms of CS courses)

Automatic Control (ST5), Optimization (ST7)

Syllabus
This new course is based on a **collaboration with Parrot Drones, ONERA and the Heudiasyc laboratory** and has the following structure:

- Introduction: a brief history, industrial and academic context;
- Dynamic modeling of multi-agent systems (MAS);
- Specific tools for MAS: notions of vehicles fleet/swarm, communication graph, consensus;
- Modeling and handling of Parrot drones;
- Control techniques of multi-agent systems;
- Taking into account constraints in the cooperative control law;
- Refinement of control laws and analysis of results;
- Multi-agent systems in space missions.

A tutored case study is envisaged as a guideline throughout this course in order validate the proposed control techniques both in simulation and on an indoor experiment of a fleet of Parrot drones.

Class components (lecture, labs, etc.)
This course is composed of **interactive** l**ectures, tutorials** and a **case study** that will serve as a guideline throughout this elective module and will lead to indoor experimentations on UAVs formations. The case study will follow the progress of the course and will allow acquiring practical skills. Active learning methods such as *Problem-Based Learning (PBL)* in small tutored groups are envisaged for the case studies on UAVs formations.
Students will discover dynamic multi-agent systems through various examples, exercises, discussions, and theoretical and practical guidance. An estimate of the hourly volume (35h) is as follows: 18h for interactive lectures, 6h for tutorials, 9h for the case study and 2h for the evaluation of interactive posters and peer assessment.

Grading
The evaluation procedure is designed to respect the alignment of objectives - activities - evaluations. A report (aligned with the objectives 1 to 5), containing a state-of-the-art and the analysis of the results obtained during the case study, will be delivered and evaluated. The results will be presented using an interactive poster (aligned with objectives 3, 4 and 5) in front of a committee and with a cross-examination of the other groups (peer assessment). The real-time feedback (aligned with objectives 2 to 5) gathered by teachers is also a tool for assessing the students' skills and knowledge. The final grade is computed from the report evaluation (50%), the interactive poster evaluation (both design and presentation) (40%), and

the evaluation of the activities (e.g. interactive MCQs, exercises) during the proposed teaching activities (10%).

Course support, bibliography
References

- *A Massive Open Online Course on Drones and Aerial Multi Robot Systems* (*DroMOOC*), www.onera.fr/dromooc, University Paris-Saclay, 2018.
- K.K. Oh, M.C. Park, H.S. Ahn, "A survey of multi-agent formation control", *Automatica*, vol. 53, pp. 424-440, 2015.
- J.A. Guerrero, P. Castillo, S. Salazar, R. Lozano, "*Mini Rotorcraft Flight Formation Control Using Bounded Inputs*", *Journal of Intelligent & Robotic Systems*, vol. 65, pp. 175-186, 2012.
- J. Guerrero, R. Lozano, "*Flight Formation Control*", John Wiley & Sons, 2012.
- I. Prodan, "*Commande des systèmes dynamiques Multi-Agents en présence de contraintes*", PhD thesis, Supélec, 2012.
- M.T. Nguyen, "*Commande prédictive sous contraintes de sécurité pour des systèmes dynamiques Multi-Agents*", PhD thesis, Université Paris-Saclay, 2016.
- G. Rousseau, C. Stoica Maniu, S. Tebbani, M. Babel, N. Martin, "Quadcopter-performed cinematographic flight plans using minimum jerk trajectories and predictive camera control", *European Control Conference*, Limassol, Cyprus, 12-15 June 2018.
- Y. Rochefort, H. Piet-Lahanier, S. Bertrand, D. Beauvois, D. Dumur, "Model predictive control of cooperative vehicles using systematic search approach", *Control Engineering Practice*, vol. 32, pp. 204-217, 2014.
- N. Michel, S. Bertrand, G. Valmorbida, S. Olaru, D. Dumur. "Design and parameter tuning of a robust model predictive controller for UAVs", *IFAC World Congress*, Toulouse, France, 2017.
- Wilson, S., Glotfelter, P., Wang, L., Mayya, S., Notomista, G., Mote, M., & Egerstedt, M. The Robotarium: Globally Impactful Opportunities, Challenges, and Lessons Learned in Remote-Access, Distributed Control of Multirobot Systems. IEEE Control Systems Magazine, 40(1), 26-44, 2020.
- C. Stoica Maniu, C. Vlad, T. Chevet, S. Bertrand, A. Venturino, G. Rousseau, S. Olaru, "Control systems engineering made easy: motivating students through experimentation on UAVs", 21th IFAC World Congress, Demonstrator Late Breaking Results, Berlin, Germany, 12-17 July, 2020.

Examples

- https://www.youtube.com/watch?v=hyGJBV1xnJI

- https://www.youtube.com/watch?v=YQIMGV5vtd4
- https://www.youtube.com/watch?v=fdrmahUPwaI
- http://www.asctec.de/en/uav-uas-drones-rpas-roav/asctec-hummingbird/

Resources
Pedagogical team: Cristina Maniu, Cristina Vlad, Sorin Olaru

Teaching staff (to be confirmed): Gauthier Rousseau (Parrot Drones), Sylvain Bertrand (ONERA), Pedro Castillo (UTC Heudiasyc), Cristina Maniu, Cristina Vlad, Sorin Olaru, Antonello Venturino.

The case studies will be conducted in small tutored groups of 5 to 6 students.

Funding via the project MEECOD (« Moderniser l'Enseignement par l'Expérimentation sur la Coordination de Drones »), *with the support of UPSaclay on « Initiatives Pédagogiques – Oser ! » 2018, N°FOR-2018-070*, was obtained for the purchase of the necessary equipment (Parrot UAVs: Mambo and Bebop etc.) for this course and the construction of an indoor space dedicated to UAVs flight tests. The development of this flight arena is in progress.

Learning outcomes covered on the course
After completion of this course, students will be able to:

- Describe and recognize the behavior of a multi-agent system (state-of-the-art on the subject);
- Model a multi-agent system via a state-space representation;
- Analyze time-domain or frequency specifications and propose a control law for a multi-agent system in order to fulfill the considered specifications;
- Design a control law for the multi-agent system and validate it in simulation;
- Validate the proposed control law on an experimental testbed (a UAVs formation).

Description of the skills acquired at the end of the course

- The first item of "Acquis d'apprentissage" contributes to "Core skill C2.3 Rapidly identify and acquire the new knowledge and skills necessary in applicable/relevant domains, be they technical, economic or others”.

- The second item corresponds at the same time to “Core skill C1.2 Select, use and develop modelling scales, allowing for appropriate simplifying hypotheses to be formulated and applied towards tackling a problem” and “Core skill C1.3 Apply problem-solving through approximation, simulation and experimentation/Solve problems using approximation, simulation and experimentation”.
- The items 3 et 4 address “Core skill C3.6 Evaluate the efficiency, feasibility and strength of the solutions offered/proposed solutions” and “Core skill C2.4 Create knowledge within a scientific paradigm”.
- The items 4 and 5 answer “Core skill C1.4 Design, detail and corroborate a whole or part of a complex system” and “Core skill C3.5 Put forward new tools with either continual progress or disruptive solutions as the goal”.
- The case-study will give the opportunity to deepen “Core skill C8.1 Work collaboratively in a team”, “Core skill C3.1: Be proactive and involved” and “Core skill C9.3 Act ethically, with integrity and respect for others”.
- The interactive poster, with the peer assessment, scheme will contribute to “Core skill C7.1 Persuade at core value level; to be clear about objectives and expected results. To apply rigour when it comes to assumptions and structured undertakings, and in doing so structure and problematise the ideas themselves. Highlight the added value”.

2EL1210 – Exposure of people to electromagnetism and electromagnetic compatibility

Instructors: Dominique LECOINTE
Department: ELECTROMAGNETISME
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : No

Description

Maxwell's theory has been a source of innovation and technological progress for more than a century and it is remarkable to note the extent of the industrial sectors impacted by the applications of this theory:

- the telecommunications sector at the heart of the information society,

- the aeronautics, automobile and transport sector,

- the electrical energy sector,

- the defense and security sector,

- the health and environment sector,

- the building and public works sector,

- the internet and connected objects sector.

Unfortunately, these successes and technological advances are not without compensation. The electromagnetic pollution generated by all these electrical and electronic systems has become one of the societal challenges of the 21st century. Potential victims of this pollution are electronic systems (electromagnetic compatibility) and people (exposure). Control of this pollution is the goal of electromagnetic compatibility and exposure of people to electromagnetic waves. The engineer faces a scientific but also economic challenge to meet this challenge.

Quarter number

SG6

Prerequisites (in terms of CS courses)
none

Syllabus

- Presentation of the issues
- TP CEM
- EMC: sources of disturbance
- EXPO: Field Sources
- TD CEM: sources and order quantities
- EMC: coupling and protection
- TD EMC: EMC systems: electromagnetic topology
- EXPO: biological effects
- EXPO: limits, exposure index
- TD EXPO: fixed emitters
- TD EMC: quantification of coupling phenomena
- EMC means of testing, standards
- EXPO: test methods
- TD EXPO: mobile telephony
- CEM EXPO: simulation
- TD EXPO: intermediate frequencies

Class components (lecture, labs, etc.)
- 14 courses
- 6 TD (the 2 MCQs will take place during 2 TD)
- 1 TP

Grading
1MCQ without document of 15 mn (coefficient 1) 1MCQ without document of 15 mn (coefficient 1) 1 final examination without document of 2h00 (coefficient 2) An unjustified absence from a MCQ leads to a score of 0 A justified absence of MCQ leads to the neutralization of the MCQ

Course support, bibliography
Compatibilité électromagnétique de P. Degauque et J. Hamelin, édition Dunod
Exposition humaine aux champs électromagnétique de P. Staebler, ISTE editions

Resources

- Teaching team (names of professors): Dominique Lecointe, Dominique Picard
- Size of TD: 4 groups of 20 students (maximum)
- TP : PTMS room (Bréguet building)

Learning outcomes covered on the course

At the end of this lesson, the student will be able to:

- pose the EMC problem when designing a complex system.

- identify, according to the frequency bands, the physical phenomena involved.

- use and implement the appropriate models (control of orders of magnitude, taking into account economic constraints).

- use rigor and critical thinking to analyze and solve people's exposure problems.

- argue based on national and international regulations.

These different learning outcomes validate milestones 1 and 2 in skill C1.1, milestones 1 and 2 in skill C1.2, milestones 1.A and 1.B in skill C1.3, and milestone 2 of Skill C1.5.

Description of the skills acquired at the end of the course

These different learning outcomes validate milestones 1 and 2 in skill C1.1 : Examine problems in their entirety and beyond their immediate parameters. Identify, formulate and analyse the scientific, economic and human dimensions of a problem, milestones 1 and 2 in skill C1.2 : Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when addressing a problem, milestones 1.A and 1.B in skill C1.3 : Solve problems using approximation, simulation and experimentation, and milestone 2 of Skill C1.5 : Bring together broad scientific and technical concepts in a core structure contained within the framework of an interdisciplinary approach.

2EL1220 – Antenna design for advanced applications

Instructors: Andrea COZZA
Department: ELECTROMAGNETISME
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : No

Description

Antennas are the centerpiece of wireless communications, spawning innovations and technology advances in many sectors addressing social challenges in the 21st century, such as intelligent transportation systems, autonomous vehicles, satellite navigation and communications, or remote sensing and non-destructive testing, as well as biomedical applications.

In this course, the main properties of antennas and considerations related to their choice and design will be discussed, while taking into account from the start design constraints set by the application context. The teaching method will be focused on understanding how antennas are used in practice, when antenna design must respond to external constraints. This will be illustrated on satellite imagery, with applications such as biomass estimation, flooding detection or studying the craters on the Moon.

The teaching philosophy will be centered on problem-solving and the design of complex engineering applications, by stressing the importance of maintaining a global approach. The course will foster this fundamental competence with a hands-on approach, with students working on a broad set of application scenarios, thanks to numerical simulation tools recreating real-life configurations. The proposed design approach will be based on interdisciplinary teaching, helping students develop integration skills, which are of paramount importance for any modern engineer.

Quarter number

SG8

Prerequisites (in terms of CS courses)

No prior knowledge is required to attend this course.

Syllabus
CM1 -Introduction to antennas (1h30)
CM2 - Main antenna families 1/2 (1h30)
PC1 - Link budgets and satellite coverage (1h30)
CM3 - Main antenna families 2/2 (1h30)
PC2 - Parabolic-dish antenna design (1h30)
CM4 - Antenna arrays (1h30)
PC3 - Optimization of a linear array for macrocells (1h30)
PC4 - 5G beamforming (1h30)
CM5 - Full-wave Electromagnetic simulation techniques (1h30)
BE1 - Design and simulation of an automotive radar antenna (3h00)
PC5 - UWB pulse radiation (1h30)
CM6 - Introduction to radar remote sensing (1h30)
PC6 - Synthetic Aperture Radar (SAR) processing (1h30)
BE2 - Experiments in anechoic and reverberation chambers (3h00)
CM7 - Frequency, resolution in spaceborne and airborne applications (1h30)
BE3 - Investigating forest and antenna center frequency (3h00)
PC7 - Frequency and biomass estimation (1h30)
CM8 - Polarization and information (1h30)
BE4 - Investigating a city (3h00)
PC8 - The Moon (1h30)

where CM are lecture classes, PC tutorial classes, BE numerical workshops and TP laboratory demos.

Class components (lecture, labs, etc.)
This teaching is based on a mix of formal lectures (CM) (theoretical elements and introductions), tutorials (PC) (designing a specific part for an application) and practical classes (BE) for numerical simulations on a computer. Laboratory demonstrations (TP) will also be organized in CentraleSupelec facilities in order to introduce students to experimental aspects, by testing prototypes on which they can verify the viability of the solutions introduced during lectures and tutorial classes.

Grading
In view of the stated goal to deal with real-word scenarios, a standard written exam would be inadequate and ineffective. Engineering skills will rather be evaluated based on : two MCQ at the middle and end of the course, testing the knowldege acquired by the students (individual tests), covering 50 % of the final markwritten questions dealing with analysis and problem-solving skills asked during the numerical simulation sessions (group tests), covering 50 % of the final mark Attendance to TD/PC tutorial classes is compulsory. For each unjustified absence a 0.25 point penalty will be applied to the final mark. In case of a justified absence to one of the intermediary examinations, the grade of this latter is replaced by the grade of the final examination.

Resources

- Teaching staff : Andrea Cozza, Régis Guinvarc'h, Laetitia Thirion-Lefèvre
- Maximum enrollment (tutorial classes): 35 students per group
- Software: Microwave Studio (CST), Matlab.
- Equipment-specific classrooms : Mode-stirred reverberation chamber, anechoic chamber.

Learning outcomes covered on the course

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

- understand the operating principles of the main antenna families and their characteristics
- identify constraints inherent to advanced applications that go from automotive to non-destructive testing
- develop solutions to identified problems using cutting-edge numerical tools

2EL1310 – Renewable energies

Instructors: Amir ARZANDE
Department: ENERGIE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : Yes

Description

The objective of this course is to present the potentials of systems using renewable energy sources.
The first part is devoted to the main components for producing energy from renewable sources.
A second part concerns the integration and management of energy within the transport and the distribution systems. The conversion and storage elements used in this framework will be discussed.

Quarter number

SG8

Prerequisites (in terms of CS courses)

Elective 1A "Electric energy" or equivalent

Syllabus

- Main sources of energy production from renewable sources

  Wind, Solar PV, Solar Thermal, Biomass, Rankin Cycle

- Integration and energy management

  Wind energy in electricity networks

  PV solar energy in electricity networks

- Hydrogen sector

  Production, storage, use

- Case of autonomous isolated networks.

  Modeling and sizing of elements. Management of power flows

Class components (lecture, labs, etc.)
L(1-6) // T1-PW(7-10) // L(11-12) // T2-PW(13-16) // L(17-18) //T3-PW(19-22)// EE

Grading
The evaluation will be in forme of a written examination of 2 hours with documents. At the beginning of each class, students sign the call sheet. The practical work will count for 30% in the final grade of the module. The unjustified absence at one session of practical work will result in a grade of 0 for the practical work concerned

Resources
Teaching staff (names of lecturers): Amir Arzandé
Size of tutorial class (default 35 students): 18 (for a staff of 72 students)
Laboratory for practical work (department and accommodation capacity): practical works in groups of 2 or 3 (depending on the number of students) at the Energy Department

Learning outcomes covered on the course

- Master the characteristics of the various components involved in the generation, conversion and management of energy from renewable sources

- Understand the difficulties related to the integration of these means of production in the electrical networks

- Solve simple sizing problems of energy supply systems from renewable sources.
- Evaluate the economic aspects

Description of the skills acquired at the end of the course

C1.3 Apply problem-solving through approximation, simulation and experimentation.
C1.4 Design, detail and corroborate a whole or part of a complex system.
C3.7 Make pragmatic and informed choices with the aim of producing tangible results.

2EL1320 – Energy conversion

Instructors: Marc PETIT, Bruno LORCET
Department: ENERGIE
Language of instruction: ENGLISH, FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : Yes

Description

The design of systems for the production and use of energy must now be done with respect for the environment and with strict criteria for sustainable development. In addition, the availability of energy in a suitable form is the key to developing new applications in all areas, from transportation to mobile device design. Thus, all sectors of activity must today be given the means to master electrical energy, the only vector capable of meeting these needs.The energy conversion course introduces the main objects, motors and generators, allowing transformations between electrical energy and mechanical energy. It also deals with principles and electronic devices to optimize the transfer of energy between source and electric load. The converters concerned are ubiquitous in the transport of energy and renewable energies, but also in most modern objects consuming electricity.

The course begins with the positioning of the principles and systems that will be studied in relation to the basics already acquired by students in the field of electrical energy. The focus is on the industrial and economic stakes of energy management.The first part of the course is devoted to the study of AC rotating electrical machines, which are today major players in the production and consumption of electrical energy. Based on the basics of low-frequency electromagnetism and mechanics, the principles of synchronous and asynchronous machine operation are introduced in order to obtain a circuit model that can be used in a steady state. It then becomes possible to draw up an energetic balance of the conversion and to present some modes of piloting.In a second part, we discuss the components and electronic power converters. The importance of electronic switching operation and its connection with the topological and thermal aspects of the design is emphasized. The various structures are then presented using a methodology that allows classification of the converters according to the sources and electrical loads concerned and the possible reversibility of the energy transfer.

Quarter number
SG6 in French et SG8 in English

Prerequisites (in terms of CS courses)
Elective 1A "Electric energy" or equivalent

Syllabus
Introduction
Energy conversion and electrical engineering
General Concepts on AC Machines
Sinusoidal field distribution - Rotating field creation - Practical realization
Synchronous machine in steady state
Principle and practical realization - Fundamental equations - Equivalent diagram - Alternator operation - Motor use
Asynchronous motor in steady state
Principle and practical realization - Fundamental equations - Equivalent scheme - Implementation on a fixed frequency network - Variable frequency power supply
Basics of power electronics
Principles of static converters: realized functions, classical structures - Ideal switch, real switches: switching regime, losses - Main components: fundamental properties, control principles, areas of use, limits
DC-DC converters
Objectives - Chopper: fundamental structures - Different operating regimes - Reversibility - Applications
DC to AC converters
Objectives - Single-phase inverters: fundamental structures - Operation modes, control laws - Three-phase inverters
AC-DC converters
Objectives - Rectifier bridges: single-phase and three-phase basic assemblies - Reversibility, line commutated inverter - Impact on the power source, power factor

Class components (lecture, labs, etc.)
L(1-6) // T1-TL(7-10) // L(11-12) // T2-TL(13-16) // L(17-18) //T3-TL(19-22)// EE

Grading
The evaluation will be done by a written examination of 2 hours with documents. The teaching laboratory will be taken into account for 30% in the final grade of the module. Absence from a session will give the score 0

to the relevant TP.

Course support, bibliography

Théodore Wildi, « Electrical machines, drives and power systems »

Resources

Teaching staff (names of lecturers): Bruno Lorcet, Marc Petit
Size of Tutorial (default 35 students): 18
Teaching laboratory (department and capacity): TL at the Energy Department

Learning outcomes covered on the course

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

• analyze or build an energy conversion chain
• to master all the basic components of electrical engineering
• to choose and implement an AC machine in the context of a stabilized speed application
• to make a choice of power converter and to adapt structure and control to a problem of energy conversion

Description of the skills acquired at the end of the course

C1.3 Apply problem-solving through approximation, simulation and experimentation.
C1.4 Design, detail and corroborate a whole or part of a complex system.
C3.7 Make pragmatic and informed choices with the aim of producing tangible results.

2EL1410 – Heat Transfer

Instructors: Benoît GOYEAU, Gabi-Daniel STANCU
Department: ENERGÉTIQUE
Language of instruction: FRENCH, ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : Yes

Description

Heat transfer covers broad scientific and technical domains. The field of application of this discipline is characterized, among other things, by considerable spatial and temporal scales: from the nanometer (thematic of the heat transfer at nano-scale) to interstellar distances (astrophysics), from the femtosecond (thermal response of a ultra-short laser) to the characteristic time of the genesis of the universe (thermal evolution of stars). Heat transfer concerns also society subjects and major challenges such as energy (energy optimization of industrial processes, thermal insulation of buildings, ...), environment (global warming, atmospheric greenhouse effect, etc.) or transport (optimization of thermal engines, fuel cells and hydrogen sector, ...). It is inherently a discipline in which the physical phenomena are of very different natures, coexist and are coupled.

This course develops and extends the concepts of heat transfer introduced in the courses "Transport phenomena" and "Modeling and simulation of unsteady heat transfer". Furthermore, the emphasis here is on the achievement of basic notions (via simple exercises - EAI) and on the techniques of physical modeling of the heat transfer (via synthesis problems- PbS).

Domain interests:
Design, master and control any system or process in any field where heat transfers appear such as residential and tertiary housing, transport, industry, energy production, etc.. Some universe sciences (meteorology, geophysics, ...) as well as the environmental sciences also rely partly on the control of heat transfers.

Teaching objective:
Address the main heat transfer modes in simple cases. This scientific training is intended for future generalist engineers, a priori not specialists in the discipline.
This is a basic teaching of: steady and unsteady conduction; radiation

between opaque bodies in a transparent environment; forced, natural, laminar and turbulent convection (phenomenological approach).The treatment of exercises and problems during tutorials is an opportunity to apply the knowledge introduced during lectures and to develop simple energy balance models. It involves solving concrete industrial, environmental or metrological problems (using an inductive approach). Using simple examples, some exercises of a didactic character introduce fundamental notions in heat transfer. Synthesis problems are proposed at the end of the course. In these, the main difficulty is to build the thread of the solution (confrontation with unclear and uncertain).
In addition, many exercises are treated in the course book. They are an excellent training.

Quarter number
SG6 and SG8

Prerequisites (in terms of CS courses)
Ideally, the students have taken the courses "Transport Phenomena" (elective course 1A, SG1or SG3) and "Modeling and simulation of unsteady heat transfer" (specific course in energy 1A, ST2). However, students who have not taken the two courses will be able to follow this elective but they will have, before the sessions, to work the courses that are available on the E-learning platform "E-SELF-LEARNING".

Syllabus
• Session 1 Lecture BASICS OF HEAT TRANSFER: Conduction, convection, radiation. Introduction to conducto-convective transfer.Steady state energy balance of a fixed system at rest. Electrical analogy.
o Tutorial (EAI) Wall between two fluids; Temperature profile in a 1D-system; (PbS) Insulation of a cryogenic container
• Session 2 Lecture FIN AND FIN APPROXIMATION
o Tutorial (EAI) Heated plate; Cooling of an electronic circuit; (Pbs) Efficiency of an home radiator; Liquid temperature measurement - glove finger (home work)
• Session 3 Lecture BASICS OF THERMAL RADIATION: Concept of: opaque body, transparent medium, emitted, absorbed, reflected, leaving, incident and radiative fluxes. Boundary conditions in the presence of radiative exchanges. The concept of directional spectral intensity. First expression of the radiative flux. Concept and properties of the equilibrium radiation.
o Tutorial (EAI) Calculations of solid angles and fluxes; Spectral integral calculations of Planck's law; (PbS) Principle of infrared remote sensing of a body
• Session 4 Lecture RADIATIVE PROPERTIES AND RADIATIVE TRANSFER: Characterization of the surface of an opaque body: notions of emissivity, absorptivity and reflectivity.Concept of: gray body, black body and body with isotropic radiative properties. Simple models of radiative transfer: (i) isothermal convex opaque body surrounded by an isothermal black body;

(ii) isothermal convex opaque body of small dimensions surrounded by an opaque isothermal enclosure.
o Tutorial (EAI) Radiation between two spheres; (PbS) Temperature of a body exposed to solar radiation
• Session 5 Lecture GENERAL METHOD OF RADIATIVE TRANSFER BETWEEN OPAQUE BODIES IN TRANSPARENT ENVIRONMENT: Basic assumptions of the method. Expression of the leaving and incident fluxes. Expression of the leaving energy rate. Concept of view factor - properties. Equations for a closed enclosure made up of gray surfaces. Generalization to non-gray surfaces.
o Tutorial (EAI) Radiation « face to face »; (PbS) Radiative screen - temperature measurement by a thermocouple
• Session 6 Lecture UNSTEADY DIFFUSION: HEAT CONDUCTION (1/2): Energy balance equation and boundary conditions. Notion of thermal diffusivity. General theorems: superposition and Π theorems. Application to a semi-infinite geometry (response to short times): problems of imposed temperature, imposed flux and forced periodic excitation
o Tutorial (EAI) Modeling of a 2D unsteady conduction problem; 1D unsteady conduction - analytical solution in case of imposed flux; (PbS) Thermal inertia of a building (1/2)
• Session 7 Lecture UNSTEADY DIFFUSION: HEAT CONDUCTION (2/2): Application to a semi-infinite geometry (response to short times - continued): problem of the thermal contact of two bodies. Case of finite media. Conductive and conducto-convective characteristic times, Biot number – recall the fin approximation
o Tutorial (EAI) Cooling of a transparent ball (PbS) Thermal inertia of a building (2/2); Laser treatment of steel
• Session 8 Lecture PHENOMENOLOGICAL APPROACH OF EXTERNAL FORCED CONVECTION: Diffusion (at wall) and convection (far from wall) fluxes. Concept of fluid viscosity. Problem of the plate at imposed temperature. Dimensional analysis. Correlation general form for external forced convection. Introduction and physical meanings of characteristic dimensionless numbers. Similarity notions in forced convection. Criteria of transition between laminar and turbulent regimes in standard configurations. Evolution of the local transfer coefficient along a plate; leading edge effect.
o Tutorial (EAI) Bay window on forced external convection; (PbS) Conductor, prudence !
• Session 9 Lecture INTERNAL FORCED CONVECTION: Basic notions on establishments of mechanical and thermal regimes and on established regimes in ducts of constant cross-section. Concept of mixing temperature. Nusselt number expression in laminar and turbulent regimes for flows in circular cross-section; physical discussion of results. Cases of ducts of non-circular cross-section; concept of hydraulic diameter.
o Tutorial (EAI) Calculation of the transfer coefficient in a semicircular channel; (PbS) Helium as a heat-exchanging fluid; Circulation of water in a tube (home work)

• Session 10 Lecture DIMENSIONAL ANALYSIS OF NATURAL CONVECTION: Physical phenomenon - approximation of Boussinesq. Mechanical and thermal boundary layers. Dimensional analysis - similarity. Criterion of transition between laminar and turbulent regimes. Expressions of transfer coefficient. Specificities of internal natural convection. Iterative character of the natural convection calculation.
o Tutorial (PbS) Thermal study of double glazing
• Session 11
o Tutorial SYNTHESIS PROBLEMS (PbS) Energy recovery for residential tertiary; Air conditioning of a building in a hot and sunny region (home work)
• Session 12 FINAL EXAM

Class components (lecture, labs, etc.)
The course is proposed in SG6 (in English) and in SG8 (in French) in the format of 11 sessions of 3 hours durration.

Grading
The first two learning outcomes constitute the minimum level of knowledge expected for any student who has taken this course. They will be evaluated during the course by short multiple-choice tests. These unrated tests will allow students to self-assess and teachers to measure the level of understanding of some fundamental notions and to detail the difficult points. Regarding the modeling activity of thermal systems, it is a complex skill to acquire. Students will learn this progressively during tutorials classes. The last session of the teaching will be an opportunity to consolidate all the modeling achievements. The learning outcomes will be assessed in the final exam (2H), which will consist of two parts. The first will focus on the assessment of the first two learning outcomes. In the second, students will be subjected to a complex modeling problem in order to evaluate the learning outcome modeling of thermal systems.

Course support, bibliography
• Book in English: « A first course in heat transfer » J. Taine, E. Iacona Editions Dunod 2011.
• Book in French: « Transferts Thermiques » Partie 1, J. Taine, F. Enguehard, E. Iacona, Dunod 2014.
• Platform « E-Self-Learning « in English : http://e-mentor-en.ecp.fr/ course presented by G.D. Stancu.
• Platform « E-Self-Learning « in French : http://e-mentor2.ecp.fr/ course presented by J. Taine.

Resources
•Teaching staff (names of instructors): Gabi Daniel Stancu, Benoit Goyeau
• Size of tutorial (TD) classes: 35
• Platforms « E-Self-Learning « in French and in English
• Software tools and number of licenses needed: non

• Experimental rooms (department and capacity): non

Learning outcomes covered on the course
At the end of this course, the students:
o Will be able to identify the different heat transfer modes present in a given configuration,
o Will be able to write and use appropriate energy balances in their local and global forms and continuity equations at the interfaces, thus, will be able to determine thermal fluxes and temperature fields in a system, and therefore will be capable to calculate local and global characteristics needed for the design of thermal systems
o Will have acquired modeling skills of thermal systems:
- List exhaustively the heat transfer phenomena present in a given system,
- Use scale analysis: (i) to make orders of magnitude estimates in order to discriminate predominant phenomena from those that can be ignored; (ii) to simplify problems a priori in three-dimensional geometries and / or unsteady towards models with analytical solutions,
- Use an inductive problem-solving approach: make appropriate and justified hypotheses which will be validated a posteriori by the resulting solutions,
- Reformulate a multi-physical and multi-scale problem with complex coupling phenomena, in a simplified version in which only the predominant phenomena have been considered,
- Model complex thermal systems and use fundamental energy balances to solve engineering problems.

Description of the skills acquired at the end of the course
• C1.2 « Use and develop adapted models, choose the right modeling scale and the simplifying assumptions relevant to the problem»,
• C1.3 « Solve problems using approximations »,
• C2.1 « Have deepened a field or a discipline relating to the basic or engineering sciences»,
• C2.2 « Transpose to other disciplinary fields, generalize knowledge »,
• At the end of the course, the practice of system sizing introduces to the competence C3.8 « Know how to design»,
• The English session of the course concerns the competence C5.1 « Speak at least three languages with an excellent level of English and French (written and spoken) as working languages»
• Finally, the use of the E-SELF-LEARNING platform, which includes the course content and a database, introduces to the competence C6.1 «Identify and use the software necessary for everyday work».

2EL1420 – Fluid Mechanics

Instructors: Ronan VICQUELIN
Department: ENERGÉTIQUE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : Yes

Description

The Fluid Mechanics course extends the fundamental notions, equations, and skills previously established during the course *Sciences des Transferts* on transport phenomena to a mastery of the various complexities of fluid flows, their dynamics, and systems whose properties are governed by fluid mechanics. The course allows for reaching a confirmed level in this discipline and the corresponding applications before considering more advanced and specialized studies. The course and practice sessions take into account the recent evolutions of the field by combining experimental, numerical, and theoretical approaches to train to engineer practices and future stakes (data analysis, modeling, simulations, measurements).

The course consists of three blocks. The first one deepens the fundamental notions through theoretical tools, processing, and analysis of experimental and numerical data. A second block is dedicated to the analysis of compressible flows in different regimes (subsonic, supersonic, shock waves), thus allowing to address a vast field of applications previously out of reach when considering incompressible flows. Finally, students are invited to choose the theme of their third block in order to briefly open to a specialization among Aerodynamics, Meteorological and climatic flows, Aeronautical and space propulsion, Energy systems, Environment ...

Quarter number

SG6

Prerequisites (in terms of CS courses)

The course follows a previous one entitled *Sciences des Transferts / Transport Phenomena*. Students enrolled in this course must already be familiar with fundamental concepts and skills in fluid mechanics:

- Dimensional analysis
- Local and macroscopic balance equations for mass, species, momentum and energy
- Evolution of different fields (velocity, pressure, temperature) and their interactions
- Determination of stresses, forces, powers, efficiencies, head losses
- Boundary layer

Syllabus

Block #1: Advanced Fluid Mechanics (4 sessions)

- Session 1: Fundamental equations and potential flows
- Session 2: Analytical solutions et exact profile in boundary layers
- Session 3: Macroscopic balances and jump conditions through interfaces
- Session 4: Instabilities and Turbulence

Block #2: Compressible flows (4 sessions)

- Session 5: Gas dynamics – Isentropic flows
- Session 6: Critical conditions and isentropic efficiencies
- Session 7: Shock waves
- Session 8: Oblique shock wave and nozzle flows

Block #3: Thematic specialization (three sessions)

- Choice between different themes such as Aerodynamics, Meteorological and climatic flows, Aeronautical and space propulsion, Energy systems, ...

Class components (lecture, labs, etc.)
11-course sessions: 3h00 each (1h30 of lecture followed by 1h30 of practice for sessions in blocks 1 and 2)

Grading
3 evaluations associated to the different blocks :

- Block #1 (25%) : short tests (2 X 15 min.)
- Block #2 (50 %) : 2h-long written exam scheduled during the last session
- Block #3 (25%) : poster preparation

Resources

• Teaching staff (instructor(s) names): R. Vicquelin

• Maximum enrollment in practice session (default 35 students): 35
• Software, number of licenses required: none
• Equipment-specific classrooms (specify the department and room capacity): none

Learning outcomes covered on the course

At the end of the course, the student will be able to:

- Model complex systems, a necessary step to their conception and optimization:
  - Make approximations et estimations,
  - Simplify an apparently complex system
  - Use fundamental balances to solve practical problems
- Characterize a system involving fluid flows thanks to several perspectives: simplified analytical solutions, results from numerical simulations, experimental data.
- Apply these skills to complex flow (unsteady, compressible)
- Face another disciplinary or application field related to fluid mechanics to show a rather autonomous adaptation to a new context

Description of the skills acquired at the end of the course

Core skills in CentraSupélec curriculum:

At the end of the course, the student will be able to:

- C1.2: Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when addressing a problem
- C1.3: Apply problem-solving through approximation, simulation and experimentation. / Solve problems using approximation, simulation and experimentation
- C2.1: Thoroughly master a domain or discipline based on the fundamental sciences or the engineering sciences.
- C6.5: Operate all types of data, structured or unstructured, including big data.

2EL1430 – Nuclear engineering

Instructors: Pascal YVON
Department: ENERGÉTIQUE
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : No

Description

This course will present the operating principles of nuclear reactors and describe in details all the stages of the civilian nuclear fuel cycle. The students will be able to appreciate, from technical, economical and environmental perspectives, the advantages and drawbacks of this low carbon source of energy, and its role in present and future world energy landscapes.

Quarter number

SG8

Prerequisites (in terms of CS courses)

Basic notions of physics and chemistry

Syllabus

- Principles of nuclear fission
- Operation of pressurized water reactors
- Interactions neutrons matter
- Generation IV reactor systems
- Natural and secondary ressources, mining methods, "yellow cake", uranium chemistry
- Uranium enrichment: isotopic separation techniques (gaseous diffusion, ultra-centrifugation, others ...)
- Fuel fabrication and in pile behavior
- Circular economy, reprocessing and waste management: spent fuel recycling
- Transport of nuclear materials
- Futures trends and R&D: a young proven energy with even more promises

Class components (lecture, labs, etc.)

33 h of Lectures

Grading

Written exam of 2 hours (partly with class notes and partly without class notes) Oral repeats

Learning outcomes covered on the course

- Operating principles of pressurized water reactors
- Abundance of resources of uranium, the only natural fissile material
- Introduction to mining, enrichment and reprocessing technologies for the nuclear "fuel"
- Impact of neutron irradiation on materials
- Fabrication and behavior of nuclear fuel
- Radioactif waste management: issues and solutions
- Future developments and prospective for nuclear processes and technologies

Description of the skills acquired at the end of the course

Good understanding of the operation of pressurized water reactors and of the nuclear fuel cycle. Understanding of the stakes of electricity production and of the position of nuclear energy in a low carbon mix.

2EL1440 – Reactive media

Instructors: Benoît FIORINA
Department: ENERGÉTIQUE
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : No

Description

Reactive media cover a vast field of studies that fit perfectly into the current energy and environmental context. From a scientific point of view, reactive media include combustion and plasmas. From one side, combustion accounts for 80% of primary energy conversion, and is present in the energy, transport and process sectors. On the other side, plasmas represent more than 99% of the visible matter in the universe. Plasma are used in a wide range of industrial applications: energy, semiconductor manufacturing, transformation and treatment processes, and health.

The aim of this course is to introduce fundamentals of combustion and plasmas. It focuses on the importance of numerical modelling, which is a key element of research and development strategies in reactive systems engineering. To illustrate the field of application of reactive media in the field of energy, students will build a multi-physics numerical tool to simulate an emerging and promising technology based on plasma-assisted combustion of a hydrogen turbine.

Quarter number

SG6

Prerequisites (in terms of CS courses)

none

Syllabus

1. General introduction. Industrial applications and scientific challenges
a. Combustion - (1h30)
b. Plasmas – (1h30)

2. Description of a reactive system
a. Lecture (1h30)
i. Chemical thermodynamics
ii. Mixture equivalence ratio
iii. Computation of burnt gases temperature
b. Class Work (1h30) “Decreasing CO2 emissions by addition of di-hydrogen”

3. Numerical tools
a. Matlab initiation (1h30)
i. Using Matlab basic functions
ii. Using the chemical package
b. Class Work (1h30) “Computation of adiabatic combustion temperature of H2-O2 and H2-air reactive systems under global-step reaction assumption ”

4. Thermodynamical equilibrium
a. Lecture (1h30)
i. Second law of thermodynamic
ii. Methods for computing chemical equilibrium state
b. Class Work (1h30) “Computation of equilibrium composition in H2-O2 and H2-air reactive systems ”

5. Combustion chemical kinetics
a. Lecture (1h30)
b. Class Work (1h30) “Computation of auto-ignition in a constant pressure reactor”

6. Plasma production from electric discharges
a. Lecture (1h30)
b. Class Work and experimental demonstration (1h30)

7. Two temperature chemical kinetics in plasma
a. Lecture (1h30)
b. Class Work (1h30)

8. Optimization of energy in plasma discharges
a. Lecture (1h30)
b. Class Work (1h30)

9. Plasma assisted combustion
a. Experiments and models (0h45)
b. Simulations (0h45)
c. EM2C visit and mini-project presentation (1h30)

10. Mini-project : numerical simulation of plasma-assisted combustion

(3h00)

11. Mini-project : numerical simulation of plasma-assisted combustion (3h00)

Class components (lecture, labs, etc.)
Lecture, tutorial and computer work

Grading
Restitution of the work carried out in TD and during the mini-project in the form of an oral presentation

Course support, bibliography
Nasser Darabiha, Emile Esposito, François Lacas et Denis Veynante, Poly de combustion de CentraleSupélec.
- Kenneth Kuo, Principle of Combustion, published by John Wiley & Son, 2005
- Principles of Plasma Discharges and Materials Processing, Michael A. Lieberman and Allan J. Lichtenberg, John Wiley and Sons, New York, 2nd edition, 2005
- Partially Ionized Gases, M. Mitchner and C.H. Kruger, John Wiley & Sons, New York, 1973.
- Gas Discharge Physics, Yu. P. Raizer, Springer Verlag, Berlin, 1997

Resources
Teaching team: Pr. Benoît Fiorina and Pr. Christophe Laux.

Learning outcomes covered on the course
To dimension reactive systems, an engineer has to make approximations and calculate orders of magnitude. He has to calculate mass, chemical species and energy balances. He must determine the thermochemical equilibrium of a reactive system and know how to exploit thermochemical imbalances. In particular, this course provides the following skills:

- Understand the industrial, energy and environmental stakes of combustion and plasmas.

- Be able to establish the fundamental equations for dimensioning combustion and plasma systems

- Characterize the thermodynamic and chemical transient and equilibrium states of a reactive system

-Be able to program (under Matlab environment) a numerical simulation tool for chemical reactors with detailed kinetics. The code developed by the student will be based on a MATLAB library of pre-existing thermochemical functions.

Description of the skills acquired at the end of the course

To design reactive systems, engineers must make approximations and calculate orders of magnitude. They must carry out mass, chemical and energy balances. They must determine the thermo-chemical equilibrium of a reactive system and know how to exploit thermo-chemical imbalances. This course provides for that purpose the following skills:

- Understand the industrial, energy and environmental challenges of combustion and plasmas
- Establish the fundamental equations for designing combustion and plasma systems
- Characterize the thermochemical transient and equilibrium states of a reactive system
- Program (under Matlab environment) a numerical tool for chemical reactors with detailed kinetics. The code developed by the students will be based on a pre-existing MATLAB library of thermochemical functions.

2EL1520 – Object oriented software Engineering

Instructors: Paolo BALLARINI, Dominique MARCADET
Department: INFORMATIQUE
Language of instruction: FRENCH, ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

Software engineering (SE) is a discipline concerned with concepts, techniques and tools aimed at the production of quality software. SE can be seen as an iterative process, that, starting from a set of requirements, yields a software product through the execution of different phases, inlcuding : design, development, documentation, maintainance, testing. The quality of the produced software is evaluated with respect to different factors, typically : the compliance with the requirements, the « openness » to modifications/extensions, the ease of maintenance/testing.

This course aims at providing engineering students with an overview to the problem of software design and development by means of the object oriented programming (OOP) paradigm. By learning the Java programming language students will acquire basic skills in the software development process using a state-of-the-art Integrated Development Environment (IDE). By focusing on object-oriented modeling, the UML language, the Javadoc-based code documentation, the Junit-based development of unit-tests, students will acquire basic skills essential to the realization of industrial software.

Quarter number

SG6 in French and SG8 in English

Prerequisites (in terms of CS courses)

- 1CC1000 : Information Systems and Programming
- 1CC2000 : Algorithmics and Complexity

Syllabus

- Introduction to object oriented programming in Java: classes, objects, encapsulation
- Classes composition and inheritance
- Abstract classes, interfaces
- Exception handling, generics, collections
- Introduction to software engineering: UML diagrams
- Design patterns and applications
- Devolopment of test units with JUnit framework
- Multi-threaded programming
- Introduction to graphical user interface programming in Java
- Solution of a design problem through development of a final project

Class components (lecture, labs, etc.)

- Lectures: 16h30
- Tutorial classes: 16h30
- Project development: 24h00
- Exam: 2h00

Grading

40% on integrated project 60% on final examination (2h00)

Course support, bibliography

- Books: "Effective Java", Joshua Bloch; "Thinking in Java", Bruce Eckel.
- Lecture notes (Paolo Ballarini)
- 11 Lectures slides
- 11 Tutorials with solutions

Resources

- Lecturer: Paolo BALLARINI
- 4 Tutorial classes: Paolo Ballarini, Arnault Lapitre, ??, ??.
- Software tools: Java JDK, Eclipse/Papyrus IDE

Learning outcomes covered on the course
At the end of this course, the students will :

- be able to apply the basic elements of object oriented programming using the Java language;
- be able to solve a mildly complex programming problem using the Java language;
- be familiar with the different phases of software development cycle and choose some appropriate tools;
- be able to chose an adequate level of abstraction when working on a specific phase;
- be able to apply the principles of UML modeling in the process of software design and development;
- know how to conceive and develop simple graphical user interface programs;
- know how to apply basic design principles for development of flexible/maintainable software solutions;
- be familiar with multi-threading programming.

Description of the skills acquired at the end of the course
C6.3 : Specify, design, develop and test software

2EL1540 – Theoretical computing

Instructors: Marc AIGUIER, Pascale LE GALL
Department: INFORMATIQUE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

This teaching gives a part of the fundamentals of computer science on its two paradigms of computation, which are reduction (calculation step by step) and resolution (logical inference / automatic reasoning).

Quarter number

SG8

Prerequisites (in terms of CS courses)

Cours Algorithmes et Complexité (ST Modélisation) et goût pour l'abstraction mathématique

Syllabus

The course addresses the following fundamental notions:

- Induction and recurrence (well-founded sets ...).
- Computability (Gödel/Herbrand's recursive functions, Turing machines and all the associated indecidability results).
- Mathematical logic (syntax, semantics and proof systems). Propositional and first-order logics will be detailed.

The course is composed as follows:

- Induction and recurrence.

The following notions will be presented: set theory (ordering and preordering, upper and lower bounds, well-founded sets and induction, formal systems, proofs, correctness and completeness).

- Propostional logic.

The following notions will be presented: syntax, semantics and proof systems, binary decision tree, tableaux method, DPLL algorithm, satisfiability, SAT-solvers, and proof systems (resolution, sequent calculus and natural deduction).

- Computability and complexity.

The following notions will be presented: primitive recursive and recursive functions, computable and non-computable problems, Turing machine, equivalence theorems, Church thesis, and complexity theory.

- First-order logic.

The first-order logic is an extension of propositional logic, and is the privileged logic for describing data type structures.

Class components (lecture, labs, etc.)

The course will be divided into 15 hours of lectures and 15 hours of tds.
A project with a computer realization will be proposed during this teaching.
The latter will be returned in the week following the examination.

Grading

The assessment will be done through a project and a written 2hours exam.
The final mark will be shared in 40% for the project and 60% for the written exam. For this exam, only the handout and personal notes are allowed.
Electronic devices (laptops, mobile phones and tablets) are not allowed.

Course support, bibliography

Students will be provided with a handout in French, as well as TD subjects with correction elements.

Resources

- Equipe enseignante (noms des enseignants des cours magistraux) : Marc Aiguier et Pascale Le Gall

- Taille des TD : At most 35 students per class

- Outils logiciels et nombre de licence nécessaire : Used software (prolog, solvers, proof assistants) will be free access software, which students will install on their personal machine.

Learning outcomes covered on the course
Understand the fundamental principles and the formal (i.e. mathematically based) tools that underlie all methods of designing, verifying and implementing computer systems.

Formalizing computing problems and mastering the fundamental theoretical tools necessary to reason about these formalizations. These theoretical tools are based on computation models classically used for the complexity analysis of the algorithms (see the course “Algorithms and Complexity”), as well as on reasoning methods based on mathematical logic.

Description of the skills acquired at the end of the course
Formalizing computing problems and mastering the fundamental theoretical tools necessary to reason about these formalizations. These theoretical tools are based on computation models classically used for the complexity analysis of the algorithms (see the course “Algorithms and Complexity”), as well as on reasoning methods based on mathematical logic.

2EL1550 – High Performance Computing

Instructors: Stephane VIALLE
Department: INFORMATIQUE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

Students will acquire:

- Some understanding of stakes and locks of intensive numerical simulation applied to any research and development issues.
- Some understanding of parallel algorithmic and experience of each step of a computing code parallelization.
- Some knowledge and experience about parallel computing environments.

Quarter number

SG6

Prerequisites (in terms of CS courses)

- SG1 common course « *Systèmes d'Information et Programmation* » (1CC1000)
- ST2 common course « *Algorithmique et complexité* » (1CC2000)
- *Basic knowledge in linear algebra*

Syllabus

1. **Parallel and distributed architectures:** components of a supercomputer; memory hierarchy; energy aspects; need for fault tolerance.
2. **Optimization and parallelization of loops in shared memory:** optimization and vectorization in series, algorithmic and

multithreaded programming with OpenMP, analysis and rewriting of loops.

3. **Distributed algorithms by sending messages:** data circulation and point-to-point communications in MPI (mpi4py): application deployment and distributed execution in MPI (OpenMPI + mpi4py); data distribution and collective communications in MPI (mpi4py); linear algebra, direct methods and iterative methods.
4. **Parallel scientific computing:** strategies for solving large linear problems; iterative methods of substructuring; domain decomposition methods.
5. **Performance measurement and analysis:** measurement methodology; speedup and efficiency metrics and limits; scaling metrics and limits.

Class components (lecture, labs, etc.)

Mathematic approaches and algorithms introduced during the lectures will be implemented and experimented on computing clusters during the tutorials, and performance will be measured and analyzed. Experimentation will be an important part of the course, allowing a deep understanding of the lecture issues.

- **Composition of the course:** lectures 21h00, tutorials on computers 12h00 and final written exam 2h00

- **Possible course schedule:**
  - lectures 6 x 1h30 + tutorial (on computing servers) 2 x 1h30 ; lectures 4 x 1h30 + tutorial (on computing servers) 4 x 1h30 ; lectures 4 x 1h30 + tutorial (on computing servers) 2 x 1h30
  - final written exam (2h00)
- **Tutorials (close to 36% of the course):**
  - tutorials on computing servers will be grouped by 2 (i.e. 3h of experimental tutorial),
  - the groups of tutorials on machines will be made up by level of experience in IT,
  - developped codes will run on computing clusters of the *Data Center for Education* of CentraleSupélec or the Mésocentre Moulon (CentraleSupelec-ENS Paris Saclay), available from computing classrooms, or from student laptops.

Grading

Relative weights of the different examinations:

- 50% : Report of some tutorials on computing servers
- 50% : written exam of 1h30 (at the end of the course)
- In case of a justified absence to one of the tutorials on computing servers, the grade of this latter is replaced by the grade of the final examination. In case of unjustified absence a score of 0/20 will be applied for this tutorial on machines.
- The remedial exam will consist entirely of a written exam, similar to the initial exam.

Evaluation of the different learning outcomes:

- The first set of learning outcomes (AA1*) will be evaluated based on the knowledge of theoretical concepts presented during the lectures. Evaluation will be done during the lecture (contrôle continu) and during the final exam (examen final), with lecture' content based questions, and applications' exercices.
- The second set of learning outcomes (AA2*) will be evaluated from the solution presented after the tutorial session (TDs) on computers. This will be based on the quality of the code, performance of the parallel execution, results of the simulation, management of the ressource' time and the observation of the skills of the students.
- The third set of learning outcomes (AA3*) will be evaluated based on the synthesis of the complete high performance computational chain introduced during the lectures and investigated during the tutorials. This will cover, choice and design of the numerical methods, tuning of the algorithms, and implementation on parallel and distributed computers.

Course support, bibliography
Documents supplied to the students:

- Frédéric Magoulès, François-Xavier Roux, Guillaume Houzeaux. Parallel Scientific Computing. Wiley & Sons, Inc., 2015. Hardcover 354 pages (in English). *This course support is available in other languages: in French (Dunod, 2017), in Spanish (CIMNE, 2014), in Japanese (Morikita Publishing Co Ltd, 2015), in Hungarian (Pollack Press, 2018).*
- Numerical Methods: Slides of the lectures
- Parallel and Distributed Computing: Slides of the lectures.

Others suggested books:

- W. Gropp, E. Lusk, A. Skjellum. "Using MPI". MIT Press. 1999.

- R. Chandra, R. Menon, L. Dagum, D. Kohr, D. Maydan, J. McDonald. "Parallel Programming in OpenMP". Morgan Kaufmann Publishers. 2000.
- B. Chapman, G. Jost, R. Van Der Pas.. "Using OpenMP". MIT Press. 2007.

Resources

- **Teaching staff: Frédéric MAGOULES** and **Stéphane VIALLE**
- 64% of lectures and 36% of tutorials, with tutorial groups of 25 students working on high performance computers.
- Remote access to different computing servers and clusters (Data Center for Education of CentraleSupelec, and/or mésocentre CentraleSupelec-ENS Paris Saclay).
- Experimentation based on standard Opensource software: C/C++/Python languages, multithreading library for multicore machines (OpenMP), message passing library for computing clusters (MPI: MPICH2/OpenMPI), optimized scientific libraries (OpenBLAS).

Learning outcomes covered on the course

When finishing the course, the students will be able to:

1. **[Learning Outcomes 1* (AA1*)]** contributing to core skill **C1.2:**
    1. to tune existing numerical methods for high performance computing (HPC)
    2. to develop innovative numerical methods for high performance computing (HPC) in order to solve complex problems

1. **[Learning Outcomes 2* (AA2*)]** contributing to core skill **C2.1**:
    1. to design parallel algorithms for intensive simulations, according to high performance computing requirements
    2. to implement parallel algorithms for intensive simulations on supercomputers or clusters of multi-core PC
    3. to manage a limited set of computing resources when running an intensive simulation

- **[Learning Outcomes 3* (AA3*)]** contributing to core skill **C6.4**:
    - to implement a complete and consistent high performance simulation:
        - to choose models under both the constraints of accuracy and scalability,

- to choose efficient parallel implementation strategies
- to achieve a simulation campaign with (always) limited ressources

Description of the skills acquired at the end of the course

- **C1.2** : Select, use and develop modelling scales, allowing for appropriate simplifying hypotheses to be formulated and applied towards tackling a problem (Learning Outcomes **AA1***).
- **C2.1** : Thoroughly master a domain or discipline based on the fundamental sciences or the engineering sciences (Learning Outcomes **AA2***).
- **C6.4** : Solve problems through mastery of computational thinking skills (Learning Outcomes **AA3***).

2EL1560 – Models and Systems for Big Data management

Instructors: Nacera SEGHOUANI
Department: INFORMATIQUE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

Existing data management technologies continue to evolve and adapt to challenges related to the heterogeneity, the volume and the velocity of data. NoSQL (Not only SQL) databases are a family of DataBase Management Systems (DBMS) which differs from the traditional relational SGBD paradigm. The purpose of such DBMSs is the simplicity of design, the horizontal scaling, the real-time access, the availability and performance in a distributed infrastructure.

The objective of *Models and Systems for Big Data Management* course is to study the theoretical foundations, the conceptual models and technologies for storing, monitoring and querying big data. From SQL to NoSQL, NoSQL data representation models, data querying and analytics, data distribution algorithms, performance measures and in-memory storage in a distributed environnement are the main aspects addressed in this course.

Quarter number

SG6

Prerequisites (in terms of CS courses)

- Basic knowledge of relational databases and SQL query language.
- Desired basic knowledge of client/server architecture.

Syllabus

- Conceptual models for data representation SQL (relational) and NoSQL (document, key-value, column, graph).
- Data querying and analytics languages. Indexation.
- Transaction concepts, ACID properties, CAP theorem.

- Main concepts related to data distribution in a cluster. Partitioning graph data algorithms.
- Practical works on data modeling, querying real data (social network data, Wikipedia, ...).
- Softwares : Oracle, MongoDB, Cassandra, Neo4J, Giraph, ElasticSearch.

Class components (lecture, labs, etc.)
The course is organized as follows:

- 11 slots of 1h30 of lecturer,
- 5 slots of 3h practical/lab works, groups of 25 students (maximum).

Grading
Continuous assessment during practical/lab work classes, project, written exam (2h):
60% written exam,
20% project ,
and 20% continuous controls (3 best marks).

Resources

- Slides, corrected practical exercices/works, QCMs, bibliography references and online tutorials.
- Installation and use of free licence softwares.
- 1 lab instructor by group of 25 students (maximum).
- Lab works instructors: Idir Ait Sadoune, Yuting Feng, Francesca Bugiotti.

Learning outcomes covered on the course
At the end of this course, students will be able to:

- choose a data management model which fits with the application and the data nature.
- define, deploy, manipulate a SQL and NoSQL database.
- define a NoSQL distributed database and its scaling up.

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

- Modeling, deploying, querying a SQL and NoSQL database.
- Data distribution algorithms.

2EL1580 – Artificial Intelligence

Instructors: Fabrice POPINEAU
Department: INFORMATIQUE
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

What do web-based information retrieval, personal assistant development, autonomous driving or automatic planning have in common?
These are all complex real-world problems that artificial intelligence (AI) aims to solve by addressing them with rigorous methods.
In this course, you will study the fundamental principles that guide these applications and implement some of these systems.
Specific topics include automatic learning, research, gaming, Markov decision processes, constraint satisfaction, graphic models and logic.
The main objective of the course is to provide you with a framework to address new AI problems that you may encounter in the future.
The ethical and philosophical aspects of AI will also be discussed.

Quarter number

SG8

Prerequisites (in terms of CS courses)

Information Systems and Programming Courses
Algorithmic and Complexity Course
Basics of probability: random variable, Bayes theorem

Syllabus

- Introduction - Presentation of the domain
- Agents and agent architectures
- Machine learning and reflex agents
    - Linear predictors
    - Loss function and optimization
    - Neural networks
- State representation and search

  - Planners
  - Adversarial search
  - Utility functions
  - Markov decision processes
  - Reinforcement learning
- Variable-based representation
  - Uncertain knowledge
  - Probabilistic reasoning
  - Bayesian Networks
  - Simple and complex decision making
- Logic-based representation
  - Propositions and predicates
  - Syntax vs. semantics
  - Inference systems
- Conclusion
  - Deeper on deep learning
  - Future of AI

Class components (lecture, labs, etc.)

The course scheduling includes 7 x 3h of lectures and 4 x 3h of supervised work.
The supervised work sessions are inserted every second class lecture.

Grading

A 2-hour table-top examination with documents will result in a final exam check mark.

Course support, bibliography

Artificial Intelligence : a Modern Approach, 3rd ed. (English)
Auteurs : Stuart Russel, Peter Norvig
ISBN : 9780136042594
Editeur : Pearson

Resources

- Teaching team (names of the teachers of the lectures): Fabrice Popineau (lectures)
- Size of the supervised work sessions (by default 25 students): 25 students, supervision capacity of 100 students with teachers (Bich-Liên Doan, Arpad Rimmel, Yolaine Bourda, ...)
- Software tools and number of licenses required: No licenses. Free tools: Python, Prolog,...

Learning outcomes covered on the course

By the end of this unit, students will be able to:
- identify the problems for which artificial intelligence techniques are suitable and when it is the case to identify the appropriate techniques,
- formalize a given problem in the language/framework of different AI techniques,
- implement elementary AI algorithms (e. g. state space search algorithms),
- design and implement an evaluation of different algorithms on a formalization of a problem, and draw conclusions from this evaluation.

Description of the skills acquired at the end of the course

C6.4 Solve problems in a computational thinking process
C6.5 Use any type of data, structured or unstructured, including massive data.

2EL1590 – Cloud computing and distributed computing

Instructors: Francesca BUGIOTTI, Gianluca QUERCINI
Department: INFORMATIQUE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

Nowadays, the marketing strategies of most companies is based on the analysis of massive and heterogeneous data that needs a considerable amount of computational power. Instead of purchasing new hardware and software infrastructures, companies often resort to the computational and storage power offered by *cloud computing* platforms over the Internet.

The objective of this course is to present the fundamental principles of *distributed systems* and *distributed computing* that are at the heart of *cloud computing*.
The course will cover the principles of virtualization and containerization and the methods and tools used for distributed processing (for instance, *MapReduce, HDFS,* and *Spark*).
The course will also introduce advanced techniques and algorithms for the analysis of massive and heterogeneous data (PageRank, supervised learning, and *clustering*).

Quarter number

SG8

Prerequisites (in terms of CS courses)

Python programming, databases, basics of networking will be appreciated.

Syllabus

Chapter 1. **Introduction**.

- Terminology: centralized computing, parallel computing, distributed computing, cloud computing.
- Context: Internet of Things, Big Data.
- Hardware considerations: advances in CPU processors, GPU, multithreading technology.

- Computer clusters: some design principles.
- Basic concepts of distributed computing.

Chapter 2. **Virtualization**.

- Implementation of virtualization.
- Virtualization structures.
- Virtualization of CPU/memory/IO.
- Virtual clusters.
- Virtualization and data centers.

Chapter 3. **Containerization: Docker**

1. Containerization principles.
2. Docker architecture.
3. Images, containers, volumes and networks in Docker.
4. Deployment of application with Docker.

Chapter 4. **Multi-service applications and orchestration.**

1. Microservices architecture.
2. Orchestration principles.
3. Presentation of Kubernetes.

Chapter 5. **Multi-service applications in the cloud.**

- Service models : IaaS, PaaS, SaaS.
- Introduction to the public cloud infrastructures : GAE, AWS, Azure.
- Deployment of multi-service applications in the cloud.

Chapter 6. **Cloud programming and software environments**.

- Parallel computing, programming paradigms.
- Hadoop MapReduce.
- Apache Spark.

Chapter 5. **Data analysis**.

- Graph and stream processing.
- PageRank.
- Machine learning basics.
- Spark MLlib.
- Clustering (k-means).

Class components (lecture, labs, etc.)

- **Introduction. Lecture**: 3h
- **Virtualization. Lecture**: 2h
- **Containerization. Lecture**: 3h, **Tutorial**: 3h, **Lab assignment**: 3h (graded)
- **Multi-service applications. Lecture**: 4h, **Tutorial**: 3h
- **Programmation cloud et environnements logiciel. Lecture**: 6h, **Tutorial**: 3h, **Lab assignment**: 3h (noté)
- **Exam**: 2h

5 tutorials/lab assignments of 3h each, 18h lecture , 2h exam.

Grading
Written examination at the end of the course (MCQ + exercises).
2 lab assignments are graded.

Course support, bibliography

- Hwang, Kai, Jack Dongarra, and Geoffrey C. Fox. *Distributed and cloud computing: from parallel processing to the internet of things*. Morgan Kaufmann, 2013.
- Erl, T., Puttini, R., & Mahmood, Z. (2013). *Cloud computing: concepts, technology & architecture*. Pearson Education.
- Tel, G. (2000). *Introduction to distributed algorithms*. Cambridge university press.
- Miner, D., & Shook, A. (2012). *MapReduce Design Patterns: Building Effective Algorithms and Analytics for Hadoop and Other Systems*. O'Reilly Media, Inc.
- Karau, H., Konwinski, A., Wendell, P., & Zaharia, M. (2015). *Learning spark: lightning-fast big data analysis*. O'Reilly Media, Inc.

- Schenker, Gabriel. Learn Docker - *Fundamentals of Docker 18.x.* Packt Publishing,. Print.

Resources
Teaching staff: Francesca Bugiotti, Gianluca Quercini, Idir Ait Sadoune, Marc-Antoine Weisser, Arpad Rimmel
Maximum lab enrollment: 25 students
Software, number of licenses required: Use of free software

Learning outcomes covered on the course
At the end of this course, the students must be able to:

- Understand the fundamental concepts of cloud computing.
- Master the notion of virtualization and containerisation in the cloud.
- Be acquainted with the different cloud platforms.
- Use the distributed computing paradigms, such as MapReduce and Spark.
- Design distributed algorithms on data.

Description of the skills acquired at the end of the course

- Operate all types of data, structured or unstructured, including big data.
- Conceive, design, implement and authenticate complex software.

2EL1710 – Advanced probabilities

Instructors: Erick HERBIN
Department: MATHÉMATIQUES
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

This theoretical course is a follow-up to the 1st year Mathematics course, which includes the basic concepts of probability theory. It introduces the foundations of the general theory of stochastic processes, taking into account the temporal evolution of random concepts.

These probabilistic models constitute the basic mathematical objects for modelling phenomena with high variability, uncertainty or complexity that make it impossible to describe them in detail. Among them, Brownian motion is widely used to describe phenomena (natural, physical, biological or financial) based on stochastic differential equations. It is at the crossroads of important classes such as martingales, Markov processes or Gaussian processes, from which it inherits properties.

The objective of this course is the theoretical study of the first two families of stochastic processes, in the particular case where the parameters are in a discrete space, and then to introduce Gaussian processes indexed by the real ones. The course is in the classic format of a mathematics course in which the fundamental theorems are demonstrated on the board.

Quarter number

SG6

Prerequisites (in terms of CS courses)

CIP course of the CentraleSupelec curriculum or last year courses of a Mathematics Licence: Integration, Measure Theory, Probability.

Syllabus

Discrete time martingales (15h): study of discrete time martingales; martingales and game strategy; convergence results

Markov chains (12h): transition operators, Markov ownership and canonical Markov chain; state classification, recurrence/transience; asymptotic results
Gaussian processes and introduction to Brownian motion (6h): law of a stochastic process; Gaussian processes, white noise and introduction to Brownian motion

Class components (lecture, labs, etc.)
Lectures entirely on the board (results, proofs and examples): 22 hrs
Tutorial: 9 hrs

Grading
Home Works, Compulsory partial exam: 1 hrs 30 (without document, calculator or computer) at the halfway point of the course, Final written exam: 2 hrs (without document, calculator or computer).

Resources
Teaching team (names of the lecturers): Erick Herbin
One TD group (full complement)

Learning outcomes covered on the course
The objective of this course is the theoretical study of the first two families of stochastic processes, in the particular case where the parameters are in a discrete space, and then to introduce Gaussian processes indexed by the real ones.

Description of the skills acquired at the end of the course
Theoretical foundations for the study of stochastic discrete-time processes and Gaussian random processes. At the end of this course, students will be ready to take a 2nd year Stochastic Calculus course in Mathematics.

2EL1720 – Distributions and operators

Instructors: Pauline LAFITTE
Department: MATHÉMATIQUES
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

The goal of this theoretical course is to go back to the sources of the concepts of functional analysis that were introduced in the Analysis and Partial Differential Equations courses in first year.
Historically, the distributions and the operators were introduced to provide a formal mathematical frame for problems arising in Physics. In this way, the concepts of functions were generalized into a theory that allows to treat rigorously fundamental questions of analysis (exchanging limits, exchanging limits and integrals, Fourier transform)...
These concepts provide an answer to the main question : in which functional space do we have to search for the solution of the problem so that it is well-posed, that is, it admits one and only one solution that depends continuously on the data ? In particular, the concept of (general) topology on such spaces plays an essential role in the study of the question of continuity and, more generally, the question of convergence. Depending on the considered cases, they can be defined by a distance, a norm, a family of semi-norms...
In the general frame of the stochastic processes (or random functions), the distributions and the operators are the basic mathematical tools to study Gaussian processes or extensions of the classical Brownian motion. The concepts introduced in this course constitute the basis of the spectral or integral representation of these processes, which allow their fine study (geometric property, Markov property, definition of a stochastic integral, etc.)

Quarter number

SG6

Prerequisites (in terms of CS courses)

CIPPDE

Syllabus

This course of fundamental mathematics is organized around the theoretical study of the following notions:

- Hahn-Banach's theorems
- Unbounded operators
- Weak topologies
- Advanced concepts of distributions
- Bochner's theorem

For each of these subjects, the main results are rigorously proved on the blackboard.

Class components (lecture, labs, etc.)
Lectures during which the concepts and results are introduced and proved on the blackboard. These are complemented by tutorials.

Grading
Homeworks, Personal project, Written midterm exam: 1.5 hr, Written final exam: 2 hr ; no documents allowed.

Course support, bibliography
Course notes and partial solutions of the exercises.

Resources
Lecturer: Pauline Lafitte
One lab group

Learning outcomes covered on the course
Mastering the theoretical bases of functional analysis: the students will have all the required qualities of rigorous reasoning that are necessary for modeling and analyzing mathematically.
C2.1 : Thoroughly master a domain or discipline based on the fundamental sciences or the engineering sciences.
C3.1 : Be proactive and involved, take initiatives
C3.2 : Question assumptions and givens. Overcome failure. Take decisions

Description of the skills acquired at the end of the course
This course gives an important basis for students who want to attend a Master 2 connected to fundamental mathematics (for instance in Analysis, Partial Differential Equations or Probability).
C2.1 : Thoroughly master a domain or discipline based on the fundamental sciences or the engineering sciences.
C3.1 : Be proactive and involved, take initiatives
C3.2 : Question assumptions and givens. Overcome failure. Take decisions

2EL1730 – Machine Learning

Instructors: Fragkiskos MALLIAROS
Department: MATHÉMATIQUES
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

Machine learning is the scientific field that provides computers the ability to learn without being explicitly programmed (definition by Wikipedia). Machine learning lies at the heart of many real-world applications, including recommender systems, web search, computer vision, autonomous cars and automatic language translation.

The course will provide an overview of fundamental topics as well as important trends in machine learning, including algorithms for supervised and unsupervised learning, dimensionality reduction methods and their applications. A substantial lab section will involve group projects on a data science competition and will provide the students the ability to apply the course theory to real-world problems.

Quarter number

SG6

Prerequisites (in terms of CS courses)

Notions of linear algebra, probabilities, and scientific programming in Python (numpy).

Syllabus

The course will cover the following topics:

- Introduction to Machine Learning
- Dimensionality reduction
- Model selection and evaluation
- Linear and logistic regression

- Probabilistic classifiers and linear discriminant analysis
- Non-parametric learning and nearest neighbour methods
- Tree-based methods and ensemble learning
- Support Vector Machines
- Neural networks
- Unsupervised learning: clustering
- Introduction to reinforcement learning

More details about the syllabus of the will be given in the website of the course: http://fragkiskos.me/teaching/2E1730-F20/

Class components (lecture, labs, etc.)

- Lectures (12 sessions x 1h30)
- Labs (10 sessions x 1h30)
- Written exam (2 hours)

Grading

The evaluation of the course will be based on the following:Two assignments: the assignments will include theoretical questions as well hands-on practical questions that will familiarize the students with basic machine learning tasks.Project: The students are expected to form groups of 3-4 people, propose a topic for their project, and submit a final project report. Final exam: Final exam in the material covered in the course.The grading will be as follows: Assignment 1 (individually):10%; Assignment 2 (groups of 3-4 students):15%; Project (groups of 3-4 students):15%; Final exam:60%

Course support, bibliography

There is no single requiered textbook for the course. We will recommend specific chapters from the following books:

- Shai Shalev-Shwartz and Shai Ben-David. Understanding Machine Learning: From Theory to Algorithms. Cambridge University Press, 2014.
- Christopher M. Bishop. Pattern Recognition and Machine Learning. Springer, 2011.
- Trevor Hastie, Robert Tibshirani, and Jerome Friedman. The Elements of Statistical Learning: Data Mining, Inference, and Prediction. Second Edition, Springer, 2017.
- Jure Leskovec, Anand Rajaraman, and Jeff Ullman. Mining of Massive Datasets. Cambridge University Press, 2014.

Please see the website of the course for more details: http://fragkiskos.me/teaching/2E1730-F19/

Resources

The course will be taught jointly by Fragkiskos MALLIAROS and Maria VAKALOPOULOU.

A detailed list of resources is given in the website of the course: http://fragkiskos.me/teaching/2E1730-F20/

Learning outcomes covered on the course

We expect that by the end of the course, the students will be able to:

- Identify problems that can be solved using machine learning methodologies.
- Given a problem, identify and apply the most appropriate algorithm(s).
- Implement some of those algorithms from scratch.
- Evaluate and compare machine learning algorithms for a particular task.
- Deal with real-world data challenges.

2EL1740 – Algebra and cryptology

Instructors: Remi GERAUD
Department: MATHÉMATIQUES
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : No

Description

This lecture is an introduction to the tools and techniques of modern mathematics, with a view towards scientific and technological applications.

Exploring the crossroads where pure mathematics, computer science and information theory meet, we will address questions such as

- How do you communicate with a deep space probe?
- How can one assess the authenticity of a digital document?
- How does one find very large prime numbers? How can one factor large integers into their prime divisors?
- and many others

These questions will lead us to introduce algebraic structures (categories, groups, rings, modules, spectra...) and to study their relationships and symmetries, but it will also hint at us that otherwise familiar notions (points, spaces, functions, numbers...) can be thought in a radically new and unifying way.

Applications of these tools to code theory and cryptology in the 20th and 21st centuries will be the governing thread of these lectures.

This lecture aims at providing students with:

- A cultural overview of the evolution of mathematics during the 20th and 21st century, along with the language that will enable them to pursue in that field
- A strong command of computational algebra, especially in finite rings and fields, and elliptic curves (rational points and divisors)
- An understanding of the mathematical foundations underpinning modern cryptology

Quarter number
SG8

Prerequisites (in terms of CS courses)
This lecture does not require an advanced mathematical background, but some fluency in computer programming is recommended.

That being said this lecture comes with a heavy workload necessary to develop an intuition of the discussed notions.

Syllabus
(Note: this is a tentative programme that may change and does not necessarily follow the lectures' ordering)

- Category of commutative groups, structure theorem for finitely generated commutative groups.
- Category of commutative rings, structure and typology. Category of modules. Spectra, Zariski topology. Units and factorisation in a ring.
- Functoriality of the spectrum. Polynomial rings. Fields, finite fields, splitting fields and their constructions. Cryptographic applications (GCM, AES, SSS) and codes (GRS).
- Smooth algebraic varieties, projective varieties, rational points, function fields, Riemann--Roch theorem. Cryptographic applications (ECDH) and codes (Goppa).
- Weil divisors and pairing, Tate--Lichtenbaum and reduced Tate pairings, Miller's algorithm. Cryptographic applications (MOV, BLS).
- Primality and factoring, Fermat and Miller--Rabin tests, Carmichael numbers. Pocklington's theorem. Shanks, Pollard, Dixon--Kraitchik's algorithms, generalised number field sieve.
- Code theory, Singleton, Shannon, and Hamming bounds. Berlekamp--McEliece--Van Tilborg theorem. McEliece cryptosystem.

Class components (lecture, labs, etc.)
Blackboard lectures (notes will be provided to the attendance).
Exercises are provided, some of which will be solved in detail. (Optional) homework assignments will be given.
A textbook is provided which complements lectures, and additional references will be given for specific aspects.
Tutorials : 10,5 h
lectures : 21h

Grading
There will be a midterm (1h30, sitted, no documents allowed) and a final exam (2h). Self-evaluation exercises are also provided. The final grade will be whichever of the following two is highest: - Final exam grade - 1/3 midterm grade + 2/3 final exam grade

Resources
Lectures will mostly rely on the blackboard, with computer tools being used in later exercises. Relevant software will be provided as needed.

Teaching staff: Rémi Géraud-Stewart.

Learning outcomes covered on the course
At the end of this course, the students will be able to

- Recognise the presence of underlying algebraic structures in engineering problems
- Understand the issues addressed by cryptology and code theory, know and recognise their leading industrial applications
- Master the mathematical language in which algebraic questions are formulated and analysed

Description of the skills acquired at the end of the course
1. Recognise the presence of underlying algebraic structures in engineering problems

- C.1.2 : identify the structures that were discussed during lectures
- C.6.1 : invoke the relevant technological tools

2. Understand the issues addressed by cryptology and code theory, know and recognise their leading industrial applications

- C.6.7 : understand the technical aspects and difficulties related to communication and information transfer
- C.3.6 : evaluate technical solutions against specific needs and constraints
- C.6.1 and C.1.4 : introduce relevant tools and correct configurations

3. Master the mathematical language in which algebraic questions are formulated and analysed.

1. C.2.3 : practice acquiring new skills to approach a given problem

2EL1750 – Advanced statistics

Instructors: Sarah LEMLER
Department: MATHÉMATIQUES
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

The Advanced Statistics course aims to present various statistical methods for the estimation, the prediction and for determining the properties of the proposed estimators. We will develop two themes:

1. multivariate linear regression
2. non-parametric statistics

The course covers both the theoretical aspects of these concepts but also proposes a practical application of the models and methods considered using TPs with R software on data sets from different domains.

To be downloaded before the first TP:

- the R software https://www.r-project.org/
- the RStudio interface https://www.rstudio.com/

Quarter number

SG8

Prerequisites (in terms of CS courses)

For this course the prerequisites are as follows:

You must be familiar with the concepts seen in Statistics and Learning in 1st year, in particular:

- estimators,
- confidence intervals,
- the tests,

- the first notions on the linear model

Syllabus
We will develop two themes:

- multivariate linear regression,
- non-parametric statistics.

Class components (lecture, labs, etc.)
The course will be done on the board (for the most theoretical part) or from projected slides when it will be necessary, for example, to present an application made from the R software.

There are 35 hours scheduled for this course, including 2 hours for the final exam, about 15 hours of TP/TD (can be modulated) and 18 hours of classes.

Grading
The course consists of two evaluations: a homework assignment (DM) to be written in pairs to be returned halfway through the course (the date will be specified during the first class)a 2-hour final exam (EX) covering the entire course. The score of this course will then be the average of the scores of the two previous evaluations (DM+EX)/2, rounded to the nearest half point. Failing students can re-take the exam in a second session EX2 in the same way as the first session exam EX. The course's score after the second session is the one of the exam EX2 (without the DM).

Course support, bibliography
The 1st year course material of Statistics and learning written by Paul-Henry Cournède

Resources
At the end of each course, TDs or TPs exercises will be proposed to familiarize themselves with the theoretical concepts seen in class and put them into practice to answer concrete problems, possibly based on data sets.

Learning outcomes covered on the course

- Use of parametric and non-parametric statistical estimation techniques
- Validate a model and understand the limits of a statistical model
- Propose, implement and calibrate a predictive model
- Use the R software and interpret results

Description of the skills acquired at the end of the course

- Use of parametric and non-parametric statistical estimation techniques
- Validate a model and understand the limits of a statistical model
- Propose, implement and calibrate a predictive model
- Use the R software and interpret results

2EL1760 – Scientific calculation

Instructors: Hachmi BEN DHIA
Department: MATHÉMATIQUES
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

The course is both a rigorous and applied brick, contributing to the design of complex mechanical systems through modeling, mathematical analysis, approximation and controlled simulations of engineering problems in solids and fluid mechanics. This covers sectors such as Energy, transportation and aerospace.

The educational goal is that students following this course gain a good understanding of the chain integrating modeling, mathematical analysis and simulation for the study of such complex systems, trough simplified still relevant of solid and fluid mechanics.

Quarter number

SG8

Prerequisites (in terms of CS courses)

Basic knowledge in Continuum Mechanics: CM Hypotheses-Classical Mechanical Fields for Solids and Fluids-basic governing equations and meaning of these equations-Basic notions of differentiation and integration-Basic notions on Hilbert spaces and weak formulations of PDEs-Basic notions on stability and prime notions on space and time approximation schemes for PDEs. Roughly speaking : a first year CS level of knowledge in Mathematics and Mechanics or a third University year in Applied Mathematics to Mechanics.

Syllabus

The course is composed of two successive parts of 5,5 x 3h, each.
1. Compressible fluid flows simulation :
- Flow models, discontinuous solutions, Entropy, Basic solvers, extensions
- Practical implementation

2. Modeling, mathematical analysis and controlled simulation in solid mechanics
-Derivation of linear elasticity equations: strong and weak forms
-Mathematical analysis of the primal weak problem. Vectoriel Finite element approximation. A priori error estimation
-Practical implementation and approximation of a singular problem (as mini-project)

Class components (lecture, labs, etc.)

Classical Lectures, Tutorial, Projects

Grading

Written exam, oral exam, ProjectEvaluation (first session) : Written exam (coef 2), Project (coef 1)Evaluation (second session) : Oral or written exam

Course support, bibliography

- Handout PDEs (first CS year) and Handouts for the two parts (Fluid and Solid) of the course (and references therein)
- Matlab, Scilab, Python...

Resources

Hachmi Ben Dhia (Professeur des Universités, CentraleSupélec), Laboratoire MSSMat et Fédération de Math CS

Frédérique Laurent-Nègre (Chercheur CNRS), Laboratoire EM2C et Fédération de Math CS

External Assistants (PW, Projects)

Computer Rooms

Learning outcomes covered on the course

Some Basic mathematical methods and tools for the analysis of continuous problems of Mechanics of solids and fluids

Some Numerical methods for approximating continuous problems (Finite Difference, Finite Volume and Finite Element)

Estimation of errors between continuous and approximate solution and mathematical control of convergence.

Analysis of engineering problems governed by Partial Differential Equations (PDEs)

Practice of numerical simulation, taking into account the mathematical properties of these PDEs
Initiation to the best fit choice of the numerical methods

Description of the skills acquired at the end of the course
Analysis of engineering problems governed by Partial Differential Equations (PDEs)
Practice of numerical simulation, taking into account the mathematical properties of these PDEs
Initiation to the best fit choice of the numerical methods

2EL1810 – Structural vibration and acoustics

Instructors: Pierre-Etienne GAUTIER
Department: MÉCANIQUE GÉNIE CIVIL
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : Yes

Description

Dynamic vibration and propagation phenomena in mechanics, play an essential part in many areas: geophysics, building resistance to wind and seismic events, stability and comfort of aeronautical and terrestrial vehicles.
Acoustic questions are also of significant importance e.g. in transportation problems both for internal comfort and external noise questions.
The aim of this course is to provide students with essential knowledge, methods and tools for the analysis and quantification of these phenomena in structural dynamics and acoustics.

Quarter number

SG6

Prerequisites (in terms of CS courses)

1EL5000 - Continuum mechanics

Syllabus

- Introduction to vibration: discrete Multi Degree of Freedom (MDOF) systems
- Beam Theory (Euler-Bernoulli) Application to beam dynamics and vibration
- Virtual Power Principle on 3D and beams applications
- Finite Elements for Dynamic problems- Dynamic response
- Dynamic response to random loads
- Hands-on session: FE modeling of a building under seismic and wind excitation
- Acoustics 1: equations and basic sources (monopoles, dipoles)
- Acoustics 2: Waveguides and applications
- Acoustics 3: Acoustic modes in bounded domains

- Wave propagation in infinite media (Soils, acoustics in presence of wind or temperature gradients)
- Paper analysis by groups of two students
- Final exam

Class components (lecture, labs, etc.)
S1 to S5: Lectures + tutorial classes
S6: Hands-on sessions: groups of 4
S7 to S10: Lectures + tutorial classes
S11: Paper analysis by groups of 2

Grading
2-hr written exam (coeff 0.7) + analysis of a scientific paper (coeff 0.3)

Course support, bibliography
Lecture notes +course slides

Resources
Instructor: Pierre-Etienne Gautier
Tutorial classes: 35 students
Software: Comsol Multiphysics or Finite element code

Learning outcomes covered on the course

At the end the students will be able to:

- model the dynamic behaviour of structures using a relevant model : (3D , beams,...)

-model the acoustic behaviour of an enclosure

-model vibroacoustic behaviour in simple cases

-know and model dynamical environmental effects (Wind , seism...)

-Implement the Finite Element Method for complex shapes and dynamical problems

-implement a low frequency strategy of solving such problems using a modal approach, both in time and frequency domains (for vibration, acoustic or simple vibro acoustic problems)

Description of the skills acquired at the end of the course

C1.2 Ability to model the dynamical behaviour r of a structure

C1.2 Ability to model enviromental external effects (Wind, seism)

C1.2 Ability to model acoustic and simple vibroacoustic problems

C1.3 Ability to solve vibration and acoustic problems in low frequency domain, using a modal approach, either in time or in frequency domain

2EL1820 – Life materials

Instructors: Elsa VENNAT
Department: MÉCANIQUE GÉNIE CIVIL
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : Yes

Description

This course focuses on multi-scale mechanical problems of living organisms. First, a few tools are set up to describe, model and solve a biomechanical problem: reminder of Continuous Media Mechanics, anisotropy, viscoelasticity, finite element method, homogenization. In a second step, these tools are used to characterize different living materials (bone, tooth, cells...) through digital and experimental work. Thus, a complete approach is carried out to characterize biological tissues in three phases.

- Bibliographical research
- Observations at different relevant scales: morphological characteristics, structural evolution (e. g. bone remodeling)
- Mechanical tests, finite element modeling and critical analysis

Quarter number

SG8

Prerequisites (in terms of CS courses)

1EL5000 - Mécanique des milieux continus

Syllabus

- Modeling the behaviour of materials:
  - Continuum Mechanics (recalls)
  - Anisotropy
  - Viscoelasticity
- Experimental and numerical approach:
  - Introduction to bibliographic research
  - (morphological and mechanical) characterization/modelling of tissues or cells in an experimental and numerical way

- Opening seminar with the participation of researchers working on "Biomechanics" in the broad sense

Class components (lecture, labs, etc.)
12h course ; 21h pratical work

Grading
Continuous control (50% of the mark) ; oral and/or report on practical work (50% of the mark)

Resources
Teacher : Elsa VENNAT
Softwares : Comsol Multiphysics, ImageJ (or FIJI)

Learning outcomes covered on the course

At the end of this course, the students will be able to, among other things:

describe the behaviour of biological tissues from experimental curves,
use the symmetries of its morphology to propose a simplified form for its rigidity matrix,
propose an experimental protocol to characterize a tissue in tension/compression and to analyse the results of such a test,
describe the tests to characterize the viscoelasticity of a tissue,
propose a rheological model to model the viscoelastic behaviour of a tissue,
conduct a bibliographic study,
characterize a porous biological tissue by image analysis using ImageJ software,
propose a finite element model of this porous medium to evaluate its Young's modulus or permeability

2EL1830 – Non-linear behavior of materials

Instructors: Véronique AUBIN
Department: MÉCANIQUE GÉNIE CIVIL
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : Yes

Description

The design of material structures and their optimization (in terms of service life, performance, cost) requires the ability to predict the response of the materials considered for this application under the stresses imposed during their service life (load, temperature, stress, humidity, etc.).

The objective of this course is to highlight the mechanical behaviour and durability of the main classes of materials under various loading conditions, to understand the physical basis of the micro-mechanisms involved, and to use relevant modelling for design, as part of numerical methods. The concepts are introduced as part of the mechanics of continuous media, and use concepts related to the Materials course.

Applications in transport, energy, electronic systems and civil engineering.

Quarter number

SG6

Prerequisites (in terms of CS courses)

1EL5000 Continuum mechanics or 1EL4000 Materials,
1CC3000 Model representations and analysis

Syllabus

1. Introduction, approach of modelling: Case study on a thermal-elasticity problem (recalls)
2. Anisotropic elasticity of composite materials: Introduction to composite materials (nature, interest using Ashby maps, manufacturing process). Anisotropic linear elasticity. Calculation of the properties of the equivalent homogeneous medium.

3. Homogenization of heterogenous materials: Homogenization scheme. Voigt and Reuss bounds.
4. Polymer and elastomer viscoelasticity: Introduction to polymers (nature, behavior with respect to temperature). Viscoelasticity. Time dependent behavior.
5. Mechanisms of plasticity in metallic alloys: Structure and defects of crystalline materials. Dislocations and Schmid factor. Hardening of alloys.
6. Elastoplasticity: Description of elastic domain changes. Strain decomposition. Incremental 3D elastoplasticity.
7. Case study: choice of a model. (On 2 given cases, analyze the problem, propose/create a model able to account for the physical mechanisms observed.)
8. Identification of constitutive laws: introduction to optimization (objective function, sensitivity, minimization)
9. Safety of structures - damage and fracture: introduction to concrete (nature and specificities in behavior and damage). Volume damage. Crack sustainability.
10. Case study (use of the various concepts of the course on a given application)
11. Case study(use of the various concepts of the course on a given application)
12. Final examination

Class components (lecture, labs, etc.)
- Sessions 1 to 6: lecture + directed study session
- Session 7: working session
- Sessions 8 and 9: lecture + directed study session
- Sessions 10 and 11: working session
- Session 12: final exam 2H

Grading
The final examination consists in one exam (70% of the grade) and a report on a case study (30% of the grade).
The final case study allows to evaluate learning outcomes #1, 4 and 5, whereas the exam gives the opportunity to evaluate learning outcomes #1, 2, 3 and 4. Every learning outcome is evaluated separately. A feed-back is given to the students on the skills they have developed.
As examination and case study report assess different skills, both will be required for remedial where applicable.

Course support, bibliography
No handout, but a list of books.
Chaboche and Lemaître, Mechanics of Materials, Dunod
Roesler, Harders, Baeker, Mechanical Behaviour of Engineering Materials,

Springer, 2007
Besson, Cailletaud, Chaboche, Forest, Non linear Mechanics of Materials, Hermès, 2001

Resources

- Teaching staff (instructor(s) names): Véronique Aubin, Camille Gandiolle, Jan Neggers
- Maximum enrollment (default 35 students): 70
- Software, number of licenses required: Matlab

Learning outcomes covered on the course

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

- analyse a material structure, list the loadings applied to it, explain the criteria to which it must respond (performance, economic, etc.).
- interpret the experimental mechanical behaviour of a given material from the physical mechanisms involved, discriminate between several possible interpretations.
- select, use and enrich a constitutive law suitable for the observed experimental behavior
- identify the parameters of this model from the experimental information. Have a critical analysis of the simulation results obtained.
- Persuade at the level of core values; to be clear about objectives and expected results. To apply rigour when it comes to assumptions and structured undertakings, and in doing so structure and problematise the ideas themselves. To make the added value known.

Description of the skills acquired at the end of the course

The first learning outcome allows to reach milestone 1 of skill C1.1. (Examine problems in their entirety and beyond their immediate parameters. Identify, formulate and analyse the scientific, economic and human dimensions of a problem)
Learning outcomes #2 and 3 allow to reach milestones 2 or 3 of skill C1.2. (Develop and use appropriate models, choosing the correct modelling scale and simplifying
assumptions when addressing a problem)
Learning outcome #4 allows to reach milestone 2B of skill C1.3 (Solve problems using approximation, simulation and experimentation)
Learning outcome #5 allows to reach milestone 1 of skill C7.1 (Persuade at core value level; to be clear about objectives and expected results. To apply rigour when it comes to assumptions and structured undertakings, and in doing so structure and problematise the ideas themselves. Highlight the added value)

2EL1840 – Advanced Mechanics for Civil Engineering: "Building on Mars"

Instructors: Brice BOSSAN
Department: MÉCANIQUE GÉNIE CIVIL
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : Yes

Description

The aim is to materialize a project for the construction of a village on Mars, and therefore to simultaneously exercise innovation and scientific skills, and also to work in project mode ...
Through this problematic posed by a constrained and different environment from that of the Earth, students develop their innovation capacities and acquire skills in Civil Engineering, Materials, Thermal, Construction & Logistics, and also Environmental...
As the tutorials are done in sub-groups, students acquire skills in teamwork, transdisciplinary project management, reporting and scientific communication during project reviews and the final defense.

Quarter number

SG6

Prerequisites (in terms of CS courses)

Syllabus

Session 1 (3h): launching lecture, constitution of the 4 project groups, commented bibliography in 4 groups of 25 students by their science and innovation facilitators.
Sessions 2 and 3 (4 times 1.5h): 4 thematic conferences followed by Q&A with students
Sessions 4, 6, 8, 10 (4 times 3 hours): tutorials in 4 groups of 25 students (working in parallel) with a science facilitator present and a presentation (conf-call) by the "innovation" facilitator for each group. The scientist then gives the theoretical and applied lessons that the students need to progress in their work.

Sessions 5, 7, 9 11 (4 times 3 hours): alternating with sessions 4, 6, 8 and 10, the project review (carried out in the lecture hall by the 4 rapporteurs of the 4 groups, with their scientific moderator) allows the 100 students to measure the progress of the work on all the themes, to make coherent choices and to record what they have learned, then to identify the locks to be lifted for the good continuation of the work they will do in TD, and in personal work.
Session 12: restitution of the work via a presentation in the lecture hall of the 4 groups of 25 as well as a synthesis of the solution by the 4 rapporteurs of the 4 groups. The evaluation of the students is done by the course leaders + the scientific and innovation facilitators.

Grading
The individual evaluation of the students is done "continuously" by the Scientist during the TD/TP, that of the group is done during Session 12.

Course support, bibliography

Resources
Teaching staff: B.Bossan is responsible for the organization of the elective. Each theme is piloted by a "Scientist+Innovator" pair. The launching lecture (Session 1) is proposed by a recognized personality.
Size of the TDs: 4 groups of 25 students

2EL1850 – Simulation of multiphysic couplings with FEM

Instructors: Andrea BARBARULO
Department: MÉCANIQUE GÉNIE CIVIL
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

The aim of this class is to give theoretical and applied insights on multi-physic coupling simulations such as : thermomechanical, piezoelectric, vibro-acoustic, magneto-mechanic.

Quarter number

SG8

Prerequisites (in terms of CS courses)

Partial Differential Equations
1EL1000 - Electromagnetism or 1EL4000 - Materials or 1EL5000 - Continuum mechanics or 1EL7000 - Introduction to mass, momentum and heat transfer

Syllabus

- S1-S2 Variational formulation and 1D FEM (Project: Beam with thermo-mechanical coupling)
- S3-S4 2D FEM (Project: Heated room with open window (Weak coupling Thermic and Fluid Mechanics))
- S5 Multiphysic coupling techniques (Application: Thermal micro-actuator)
- S6-S7 Model error estimation (Project: Project: Heated room with open window (Error estimation))
- S8-S9 Time and frequency dependent problems (Project: Electromagnetic compatibility in a room (Electromagnetic wave dynamic and Transmission liner))
- S10-S11 Hands-on session: MEMS design and performance analysis (Stent, Accelerometer, Energy harvester…)
- S12 Final exam

Class components (lecture, labs, etc.)
S1 to S9 : lecture 1h30 + numerical projet on Comsol 1h30
S10 to S11 : Hands-on sessions: MEMS design in groups of 4

Grading
2-hr written exam (1 theory + 1 on simulation tool): 65% of the final score
Project evaluation: 35% of the final score

Resources
Instructors: Andrea BARBARULO, Guillaume PUEL
Tutorial classes: 25 students
Software: Comsol Multiphysics (Structural mechanics, MEMS)

Learning outcomes covered on the course

- Solve and model a multi-physic problem including solid mechanic, thermic, fluid mechanic, electricity and magnetism
- Design of sensor and actuators thanks to the use of different and coupled physics and technologies
- Model and solve a multi-physic problem with a commercial finite element code with a specific attention to solution accuracy.

2EL1860 – Building the city - town planning, architecture and engineering

Instructors: François COINTE, Frédérique DELMAS-JAUBERT
Department: MÉCANIQUE GÉNIE CIVIL
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : No

Description

Raise awareness among students about the problems of building the city: what do we build and for whom?

- To master the fundamental concepts and role plays of the construction through case studies, as well as the tools of the engineering at the service of the act of building and to make want to deepen in more detailed courses
- Introduce them to the diversity of trades necessary for the act of building
- Make them aware of the scientific and technical barriers that limit value creation

Quarter number

SG8

Prerequisites (in terms of CS courses)

none

Syllabus

1. introduction and definitions:
   - Architecture and engineering
   - Public buildings
   - Office buildings
   - Housing
   - Public spaces
   - Networks and urban engineering
   - Civil engineering works
2. a history of Paris and Greater Paris

3. Case study: in a given territory, identify each structure and all its actors: financier, decision-maker, architect and designers, constructor, operator
4. development financing : Housewares and Developer
5. Grand Paris express, past and future : the new automatic metro around Paris

6. Architecture, a way to improve the territory
7. smart city and big data : who are the makers of smart city ?
What kind of data ?
What king of regulation ?

8. People need to move : the territory is made of cities

Class components (lecture, labs, etc.)
Lessons + in situ lessons (visits)

Grading
Students are graded on a case study carried out mainly in tutorials, including assessment of attendance and participation in tutorial sessions.
Breakdown of the score out of 20:
- historical and analytical study of a territory, score by group out of 8
- study of one of the buildings (rather contemporary) in this area, individually, individual score out of 8
- attendance and individual participation in supervised tutorial sessions, individual score out of 4

Course support, bibliography
Institut Paris Région https://www.institutparisregion.fr/documents-historiques-de-reference.html
APUR–Atelier Parisien d'URbanisme https://www.apur.org/fr
Pavillon de l'arsenal–espace d'exposition de la Ville de Paris sur l'architecture et la ville https://www.pavillon-arsenal.com/
Cité de l'architecture et du patrimoine https://www.citedelarchitecture.fr/f

Resources
Team : François Cointe, Ulisse Vizzardi, Didier Lourdin, Olivier Ledru, Frédérique Delmas Jaubert

Learning outcomes covered on the course
At the end of this lesson, the student will be able to:

- Know and understand the main paradigms of the construction of the city

- Identify the economic and non-economic stakeholders of a construction project and its challenges
- Distinguish the principals, funders, designers, builders, and operators
- Know and understand the associated value chains of real estate, construction and urban services
- Compare the positions of the main companies in the sector and their innovation logic

2EL1910 – Fundamental laws of the Universe: particle and gravitation physics

Instructors: Jean-Marc LE GOFF, Nathalie BESSON
Department: PHYSIQUE
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : No

Description

This course is an introduction to the four fundamental interactions: particle physics on the one hand and gravitational physics and cosmology on the other, from both theoretical and experimental points of view.

Quarter number

SG8

Prerequisites (in terms of CS courses)

None

Syllabus

A. Particle physics

A.1 Historical introduction to elementary particles
A.2 Special relativity and relativistic dynamics
A.3 Fundamental Interactions
A.4 Standard model of particle physics

B. Gravitation

B.1 General relativity: principle of equivalence, equation of motion, Einstein equation
B.2 Schwarzschild geometry: massive particle orbits, photon orbits
B.3 Black holes: horizon, Kruskal-Szekeres coordinates, astrophysical black holes

B.4 Cosmology: geometry and expansion of the Universe, thermal history, structure formation (CMB), dark matter, dark energy

Class components (lecture, labs, etc.)
Nine one-and-a-half-hour classes in reverse class on particle physics and nine one-and-a-half-hour classes in reverse class on gravitation and cosmology. Six hours of TD for final exam preparation.

Grading
Final exam [70% of the grade], continuous examination [30% of the grade]

Course support, bibliography
Videos, course slides, written materials and also bibliographical references distributed during the course.

Resources
Reverse class teaching. At home videos, slides, and written materials. Face-to-face, summary of the course, question-and-answer session, and finally exercises that count as continuous assessment.

Learning outcomes covered on the course
- get familiar with concepts of elementary particle and fundamental symmetry
- master the concepts of spacetime and quadrivector
- identify the relevant inertial referentials in a problem and control Lorentz transformations.
- Understand the difference between conservation and invariance and how to apply energy-momentum conservation in space-time.
- master the basics of tensor algebra with Einstein's notations
- calculate relativistic corrections for the Global Positioning System
- analyse what happens near a black hole using the Kruskal diagram

Description of the skills acquired at the end of the course
1. C1.2 - milestone 1 Know how to use a model presented in the lecture in a relevant way
2. C1.3 - Milestone 1B Solve a problem with approximation practice

2EL1920 – Quantum and Statistical Physics (part II)

Instructors: Jean-Michel GILLET
Department: PHYSIQUE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

This course is both the continuity of the first year course and its complement.
It allows us to come back to certain aspects which, due to lack of time, have been covered too superficially for an effective use and to improve the understanding of a selection of basic concepts. It will be an opportunity to discuss the statistical physics of open systems (grand-canonical ensembles) and quantum statistics (bosons and fermions). Links will be established with the basis of Hamiltonian (and Lagrangian) mechanics. The course also aims to offer an extension to the quantum physics of atoms and molecules.

Quarter number

SG6

Prerequisites (in terms of CS courses)

Prerequisite is:
The first year course on Quantum and Statistical Physics

Syllabus

We will discuss a selection of topics among which (non-contractual):
Basics of Lagrangian and Hamiltonian mechanics
Complements on the quantum harmonic oscillator
Complements on kinetic moment
Statistical physics of open systems
Quantum statistics
fermions
bosons
Fine and hyperfine structure of the atom
Variational theorem
The N-electron atom
Structure and properties of the atomic nucleus

Class components (lecture, labs, etc.)
Lectures, exercises, reading and computer project
8 lectures
2 seminars (3h chacun).
10 exercices/projects

Grading
The evaluation is done by means of 3 components: - Periodic tests (2 quiz-MCQ) of about 15 minutes max done during TD sessions and corrected by an automated system for quick results and better monitoring of student progress. - The grading system includes the quality of the interaction and engagement (while solving the exercises, answering oral questions during tutorials, lectures, numerical simulations) - A written test (2h max) whose questions relate potentially to the entire program and which allows in particular to evaluate the knowledge, the mastery of the methods set out above and the associated skills. The tests and project will be 30 % of the final grade. In case of a justified absence to one of the intermediary examinations, the grade of this latter is replaced by the grade of the final examination.

Course support, bibliography
The textbook is “Application-Driven Quantum and Statistical Physics” (Vol. 1 et 2, World Scientific). Additional handout may be given.

Resources
Teaching staff (instructor(s) names): C. Paillard, G. Schehr, T. Antoni, M. Ayouz, E. Klein, J-M Gillet
· Maximum enrollment (default 35 students): 90
· Software, number of licenses required: Python
· Equipment-specific classrooms (specify the department and room capacity): small amphitheater for lectures, 3 rooms for tutorials

Learning outcomes covered on the course
At the end of the course, a student will be able to :
- justify the structure of the first rows of the periodic table aswell as the bonding mechanisms.
- decide the need for a quantum approach to temperature-dependent problems.
- differentiate a fermionic behavior from that adopted by bosons. He can then justify different components involved in response functions, such as specific heat, especially at low temperatures.

- propose a method of quantum modeling for some important properties of an ideal molecular gas but will know ways to take into account certain interactions.
- identify the key elements at the origin of the nuclear properties and to offer a simple modeling.

Description of the skills acquired at the end of the course

The skills targeted are
C1.2 (milestone 1 or 2): Study a problem as a whole, the situation as a whole. Identify, formulate and analyse a problem in its scientific, economic and human dimensions
and C1.3 (milestone 1): Solve the problem with approximation, simulation and experimentation

2EL2010 – Understanding, optimization and simulation of biotechnological processes

Instructors: Filipa LOPES
Department: PROCÉDÉS
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : Yes

Description

Biotechnology is defined as "the application of science and technology to the transformation of materials by biological agents and enzymes to produce goods and services". Its fields of application are very broad and include many industrial applications, particularly in the health, food, waste treatment, energy production, cosmetics or pharmaceuticals sectors. Biotechnological processes are undergoing very strong development and recruitment.
The overall objective of course is to introduce the modern approaches to bioprocess engineering necessary to understand, improve, optimize and design innovative, competitive and more environmentally friendly bioprocesses.
In this context, the bioprocess and its different stages (from the choice of the microorganism to the recovery of products of interest and including the bioreactor) will be addressed by a multi-scale (from the cell to the bioreactor) and multidisciplinary approach at the interfaces, guided by simulation and optimization tools. This course is located between transfer sciences, process engineering, physics and life sciences. The concepts covered in this course will be used for some other courses of the dominant (Life science, health and Environment, Energy,...) as well as in support of some Project Poles (Biotechnology and Health, Energy,...).

Quarter number

SG6

Prerequisites (in terms of CS courses)

Transport Phenomena (1A)

Syllabus

Microbiology :
- The cell;
- Microbial metabolism and its regulation.

Principles of bioprocess engineering:
- The bioreactor;
- The implementation of a bioprocess;
- Studies of emblematic examples: methanisation, alcoholic fermentation, microalgae, activated sludge, etc.
- Operating modes;
- Mass transfer within the bioreactor.

Multi-scale modeling of the bioprocess:
- Macroscopic modeling ;
- Metabolic modeling ;
- Ownership of mass balance models;
- Calibration and validation of models.

Introduction to Life Cycle Assessment.

Processes for the separation and purification of molecules of interest: overview of techniques used in biorefinery, comparison and coupling of processes, reasoned choice guide and case studies.

Class components (lecture, labs, etc.)
The general principles will be discussed and illustrated with examples and industrial applications in lectures and tutorials. Students will therefore apply the knowledge acquired on practical engineering cases. In parallel, the students, gathered in teams, will develop a project whose aim is to propose a bioprocess scheme for a given industrial application. In this context, a practical work on bioprocess modelling will be carried out.

Grading
Final control (written) (65%) and oral presentation of the project by the team (35%).

Course support, bibliography
Presentations of the speakers and books (Madigan, M. (2007). Brock Biology of microorganisms; Doran, P. M. (1995). Bioprocess engineering principles. Academic press,...).

Resources
Teaching team (names of the teachers of the lectures): Filipa Lopes (Process Dep.), Julien Lemaire (Process Dep.) and Olivier Bernard (Biocore team, Inria).

Learning outcomes covered on the course
By the end of this course, the student will be able to:

- Explain the basics of living organisms functioning.
- Identify the phenomena (chemical, physical and biological) that occur within the bioreactor.
- Write the reaction network characterizing the main mass flows within the bioreactor, and adapted to the objectives of the model.
- Identify the mathematical expressions of the reaction kinetics associated with the reaction network.
- Study the main properties of dynamic bioreactor models (positivity of variables, boundarity, equilibrium, local stability).
- Calibrate a bioreactor model from experimental data.
- Explain the principle of operation of different downstream processes usually used in biotechnology, identify their applications and estimate their advantages and disadvantages.
- Propose the most appropriate techniques or design combinations in order to respond to a problem with technical, economic and environmental components.
- Sizing and estimating the performance of membrane processes based on mass balances and the modelling of transfer kinetics.
- Propose a bioprocess scheme for a given application.

Description of the skills acquired at the end of the course
- C1.1 : Examine problems in their entirety and beyond their immediate parameters. Identify,formulate and analyse the scientific, economic and human dimensions of a problem Milestone 1
- C1.2,: Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when addressing a problem Milestone 1
- C 1.3,: Apply problem-solving through approximation, simulation and experimentation. / Solve problems using approximation, simulation and experimentation Milestone 2B
- C3.7,: Make pragmatic and informed choices with the aim of producing tangible results. Milestone 1
- C7.1 : Persuade at core value level; to be clear about objectives and expected results. To apply rigour when it comes to assumptions and structured undertakings, and in doing so structure and problematise the ideas themselves. Highlight the added value, Milestone 1

2EL2020 – Physics of divided matter

Instructors: Hervé DUVAL
Department: PROCÉDÉS
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : Yes

Description

"God made solids, but surfaces were the work of the devil" (Wolfgang Pauli)
The behavior of dispersed media such as bubbles, drops, liquid films or colloids is strongly influenced by capillary and surface forces. Correlatively, body forces such as gravity play a secondary role. The present course focuses on dispersed systems with characteristic size ranging from 1 mm down to 10 nm.
These systems can be found everywhere around us. Applications concern biology (super-hydrophobic leaves, surfactant film in lungs, cavitation bubble made by a pistol shrimp), environmental science (dynamics of raindrops and their role in the biosphere, sediment siltation in estuaries), technology (fabrication of cosmetic and pharmaceutical emulsions, food industry, fire-fighting or insulating foams, surface treatments, lab-on-a-chip) and daily life (tears of wine, rising humidity and deterioration of houses and historical stone monuments). Numerous industrial innovations are based on the implementation and control of these systems.
The present course introduces the basic concepts of the physics of surfaces and addresses various interfacial phenomena encountered in dispersed systems: capillarity and wetting, colloidal interactions and Brownian motion, interface dynamics and associated instabilities. The role of interfacial energy in phase transformations (nucleation step) will be also discussed.

Quarter number

SG8

Prerequisites (in terms of CS courses)

Transport phenomena (recommended)

Syllabus

The course is divided into three parts: 12 hours of **lectures and related tutorials**, 12 hours devoted to **case studies**, 11 hours dedicated to the realization of a **miniproject**.

Basic concepts (4 x (1.5h lecture + 1.5h tutorials))

1) Notion of surface tension
   Physical origin
   The thermodynamic and mechanical points of view
   Capillarity: Laplace's law
   Interfaces and boundary conditions of the Navier-Stokes equations
   Area minimisation and minimum surfaces
   Tutorial #1: Liquid menisci, capillary forces, wet hair and insects on water

2) Wetting
   Ideal solid surfaces: Young-Dupré's law
   Contact angle hysteresis
   Influence of surface roughness
   Influence of chemical heterogeneities
   Towards superhydrophobic surfaces
   Contact line dynamics
   Tutorial #2: Modeling equilibrium contact angles on textured surfaces

3) Surfactants: equilibrium and dynamics
   Amphiphilic molecules
   Surface concentration and Gibbs adsorption equation
   Micelles and critical micellar concentration
   Dynamic surface tension and dynamics of surfactants
   Interfacial rheology
   Tutorial #3: Formation and drainage of a soap film

4) Colloidal scale
   Colloids and colloidal systems
   Brownian movement and Brownian limit
   Interaction forces between surfaces: van der Waals force, osmotic pressure effects
   DLVO Theory - Why do estuaries silt up?
   Thin liquid films and disjunction pressure
   Tutorial #4: Evaporation in a microchannel

Case studies (4 x 3h)

Each case study offers the opportunity to examine physical phenomena of industrial or practical interest, to apply the concepts introduced in the lectures and to become familiar with state of the art modelling methods and mathematical tools. The case studies are carried out by groups of 3 to 4 students and supervised by a teacher. The duration of 3 hours per study allows each group to get to grips with the subject and to work on its own, with the methodological support of its supervisor. At the end of the 3 hours, each group reports its work in a note (handwritten or by word processing, as desired).

5) Capillary rise and imbibition
From raw sap rising in trees to the manufacture of composite materials
Equilibrium height in a vertical tube
Dynamics of capillary rise: inertial and viscous regimes
Capillary rise in a corner

6) Drainage and deposition of liquid films on a vertical flat plate
From anti-corrosion coatings on steel sheets to anti-reflective coatings on eyeglass lenses
Drainage of a liquid film
Dip coating
Scaling
Landau-Levich-Derjaguin theory: dynamic meniscus and asymptotic matching

7) Drop spreading
Coatings, inkjet printing and criminal investigations
Dynamic contact angle and contact line speed
Case of the perfect wetting: Tanner's Law
Influence of impact velocity on the maximum spreading diameter
The different impact regimes

8) Fragmentation of a film or jet into drops
Water jet, dew and microfluidic drop generation
Surface waves
Rayleigh-Plateau instability
Dripping / jetting transition

Miniproject (9h+2h)

The mini-project is carried out in groups of 3 to 4 students. Each miniproject is part of a theme (related to the physics of divided matter) and focuses on a specific phenomenon, system or object. The student apply and deepen the various concepts previously discussed in class but also explore other aspects of the physics of divided matter. As an example, for the academic year 2019-2020, the themes chosen by the students were: emulsions, foams and calefaction. Starting from the selected theme, each group has to

- address an issue (for example: the creaming of emulsions, the Leidenfrost effect during the quenching of workpieces, the comparative stability of Champagne foam and beer foam),
- carry out and present a “kitchen experiment” to illustrate the theme and/or the problem
- identify the physical mechanisms involved in the focused problem
- optionally: design an experiment to investigate the problem, carry out a test campaign, analyze the experimental results and propose a simple model that accounts for the results OR develop a more complex model, implement it on the computer, run a parametric study and discuss the results.

The deliverables are :
- A ppt file that reports on the work done (the support of the oral presentation + appendices detailing the experiments, calculations, list of bibliographical references)
- A 20 min oral presentation with a demonstration of the code or a movie of the running experimental set-up, followed by 20 min of questions (duration adjusted for the number of groups)

Class components (lecture, labs, etc.)

The course is divided into three parts (see Contents for more details): 12 hours of lectures and related tutorials, 12 hours devoted to case studies, 11 hours dedicated to the realization of a miniproject.

Grading

Continuous assessment (mark out of 6, based on the notes delivered after each case study) + Course project (mark out of 14, based on ppt file + oral presentation + answers to questions)

Course support, bibliography

- Provided course material: lecture slides, problem statements and solutions
- References:

- P.G. de Gennes, F. Brochard-Wyart and D. Quéré, Capillarity and Wetting Phenomena: Drops, Bubbles, Pearls, Waves, Springer, New York, 2004.
- J. Israelachvili, Intermolecular and surface forces, Academic Press, Elsevier, 3rd edition, 2011.
- E. Guyon, J.P. Hulin, L. Petit, Hydrodynamique physique, EDP Sciences, 3ème édition, 2012.

Resources

- Teaching staff (instructor(s) names): Hervé Duval, Marie-Laurence Giorgi, Jacopo Seiwert
- Maximum enrollment (default 35 student): 35
- Software, number of licenses: ImageJ (open source), python and the libraries scipy, matplotlib and numpy (open source)
- Equipment - specific classrooms (specify the department and room capacity): none

Learning outcomes covered on the course

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

1. List and explain the mechanisms and physical phenomena involved in the most common dispersed systems, from industry or daily life;
2. Define and calculate the associated characteristic length- and time scale;
3. Interpret the dynamic behaviour of any dispersed system;
4. Construct a model that captures the essence of the physical phenemona that take place in a dispersed system
5. Propose an experimental setp-up/protocol to validate this model

Description of the skills acquired at the end of the course

C1.1 : Examine problems in their entirety and beyond their immediate parameters. Identify, formulate and analyse the scientific, economic and human dimensions of a problem, milestone 1: learning outcomes 1 and 3
C1.2 : Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when addressing a problem milestone 2: learning outcomes 1-4
C2.1: Thoroughly master a domain or discipline based on the fundamental sciences or the engineering sciences. all learning outcomes
C1.3 : Solve problems using approximation, simulation and experimentation, milestones 1A and 1B: learning outcomes 2

2EL2030 – Genomics and synthetic biology in health and industrial biotechnology

Instructors: Behnam TAIDI
Department: PROCÉDÉS
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : No

Description

The recent advent of high-throughput molecular biology techniques and the in-depth understanding of genetics based on advances in sequencing methods have overwhelmed medical and industrial biotechnology. In addition, synthetic biology (where novel biological and biologically based parts, devices and systems are (re)designed and constructed to perform new functions that do not exist in nature) has opened up a whole new field of opportunities where the engineers interact with biologists, chemists and computer scientists to conceive and make diagnostic and therapeutic devices.
A course is provided for the students to immerse themselves in the universe of genetics and synthetic biology where the latest concepts and industrial applications are unveiled and discussed.
The aim of this course is to teach the future engineer the structure, functioning and regulation of the genome and how this can be related to industrial and medical applications. In addition, by learning the nature of analogue signals and digital genetic data, the engineer will be able to choose the most pertinent methods for data processing and interpretation. This will transform the pool of information into informative knowledge that could be used for the provision of new products and services.
Thus, at the end of the course, students will have a strategic vision on how to progress in the field of genomics and synthetic biology: from the exploration of unprecedented data accumulation to the extraction of innovative knowledge and the transformation of the data into new rational and useful knowledge.

Quarter number

SG6

Prerequisites (in terms of CS courses)

None

Syllabus
The syllabus consists of four modules; two of these are common foundation courses that pave the way for the subsequent two modules that focus on the application of synthetic biology to human health and the industrial biotechnology business.

Introduction: Genome structure and regulation, cloning techniques, Synthetic Biology

Genomic analyses by high-throughput methods: From genomic DNA to RNA

Human health applications: Modifying and reprogramming the genome as a basis for gene and cellular therapy, based on stem cells and induced pluripotent stem cells (IPSC).

Industrial-Biotechnology applications: Engineering the genome, the cellular chassis, allocation of resources, circuits engineering, metabolic engineering, the role of computer aided design in synthetic biology and metabolic engineering, introduction to iGEM

Class components (lecture, labs, etc.)
The course module is organized in lectures, to introduce knowledge and methodological tools

Grading
Homework: an individual ten-minute presentation on a biological topic will be requested (20% of the overall grade); these oral presentations take place during the class sessions.2-hr final written exam (no documents and no computer allowed), (80% of the overall grade)

Course support, bibliography
Course slides available online

Resources
- Teaching staff (instructor(s) names): Diana LE ROUX (CEA), Jean Loup FAULON (INRA), Ioana POPESCU (University of Evry-val-d'Essonne), Matthieu JULES (AgroParisTech)
- Maximum enrollment (default 35 students): 35
- Software, number of licenses required: Knime analytics platform (open source)
- Equipment-specific classrooms : Computer room equipped with desktop (Linux or Windows OS) for a 4 hour module

Learning outcomes covered on the course
On completion of the course, students should be able to:

- aware of technical tools and developments that enable to better understand how genomes are structured and have a control action
- understand the contributions of genomes to one's identity and understand the general principles that drive physiologic and pathologic immune evolution
- appreciate how genomic information can be used for developing improved therapeutics
- learn about the current status of stem cells and the new therapeutic developments
- have a strategic vision of the way to get ahead in the field of genomics: from data mining to the extraction of innovative knowledge

Description of the skills acquired at the end of the course
C1.1. : Examine problems in their entirety and beyond their immediate parameters. Identify, formulate and analyse the scientific, economic and human dimensions of a problem Milestone 1
C1.2. : Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when addressing a problem Milestone 1
C1.4. : Design, detail and corroborate a whole or part of a complex system. Milestone 1

2EL2040 – Chemical Engineering: application to environment and sustainable production

Instructors: François PUEL
Department: PROCÉDÉS
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : No

Description

Process Engineering consists in **designing, operating and optimizing environmentally friendly processes** for **the development of various products and services** in many traditional and high-tech sectors (agri-food, biotechnology, cosmetics, fine chemicals, materials, oil, pharmaceuticals, water and waste treatment, etc.) and **for the production** of traditional (nuclear, thermal, etc.) and renewable **energies**. Its methodologies are widely used to ensure the **recycling and recovery** of many products and the **purification** of liquid and gaseous effluents, thus becoming a key tool in the global sustainable development strategy. The challenges associated with this environmental dynamic are multiple: reduction of energy and raw material consumption, costs, waste, risks and dangers. Process intensification turns out to be the major lever to address them.
Bioprocesses have developed very strongly in the last decades for two reasons: (i) the use of living organisms, acting as processing plants, to transform matter, purify polluted systems (liquid, solid), (ii) the use of biomass to replace fossil resources, which requires taking into account the specificities of this raw material.
This course is an introduction to Chemical and BioChemical process Engineering and its methodologies, allowing students to acquire general tools that can be easily transposed to multiple fields. It is fully in support of the current environment, energy and health challenges.

Quarter number

SG8

Prerequisites (in terms of CS courses)

None

Syllabus

1. Introduction to Process Engineering for Sustainable Development; steady state material balance

Case study: Process for the production of 1st generation bioethanol (*conversion of renewable raw materials by white biotechnologies*)

2. Flow models (perfectly agitated and plug flow)

Case study:

Valorization of Whey (*Valorization of residues from the food industry by white biotechnology*)

Dimensioning of biological treatment tank basin of an urban wastewater treatment plant (*process in the service of the environment, reduction of reactor volumes and groundwater footprint*)

3. Thermal balances: calorific / enthalpic

Case study: Dimensioning of a backer yeast production reactor in batch mode (*optimisation of the reactor geometry and its thermal regulation*)

4. Liquid-vapor balances equilibria, single and multi-stage distillation

Case study: Flash distillation flash of ethanol/water mixture ; Multistage distillation of bioethanol (*alternative to fossil fuels*)

5. Mass Transfer: Diffusion & Convection

Case study: Production in raceway of Spirulina Mocroalgae (*sustainable production of nutrient for food and feed*)

6. Mass Transfer: Permanent Contact Technologies

Case study:

Treatment of a gaseous effluent. Removal of a pollutant (*environmental process*)

Biogas purification for biomethane production by membrane technology (*production of a renewable energy carrier for conventional uses*)

Class components (lecture, labs, etc.)

The course module is organized in lectures -16.5h), to introduce knowledge and methodological tools, which will be then applied through case studies(16.5h).

Grading

Homework: Presentation, by group, of a bibliographic project whose topic is an extension of the course (40% of the grade); these oral presentations take place during the last class session.Individual final written exam: 2-hour case study (60% of the grade).

Course support, bibliography

- **Slideshows**

• Techniques de l'ingénieur :
+ Charpentier J., Génie des procédés, développement durable et innovation – Enjeux et perspectives, 2013
+ Moulin J.P., Pareau D., Rakib M., Stambouli M., Transfert de matière – Méthodologie, 2000
+ Moulin J.P., Pareau D., Rakib M., Stambouli M., Isambert A., Transfert de matière – Distillation compartimentée idéale, 2001
+ Moulin J.P., Pareau D., Rakib M., Stambouli M., Transfert de matière- Autres opérations compartimentées, 2002
+ Buch A., Rakib M., Stambouli M., Transfert de matière- Cinétique du transfert de matière entre deux phases, 2008
+ Sun L.M., Thonnelier J.Y., Perméation gazeuse, 2004
+ Vuillermaux J., Réacteurs chimiques – Principes, 1994
+ Boulinguiez B., Le Cloirec P., Purification de biogaz – Élimination des COV et des siloxanes, 2011

• General Books: Perry Chemical Engineer's Handbook, 8th edition, 2007, McGraw-Hill, New York

• Specific books:
- *Reactor and bioreactor engineering*
+ Coulson and Richardson’s Chemical Engineering – Volume 3A: Chemical and Biochemical Reactors and Reaction Engineering, 4th Edition, 2017, Elsevier. Oxford
+ Fogler H.S., Elements of chemical reaction engineering, 5th Edition, 2016, Pearson Education, Englewood Cliffs
+ Levenspiel O., Chemical Reaction Engineering, 3rd edition, 1999, John Wiley and Sons, New York
+ Villadsen J., Nielsen J., Lidén G., Bioreaction Engineering Principles, 3rd Edition, 2011, Springer, New York
- *Heat and mass transfer*
+ Bergman T.L., Lavine A.S., Incropera F.P., Dewitt F., Fundamentals of Heat and Mass Transfer, 7th Edition, 2011, John Wiley and Sons, New York
+ Coulson and Richardson’s Chemical Engineering – Volume 1B: Heat and Mass Transfer: Fundamentals and Application, 7th Edition, 2018, Elsevier, Oxford
+ Cussler E.L., Diffusion Mass Transfer in Fluid systems, 3rd Edition, 2009, Cambridge University Press, Cambridge
+ Treybal R., Mass Transfer Operations, 4th Edition, 1982, McGraw Hill, New York
- *Bioethanol production*
+ Cardona C.A., Sanchez O.J., Gutierrez L.F, Process synthesis for fuel ethanol production, 2010, CRC Press, Boca Raton
+ Naik S.N., Goud V.V., Rout P.K., Dalai A.K, Production of first and second generation biofuels: A comprehensive review, Renewable and Sustainable Energy Reviews 14, 2010, 578–597

+ Vohra M., Manwar J., Manmode R., Padgilwar S., Patil S. Bioethanol production: Feedstock and current technologies, Journal of Environmental Chemical Engineering 2, 2014, 573–584

Resources

Teaching staff (instructor(s) names):Francois PUEL / Victor POZZOBON / Cristian PUENTES
Maximum enrolment (default 35 students): 60
Software, number of licenses required: Excel, Python
Equipment-specific classrooms (specify the department and room capacity): None

Learning outcomes covered on the course

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

- List the type of mass transfer and its coupling to heat transfer,
- Identify the different mass transfer mechanisms (diffusion / convection) working in a given configuration and the potential coupling between heat and mass transfer,
- Write mass balances, taking into account, if necessary, chemical or biochemical reaction kinetics,
- Simplify a seemingly complicated problem, where several transfer phenomena coexist, by taking into account only the main ones,
- Formalize phenomena into equations through elemental balances,
- Design conversion and separation technologies based on thermodynamic and kinetic considerations.

Description of the skills acquired at the end of the course

- C1.1. : Examine problems in their entirety and beyond their immediate parameters. Identify, formulate and analyse the scientific, economic and human dimensions of a problem **Milestone 1**
- C1.2. : Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when addressing a problem **Milestone 1**
- C1.3. : Solve problems using approximation, simulation and experimentation **Milestone 1B**
- C7.1. : Persuade at core value level; to be clear about objectives and expected results. To apply rigour when it comes to assumptions and structured undertakings, and in doing so structure and problematise the ideas themselves. Highlight the added value **Milestone 1**

2EL2120 – Design Science

Instructors: Bernard YANNOU
Department: SCIENCES ENTREPRISE
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Business Sciences
Advanced level : No

Description

This course allows to understand the major concepts of Design Science and Engineering, and to practically experiment the design of products, services and business models on various examples. The design examples are, among others: launch of a brand new hotel chain, design of a corner kitchen bench, of a commercial airplane, of a smartphone for more inclusiveness, perceptual and emotional design of a wine glass, service design in the context of a classy restaurant or an hostel reception, design a carpool service, business model of a travel agency.
The lecture is reduced to 1 hour out of 3 per session, in order to leave room for rich and varied contexts of experimentation (case studies during exercises, practice of design platforms, debates, regular funny kahoot quizz, and final poster session). One debate is organized by students themselves with 4 invited design managers.

Quarter number

SG6

Prerequisites (in terms of CS courses)

no prerequisite

Syllabus

The 11 course sessions cover a variety of design topics.

1. Introduction

This session introduces the activity of designing from a historical perspective, the vocabulary and stakes of design, the design communities and the convictions of a group of academics that design is a scientific discipline. “What is design? What can be designed? Why is it a science?” are the questions addressed by the lecture and debated by the students.

2. Design process

The interest of describing design processes is illustrated. Prescribing a design process is done with the underlying idea that it is likely to have a good design outcome when a quality design process has been conducted. Four types of prescribed design processes are presented. First, some generic and simple models are described such as Design Thinking, double-diamond and Radical Innovation Design. Second, some Engineering Design (ED) models, well adapted to design complex engineering systems, are presented. Third, New Product Development (NPD) models like the Stage-Gate® model of Cooper are presented in the context of large industrial and business projects where market analysis, innovation strategy and project management are important. Finally, it is shown that large companies are generally adopting a fourth approach that of hybridizing the ED and NPD approaches, with the use of Design Thinking in the system innovation part.

3. Capturing and expressing the need - Part I: conventional requirements engineering

Design requirements describe the characteristics that a product must have to meet the needs of the stakeholders. They are made of functional requirements (service functions) and non-functional requirements (quality attributes and constraints).

4. Capturing and expressing the need - Part II: non-conventional requirements engineering

Non-conventional requirements engineering techniques are evoked: Use case, user story, emotional engineering, perceptual design, opinion mining. They constitute a wide range of requirements specification techniques available to designers.

5. Design a product

The concept of product architecture is defined. The process of designing is presented as a top-down multi-level structural design while adopting design principles. It is shown how a function is represented as a flow inside a structure representation and how a value analysis allows to balance the design choices of the structure with the functional requirements.

6. Design a service

Goods and services can be viewed as supporting human activities and a design process can be considered as a transformation of a user activity system. Service blueprinting is presented as the means to represent a service and to improve it. The tools for designing a product and designing a service are finally compared. The conclusion leads to the necessary hybridization of product design and service design methods, and consequently advocates for the design of Product-Service Systems (PSS).

7. Design for, by and with people

It is imperative to know how to design for people (designers learn from the usage expertise of people), design with people (users are active participants in the design process) and design by people (designers help users to become design actors and make their own decisions). In the first part (for and with people), personas and customer journey maps are studied as major tools. In the second part, it is illustrated how human models and human beings may be used in the design process. One speaks of Human-in-The-Loop (HiTL) simulations.

8. Universal design

The observation can be made that, still today, most of the time companies design products and services in the "one size fits all" mode for a perfect "averaged" customer. In consequence, designers do not consider the diversity of people and of activity contexts during the design process so as to ensure that the design outcome effectively delivers its expected value with a satisfactory user experience. Impaired, elderly and young people are example of often ignored (not so small) minorities. Universal design – also "called design" for all or "inclusive design" - is defined as the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design. The inclusive design process of EDC Cambridge is presented in details and some extensions are proposed. We show how user capabilities/disabilities are categorized into: vision, hearing, thinking, reach & dexterity, mobility and mapped onto the Perceiving-Thinking-Acting interaction process with a product or service, explaining the difficulty to get a satisfactory usage of a product or service if one insufficient ability interferes with the interaction process. This inclusive design process is not intended to be used only in extreme situations, but it pretends to be a generic design process to follow as soon as the product or service to design requires a human interaction.

9. Design a business model

The business model is the concept that allows a company to make money, the business plan is the operational plan to achieve it. A business model describes the rationale of how an organization intends to create, capture and deliver value. Several canvases are presented to represent and design it, among them the famous Business Model Canvas (BMC). It is then showed that the BMC may be not enough for guaranteeing success on the market. A BMC-RID variant has been proposed to consolidate its weakest points.

10. Prototype, test and validate

The cycle « Prototyping – Testing/Experimenting – Evaluating – Validating » is situated at the end of a design process. It is shown that the design of a prototype derives from the design of an appropriate experiment with expected evaluations, deriving from a subset of challenging performances (specified in the requirements specifications), deriving from a value proposition, deriving from an activity to improve. Numerous techniques of virtual and physical prototyping are presented, notably videos for illustrating existing usage scenarios and dreamt usage scenarios. Finally, the importance of documenting during the design process and especially the prototyping stage is evoked.

11. Life and improvement of a product

DFX, formed from the initials of Design For X, is the set of rules (design guideline) to be observed in the design of a product or system to improve the term that would replace the letter X. Each design guideline addresses a given issue that is caused by, or affects the traits of, a product. The design guidelines usually propose an approach and corresponding methods that may help to generate and apply technical knowledge to control, improve, or even invent particular traits of a product.
Let us mention those linked to life cycle stages: Design for Manufacturing, Design for Assembly, Design for Logistics (or Distribution), Design for Disassembly, Design for Testability, Design for Quality, Design for Reliability, Design for Safety, Design to Cost (to Global Lifecycle Cost), Design for Serviceability, Design for Aesthetics, Design for Ergonomics, Design for Robustness (robust design), Design for Maintainability (repairability, upgradability). And let us mention those linked to environment: Design for Environment (ecodesign, Life Cycle Assessment), Design for End of Life, Design for Energy, Design for Maintainability (repairability, upgradability), Design for Long Life Duration (obsolescence). This last category is particularly further detailed. The stakes of sustainable design are sketched. The categories of environmental impacts are commented. The definition and process of eco-design are provided, one eco-design tool described.

Class components (lecture, labs, etc.)

Each class session is typically composed of 10 minutes funny Kahoot quizz on the previous course, 1h presentation of the daily topic, and 1h30 of exercises. During one session a debate is organized by students themselves with 4 invited design managers.
There are 60 WLH in total, compared to the 33 hours of lectures and exercises and 2h of final poster session. The 25 additional hours are decomposed in 1h30 in average for completing the exercise after each session by groups of 4, and 7 hours to prepare the final poster session (also by groups of 4). The groups of 4 are changed two times so as for each student to work in three different groups.

Grading

The final grade is composed of 50% of the homeworks (per groups of 4) and 50% of the final poster (also by groups of 4), knowing that one student will belong to at least 3 to 4 successive groups. There will be between 4 and 6 homeworks, selected among the 11 sessions of exercises.
The final poster session consists in a poster session illustrating a trend, method, tool, concept or particular project or designer of Design Engineering & Science. Let us call it an object.
The poster objects have been the following in 2020: *Jugaad innovation,*

Minimum Viable Product, Bottom of the Pyramid, The practice of Design Thinking in companies, TRIZ theory, Radical Innovation Design, Use of focus groups in marketing , Idea selection in companies, Innovation funnels, Product obsolescence, Prototyping a service, The servitization, Human-in-the-loop simulations, Robust design, Reliable design, Examples of industrial product platforms, Product family, Co-design, Human factors in design, UX design, Ecodesign, Eco-innovation, Design-to-Cost, Lightweight design, Slow design, Sustainable design, The design of Starck, The design of Le Corbusier, Design for the elderly, Design for children, Design for developing countries, The design of Eiffel, The design of Le Baron Jenney, The teaching of ”design of machines” in the history of Ecole Centrale Paris and Supélec, The teaching of ”design of buildings” in the history of Ecole Centrale Paris and Supélec.
The poster must illustrate:

- The principles of your object
- Its stakes
- Its successes and failures so far
- Its economical interests
- Its compatibility and interests in regards with the U.N. Sustainable Development Goals (SDGs)
- Your clear-cut opinion “We should do that or avoid to do that…”

... and it must be illustrated, cool, informative and original!
A very funny, participative and intensive poster presentation is organized. By poster groups, you present your poster several times: to 2 juries of professors, and to 2 groups of classmates and, of course, you are yourself twice in a jury to evaluate the posters of your classmates. Each presentation is 5 min. + 8 min. Q&A. A video (January 2020) of the last poster session event can be seen here: https://web.microsoftstream.com/video/79bf09a7-d0bd-4aca-8ab9-d017bddb34ca

Course support, bibliography

- Yannou, B. & Farel, R. eds. 2011. Déployer l'innovation : Méthodes, outils, pilotage et cas d'étude, Paris: Techniques de l'Ingénieur, ISBN 978-2-85059-129-7. Accès direct à ces fiches pratiques à http://www.techniques-ingenieur.fr/fiche-pratique/genie-industriel-th6/deployerl-innovation-dt30/ de Centrale
- Yannou B., Deshayes P., 2006. Intelligence et innovation en conception de produits et services. collection "L'esprit économique", série "Economie et innovation", Paris: L'Harmattan-Innoval, ISBN 2-296-00644-2.
- Yannou B., Bigand M., Gidel T., Merlo C., Vaudelin J.-P., 2008. La conception industrielle de produits - Volume I : Management des

Hommes, des projets et des informations, Paris: Hermès Sciences, Lavoisier, ISBN 2-7462-1921-2.

- Yannou B., Robin V., Micaelli J.-P., Camargo M., Roucoules L., 2008. La conception industrielle de produits - Volume II : Spécifications, déploiement et maîtrise des performances, Paris: Hermès Sciences, Lavoisier, ISBN 2-7462-1922-0.
- Yannou B., Christofol H., Troussier N., Jolly D., 2008. La conception industrielle de produits - Volume III : Ingénierie de l'évaluation et de la décision, Paris: Hermès Sciences, Lavoisier, ISBN 3 978-2-7462-1923-6, ISBN général 978-2-7462-1920-4.
- Pahl G., Beitz W., Engineering Design: A Systematic Approach, Springer, Technology & Industrial Arts, ISBN 3540199179, London, New-York, 1996
- Ulrich K.T., Eppinger S.D., Product Design and Development, McGraw-Hill, New York, 1995
- Otto K.N., Wood K.L., Product Design - Techniques in Reverse Engineering and New Product Development, Prentice Hall, New-Jersey, 2001.
- Yannou B., 1998. Chapitre 3 : Analyse de la Valeur, In Conception de produits mécaniques : méthodes, modèles et outils, Vol. ISBN 2-86601-694-7, Tollenaere M., eds Hermes, pp. 77-104.

Resources

Teachers: Bernard Yannou (lead teacher), Flore Vallet, François Cluzel
Size of exercise classroom: 35 students
Online softwares and design platforms

Learning outcomes covered on the course

- Understand the major concepts of design science and engineering
- Experiment practically with product design, service design and business model design
- Understand the stages of a design process and the different methods and theories that may be useful to deal with design issues
- Be able to investigate on a design issue or design trend, to document it and to find appropriate attitudes and methods to solve it
- Understand how end-users and design experts can intervene along a design process

Description of the skills acquired at the end of the course

- C1.1 : Milestone 2: Know how to conduct a questioning process to address the different aspects of the problem and highlight its interactions with the outside world, based on a scientific and economic culture
- C1.4 : Milestone 1: Specify and design a system or part of a system
- C3.6 : Milestone 1: Evaluate the effectiveness, feasibility and robustness of the proposed solutions according to the expectations of the problem to be addressed
- C4.1 : Milestone 1: Identify the client(s) of a situation or project. Identify your main objectives and needs,
- C4.2 : Milestone 2: Propose one or more solutions that optimize value for stakeholders, including the customer, and distinguish value and cost from a solution.

2EL2130 – Agile management of complex projects

Instructors: Ludovic-Alexandre VIDAL, Franck MARLE
Department: SCIENCES ENTREPRISE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Business Sciences
Advanced level : No

Description

This course aims at discovering by practicing the main concepts, methods, and tools related to complex project management, notably using modern management principles (network-based organization, agility).
After a methodological introduction, the module is structured around a project where students are connected to other students' teams.
This application project aims at practically coping with decision-making issues under complex and uncertain contexts. It makes some links with diverse mathematical approaches, like graph theory, network theory, decision theory, multicriteria decision-making, and uncertainty management.
The course alternates open (project) and closed (exercices) sessions, in the same way as diverging (creativity) and converging (decision) moments.

Quarter number

SG8

Prerequisites (in terms of CS courses)

None

Syllabus

- Introduction to advanced project management techniques notably applied to risk management (on an ongoing project).
- Project objectives and requirements definition
- Creativity, alternative solutions generation
- Alternatives classification + team organization (assignments, interfaces)
- Alternatives assessment and pre-selection of 3 scenarios (with preliminary visualization)
- Final choice by coordination with other teams

- Visual display of final solution

Class components (lecture, labs, etc.)
Lectures, exercices and project slots. Deliverables are submitted all along the course. No final oral defense.

Grading
A deliverable-based assessment at team level, plus an individual appreciation of contribution to teamwork and team results.

Resources
Digital tools are available to assist project teams to organize themselves, to formalize the creation of their deliverables, and to make them visual (digital mock-up for instance).

Learning outcomes covered on the course

- A1: To comprehend a complex problem (design, construction, or urban planning) and express it into interrelated objectives, deliverables, functions. Skills C1.1 and C4.1.
- A2: To transform objectives into project activities and system functions into solutions. Skills C1.4, C9.1, and C9.2.
- A3: To evaluate, prioritize, and select activities and solution alternatives. Skills C1.5, C3.1, 3.2, 3.3, 3.4, 3.7 and C4.2.
- A4: To live in a team with a commitment based on autonomy and respect for what has been forecasted. Skills C6.1, C6.2, C7.2, and C8 (all).
- A5: To render team results, while distinguishing system deliverables, project deliverables, and team retrospective. Skills C7.1 and C7.4.

Description of the skills acquired at the end of the course

- C1.1 : Examine problems in their entirety and beyond their immediate parameters. Identify,formulate and analyse the scientific, economic and human dimensions of a problem (A1),
- C1.4 : Design, detail and corroborate a whole or part of a complex system. (A2)
- C1.5 : Bring together broad scientific and technical concepts in a core structure contained within the framework of an interdisciplinary approach. (A3);
- C3.1 : Be proactive and involved, take initiatives

- C3.2 : Question assumptions and givens. Overcome failure. Take decisions
- C3.3 : Undertake ambitious projects with a high level of impact and be able to quantify this impact.
- C3.4 : Take decisions in an environment that may not be fully transparent, embracing the unexpected and calculating risk.
- C3.7 : Make pragmatic and informed choices with the aim of producing tangible results. (A3);
- C4.1 : Think in client terms, identify and analyse customer needs, the constraints of other stakeholders including societal challenges.(A1)
- C4.2 : Know how to identify the value that a given solution affords a client and the market. To be able to detect opportunities and seize them. (A3);
- C6.1 : Identify and use the necessary software for one's work (including collaborative tools) and adapt digital responses according to the context.
- C6.2 : Engage in design thinking using classic and agile conception and prototyping tools (CAD, 3D printing etc.) (A4)
- C7.1 : Persuade at core value level; to be clear about objectives and expected results. To apply rigour when it comes to assumptions and structured undertakings, and in doing so structure and problematise the ideas themselves. Highlight the added value
- C7.4 : Persuade by working on communication techniques Master spoken, written and bodylanguage, as well as basic communication techniques. (A5)
- C7.2 : Persuade through interpersonal relations to understand the needs and expectations of multiple participants in a dialogue, elicit reactions and create a climate of trust (A4)
- C8.1: Work collaboratively in a team.
- C8.2 : Train and motivate a group, demonstrating effective leadership.
- C8.3 : Engage outside expertise to go the extra mile. Identify and develop strengths and talents.
- C8.4 : Work using project management techniques appropriately tailored to the situation. (A4)
- C9.1 : Understand and analyse the consequences of one's choices and actions.
- C9.2 : Identify, within a given structure, the scope of liability as well as socio-ethical and environmental responsibilities. (A2)

2EL2140 – Strategy, Marketing and Organization

Instructors: Éléonore MOUNOUD
Department: SCIENCES ENTREPRISE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota : 100
Elective Category : Business Sciences
Advanced level : Yes

Description
This course allows students to implement in a relevant and reasoned way the principal models of strategy and marketing. It develops the notion of business model and how to use it to account for past and future transformations of businesses and companies. The strategic issues related to the development of services, the globalization of value chains, and innovation are thus addressed through case studies. The societal challenges of digital transformation and ecological transition as well as their impact on business models will also be addressed (circular economy). The course invites the students to a personal reflection on the complementarity but also the rivalry between these two transitions based on case studies presented by lecturers on the digital transition, the energy transition and the scarcity of resources (sobriety principle).

Quarter number
SG6

Prerequisites (in terms of CS courses)
Business management course: marketing mix, PESTEL analysis, SWOT analysis, Ansoff matrix, business development modes, value chain, Porter's 5 forces analysis, generic strategies
Start up Week : définition du business model et canevas

Syllabus
1. Nespresso case study / detail of business model components
2. Conference on Global Coffee Sector Analysis (The Basic) / Globalization of CGV Value Chains / Social Costing
3. Case Study Michelin Solutions / Strategies in Services / TCO Calculation / Functionality Concept
4. Conference on the technological issues of ecological transition / (case of

mobility)
5. Workshop on digital transformation (methodologies from a consulting firm)
6. SKF Case Study / Understanding B to B Marketing and Globalization
7. Testimony of a group leader and start-ups: case studies Vallourec / Metalvalue
8. Tetrapak case study / innovation management
9. Conference: Circular economy / waste, recycling, industrial ecology
10. Synthesis session by group: low tech VS hi tech - Digital transition and ecological transition: complementary and rival

Class components (lecture, labs, etc.)
lectures 4 hours
case studies 10 hours
conferences 10 hours
workshop 3 hours
synthetis (reflexive workshop) 3 hours
written exam 2 hours, oral exam 1 hour

Grading
Preparation of the sessions (5 reading notes prior to the case studies),Evaluation: participation (25%), oral examination (25%), written examination (50%)

Course support, bibliography
Strategor

Resources
Eléonore Mounoud, responsable du cours
Patrick Pichant, consultant, ex directeur marketing Arcelor, intervenant
Christophe Alliot, fondateur du cabinet Le Basic
Damien Detcherry, centralien, blogueur
Alain Honnart, ex directeur industriel Vallourec, directeur Métal Value
un consultant de Cap Gémini invent et/ou un consultant de EY Parthenon
un conférencier sur l'économie circulaire

Learning outcomes covered on the course
At the end of this course, students will be able to:
• Formulate the positioning and value proposition of a company to its customers
• To detail the business model of a company and to diagnose its coherence
• Identify the challenges of internal or external transformations

(transitions) relevant to a company and how to respond to them
• To propose a logic of transformation of a company (services, innovation, globalization, transitions) as well as its competitive and organizational challenges (competitiveness, agility, transversality)

Description of the skills acquired at the end of the course
CentraleSupelec competences:
C4.1 :Think in client terms, identify and analyse customer needs, the constraints of other stakeholders including societal challenges.
C4.2: Know how to identify the value that a given solution affords a client and the market. To be able to detect opportunities and seize them.
C9.2,: Identify, within a given structure, the scope of liability as well as socio-ethical an environmental responsibilities.
C9.4 : Demonstrate rigour and critical thinking in approaching problems from all angles, be they scientific, social or economic.

2EL2150 – Corporate finance and Law

Instructors: Maxime GUYMARD, Valérie FERAY
Department: SCIENCES ENTREPRISE
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Business Sciences
Advanced level : Yes

Description

The course goes into law and finance in depth after the first and second-year introductory course. It also gives an opening on various Finance/Law professions via speakers working for different business companies (entrepreneurship, insurance, banking, and audit, Innovation & Intellectual Property Director, IP attorneys, attorneys-at-law).

Quarter number

SG6

Prerequisites (in terms of CS courses)

Business Management (1st year), Introduction to Corporate Finance (1st year), Introduction to Law (2nd year)

Syllabus

The discussed subjects of this course will be divided in 3 parts: one third in Law, one third in Corporate Finance, one third in both Finance and Law.

Law
Themes of lectures:
- Patentability, patent prosecution and related costs
- GDPR
- Software protection
- Labor law

Finance
Themes of lectures:
- In-depth study of accounting basics: balance sheet, income statement (P&L), cash flow statement
- Solvency
- Profitability (ROCE, ROE)

- Weighted Average Cost of Capital (WACC)
- Financial criteria to select an investment (NPV, IRR)
- Start Up financial management
- Bankruptcy and restructuring
- Introduction to Market Finance (stocks, bonds, derivatives)

Themes of conferences:
- Financial Management of an Insurance Company (speaker from AXA)
- Business Valuation (speaker from KPMG)
- Project Finance (speaker from BNP Paribas)
- Venture Capital and Private Equity

Class components (lecture, labs, etc.)
Lectures (14 * 1:30); Tutorials (8 * 1:30), Final Exam (1*2:00)

Grading
Final written exam (100% of final mark)

Resources

• **Teaching staff** (instructor(s) names):
Law: Valérie FERAY (main lecturer - Founder and managing partner - IPSILON), Pierre-Jacques CASTANET (speaker and teaching assistant - attorney-at-law specialized in labour law), Mardson McQUAY (speaker and teaching assistant - Senior IP Attorney - King Abdullah University of Science and Technology), Guillaume HENRY (speaker and teaching assistant - attorney-at-law), Ghislain DEMONDA (speaker and teaching assistant - Patent engineer - IPSILON)

Finance: Maxime GUYMARD (main lecturer), Jean-Baptiste MONLOUIS (speaker and teaching assistant – KPMG), Selma ELMADHI (speaker and teaching assistant – KPMG),

• **Maximum enrollment** (default 35 students): 105 max for the course (35 students for 3 tutorial groups)

Learning outcomes covered on the course

In Finance:
- Know how to read and interpret the financial statements of a company (balance sheet, income statement, cash flow statement)
- Evaluate the profitability and solvency of a company

- Know the financial criteria for making an investment decision
- Understand the basics in Market Finance (stocks, bonds, dérivatives)
- Know the different professions in Finance

In Law:

- Labour law : learn the basics as employer and employee **(this 3-hour course+tutorial will be exceptionnally held in French - an English abstract will be provided for non-French speaking students)**
- Patentability, patent prosecution, related costs: learn which subjects can be protected by patents, how to assess the prior art to determine patentability, the prosecution steps from filing up to grant of a patent and the related costs
- GDPR: understand the ins and outs of this EU directive that impacts several activities in which engineers and entrepreneurs are involved
- Software: learn the basics and various protection solutions, the pros and cons of each of them and the corresponding pitfalls

Description of the skills acquired at the end of the course

C 1.1 - Examine a problem in full breadth and depth, within and beyond its immediate parameters, thus understanding it as a whole. This whole weaves the scientific, economic and social dimensions of the problem.
C 3.7 - Make pragmatic and informed choices with the aim of producing tangible results.
C 4.1 - Think in client terms, identify and analyse customer needs, the constraints of other stakeholders as well as include societal challenges.
C7.1 Persuade at the level of core values; to be clear about objectives and expected results. To apply rigour when it comes to assumptions and structured undertakings, and in doing so structure and problematise the ideas themselves. To make the added value known.
C 9.4 - Demonstrate rigour and critical thinking in approaching problems from all angles, be they scientific, social or economic.

2EL2160 – Environmental economics, energy and sustainable development

Instructors: Vincent RIOUS, Pascal DA COSTA
Department: SCIENCES ENTREPRISE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Business Sciences
Advanced level : Yes

Description

The objective of the "Economics of the Environment, Energy and Sustainable Development" course is to address:
i) the major environmental issues of the 21st century and the human factors that structure them (demography, economy, development, etc.);
(ii) the theories in the field that have, in particular, founded economic principles that must be adopted in response to these issues (optimal carbon tax and environmental taxation, fight against negative externalities, etc.);
(iii) economic and regulatory policies in practice, both at the environmental and energy levels (European energy-climate packages, low-carbon electricity mix, etc.).

Quarter number

SG8

Prerequisites (in terms of CS courses)

Common economics course.

Syllabus

- Origins of economic growth and effect on the "unavailability" of natural resources (end of cheap oil, etc.)
- Economic models for the optimal management of renewable and non-renewable natural resources
- Demographics: changing world populations
- Climate: greenhouse effect and climate change
- Resource management issues (reserves, distribution, prices): resources for energy (oil, gas, coal, uranium), raw materials (ores), water
- State of the art and new technologies for energy

Class components (lecture, labs, etc.)
Amphitheatre / Tutorials

Grading
Quizz, 1,5 hours duration / Final exam, 2 hours duration:Finale grade = Quizz (20%)+ Final exam (80%) In case of a justified absence to one of the intermediary examinations, the grade of this latter is replaced by the grade of the final examination.

Course support, bibliography
Slideshows, multidisciplinary and economics books (to come).

Resources
Course in French.

Learning outcomes covered on the course
- Know the key figures (state of play and scientific forecasts) that are the subject of so much debate in the media when they involve stakeholders in an environmental conflict, for example industrialists and ecologists.
- Understand the assumptions and models on which these figures are based.
- Raise awareness of the coupling of resources, energy, environment, climate, economy, geopolitics, demography
- Raise awareness at different levels: local to global

Description of the skills acquired at the end of the course
C1.1 Examine a problem in its full scope and depth, within and beyond its immediate parameters, in order to understand it as a whole. This set links the scientific, economic and social dimensions of the problem.

C2.1 Master a field or discipline based on the basic or engineering sciences.

C4.1 Think in terms of customers, identify and analyse customer needs, other stakeholder constraints and societal challenges.

C9.4 Demonstrate rigour and critical thinking by approaching problems from all angles, scientific, human and economic.

2EL2170 – Economics of growth and innovation

Instructors: Mehdi SENOUCI
Department: SCIENCES ENTREPRISE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Business Sciences
Advanced level : Yes

Description

Economic growth, in a broad sense, is a concept that refers to all economic changes over time. One of the strongest consensuses in economics is that which links growth to innovation. The first objective of the course is to make students aware of the study of economic growth, both long and short term, by trying to convince them that the regularities as well as the paradoxes of growth justify an analytical approach combining the exploration of facts, empirical analyses and theory-building. The second objective is to present the great economic evolutions of the world from the origins to the present day, with greater importance given to the modern era, as well as the theories related to each era and each transition. The third and more diffuse objective is to push students to question the future consequences of innovations currently underway or in the making. The course will combine theory and empirical studies following the red thread of history.

The course, demanding and research-oriented, is reserved for an audience willing to get involved. Apart from the final exam, two reports will be required (one in tutorials) which will be based on the critical reading of research papers.

Quarter number

SG6

Prerequisites (in terms of CS courses)

Economics compulsory course. Basics of econometrics (ordinary least squares).

Syllabus

1 - Economic growth as a historical phenomenon: the major trends
2 - A detour: the neoclassical model of perfect markets
3 - Neoclassical analysis of growth: successes and failures

4 - Growth, energy and the environment
5 - Growth, labor market and inequality
6 - Economic growth over the very long run
7 - The future of economic growth

Class components (lecture, labs, etc.)
Lectures (24h), Tutorials (9h), Exam (2h)

Grading
One mandatory assignment in tutorials: 1/4
One other mandatory assignment: 3/8
Final exam: 3/8

Course support, bibliography

- Slides and lecture notes
- The course will not rely on a specific textbook, but students can refer to:
    - Hal R. Varian (2014) *Intermediate microeconomics - A modern approach,* W. W. Norton & Company, 9th edition
    - Robert J. Barro & Xavier Sala-i-Martin (2003) *Economic Growth*, MIT Press, 2nd Edition
    - David N. Weil (2012) *Economic Growth,* Pearson Education
    - Charles I. Jones & Dietrich Vollrath (2013) *Introduction to economic growth,* W. W. Norton & Company, 3rd edition
- Many articles and books will be covered, including:
    - Acemoglu, Johnson, and Robinson (2001) "The Colonial Origins of Comparative Development: An Empirical Investigation." American Economic Review.
    - Acemoglu, Johnson, and Robinson (2002) "Reversal of Fortune: Geography and Institutions in the Making of the Modern World Income Distribution." Quarterly Journal of Economics.
    - Aghion, Dechezleprêtre, Hémous, Martin and Van Reenen (2016) ‘‘Carbontaxes, path dependency, and directed technical change: Evidence from the auto industry,’’ Journal of Political Economy.
    - Ashraf and Galor (2013) "The `Out of Africa' Hypothesis, Human Genetic Diversity, and Comparative Economic Development," American Economic Review.
    - Clark (2007) *A Farewell to Alms: A Brief Economic History of the World*, Princeton University Press.
    - Comin and Mestieri (2014) ‘‘Technology Diffusion: Measurement, Causes and Consequences,’’ Handbook of Economic Growth.

- Diamond (1997) *Guns, Germs and Steel: The Fates of Human Societies,* W. W. Norton & Company.
- Galor (2005) "From Stagnation to Growth: Unified Growth Theory," in Handbook of Economic Growth.
- Galor and Ozak (2016) "The Agricultural Origins of Time Preference," American Economic Review.
- Greenwood Hercowitz and Krusell (1997) "Long-Run Implications of Investment-Specific Technological Change," American Economic Review.
- Habakkuk (1962) *American & British Technology in the 19th Century: The Search for Labour-Saving Inventions*; Cambridge University Press [2nd edition: 1967].
- Kaldor (1961) "Capital Accumulation and Economic Growth," in The Theory of Capital (F. A. Lutz & D. C. Hague, eds.); Macmillan, St. Martin's.
- Mankiw, Romer, and Weil (1992) "A Contribution to the Empirics of Economic Growth." Quarterly Journal of Economics.
- Nordhaus (1973) "The Allocation of Energy Resources," Brookings Papers on Economic Activity.
- Piketty and Zucman (2014) "Capital is Back: Wealth-Income Ratios in Rich Countries 1700-2012," Quarterly Journal of Economics.
- Romer (1990) "Endogenous Technological Change." Journal of Political Economy.
- Solow (1956) "A Contribution to the Theory of Economic Growth," Quarterly Journal of Economics.
- Solow (1957) "Technical Change and the Aggregate Production Function," Review of Economics and Statistics.

Resources
Lectures (Mehdi Senouci)
Tutorials

Learning outcomes covered on the course
At the end of this course, students will be able to:
- Model consumption, production, exchange and technical change with neoclassical models;
- Know, manipulate and interpret different theoretical models of economic growth;
- Discuss the issues of growth in an analytical logic and in knowledge of the history and facts of economic growth.

Description of the skills acquired at the end of the course

Model consumption, production, exchange and technical change with neoclassical models; is included in skills **C1.3 "Apply problem-solving through approximation, simulation and experimentation. / Solve problems using approximation, simulation and experimentation"**, and **C2.3 "Rapidly identify and acquire the new knowledge and skills necessary in applicable / relevant domains, be they technical, economic or others."**
Know, manipulate and interpret different theoretical models of economic growth; is included in skills **C1.1 "Examine problems in their entirety and beyond their immediate parameters. Identify, formulate and analyse the scientific, economic and human dimensions of a problem", and C2.3 "Rapidly identify and acquire the new knowledge and skills necessary in applicable / relevant domains, be they technical, economic or others."**
Discuss the challenges of growth in an analytical logic while being aware of the history and facts of economic growth; is included in skill **C7.1 "Persuade at core value level; to be clear about objectives and expected results. To apply rigour when it comes to assumptions and structured undertakings, and in doing so structure and problematise the ideas themselves. Highlight the added value".**

2EL2190 – Innovation management and business creation

Instructors: Éléonore MOUNOUD, Jean-François GALLOUIN
Department: SCIENCES ENTREPRISE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Business Sciences
Advanced level : No

Description

We have seen over the past 20 years lots of startups chalenging large and well established corporations. We all have in mind Uber, Amazon, AirBnB, BlaBlaCar, and many more. Threat ? Opportunity ? The "start-up" phenomena should be of interest for each and every future manager in this begining of the XXIst century.

Startups have brought new models for innovation, and urge large corporation to reinvent their way to innovate.

Large companies have deployed incubators, accelerators, startup studios, corporate venture capital firms, etc. to better understand the startup culture. They practice open innovation and they develop business Relationship with startups.They have created Innovation department, to design and implement innovation strategies.

The objective of this course is to explore what is a startup, how it is launched, what are the key success factors, etc.

Some methodologies such as lean startup, Business Model Canvas, etc. wil be presented.

We will also explore how large corporations tackle with innovation and benefit from the startup ecosystem.

Quarter number

SG8

Prerequisites (in terms of CS courses)

This course is a "Discovery tour" of Innovation Management and Company creation, therefore there is no prerequisite to attend the classes.

Syllabus
The different themes will be as follows:

1 - Definition of business innovation? Why innovate? What are the issues at stake?
R&D, invention, innovation
Creativity versus innovation
Different nature and intensity of innovation
2 - Innovation strategies - Innovation portfolios - CASE STUDY
3 - Ideation - methods of creativity
4 - Innovation management - CASE STUDY
Incremental, radical innovation, etc. R&D articulation
5 - Design thinking
6 - Innovation ecosystem: startup studio, incubator, accelerator, BPI, competition, honours loans, CIR, etc.
7 - Business Model: various formalisms, including the Business Model Canvas - CASE STUDY
8 - Business Model quantity: the economic equation of the project - CASE STUDY
9 - Innovation marketing - Launch of new products
10 - Launching new activities (company creation, intrapreneurship)
11 - Project communication - pitch - Business plan / Slide deck
12 - Financing innovation
13 - Business models for sustainable innovation
14 - ESS Solidarity and social enterprise

Class components (lecture, labs, etc.)
Courses / Conferences
Case study (work to be prepared and submitted)
Mini project

The course represents about thirty hours of courses or conferences (HPE) and requires approximately the equivalent in preparation for the case studies (to be delivered).

Grading
Continuous monitoring - work to be renderedQuiz in catch-up modeThe score is an individual score for 100%.

Course support, bibliography
Lean Startup, Eric Ries

Business Model Canvas, Alexander Osterwalder
Startup Owners Manual, Steve Blank & Bob Dorf
Get Going, Guy Kawasaki
Guide pratique de la levée de fonds, Jean-François Galloüin
The Founder's dilemnas, Noam Wasserman

Resources

Learning outcomes covered on the course

At the end of the course students will be able to :
- understand what a start up entails
- decide whether company creation could be a move for them.
- identify what innovation is,
- decide whether a first job as innovator, intrapreneur, etc. could be an option for them.
-apply methods linked to the developpement of new activities : Lean startup, Business Model Canvas, LaunchPad Toolkit, etc.

Description of the skills acquired at the end of the course

We will work mainly on skills:
C3 - Act, Undertake, Innovate
C4 - Have a sense of value creation for your company and for your customers

By presenting cases in a concrete way
By providing methodological frameworks

2EL2200 – Radical Innovation Design

Instructors: Bernard YANNOU
Department: SCIENCES ENTREPRISE
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 180
On-site hours (HPE): 108
Quota :
Elective Category : Business Sciences
Advanced level : No

Description

The objective of the course is to teach you to innovate on complex systems (products-services- organizations and their business models) in a professional manner (the RID methodology is a real innovation engineering) and to learn how to put it in practice (through industrial projects proposed by Chief Innovation Officers).
Beyond Design Thinking, **Radical Innovation Design**® is a novel, complete and well-structured innovative design methodology that prioritizes the improvement of the user experience within a field of activity. It is deliberately usage driven and activity centered. RID guides innovators who want to systematically explore users' problems and unstated needs, and evaluating which ones are most pressing in terms of innovation, taking into account the effectiveness of existing solutions. RID revolutionizes the way to define innovation targets along with its unique concept of ambition perimeter, composed of selected value buckets in adequacy with company strategy. With its emphasis on problem exploration, project management and decision-making frameworks, traceability and reporting facilities, RID differs from methods based on early quick and dirty prototyping. The RID methodology has been validated in various industrial and business sectors.
Industrial projects will allow you to collaborate by groups of 5 to come up with the most relevant innovation results for a future user activity. The innovation projects will be conducted following the *Radical Innovation Design*® methodology, through an intense innovation process. During this process, you are coached by a professional coach in innovation, you manage design reviews with the company executives, and you progressively deliver intermediary outcomes which are recorded onto the RID computer platform. Last year, in 2020, three industrial projects have been led for SAFRAN "*Capture and propagation of runway conditions*", SAIPEM "*Exploration of port solutions for the maintenance of floating wind turbines*" and RATP "*Signaux de chantier et sécurité / Pétards de voie*", whereas we were all contained. Two reports are delivered for the project: the Problem Setting report after 6 weeks, the Problem Solving report two

weeks later (working in Hackathon or Innovation Camp mode).
A sole methodological know-how would be inefficient without the appropriate **soft skills to co-innovate with your teammates**. Three training modules of 6 hours are proposed to, in order, (1) Become a strong leader in innovation and learn to work with your teammates (2) Co-create in group with theatrical techniques (3) Pitch your innovation project more confidently and more persuasively.
Moreover, the act of innovating not only guides companies toward new technologies and new markets, but it actually consists in designing our future life and society. Innovation is a determining discipline that you will use in your professional life of engineer to change the world. This is why 9 highly skilled experts will deliver **tutorials on stakes and challenges of innovating**. "*How to sketch a desirable future? How can we put innovation at the service of the common good? How intelligently use AI for a better organization of health care systems (it's all about the news)*" are among a series of questions we would like to address and debate.
Consequently the 2021 RID course (108 h), which is **only given in English**, is made of **5 modules (A, B, C, D, E)**:

- A. 9 innovation tutorials
- B. The Radical Innovation Design lecture and exercises
- C. The soft skills
- D. Problem setting of your industrial project
- E. Problem solving of your industrial project

Quarter number
SG8

Prerequisites (in terms of CS courses)
No prerequisite

Syllabus

Innovation tutorials (27 CRH - 33 WLH)
Innovation is a determining discipline that you will use in your professional life of engineer to change the world, the society and everyday life. This is why nine experts will deliver tutorials on stakes and challenges of innovating, for enlarging your perspective of innovating:

1. "How can we put innovation at the service of the common good? New research and innovation practices", **Mélanie Marcel and Roxane Bibard, SoScience**
2. "Transformations in technological industries", **Michel Guiga, Vice President at Capgemini Invent**

3. “The Art of Imagining the Future”, **Mathieu Baudin, director of the Institute of Desirable Futures**
4. “Innovation for Healthcare organization”, **Dr Romain Farel, Data Intelligence program manager at DocteGestio**
5. “The blockchain: a promise of useful disruptive innovations?”, **Jérémy Sintes**
6. “Smart buildings, useful buildings”, **Olivier Sellès, head of smart building solutions at BNP Paribas Real Estate**
7. “A systemic approach to mobility within the smart city: some areas of research and innovation linked to digital”, **Dominique Barth, Professor in computer science at University of Versailles-SQ/University Paris-Saclay**
8. “Platform design for the future of Enterprise & Industry automation”, **Nicolas Rebierre, head of the software platform innovation team at Nokia Bell Labs**
9. “To innovate is to think aside”, **Philippe Costard, CEO of Synergie Design**

A 4-page personal report on the tutorials (**coeff. 3**) is produced, focusing on the points that you liked, or that questioned you, and the in-depth information that you find interesting.

Radical Innovation Design® Methodology (24 CRH – 39 WLH) - Bernard Yannou, assisted by François Cluzel

Radical Innovation Design® (abbreviated as RID) is a stage-gate, needs-based, structured methodology and engineering process. RID is based on the idea that when designing innovative experiences, products, and services, one should begin with the problems users encounter and what they seek to achieve, rather than focusing on products or technologies. This principle is referred to as “need-seeker innovation”. Need-seeking innovators work hard “to find the unstated customer needs of the future, and to be the first to address them”. It is the model of successful companies such as Apple, Tesla or Dyson, and a key notion for achieving radical innovation. To do so, RID supports the systematic modeling of classes of user profiles, usage situations, problems/pains, and existing solutions. RID studies are divided into two periods. The first period of Problem Setting corresponds to the preliminary stages of a radical innovation process where the problem is generally poorly set out; in the literature, this is referred to as the "fuzzy front end of innovation". In the second period of Problem Solving, designing the Product-Service-Organization concept and the Business Model are done in parallel. Much care and effort go into designing a problem whose solutions can create maximal value.

Radical Innovation Design® has been invented and developed in CentraleSupélec; it is a trademark of CentraleSupélec. A CentraleSupélec

spin-off, HyB'RID (see https://hyb-rid.com/), is in charge of training company executives and deploying the use of the methodology.
The teaching of the methodology *Radical Innovation Design®* will bring students rigor and method in a framework for innovating in company or startup conditions. The course is delivered through 8 sequences of courses and exercises, following the course of a typical RID process. The courses are illustrated with numerous videos and known and unknown innovations. The exercises come from recent company projects (see past projects here: http://rid.centralesupelec.fr). A digital book of exercises is customized per student. Each student fills this book along with the exercise sessions and send it back to the Professor at the end for getting a grade (**coeff. 4**).
Some serious gaming are also experimented during some course sessions. In addition, a RID computer-assisted platform is used to practice some exercises.

Soft skills for innovation (18 CRH - 18 WLH)
This sole methodological know-how would be inefficient without the appropriate soft skills to co-innovate. Three non-technical skills in innovation are taught (2 sessions for each) by practice.
(1) Disruptive Thinking for a successful RID project - Nathalie Delmas, founder of Connexion TIP
The objective is to give you access to experience the Performance CO TM methodology allowing you to achieve 'Disruptive' results and to free you to dare be, do and realize what you truly want as an individual and as a team – mainly through learning the power of being connected to oneself, others and to what's at stake.
(2) Theatrical creativity - Valérie Lejeune, Assistant Professor at UCO BN
Creativity is a critical state of mind that allows us to overcome obsolete thinking patterns and go further. Since 1950, different schools of thought have illustrated the logic of co-creation. In each case, a specific process (using either empathy, intellectualization or, sensitivity…) is proposed to establish a group dynamic, and to produce valuable ideas. In this workshop, we use the theatre medium to foster group creativity, approaching RID method ideation phases from a human angle. The creativity method A.C.T.I.N.G© (Attitudes for Creative Thinking in Group), invented by Dr. Lejeune, is the result of 10 years of recent applied research within various companies. ACTING© essentially uses theatrical techniques (raising spatial awareness, leveraging sincere emotions, storytelling) to defix and produce linguistic and imaginary elements generating new ideas.
(3) RID Pitching Workshops - Steve Brown, senior lecturer at CentraleSupélec
Our workshops will have a simple objective: to give you the linguistic, rhetorical, conceptual and organisational tools to pitch more confidently and more persuasively, in English. You will draw on and integrate key learnings from other workshops (theatrical creativity, disruptive thinking and leading). The pitches will focus on the RID pitch you'll be required to give on the final session.

Problem Setting of your industrial project (15 CRH, 50 WLH)
A series of innovation projects are proposed by large companies, startups, possibly associations or NGOs. The students express their wishes and are assigned, as far as possible, to their first choice in a group of 5 students. The companies agreed to work with a Radical Innovation Design® philosophy and process. Indeed, the initial innovation question is quickly enlarged to scrutinize a user activity in its whole, so as to capture RID value buckets. Value buckets are problems with dramatic impacts occurring in frequent usage situations and for which no satisfactory existing solution exists.
During this process, you are coached by a professional coach in innovation, you manage design reviews with the company executives, and you progressively deliver intermediary outcomes which are recorded onto the RID computer platform. You are, for instance, in charge of the investigation of the Problem Setting for capturing expertise inside and outside the company and summarizing it in relevant books of knowledge. After properly establishing value buckets expressing precisely where to augment the users' activity, you administrate a compromise to fix with the company to choose the appropriate subset of value buckets which are congruent to its strategy, skills and risk attitude. These innovation targets (ambition perimeter) are then the starting points for the next stage of Problem Solving. A first Problem Setting report must be delivered.

Problem Solving of your industrial project (24 CRH, 46 WLH)
The second part of the project occurs during the last week or 10 days of the Challenge Term (fully dedicated to that). During this short period, you must come up with:

- the dreamt usage scenario of the future activity
- the concept of a Product-Service-Organization (PSO)
- the detail design of this PSO
- a RID Minimum Viable Prototype of this PSO which demonstrates that the user activity is effectively augmented (the value buckets are lessened)
- an adapted business model
- possibly an industrial and launch plan

These elements are synthesized in a Problem Solving report (the RID computer-assisted platform generates the report skeleton) and a prototype. In addition, the students are asked to deliver an executive summary (illustrated poster), a 5 min video on the process and results, and a final presentation.
Finally, the students participate in the challenge "Go for a RIDe!" where they pitch their project in a limited time in front of an audience of about 30 teachers and experts in innovation. An innovation prize is awarded to the best project, and students are awarded the RID methodology certification

Level 2 “Easy RIDer”.
The project coaches are: Flore Vallet, Hanen Kooli-Chaabane, Aurélie Randazzo, François Cluzel, Bernard Yannou

Class components (lecture, labs, etc.)

Fundamentally focused on project-based pedagogy and simulation of industrial and sectoral innovations (transport and buildings, connected and industrial systems, health and society), this Challenge Term allows to develop with and for industrial partners innovative solutions that really aim to be subsequently industrialized and launched on the market.

Grading

The final grade is computed as follow:

- The 4-page personal report on Innovation Tutorials (coefficient 3)
- The personal book of exercises (coefficient 4)
- The Problem Setting report by group of 5 (including the Books of Knowledge) and its presentation (coefficient 5)
- The Problem Solving report by group of 5, the prototype, the executive summary, the 5-minute video, and its presentation (coefficient 5)

For the two stages of project delivery, the grade takes into account the quality and relevance of the process (careful and intelligent application of RID stages, investment in the project, organization), the quality and relevance of the project outcomes in the context of the company, the relevance of the pitch.

Course support, bibliography

A “RID guidebook” is provided to the students. This is a collection of 100 pages linked together by hypertext links in a pdf format under a non-commercial Creative Commons license for possible dissemination. This is the official glossary and textbook of the course. Each page contains a definition, a methodological part, illustrations and links to inner pages, outer documents and web resources.
In addition, the reading of the following journal papers (provided to students) and textbooks is recommended.

Recommended textbooks

- Gardoni M., Navarre A., 2017. Pratiques de gestion de l'innovation - Guide sur les stratégies et les processus, Québec, Canada: Presses de l'Université du Québec.
- Cantamessa M., Montagna F., 2016. Management of innovation and product development - Integrating business and technological perspectives, London: Springer.
- Boly V., 2004. Ingénierie de l'innovation : Organisation et méthodologies des entreprises, Paris: Hermes Lavoisier.
- Cuisinier, C., Vallet, E., Bertoluci, G., Attias, D. & Yannou, B., 2012. Un nouveau regard sur l'innovation - un état des pratiques et des modèles organisationnels dans les grandes entreprises, Paris: Techniques de l'Ingénieur, ISBN 978-2-85059-130-3.
- Christensen C., 2011. The Innovator's Dilemma: The Revolutionary Book That Will Change the Way You Do Business HarperBusiness.
- Osterwalder A., Pigneur Y., Bernarda G., Smith A., Papadakos P., 2014. Value Proposition Design, Hoboken, New Jersey: John Wiley & Sons, Inc.
- Osterwalder A., Pigneur Y., 2010. Business Model Generation, Hoboken, New Jersey: John Wiley & Sons, Inc.
- Kim C.W., Mauborgne R., 2005. Blue ocean strategy - How to create uncontested market space and make the competition irrelevant, Boston, USA/MA: Harvard Business School press.
- Yannou, B. & Farel, R. eds. 2011. Déployer l'innovation : Méthodes, outils, pilotage et cas d'étude, Paris: Techniques de l'Ingénieur, ISBN 978-2-85059-129-7. Accès direct à ces fiches pratiques à http://www.techniques-ingenieur.fr/fiche-pratique/genie-industriel-th6/deployer-l-innovation-dt30/ de Centrale
- Yannou B., Robin V., Micaelli J.-P., Camargo M., Roucoules L., 2008. La conception industrielle de produits - Volume II : Spécifications, déploiement et maîtrise des performances, Paris: Hermès Sciences, Lavoisier, ISBN 2-7462-1922-0.
- Yannou B., Christofol H., Troussier N., Jolly D., 2008. La conception industrielle de produits - Volume III : Ingénierie de l'évaluation et de la décision, Paris: Hermès Sciences, Lavoisier, ISBN volume 3 978-2-7462-1923-6, ISBN général 978-2-7462-1920-4.
- Yannou B., Bigand M., Gidel T., Merlo C., Vaudelin J.-P., 2008. La conception industrielle de produits - Volume I : Management des Hommes, des projets et des informations, Paris: Hermès Sciences, Lavoisier, ISBN 2-7462-1921-2.

Recommended journal papers (see also https://hyb-rid.com/publications-rid/)

- Lamé G., Yannou B., Cluzel F., 2018. Usage-Driven Problem Design for Radical Innovation in Healthcare. BMJ Innovations, 4 (1), 15-23, doi: 10.1136/bmjinnov-2016-000149.

- Yannou B., Cluzel F., Farel R., 2016. Capturing the relevant problems leading to pain and usage driven innovations: the DSM Value Bucket algorithm. Concurrent Engineering - Research And Applications (CERA), 1-16.
- Yannou B., Farel R., Cluzel F., Bekhradi A., Zimmer B., 2016. The UNPC innovativeness set of indicators for idea or project selection and maturation in healthcare. International Journal of Design Creativity and Innovation, 5 (3-4), 205-221.
- Bekhradi A., Yannou B., Cluzel F., Vallette T., 2017. Categorizing users pains, usage situations and existing solutions in front end of innovation: The case of smart lighting project, In 21st International Conference on Engineering Design (ICED), August 21-25, Vancouver, Canada.
- Lamé G., Leroy Y., Yannou B., 2017. Ecodesign tools in the construction sector: analyzing usage inadequacies with designers' needs. Journal of Cleaner Production, 148, 60-72.
- Bekhradi A., Yannou B., Cluzel F., Chabbert F., 2016. Importance of problem-setting before developing a business model canvas, In International Design Conference, May 16-19, Dubrovnik, Croatia.
- Jaruzelski B., Loehr J., Holman R., 2012. The Global Innovation 1000: Making Ideas Work. Available at: http://www.strategy-business.com/article/00140?gko=f41fe.
- Lamé G., Yannou B., Cluzel F., 2018. Analyzing RID methodology through the lens of innovative abduction, In International Design Conference, May 21-24, Dubrovnik, Croatia.
- Yannou B., Lamé G., Cluzel F., 2018. Adapting the FBS model of designing for usage-driven innovation processes, In IDETC/CIE 2018: International Design Engineering Technical Conferences / CIE: Computers and Information in Engineering, August 26-29, Quebec City, Quebec, Canada.

Resources

- *Teachers*: Bernard Yannou (lead teacher), François Cluzel, Flore Vallet, Hanen Kooli-Chaabane, Aurélie Randazzo, Nathalie Delmas, Valérie Lejeune, Stephen Brown, Mélanie Marcel, Roxane Bibard, Philippe Costard, Michel Guiga, Mathieu Baudin, Dominique Barth, Olivier Sellès, Jérémy Sintes, Nicolas Rebierre, Romain Farel
- *Size of exercise classes*: 23 to 33 students depending on the total number of students
- Computer-assisted RID platform

Learning outcomes covered on the course

This Challenge Term addresses the challenge of **systematic usage-driven innovation**. It will provide students with knowledge, methods and practice for both focusing on valuable issues for users in their everyday lives and delivering innovative solutions and business models. **This course is designed for engineers who want to become experts of innovation processes in the context of a given company or a startup.**

After completion of this Challenge Term, the students will be able to:

- Know the vocabulary, main principles and strategies of innovation
- Understand the superior interest of the need seeker innovation strategy
- Understand the limitations of today practice of Design Thinking in companies and the interest to adopt an innovation engineering
- Understand usage and activity driven innovation and its corporate interest
- Know and implement the principles, the process and deliverables of the Radical Innovation Design® methodology
- Develop a state of mind and behavior conducive to innovation
- Question an innovative idea
- Implement RID methodology on a real business case of a company,
- Be efficient and participative players and/or managers of innovation projects
- Know how to define and achieve the stages of innovative projects: reframing the initial issue into the boundaries of an activity; building up expertise; coming up with the innovation targets that are worth to innovate on; generating relevant and augmented usage scenarios, solution concepts and business models; administrating prototyping, experimentation, evaluation and validation
- Build a broad and multidisciplinary knowledge around innovation (history of innovations, design, research, company strategy, economics, ethics, law & protection of innovation, prospective, human progress)
- Have an experience that is easily appreciated by an innovative company and, why not, open up possibilities for future collaboration (internships, caesura, employment...)

Description of the skills acquired at the end of the course

In general, from the CentraleSupélec Skills framework:

- C1: Milestone 2: Analyse, design and implement complex systems made up of scientific, technological, social and economic dimensions

- C2.3: Milestone 2: Rapidly identify and acquire the new knowledge and skills necessary in relevant domains, be they technical, economic or other
- C3.6: Milestone 2: Evaluate the efficiency, feasibility and strength of the proposed solutions
- C.4: Milestone 2: Create value for companies and clients
- C6.2: Milestone 2: Engage in design thinking using classic and agile conception and prototyping tools (CAD, 3D printers, …).
- C8.1: Milestone 1: Work collaboratively in a team

2EL2210 – Operations and supply chain management

Instructors: Guillaume LAMÉ
Department: SCIENCES ENTREPRISE
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Business Sciences
Advanced level : No

Description

This module provides an introduction to challenges in the management of operations and supply chains. It explores decisions involved in designing, planning and piloting production and distribution systems, both for goods and services. The main challenge in these systems is to ensure that the right product or service is delivered at the right place and the right time, in the quantity and at the quality required by the customer, while making efficient use of resources.
In this context, it is crucial to understand industrial systems at different levels (supply chain, factory, warehouse, workshops, machine), to identify processes, to assess economic and environmental challenges and to develop quantitative and qualitative methods and tools to improve the performance of these systems.

Quarter number

SG8

Prerequisites (in terms of CS courses)

none

Syllabus

This module will explore:
• The organisational dimension of production and distribution systems
• The performance of production systems through different perpectives (customer focus, goals and performance indicators, processes, resources, workplace safety, reliability, etc.)
• Qualitative and quantitative methods aimed at improving the performance of production and distribution systems
• The implementation of these approaches, including feasibility, adaptability, limitations and change management

Class components (lecture, labs, etc.)
Lectures and applications on exercises and study cases. Part of the content will be as reading assignments and videos to study individually before classes.

Grading
a project and a final written exam of 2 hours

Course support, bibliography
Lecture slides and notes, videos, study cases and exercises.

Resources
- Lectures, case studies, testimonies from professionals

Learning outcomes covered on the course
• Diagnose issues and to assess performance in industrial operations systems.
• Select the relevant fundamental tools and concepts to improve the performance of operations and supply chains.

2EL2220 – Organizational and market theories

Instructors: Yannick PEREZ
Department: SCIENCES ENTREPRISE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Business Sciences
Advanced level : No

Description

The object of this course is the analysis of organizations, based on the tools of the enlarged microeconomics. Like other fields of application in economics, Organizational economics has experienced sustained development over the past 20 years. The economics of organizations involves the use of economic analysis and its methods to understand the existence, nature, 'design' and performance of organizations. The economic analysis of organizations is carried out in comparison with the markets and it covers, beyond the firm, organizational forms of great diversity (unions, social movements, agencies, schools, ...).

Quarter number

SG6

Prerequisites (in terms of CS courses)

This course is given only in French, and all the materials are also in French.

Syllabus

1. Introduction
2. Chapter 1: Diversity of modes of organization in a market economy

    a. Markets as a structuring mode of production and trade
    b. Integrated organizations and the nature of the firm.
    c.. Hybrid forms
    d. The problem of arbitration between modes of organization

3. Chapter 2: Modes of coordination

    a. Information processes
    b. The role of contracts
    c. Nature and function of hierarchy

4. Chapter 3. Incentives and motivations

a. Incentives: basic models
b. Incentives linked to the properties of the modes of organization

5. Conclusion

Class components (lecture, labs, etc.)
The course is made up of two parts:
A first where the tools of economic theory of organizations are presented.
The second where they are implemented by student group projects working on typical situation in terms of Economics of organization

Grading
The assessment consists of two exercises.
The first is a presentation of a typical situation in a student group. This work represents 60% of the final grade.
The last is a table assignment composed of 4 questions on the essential concepts of the course. This work represents 40% of the final grade.

Course support, bibliography

Brousseau Eric – Glachant Jean-Michel, New Institutional Economics A Guidebook CUP Press.

Gibbons Robert & Roberts John, The Hanbook of Organisational Economics, Princeton.

Resources
Students must come with their laptops.
This year only one group will be open for 33 students.

Learning outcomes covered on the course

- Understand the challenges of creation, development and operation of economic organizations.
- Acquire the tools of contract theory
- Find out how to build incentives and coordinate teams
- Understand the determinants of the choice of organizational forms adapted to economic activities.

Description of the skills acquired at the end of the course

At the end of this course, the students will understand why economic organizations work or not.
They will understand the problems of hierarchical management, principal agent, moral hazards and adverse selection. They will have analyzed incentive and remuneration systems and will have analytical tools to understand inter-industry relationships.

2EL2230 – Maintenance and Industry 4.0

Instructors: Anne BARROS
Department: SCIENCES ENTREPRISE
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Business Sciences
Advanced level : Yes

Description

This course provides a solid culture on the concepts, methods and tools involved in the implementation of a predictive maintenance approach.

Predictive maintenance is one of the pillars of Industry 4.0. It is based on the use of data collected online, their processing and their integration into dynamic decision-making processes. It also relies on the provision of connected agents capable of performing tasks in real time and optimizing their management. Concretely, it is about anticipating failures, shutdowns, accidents in production processes or service systems and planning at best replacement, renewal, return to service operations, etc.

The objective of this course is to give future decision-makers the necessary culture to design, model and recommend predictive maintenance strategies. Emphasis is placed on data-driven approaches and probabilistic or statistical models that apply to any industrial system. This background should allow effective interaction with engineers "business" very close to applications and "data scientist" in charge of data processing

Quarter number

SG8

Prerequisites (in terms of CS courses)

Basic knowledge in probability and statistics, data analytics, modeling and optimisation

Syllabus

1. Maintenance and Industry 4.0: concepts (3h)

2. Modeling and quantification tools: Stochastic processes, Theory of renewal, Monté Carlo simulation, Machine Learning (3h)
3. Optimization tools (3h)
4. Corrective maintenance and resilience (3h)
5. Corrective maintenance optimisation (8h)
6. Predictive maintenance optimisation (12h)
7. Examination with use case (3h)

Class components (lecture, labs, etc.)

15h of lectures and 15h of tutorials with practical implementations of the models.

Possibility to have a proportion of the lecture in inverse class.

Grading

Use case within 3 hours with report (75% of the final grade)

Tutorial reports (25% of the final grade)

Course support, bibliography

Bibliography

- System Reliability Theory, Models, Statistical Methods and Applications, Marvin Rausand, Anne Barros, Arnljolt Hoyland, 2020, Third Edition, Wiley
- Degradation Processes in Reliability, Waltraud Kahle, Sophie Mercier, Christian Paroissin, John Wiley & Sons, 2016
- Maintenance, Replacement, and Reliability: Theory and Applications, Second Edition (Mechanical Engineering) 2nd edition by Jardine, Andrew K.S., Tsang, Albert H.C. (2013) Hardcover
- Case Studies in Reliability and Maintenanc, Wiley Series in Probability and Statistics, Wallace R. Blischke, D. N. Prabhakar Murthy, John Wiley & Sons, 2003
- Reliability and Optimal Maintenance, Hongzhou Wang Hoang Pham, 2006, Springer Science & Business Media
- Reliability and Maintenance Engineering, R C Mishra, New Age International, 2006
- Models of Preventive Maintenance (Study in Mathematics & Managerial Economics), Ilya B. Gertsbakh, North Holland, 1977

Material

Slides, Website, Jupyter Notebook

Resources

- Teaching Team (lectures en tutorials): Anne Barros, Yiping Fang, Zhiguo Zeng
- Outils informatiques: Python, Matlab

Learning outcomes covered on the course

- Design a maintenance strategy in a given application context
  - Make the appropriate modeling choice to assess the performance of a maintenance strategy
  - Know how to define and formalize relevant state variables
  - Know how to define and formalize a performance criterion
  - Know how to develop a model with the right level of abstraction from the description of scenarios or a set of transition/states
- Quantify performance from probabilistic or data-driven models
  - Know how to identify the right modeling framework based on stochastic processes (renewal process, Markov process, semi-markov, deterministic by pieces)
  - Know how to calculate probability laws or average quantities from an analytical formalism or Monte Carlo simulation
- Optimizing the performance of a maintenance strategy
  - Know how to implement parametric optimization techniques for a given performance criterion
  - Know how to formalize an optimization problem when the maintenance strategy is not fixed a priori

Description of the skills acquired at the end of the course

Validated skills:

- Design, model and recommend predictive maintenance strategies (C1.1 and C1.2)
- Being able to interact with business engineers and data scientists on this subject (C1.5 - milestone 2)
- Supervise the implementation of a predictive maintenance strategy from data collection to the practical implementation of maintenance activities (C1.5, milestone 2)
- The final case study is part of C1.3 (milestones 1B, 2B, 3B), C6.5 and C7.1

Validation mode

- Skills C1.1 (milestones 1 and 2) and C1.2 are validated during the TD sessions. Competency C1.1 is validated during the final case study for milestone 3.
- Competency C1.5 is validated during the final case study.

2EL2240 – Mobility issues

Instructors: Yannick PEREZ
Department: SCIENCES ENTREPRISE
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : No

Description

industry deeply associated with individual mobility. The first two are primarily technological in nature, they are the autonomous vehicle and the electric vehicle - battery or hydrogen. The third is related to the penetration and generalization of new information and communication technologies and the IoT in mobility which allows the implementation of the principles of the sharing economy.
The motivation for studying the combination of these three innovations is to determine the conditions for moving from a model of individual ownership of mobility goods with considerable negative externalities in terms of pollution, congestion, accidentology to uses of services. of autonomous, electric and / or shared mobility which could provide solutions to the aforementioned problems.
This transformation of the means of mobility is therefore at the crossroads of engineering approaches (how to set up autonomous mobility, what uses of 5G for mobility, how to use artificial intelligence, how to include electric vehicles in electricity networks for smart recharging based on renewable energy, etc.), the industrial economist (what underlying economic models, what regulation of uses, what games of players in an industry undergoing profound reorganization) and analyzes of mobility needs and consumer behavior (what incentives for adopting behavior, acceptance of car-sharing, new behavior and micro-mobility, multimodal transfers, etc.).

Quarter number

SG8

Prerequisites (in terms of CS courses)

nothing

Syllabus

Course 1: Introduction to energy transition and mobility.
Course 2: Electric Vehicle for Everything: Income Flow Framework
Course 3: Design pricing for EVs and renewable energy.
Course 4: Theories and applications of infrastructure deployments.
Course 5: Car Sharing Economics
Course 6: Car Sharing Economics an application in the Paris region
Course 7: Autonomous and shared electric vehicles: definitions, cost of technologies, shared mobility
Course 8: Exploring the system impact of automated taxis via simulation
Course 9: New technologies for urban and last-mile deliveries
Course 10: Mobility as a service
Course 11: New perspectives on urban mobility

Class components (lecture, labs, etc.)

During the 3 hour session, the first hour and a half will be led by a speaker (professor, researcher, town planner, economist, etc.) specializing in the topic. The tutorials will be held during the following hour and a half. In the tutorials, the students, in groups of 3, will make presentations on research articles made available to them by the speakers.

Grading

The course will be evaluated on the group work carried out during the tutorials for 60% of the final grade.
The 2-hour final exam will consist of 10 questions, one per course, for 40 % of the final grade

Course support, bibliography

Main Reference

Sperling, Daniel (2018) Three Revolutions: Steering Automated, Shared, and Electric Vehicles to a Better Future. Island Press/Center for Resource Economics

Complements

· Icaro Silvestre Freitas Gomes, Yannick Perez, Emilia Suomalainen 2020 Coupling small batteries and PV generation: A review, Renewable and Sustainable Energy Reviews 126 (2020) 109835.

· Andrew Thompson and Yannick Perez 2020, Vehicle-to-Anything (V2X) Energy Services, Value Streams, and Regulatory Policy Implications, Energy Policy 137 (2020) 111136

·	Quentin Hoarau & Yannick Perez, 2019, Network tariff design with distributed energy resources and electric vehicles, Energy Economics, Volume 83, September, Pages 26-39.

·	Olfa Tlili Christine Mansilla David Frimat Yannick Perez, 2019 Hydrogen market penetration feasibility assessment: Mobility and natural gas markets in the US, Europe, China and Japan, International Journal of Hydrogen Energy Volume 44, Issue 31, 21 June 2019, Pages 16048-16068.

·	Ramírez Díaz Alfredo, Marrero Gustavo, Ramos-Real Francisco, Perez Yannick, 2018 Willingness to pay for the electric vehicle and their attributes in Canary Islands, Renewable and Sustainable Energy Reviews Volume 98, December 2018, Pages 140-149.

·	Ramírez Díaz Alfredo, Ramos-Real Francisco Javier, Perez Yannick, Barrera Santana Josue, 2018, Interconnecting isolated electrical systems. What is the best strategy for the Canary Islands? Energy Studies Review- Vol. 22 (2018) pp. 37–46.

·	Hoarau Quentin and Perez Yannick, 2018, Interactions Between Electric Mobility And Photovoltaic Generation: A Review, Renewable and Sustainable Energy Reviews 94 (2018) 510–522.

·	Rodríguez Brito Maria Gracia, Ramírez-Díaz Alfredo Jesús, Ramos-Real Francisco J., Perez Yannick, 2018, Psychosocial traits characterizing EV adopters' profiles: The case of Tenerife (Canary Islands), Sustainability 2018, 10, 2053.

·	Codani Paul, Perez Yannick and Petit Marc 2018 Innovation et règles inefficaces : le cas des véhicules électriques, Revue de l’Energie n° 638, Mai-Juin

·	Borne Olivier, Yannick Perez and Marc Petit 2018, Market integration or bids granularity to enhance flexibility provision by batteries of Electric Vehicles, Energy Policy, Volume 119, August 2018, Pages 140–148.

·	Borne Olivier, Korte Klaas, Perez Yannick, Petit Marc and Purkus Alexandra 2018, Barriers to entry in Frequency-Regulation Services Markets: Review of the status quo and options for improvements, Renewable and Sustainable Energy Reviews. Volume 81, Part 1, January 2018, Pages 605–614.

·	Codani Paul, Perez Yannick and Petit Marc 2016, Financial Shortfall for Electric Vehicles: economic impacts of Transmission System Operators market designs, Energy, Volume 113, pp 422-431.

· Eid Cherrelle, Codani Paul, Perez Yannick, Reneses Javier, Hakvoort Rudi, 2016, Managing electric flexibility from Distributed Energy Resources: A review of incentives for market design, Renewable and Sustainable Energy Reviews, Volume 64, pp 237–247.

Resources

One large room and 4 smalls for TDs

Learning outcomes covered on the course

industry deeply associated with individual mobility. The first two are first of a technological nature, namely the autonomous vehicle and the electric vehicle - battery or hydrogen. The third is related to the penetration and generalization of new information and communication technologies and the IoT in mobility which allows the implementation of the principles of the sharing economy.
The motivation for studying the combination of these three innovations is to determine the conditions for moving from a model of individual ownership of mobility goods with considerable negative externalities in terms of pollution, congestion, accidentology to uses of services. of autonomous, electric and / or shared mobility which could provide solutions to the aforementioned problems.
Analyze the technical, economic and social potential of electric, autonomous and shared mobility. Highlight the limits of the proposed solutions, the business models under development and the needs to be met to implement this new low-carbon mobility in smarter cities.

Description of the skills acquired at the end of the course

industry deeply associated with individual mobility. The first two are first of a technological nature, namely the autonomous vehicle and the electric vehicle - battery or hydrogen. The third is related to the penetration and generalization of new information and communication technologies and the IoT in mobility which allows the implementation of the principles of the sharing economy.
The motivation for studying the combination of these three innovations is to determine the conditions for moving from a model of individual ownership of mobility goods with considerable negative externalities in terms of pollution, congestion, accidentology to uses of services. of autonomous, electric and / or shared mobility which could provide solutions to the aforementioned problems.
C1.1 Study a problem as a whole, the situation as a whole. Identify, formulate and analyze a problem in its scientific, economic and human dimensions
C1.3 Solve the problem with a practice of approximation, simulation and experimentation
C1.5 Mobilize a broad scientific and technical base as part of an approach

transdisciplinary.
C2.4 Create knowledge, in a scientific process
C3.6 Evaluate the efficiency, feasibility and robustness of the proposed solutions
C4.1 Think customer. Identify / analyze the needs, challenges and constraints of other stakeholders, particularly societal and socio-economic.
C7.1 To convince on the merits. Be clear about the objectives and expected results. Be rigorous about the assumptions and the process. Structure your ideas and argument. Highlight the value created.
C8.1 Work in a team / collaboration.
C9.4 Demonstrate rigor and critical thinking in approaching problems from all angles, scientific, human and economic

2EL2410 – Signal compression and denoising

Instructors: Gilles CHARDON
Department: SIGNAL ET STATISTIQUES
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

This course is an introduction to signal and image representations, analysis, compression and denoising, fundamentals of modern signal processing for music and video storage, image enhancing in smartphones, processing and medical and astrophysical images, etc.

Similar ideas are found in RADAR and SONAR signal processing, seismology for oil exploration...

After recalling fundamentals of functional analysis and signal processing (Sobolev spaces, Fourier transform, distributions...), this course will introduce the basics of multiresolution and time-frequency bases, particularly effective
for non stationary signals representation.

Using these tools, general principles of function and signal approximation applied to compression (MP3, JPEG, MPEG) will be introduced. Finally, application of these methods to signal denoising will be considered in a statistical context.

Quarter number

SG6

Prerequisites (in terms of CS courses)

1SL1000 CIP-EDP
1CC4000 Signal Processing

Syllabus

1- Introduction

- Sampling theorem, orthonormal basis of band-limited functions
- Generalization : signal representation in bases
- Spline bases
- Compression and approximation: linear vs non-linear approximation error

2- Multiresolution and time-frequency representations

- Riesz basis, multiresolution approximation, scaling function
- Wavelets and filterbanks
- Local block basis, overlapped basis, local cosines
- Application to images and sounds

3 - Image and sound compression

- Lossless compression (PNG, FLAC)
- Speech compression (LPC)
- Compression and approximation in orthonormal bases
- Entropy encoding, quantization
- Sparse approximations
- Perceptual models
- JPEG, MP3

4- Denoising

- Classical methods: Wiener filter, median filter
- Estimation of noisy signals
- Bayesian vs. minimax estimation
- Diagonal estimation in a basis
- Oracle and thresholding estimators

Class components (lecture, labs, etc.)
18h lectures
15h Tutorials/Labs
2h Final exam

Grading
Lab reports 30% Missed lab = 0 points for the lab Final exam 70% Remedial exam : written exam 2h with documents

Course support, bibliography
A Wavelet Tour of Signal Processing, Stéphane Mallat, Academic Press

Resources
Personal computers, Matlab, Python

Learning outcomes covered on the course

At the end of this course, the students will be able to
- Know the mathematical basis of non stationary signals representation
- Analyze signals using time-frequency representations
- Choose an appropriate representation for a given signal model
- Implement signal compression methods
- Recognize the limits of compression techniques
- Design, analyze and implement signal estimation methods

Description of the skills acquired at the end of the course

C1.2 Select, use and develop modelling scales, allowing for appropriate simplifying hypotheses to be formulated and applied towards tackling a problem.
C6.5 Operate all types of data, structured or unstructured, including big data.
C6.7 Understand information transmission.

2EL2420 – Digital image processing

Instructors: Elisabeth LAHALLE, Charles SOUSSEN
Department: SIGNAL ET STATISTIQUES
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

The goal of this course is to give a comprehensive overview of the classical approaches to image processing. The theoretical foundations will be introduced together with related algorithms. The main concepts will be illustrated and some image processing algorithms will be implemented using a simulation and data analysis software such as Matlab.

Quarter number

SG8

Prerequisites (in terms of CS courses)

- Signal processing
- Convolution
- Fourier transform and related properties
- Probability / statistics

Syllabus

Image acquisition systems and process of image formation.

Filtrage dans le domaine fréquentiel.

Examples of image processing : shape recognition, image registration, image segmentation, image restoration and reconstruction.

Image formats and basic analysis: histogram, thresholding of gray levels, Fourier transform.

Image sampling.

Image quantization.

Contrast enhancement: histogram equalization.

Color image analysis: format of color images (RGB, HSV, etc.) and basic analyses.

Linear filtering, notion of separability in the space domain.

Approche variationnelle (basée optimisation numérique) pour le débruitage et la déconvolution d’images.

Examples of smoothing and contrast filters : averaging and Gaussian filters, differential filters, Laplacian filter, Prewitt and Sobel filters, etc.

Nonlinear filtering: median filter, order filter.

Contour detection and image segmentation : active contour and region growing approaches.

Analysis of 3D and hyperspectral images: examples of image registration and image restoration / hyperspectral image unmixing.

Shape recognition using « eigenimages » in computer vision.

Class components (lecture, labs, etc.)

Basic image processing

lectures 3h, TD 2h :

Image acquisition systems and process of formation of an image.

Examples of image processing in various contexts : registration, segmentation, reconstruction.

Image formats and basic analysis: thresholding, histogram. Spatial sampling and quantization of a grey level image.

Image interpolation.

Basic analysis of a color image.

lectures 3h, TD 2h :

Linear filtering, notion of separability in the spatial domain.

Smooting filters and derivative filters: Gaussian filter, gradient and Laplacian filters, Prewitt and Sobel filters, etc.

Nonlinear filtering: median filter, order filter.

lectures 2h, TD 1h :

Filtering and Fourier analysis. Fourier transform of continuous and discrete images. Properties: Shannon theorem, filtering in the frequency domain.

Advanced image analysis

lectures 3h :

Geometrical models for image processing: pixel neighborhood, connexity, notions of regions and boundaries.

Algorithms of contour tracking and region labeling.

Image segmentation : region partioning, boundary detection, deformable contours.

lectures 3h :

Variational approach (based on the optimisation of a cost function) for image restoration and reconstruction: Tikhonov regularization, edge-preserving regularization.

lectures 3h :

Multidimensional image analysis: 3D spatial images and hyperspectrale images (2D + wavelength). Case of hyperspectrale unmixing: unmixing algorithms based on non-negative matrix factorization.

long term project: 11h

Grading

The final grade will be composed of :
- a mid-term quiz, 25 % of the final mark
- a project grade, 75 % of the final mark

Course support, bibliography

- M. Nixon & A. Aguado, *Feature extraction & Image Processing*, éd. AP, 2010.
- Jiri Jan, *Medical Image Processing, Reconstruction and Restoration*, éd. CRC Press, 2005

Resources

Room with computers and the Matlab software for practical sessions (TD).

Additional teachers (a third teacher) for practical sessions if the number of students exceeds 50 (more than 2 groups of 25).

Learning outcomes covered on the course

Basic knowledge on systems of acquisition of numerical images (cameras, microscopes, …) and the process of image formation.

Ability to analyze a numerical image.

Ability to implement elementary numerical image algorithms.

Description of the skills acquired at the end of the course

To have basic knowledge on image acquisition systems (cameras, microscopes, …) and the process of image formation.

Ability to characterize the format of a numerical image.

Ability to analyze the content of a numerical image.

Understanding simple numerical image analyses : detection of pixels in an image by thresholding the gray levels, histogram computation, linear and nonlinear filtering, smoothing and contour detection.

Learning advanced notions such as image segmentation based on geometrical models (contours and regions), image reconstruction based on the variational approach and 3D image analysis.

2EL2510 – Architecture and design of digital systems

Instructors: Anthony KOLAR
Department: SYSTEMES ELECTRONIQUES
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : No

Description

In a top-down approach, students will learn how to specify and design dedicated digital processing systems, with the goal of integration into an FPGA or ASIC.
The microelectronic back-end aspect (placement routing) will be reserved for students wishing to specialize in the field and studied in third year honors.
The course will lead to the creation of an application, for example a small processing processor, and will thus make it possible to understand the various concepts used in this one.

At the end of this course, students will be able to:
- Define and design the architecture of a digital processing chain
- Describe a model of this treatment in VHDL.
- Design a simple processor and program it

Quarter number

SG6

Prerequisites (in terms of CS courses)

Few knowledge in digital electronic

Syllabus

Class 1: Architecture of processing units: data path and sequencer - part. 1
Class 2: Architecture of processing units: data path and sequencer - part. 2
Class 3: VHDL Description
Class 4: Time Analysis of Synchronous Systems
Class 5: GPUs: Architectures and Data Path Part. 1
Class 6: GPUs: Architectures and Data Path Part. 2
Class_PC 1: Algorithmic Logic Units share. 1
Class_PC 2: The Algorithmic Logical Units part. 2
Class_PC 3: Registers, memories and pipeline part. 1

Class_PC 4: Registers, memories and pipeline part. 2
Class_PC 5: The instruction game
Class_PC 6: The instruction decoding part. 1
Class_PC 7: The cache and its strategies
Class_PC 8: The instruction decoding part. 2
Class_PC 9: Executions and conditional jumps
Cours_PC 10: The compiler

Class components (lecture, labs, etc.)
Definition of the notion of a Cours_PC:
This is a very strong interaction between a classical course and its almost immediate implementation, although here the approach is reversed: the exercises have as objectives to make realize where are the critical points without knowing the solution to there remedy. Once aware of the problem, the course brings the solution to students who are then much more sensitive. This approach is only possible under the condition that there is no clear cut between the course and the PC, hence the notion of Cours_PC.

1 project to realize partially in homework and in team:

- 4 project sessions (EL) of 1h30 in the presence of a supervisor
- 24h homework (interspersed with previous project sessions).
- 1 session of 3H with oral presentation then demonstration in front of the group of the result

The department will provide each pair of students with an FPGA-type board (the same ones used for the first-year course) that they will keep until the end of their project.

Grading
Examen - 2h - Processor Design
Project Repport

Resources

DE0 FPGA Board From Altera

Learning outcomes covered on the course
The course "Architecture of Digital Systems" will provide students with the concepts necessary to:

Define a processing architecture

Architecture of processing units: data path and sequencer
Description of each of the above functions in VHDL
Time analysis of synchronous systems

Design of a processor (Project type approach)

ALU, records and pipeline
Building a processor core
Instructional game
Instruction Decoding, Jumps and Pipeline

Data processing on graphic processor

GPU architecture: data path
Parallel programming language via CUDA type library

Description of the skills acquired at the end of the course

C1.1 Study a problem in its entirety, the situation as a whole. Identify, formulate and analyze a problem in its scientific, economic and human dimensions.
C1.3: Solve the problem with a practice of approximation, simulation and experimentation.
C2.3 Identify and quickly acquire new knowledge and skills necessary in the relevant fields, whether technical, economic or other.
C2.5 Master the skills of one of the basic engineering professions (at the junior level).
C3.6: Evaluate the effectiveness, feasibility and robustness of the solutions proposed.
C6.3: Specify, design, produce and validate software.

2EL2520 – From transistor to complex analog system

Instructors: Emilie AVIGNON-MESELDZIJA
Department: SYSTEMES ELECTRONIQUES
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : Yes

Description

Analog electronic systems are presents in everyday life devices (Smart Phone, biomedical devices, RFID sensors…), but also in more specific and advanced applications (devices for spatial environment, radar/telemetry, aeronautical devices...). The purpose of this course is to provide design methodologies for analog systems based on specification and the basics to be able to analyze an existing circuit.
The proposed approach is bottom-up. The student learns the functioning of the transistor, then how to associate blocks based on transistors (amplification, filtering, frequency translation…), then how to associate these blocks to obtain a complex system. Through this approach the student will lern to master transistors models, dimensioning methods and simulation.

Quarter number

SG8

Prerequisites (in terms of CS courses)

It is recommended to master the basics of electronic circuits to attend this course (Kirchhoff voltage and current laws, Ohms law…). The 1st year course of electronics systems is a sufficient background as well as a second year PSI background.

Syllabus

CM = Lecture
PC = Tutorial
Cours PC = between lecture and tutorial

CM1 : initiation to integrated circuits
Introduction to CMOS integrated techologies, cross sectional view of the

transistor, rough explanation of the transistor physics
CM2 : Model of integrated components
Model of passive compoents. Model of the MOS transistor in the different functioning mode.
CM3 : Fundamental circuits for amplification
Analysis of fundamental circuits based on MOS transistors (common source, common drain, common gate).
Cours PC1 : Study of circuits containing one or two transistors
PC1 : First study of a circuit containing one or two transistors
CM4 : Association of fundamental circuits
Design of fundamental blocks: bias current source, current mirror, voltage reference….
Cours PC2 : Study of circuits composed of...circuits
PC2 : Study of a transonductance amplifier (OTA)
CM5 : Switched circuits
Switched transistors. Application of switched transistors (mixer, switched capacitor filters, sample and hold circuit).
Cours PC3 & cours PC4: Study of swicthed circuits
PC3 : Study of sample and hold, switched capacitors filter.
CM6 : Design of complex analog circuit
Design of complex analog circuit (examples : synchronous/asynchronous comparator, Gm-C filter synthesis…, Gilbert cell…).
Cours PC5 & cours PC6: Study of complex analog circuits
PC4 : Design of a complex analog circuits for communication systems

The course also includes 4 project schedules of 1h30 and 2h of exam.

Class components (lecture, labs, etc.)
The course mixes theoretical approach with tutorials presenting classical practical cases commented by a teacher. This way the students get familiar with the reasoning methodology and will be able to reproduce these reasoning on other cases.

Grading
Written exam

Course support, bibliography
Tony Cahn Carusone, David A. Johns, Kenneth W. Martin “Analog Integrated Circuit Design” Wiley

R. Jacob Baker « CMOS Circuit Design, Layout and Simulation” IEEE Series on Microelectronics Systems and Wiley

Resources
It is highly recommended to practice in order to master Analog electronics, this is why this course mixes theoretical approach with tutorials presenting

classical practical cases commented by a teacher. This way the student learns the method for problem solving in analog electronics.

Learning outcomes covered on the course

After this course, the students will be capable of:

- designing an electronic assembly to achieve an analog signal processing chain,
- analyzing an electronic assembly based on transistors and passive elements

Description of the skills acquired at the end of the course

C1.4 Specify, design, build and validate all or part of a complex system
C6.2 Practice collaborative design through design or prototyping tools (CAD, 3D printers...)
C8.1 Work in team/collaboration
C2.1 Have developed a field or discipline related to the basic engineering sciences

2EL2530 – Integrated MEMS sensors

Instructors: Jerome JUILLARD
Department: SYSTEMES ELECTRONIQUES
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : No

Description

In many application fields - automotive, medicine, aeronautics and defense, telecommunications or consumer electronics (smartphones, tablets) - the development or integration of miniaturized MEMS (Micro-Electro-Mechanical Systems) sensors is now a prerequisite for the deployment of connected applications. These devices are used as sensors (accelerometers, gyroscopes, pressure sensors, microphones, etc.), actuators (inkjet printers, optical displays) or for energy conversion. They have such advantages in terms of reliability, consumption, metrology, dimensions and cost that they have rapidly become essential (but invisible) elements of our daily lives since the 1990s and will play an increasing role in our future.
This course covers theoretical and practical aspects, from the point of view of modelling (multi-physical/multi-domain modelling, model order reduction), physics (mechanical, electrostatic, fluidic, fundamental metrological limits), technology (micro-manufacturing techniques, integration, packaging), and economics (profitability). It aims at providing a comprehensive overview of the field, which will be of interest to students with a taste for "beautiful physics" and for the design of complex systems, and/or those who wish to understand the large-scale industrialization of integrated devices.

Quarter number

SG6

Prerequisites (in terms of CS courses)

Basic knowledge of electronics (opamps) - Scientific English

Syllabus

Lectures = 12h

CM1 - MEMS overview (applications: sensors, actuators, transducers, main players)
CM2 - MEMS and mechanics
CM3 - Detection and electronic interfaces
CM4 - Actuation and electronic interfaces
CM5 - Resonance and dissipation
CM6 - Fabrication
CM7 - Integration and packaging
CM8 - Influence quantities, calibration and test

Labs = 9h
PC1 and PC2. Pendular accelerometer (sensitivity / instability / dynamic range optimization) - Coventor modeling and simulation (3h)
PC3 and PC4. Resonant gyroscope (resolution / control / resonant detection) - Coventor modeling and simulation (3h)
PC5 and PC6. Process and packaging simulation - Coventor modeling and simulation (3h)

Conferences = 3h (examples)
S1 - Focus on an application / process
S2 - Focus on a company

Projects = 9h (examples)
Optimization (mechanical, electronic) and design of MEMS devices
Model order reduction of multi-physical phenomena
Characterization / testing / reverse engineering of MEMS sensors
Bibliography / state of the art / market research on MEMS applications

Class components (lecture, labs, etc.)
Lectures (12h), labs (9h), conferences (3h), projects (9h)
Lectures and documents in English

Grading
Multiple choice test on lectures / labs (50%) Project report (50%). In case of a justified absence to one of the intermediary examinations, the grade of this latter is replaced by the grade of the final examination.

Course support, bibliography
Practical MEMS, V. Kaajakari, Small Gear Publishing, 2009
Inertial MEMS, principles and practice, V. Kempe, Cambridge University Press, 2011
Micro Mechanical Transducers, Pressure sensors, Accelerometers and Gyroscopes, M.-H. Bao, Elsevier, 2000
Micromachined Transducers Sourcebook, G. T. A. Kovacs, McGraw-Hill, 1998

Resources
Coventor MEMS+ software (50 free licences granted by the company)
MEMS components, a room and equipment (notably for test) for projects
C2N clean room access
1 MEMS tapeout (SOIMUMPS process)

Learning outcomes covered on the course
Knowing the main types of MEMS sensors / actuators and their applications
Knowing the main fabrication, integration and packaging processes of MEMS devices
Knowing the main physical phenomena involved at the micro-scale (mechanics, transduction, dissipation, noise)
Understanding how MEMS inertial sensors (accelerometers, gyroscopes) work, from physics to electronics and control.
Being able to dimension such a system, and to simulate it using a professional design tool

Description of the skills acquired at the end of the course
C1.1 : Examine problems in their entirety and beyond their immediate parameters. Identify, formulate and analyse the scientific, economic and human dimensions of a problem
C1.2 : Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when addressing a problem
C2.3 : Rapidly identify and acquire the new knowledge and skills necessary in applicable / relevant domains, be they technical, economic or others.
C3.6 : Evaluate the efficiency, feasibility and strength of the solutions offered. / proposed solutions
C7.1 : Persuade at core value level; to be clear about objectives and expected results. To apply rigour when it comes to assumptions and structured undertakings, and in doing so
structure and problematise the ideas themselves. Highlight the added value

2EL2610 – Communications Theory

Instructors: Sheng YANG
Department: TÉLÉCOMMUNICATIONS
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : Yes

Description

Communication is a fundamental need in all our societies. The ever-evolving communication networks and the emerging Internet of Things have become a decisive transforming factor in a large number of industrial sectors (e.g., telecommunications, multimedia, space exploration, surveillance, control, navigation, transport, health, agriculture, construction, environment). The amount of information exchanged has increased dramatically, and connectivity is becoming ubiquitous thanks to technological innovations and advanced processing. There are many new challenges: record-breaking high throughput and long-distance optical fiber channels, ultra-reliable low-latency mobile links for critical missions, reliable connection between billions of energy-efficient objects, exploding traffic of multimedia content delivery, outer space exploration ... The communication theory allows for a deep understanding of the fundamental limits of a communication system and how existing algorithms works, and more importantly, lays down the foundation for future engineers to solve the unknown use cases.

In this course, we focus on the general point-to-point communication system consisting of a source, a transmitter, a channel, a receiver, and a destination. The student will learn the mathematical tools and methods to model, analyze, design, and optimize the key components of a communication chain. First notions of information theory will allow the student to understand the minimum number of bits needed to describe a given source losslessly, as well as the maximum number of bits that the transmitter can communicate reliably with the receiver through a noisy channel for a given resource (e.g., time, bandwidth, power). This course also aims at providing a methodology to conceive a communication system with practical constraints due to technological or regulatory limitations (e.g., reliability, latency, energy efficiency, spectral efficiency, complexity, storage capacity, cost, consumption).

Quarter number

SG6

Prerequisites (in terms of CS courses)

- Model representations and analysis
- Signal processing
- Statistics and learning

Syllabus

1- Overview of communication systems

The communication chain : source, transmitter, channel, receiver, destination.

Layering and binary interfaces.

2- Digital representation of source and coding

Signal space point of view, equivalence between sequences and waveforms.

Sequence representation of a continuous-time source, sampling theorem. Quantization.

Different source models and their properties.

Information, entropy, source coding, construction of source codes.

Examples of practical compression algorithms : Lempel-Ziv, JPEG, MP

4- Digital communication

Different communication channel models and their properties.

Additive white Gaussian noise channel. Digital modulation (PAM, QAM, PSK), Nyquist's criterion, passband modulation, baseband-passband equivalence.

Optimal detection rules, analysis of probability of error, signal to noise ratio. Practical implementation of transmitter/receiver.

4- Channel coding

Equivalence between continuous-time and discrete-time channels. Mutual information, Shannon's channel capacity.

Channel codes: linear block codes, convolutional codes, LDPC codes, polar codes.

Hard decoding, soft decoding, Viterbi algorithm. Performance analysis.

5- Communication system optimisation

Integration of the individual blocks into a complete communication chain.

Optimization of the individual parameters for a target performance.

Simulation of the end-to-end performance.

Class components (lecture, labs, etc.)
Courses (19,5 H)
Exercise sessions (7,5 H)
Lab sessions (6H)
Final written exam (2H)

Grading
Lab report (30%) Written exam (70%) In case of a justified absence to one of the intermediary examinations, the grade of this latter is replaced by the grade of the final examination.

Course support, bibliography

- R.G. Gallager. Principles of digital communication. Cambridge University Press; 2008.
- A. Lapidoth. A foundation in digital communication. Cambridge University Press; 2017.
- T.M. Cover, J.A. Thomas. Elements of information theory, Wiley, 2nd edition, 2005.

Resources
Lecturers:

- Sheng Yang teaches the lectures
- Sheng Yang, Richard Combes, Koen De Turck for the exercise sessions
- Sheng Yang for the lab sessions

Group size for the exercise sessions: 25-35 students per group (max. 3 groups)
Software: Matlab, Python

Rooms for the lab sessions: Department of Telecommunications

Learning outcomes covered on the course
At the end of the course, the student will learn the underlying mathematical principles of modern communication systems, essential both in further education and in the workplace in the long term. In particular, the student will be able to
- model, analyze, design, and optimize the key components of a point-to-point communication channel,
- construct simple source codes and channel codes for different purposes,
- build optimal decoder/detector for the receiver,
- manipulate the vector space of information sources and communication signals.

Description of the skills acquired at the end of the course
C6.7 Understand the transmission of information
C1.2 Use and develop suitable models, choose the right modeling scale and simplifying hypotheses to deal with the problem
C1.4 Specify, design, build, and validate all or part of a complex system
C2.1 Have deep knowledge of a field or discipline relating to the basic sciences or the engineering sciences

2EL2620 – Mobile communication networks and services

Instructors: Mohamad ASSAAD
Department: TÉLÉCOMMUNICATIONS
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : No

Description

Communication networks have been widely developed and spread across the globe in less than half a century. Mobility is an important element required for the needs of increasing connectivity (any where, anyhow, any time). Networks are in great (r) evolution to support the transformation of many so-called vertical sectors (telecommunications, transport, energy, health, agriculture, industry ...). Networks are evolving into programmable software networks, cloud and network convergence and virtualization of network functions.

The objective of this course is to understand the architectures of the current networks and to provide a prospective vision of the evolutions, the procedures to manage the mobility and the resource-sharing concept of a radio access. This course presents the theoretical foundations and tools used for the design, optimization, deployment and management of communication systems and networks.

Quarter number

SG6

Prerequisites (in terms of CS courses)

none

Syllabus

- General introduction and architecture of mobile networks
  - Standard bodies. Spectrum allocation
  - Services (VoIP, multimedia content broadcast,...). New services (IoT, factory of the future, etc.)
  - Introduction to cellular networks (GSM, UMTS, LTE, 5G).

- Cellular Concept
    - Cellular concept: Propagation models, radio access techniques
    - Radio resource management: power control, interference management, Optimisation
    - Network dimensioning, deployment, optimisation
- Mobility management and Quality of Service
    - Traffic and Quality of Service. Quality of Experience. Quality of coverage and connectivity.
    - Traffic models and dimensioning: Erlang formula, queueing models, etc.
    - Mobility management: handover, routing, roaming

Class components (lecture, labs, etc.)

Organization of the lectures

-General Introduction: 3h (CM)
-Cellular Concept and Radio Access: 6h (CM) - 3 (TD) - 3h (TP)
-Mobility management and Quality of Service: 9h (CM) - 3 (TD) - 6h (TP)

TP 1: Performance of radio access techniques (3)
TP 2: Capacity and coverage of wireless networks (3)
TP 3: Traffic engineering and dimensioning of networks (3h)

Grading

Grading: - Final Exam: 2h (70% of the final mark)- TP: 30% of the final mark

Resources

Lecturers: Mohamad Assaad and Salah Eddine Elayoubi
Exercices sessions (TD): 25 students per classroom
software to use (TP): Matlab

Learning outcomes covered on the course

At the end of the course, the student will be able to:

1- know the architecture and different function of wireless networks
2- model a cellular network with its main functions
3- perform a cellular network planning
4- know the principles of mobility management and quality of service in wireless networks.
5- implement cellular network models and mobility management function using Matlab.

Description of the skills acquired at the end of the course
Learning outcomes 1, 2 and 4 lead to the achievement of milestone 1 of competence C1.1, i.e. "List the parameters that influence the system under study, list the elements with which it is related" and "Identify the important parameters with regard to the problem at hand". Learning outcomes 3 and 5 lead to the achievement of milestone 1 of competence C1.2, i.e. "Know how to use a model presented in class in a relevant way". Selecting simplifying hypotheses that are appropriate to the problem at hand". Learning outcome 5 also leads to the achievement of milestone 2B of competency C1.3, i.e., "Knowing the limitations of numerical simulations and what can be expected from them, knowing how to criticize the results of numerical simulations.

2EL2630 – Applications of statistical and quantum physics to information science

Instructors: Zeno TOFFANO
Department: PHYSIQUE, TÉLÉCOMMUNICATIONS
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

This course is an opening to mathematical, informational and statistical theories and methods issued from statistical and quantum physics used in information science.

These methods are currently applied in many fields related to information processing, neural networks and deep learning, image processing, telecommunications, the semantic web, artificial intelligence, computational biology... but also more generally in the humanities and social sciences with, for example, applications in natural language processing and in finance.

The notions of entropy and information are central to this approach. For example, the study of disordered spin systems is applied to the processing of discrete information and statistical inference with important applications for example in telecommunications. More recently, operational techniques using quantum information have shown their advantage over conventional methods, the emblematic example being the quantum computer.

The purpose of the course, which is transdisciplinary in nature, is to establish connections between the training in mathematics and physics and advanced technological applications, such as digital communications, data processing, algorithmic learning and also quantum computation and information. It is intended for students wishing to familiarize themselves with research and engineering topics in top scientific and technological fields in a digital environment.

Quarter number

SG8

Prerequisites (in terms of CS courses)
analysis and probability theory, linear algebra, quantum and statistical physics and modeling.
Desired notions in information theory, machine learning, communications theory, algorithmic and complexity theory.

Syllabus

Overview and general concepts

- Scientific, historical and application panorama around the evolution of the concept of entropy in physics and information theory.
- Recent developments: from physics to information and communication sciences, to artificial intelligence and also social and life sciences.

Statistical physics, inference, and computing

- Thermodynamic equilibrium as a calculation instrument: Gibbs fields and potentials, Boltzmann machines, moments and cumulants, Feynman graphs, the replica method.
- Local interaction models (Ising and generalizations) and Bayesian inference. Application to the estimation of noisy images.
- Markov dynamic models and graphs: belief propagation algorithm, factor graphs, performance of neural network models, analysis of phase transitions in complex systems.

Statistical physics and information and communication theory

- Information measures: Shannon entropy, relative entropy, differential, mutual information, inequalities, other forms of entropy (Fisher, Renyi, Tsallis ...)
- Information and communication theory: source entropy, data compression, capacity and coding theorems of a communication channel.
- Statistics and information theory: large deviations, physics of coding theorems, interpretation by statistical physics of information measures, optimization problems.

Quantum information

- Consequences of the quantum mechanics postulates: the quantum measurement problem, quantum superposition and composition, von Neumann entropy, no-cloning and entanglement.
- Quantum computing: quantum qubits and circuits, parallel and probabilistic calculations, quantum algorithms for inference and optimization, quantum random walks.
- Applications: quantum communications and cryptography, quantum error correction, quantum tomography and estimation, quantum control,

quantum optimization and machine learning.

Class components (lecture, labs, etc.)
27 HPE magsitral courses: 18 lessons of 1h30 (CM)
6 HPE Training Classes: 4 classes of 1h30 (TD)

Grading
2 HPE: 2 hour examination (with documents)

Course support, bibliography
Nishimori H., "Statistical Physics of Spin Glasses", Clarendon 2001.
Chung F.K., Spectral Graph Theory, AMS 1991
Opper M., Saad D. (Eds.) Advanced Mean Field Methods, MIT 2001
Mézard M., Montanari A., "Information, Physics, and Computation", Cambridge, 2009.
Nielsen M., Chuang I., "Quantum Computation and Quantum Information", Cambridge, 2001
Jaeger G., "Quantum Information: An Overview", Ed. Springer 2007.

Resources
- Teaching team (names of lecturers) :
  A.O. Berthet ,   M. Pourmir ,   Z. Toffano

- Size of TD (by default 35 students)
- Software tools and number of licenses required: Matlab, Python
- Practice rooms (department and capacity) :

Learning outcomes covered on the course
At the end of this lesson the student will be able to:
1) To understand in a multidisciplinary context the importance and the impact of the concept of classical or quantum Entropy
2) Interpret with the help of the mathematical tools of Classical and Quantum Statistical Physics concrete cases for example in the field of telecommunications, big data or finance.
3) To propose solutions in new problems thanks to statistical inference, to different optimization criteria and quantuminformation learned during the course.
4) Implement modelizations in a computer environment.

Description of the skills acquired at the end of the course
Learning outcomes 1 and 2 allow to reach the milestone 1 of the C1.1 skill, *ie* "Know how to make the influence of peremeters influent on the analysed system, the list of the elements with which it is in relation "and" Knowing how to identify important parameters with respect to the given

problem".
Learning outcomes 3 and 4 enable to reach milestone 1 of skill C 1.2, that is, "Knowing how to use a model presented in the classroom in a relevant way." Making the choice of the simplifying hypotheses adapted to the problem".
Learning Outcome 4 also achieves milestone 2B of skill C 1.3, ie "Knowing the limitations of numerical simulations and what can be expected, namely, to criticize numerical simulation results. ".

2EL2710 – Design your way

Instructors: Catherine CHAPUIS, Fabienne BERGE
Department: LEADERSHIP ET MÉTIERS DE L'INGÉNIEUR
Language of instruction: ENGLISH, FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Business Sciences
Advanced level : Yes

Description

This course covers the fundamentals of self-knowledge (intellectual and relational functioning) and integrates the principles of Design Thinking in the construction of one's choices and career path. It is based in particular on the work of Stanford's Life Design Lab, which is well appreciated by students. It allows you to work on self-esteem, and to prepare for important choices to come. It also offers a framework for integrating different learning experiences at school (in class, API and APP workshops, Student organizations, sports highlights, etc.).
This course deals with the question of the freedom and responsibility of each individual in his or her school career, his or her choices of orientation, or the way to exercise his or her future profession as an engineer, based on guided introspection/reflection on concrete situations exposed (group discussions, videos, theoretical contributions). It leads to a greater awareness and capacity for individual questioning on the adequacy between one's actions and decisions, and one's own values. It gives students the opportunity to take a step back and think about their life view and work view.

It involves a significant individual commitment and work (readings, and Inter-Sessional Works).

Elective objectives: awareness of one's own individual functioning as well as that of others, for better autonomy and resilience in the face of choices and different stages of student and professional life. Awaken students to what influences their decision-making, as soon as they make their choices of curriculum and employment. Gain clarity, self confidence, and ability to inspire trust.

Quarter number
SG6 (in intensive week) eand SG8

Prerequisites (in terms of CS courses)
none

Syllabus
1 - My past and present: Self-knowledge module with an Introduction that notes the difficulty of connecting with oneself (ref to Edgard Morin and Henri Bergson) in today's volatile, complex, uncertain world - Myers Briggs Type Indicator (MBTI) well recognized preference questionnaire that allows us to identify our inner preferences (in everyday life, with others, in our work environments) - Course on multiple intelligences : identify your resources among the 8 different forms of intelligence identified (cf Howard Gardner’s model) in order to make the best use of them - Time to reflect on your values and motivational drivers to put at the heart of your life plan - time to integrate the different learning (courses, API, APP, student organizations, sports, company meetings, internship op...).

2 - My future: Use the Design Thinking tools and mindset to discover and develop the ability to generate new ideas when faced with a choice, and to adopt the right attitude at the end of a cycle (end of studies, end of a job or internship) in order to prepare to rebound towards the next cycle - Writing exercise (life view / work view) - Reflection work on 3 possible future scenarios (5-year period Odyssey plan).

Grading
Presence - Involvement - Personal and team productions (essays + video) after each TD – book readings and presentations

Resources

- Teaching team (names of the teachers of the lectures): Fabienne Bergé - Catherine Chapuis

- Size of the TDs (default 35 students): 35 students maximum

Learning outcomes covered on the course

At the end of this course, the student will be able to : make better choices, introduce yourself to recruiters, be less dependent on others, be agile in a volatile and uncertain world where you need to know where you stand, better assess your priorities and acquire good reflexes to manage the breaks or rebounds to be made during your professional life, acquire a better ability to step back, develop your ability to generate ideas.

Skills Worked: C3, C7.2, C7.3, C9

Description of the skills acquired at the end of the course

C3 : Act, engage, innovate within a scientific and technological environment

C7.2 : Persuade through interpersonal relations to understand the needs and expectations of multiple participants in a dialogue, elicit reactions and create a climate of trust

C7.3 : Persuade by working on oneself; to be at ease within any environment, to work with both confidence and empathy, managing one's emotions and using communicative strategies.

C9 : Think and act as an accountable ethical professional

2EL2720 – Tutoring of young people with disabilities

Instructors: Lionel HUSSON
Department: LEADERSHIP ET MÉTIERS DE L'INGÉNIEUR
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 30
Quota :
Elective Category : Business Sciences
Advanced level : No

Description

The tutoring of people with disabilities is a pedagogical and solidarity-based action that consists of helping young disabled people (in middle school, high school or university) to overcome obstacles and promote their access to higher education and professional integration. Conducted with the supervision and help of experts, it is an experiential learning situation that prepares the tutors, students in the school, for the subjects of diversity, while developing more globally their adaptation, responsibility and managerial capacities.
Teaching also accessible in 1A without this giving place to a replacement of the engineering sciences unit.

Quarter number

SG8

Prerequisites (in terms of CS courses)

Tutors must be able to understand and express themselves in French without difficulty.

Syllabus

1. Understanding disability and its consequences for students and on their studies
2. How to define the appropriate context and adopt the right posture for engaging and conducting a tutoring session.
3. Carry out, experience and adapt tutoring with one or more young people with disabilities
4. Take a step back from the lived experience, formalize the acquisitions of the tutored and the tutor

Class components (lecture, labs, etc.)
The tutoring is declined in 2 ways

- Group tutoring: in partnership with Sopra-Steria. A group of tutors accompanies a group of young people, to help them clarify their training projects, gain self-confidence and express themselves in a group.
- Individual tutoring: in partnership with the Fedeeh association. A tutor accompanies a young person, in the form of learning support. The sessions take place according to the tutors' availability.

- Pre-tutoring training :
  - E-learning: SPOC "disabilities".
  - 1 day (6 hours) of sensibilisation on disability.
  - 1 session (3 hrs) of training and role-playing workshop on conducting mentoring
- Approximately 10 tutoring sessions (1h30 each) to be carried out in the partner institutions during the school year according to a typically weekly rhythm adapted to the needs of the tutored students.
- 1 session (3h) for mid-term monitoring and sharing of experiences
- 1 session (3 hours) of assessment and presentation of the completed tutoring

Grading
Continuous monitoring (participation in training sessions; completion of tutoring sessions and debriefing) 50% + final evaluation ("learning journal" report and oral presentation) 50%
For the first learning outcome only simple knowledge or application is required, it will be assessed in the form of course questions, multiple choice questions in continuous assessment.
The next two learning outcomes require students to practise tutoring sessions and to step back from situations encountered. They will be assessed in two situations: in continuous assessment based on the course of the sessions (preparation and progress report and session report) and in final assessment by producing a report ("learning journal" illustrating the learning outcomes in relation to situations encountered and a reflective analysis) supplemented by an oral presentation.

Course support, bibliography
e-learning " disabilities " and tutor's booklet

Resources

- Teaching team (names of the teachers of the lectures): Lionel HUSSON and trainers from Sopra-Steria and the Fedeeh
- TD size (default 35 students): max 24
- Software tools and number of licenses required: no
- Public works rooms (department and capacity): no

Learning outcomes covered on the course
At the end of this teaching, the student will be able to :

- Understand what disability means: types of disability, consequences for individuals and societal issues for the school and the professional world.

- Mobilize pedagogical, relational and organizational skills to structure and conduct an effective work activity with one or more people.
    - by working on the relationship to the other. Understanding the needs and expectations of one's interlocutors. Taking them into account in an evolutionary way. Encouraging interaction. Create a climate of trust
    - by working on oneself. Being helpful. Being convinced. Showing empathy. Managing emotions.

- Understanding how to act as a responsible professional. Thinking, acting ethically
    - understand and analyse the possible consequences of one's choices and actions
    - perceive the scope of responsibility of the structures to which one contributes, integrating environmental, social and ethical dimensions
    - act with ethics, integrity and respect for others
    - demonstrate rigour and critical thinking in approaching problems from all angles, scientific, human and economic

Description of the skills acquired at the end of the course
At the end of this teaching, the student will be able to :

- Understand what disability means: types of disability, consequences for individuals and societal issues for the school and the professional world.

- Mobilize pedagogical, relational and organizational skills to structure and conduct an effective work activity with one or more people.
    - by working on the relationship to the other. Understanding the needs and expectations of one's interlocutors. Taking them into account in an evolutionary way. Encouraging interaction. Create a climate of trust
    - by working on oneself. Being helpful. Being convinced. Showing empathy. Managing emotions.

- Understanding how to act as a responsible professional. Thinking, acting ethically
    - understand and analyse the possible consequences of one's choices and actions
    - perceive the scope of responsibility of the structures to which one contributes, integrating environmental, social and ethical dimensions
    - act with ethics, integrity and respect for others
    - demonstrate rigour and critical thinking in approaching problems from all angles, scientific, human and economic

2EL2730 – Electif associatif

Instructors: Ludovic-Alexandre VIDAL, Guillaume MAINBOURG, Géraldine CARBONEL
Department: LEADERSHIP ET MÉTIERS DE L'INGÉNIEUR
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Business Sciences
Advanced level : No

Description

This elective course aims to enhance the skills acquired by the student through his or her heavy responsibilities and commitment to associations. It is therefore specifically designed according to the skills to be validated by the student after first examining the student's project. The selection for this elective course is made by prior interview to be sure of the validity of the project in terms of validation of skills.

Quarter number

SG6

Prerequisites (in terms of CS courses)

Belonging to a specific association / associative project.

Syllabus

Work on the mastery of these skills/knowledge through the establishment of concrete deliverables defined beforehand with the supervisors and relating to the association/project, which should allow a good evaluation of the acquisition of skills.

Class components (lecture, labs, etc.)

Specific to each student.

Grading

Establishment of precise deliverables presented and validated in the report / defense mode and delivery of the deliverables.

Resources

Supervision / outside view / advice / possible contact with professionals to increase the level of skills.

Learning outcomes covered on the course
Specific to each student.

Description of the skills acquired at the end of the course
Specific to each student, but competencies C4, C6, C7, C8 and C9 are a priori valid in this elective.

2EL5010 – Introduction to mobile applications engineering

Instructors: Virginie GALTIER
Department: CAMPUS DE METZ
Language of instruction: FRENCH
Campus: CAMPUS DE METZ
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

The mobile application market is one of the fastest growing, and analysts predict that this trend will continue for a few years as smartphones are of use in two emerging fields: augmented and virtual reality (because of their sensors such as the gyroscope or accelerometers), and the Internet of Things (IoT) and home automation (because of their WiFi or Bluetooth connections).

This course focuses on the development phase of a mobile application, after the specification of its functionalities and before its possible publication on a store. Two main strategies will be presented: web applications, with limited functionalities usable on both Android and iOS, native applications, more powerful but requiring specific developments. A wide part of this course is dedicated to concrete work, on Android to illustrate the development of native mobile apps, and with React (for example) to illustrate the development of progressive web apps. Optionally, students will also learn about securing Android applications.

The knowledge and know-how acquired during this course may be useful in some curriculum-assigned projects, or in campus associations or enterprise activities.

Quarter number

SG6

Prerequisites (in terms of CS courses)

1CC1000 –Information Systems and Programming

Syllabus

Introduction

- Overview of mobile application development strategies

- Basics of Objects Oriented Programming in Java

Android application development

- Android system overview
- Development tools
- Design and implementation of applications based on Activities, Layouts and Services

Introduction to web application development

- Basics of HTML5, JavaScript and CSS
- Design and implementation of a simple web application

Introduction to Android applications security

- Presentation of common vulnerabilities
- Protection mechanisms

Class components (lecture, labs, etc.)
The course is essentially made up of "learning by doing" sessions led by teachers and industrial experts. The introduction to the security of android applications will take the form of an escape game.

Grading
The skills acquired by the student during the course will be evaluated on the basis of a short final individual written test (1/4), the development of a personal Android application with some imposed elements (1/2) and the analysis of a provided Android application (1/4). Unjustified absence from the final test will result in a mark of 0 on this part of the evaluation, otherwise it will be made up in the form of a 20-minute oral exam. Late delivery of development work or analysis work will lead a penalty of one point for each day of delay, the deadline will be extended if supporting elements are provided.

Course support, bibliography

- *Head First Android Development.* Dawn Griffiths, David Griffiths. O'Reilly. 2015

- *Building Progressive Web Apps: Bringing the Power of Native to the Browser.* Tal Ater. O'Reilly. 2017

- *HTML, CSS, and JavaScript All in One*. Julie C. Meloni. Pearson Education. 2014

Resources
Teaching staff: Virginie Galtier, Michel Ianotto, Patrick Mercier and guest speakers
Tutorial class: 24 students
Lab sessions: computer rooms of Metz campus, 24 students /room
Software tools: free and open source software

Learning outcomes covered on the course
At the end of this course, students should be able to:

- understand and code objects oriented programs in Java
- choose a development strategy according to objectives and resources
- build a simple web application
- develop a simple Android native app
- apply some best practices for securing Android applications

Description of the skills acquired at the end of the course
C3.7 Make pragmatic and informed choices with the aim of producing tangible results
C3.8 Design, implement and reach the stage of industrialization
C4.1 Think in client terms, identify and analyze needs and constraints of other stakeholders including societal challenges

2EL5020 – Introduction to service-based applications development

Instructors: Michel IANOTTO
Department: CAMPUS DE METZ
Language of instruction: ENGLISH
Campus: CAMPUS DE METZ
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

More and more applications are built as a composition of services. The objective of this course is to present the underlying architectures and to introduce students to the development of solutions exploiting, creating and deploying services.

Enterprise applications access local or remote data, apply business logic to them, and then present or transmit the results. To ease their design, implementation and operation, they can be decomposed into layers and components. The Java Enterprise Edition (JEE) platform is designed to enable the development of these applications and their integration into existing information systems. The course will present the principles of the 3-tier architecture, with an implementation exploiting the main components of the JEE platform. The application will then be deployed in the cloud.

The application may require access to online data. Web pages are important data sources but they are designed for human interaction. A tedious process ("web scraping") needs be set up on a case-by-case basis so that a machine (a program) can recover the data exposed by web pages. Fortunately, many players such as Amazon or eBay for example offer another interface to access data, focused on resources or processes and not on graphical presentation. These "web services" simplify the data collection phase and allow their consumers to focus on their core business. This course will present how to discover a service, how to invoke it, and possibly how to build a composition of several services. It may also be relevant to open the developed application to partners (customers, suppliers ...). The course will present how to offer them such a service: how to design a service, develop and deploy it, describe it and make it discoverable.

Quarter number

SG8

Prerequisites (in terms of CS courses)

1CC1000 – Information Systems and Programming

Syllabus

Introduction

- N-tier architectures
- Application servers
- The MVC model

Data persistence in Java

- DBMS
- The JPA specification
- Object-relational mapping (ORM)

Business layer implementation

- Enterprise Java Beans containers(EJB)
- Presentation layer implementation
- JSPs and Servlets

Presentation of treatment-oriented services

- Architectural principles
- Introduction to XML
- SOAP protocol overview
- WSDL description language
- Practice: definition of a service contract, development of a server, publication of the interface to the client as a development kit

Presentation of resource-oriented services

- REST architectural style
- Introduction to JSON and OpenAPI
- Practice: development of a client application requesting online services, development, test and deployment of a service

Class components (lecture, labs, etc.)
The course includes some lectures for the introduction of the main concepts but will mainly use "learning by doing" sessions. An industrial expert might provide his business insight vision.
The approximate distribution of "student presence hours" will be as follows: 9h of lectures, 16h30 of tutorial sessions in the computer room and 9h30 of project.

Grading
Students' knowledge and skills will be evaluated regularly by short individual written tests during lessons and on the basis of a small project carried out in pairs and presented at the end of the course. Score weights: individual tests : 50%, project completion: 30%, presentation of the project: 20%. The catch-up exam will be in the form of oral exam with exercices partly done on computer. In case of a justified absence to one of the intermediary examinations, the grade of this latter is replaced by the grade of the final examination.

Course support, bibliography

- *Java EE : Développez des applications web en Java.* Thierry Richard. ENI. 2017

- *Web Services Foundations.* Athman Bouguettaya, Quan Z Sheng. Springer. 2014

Resources
Teaching staff: Virginie Galtier, Michel Ianotto, Patrick Mercier
Tutorial class: 24 students
Lab sessions: computer rooms of Metz campus, 24 students /room
Software tools: free and open source software

Learning outcomes covered on the course
At the end of this course, students should be able to:

- use an integrated development environment (IDE) to develop an application
- create an application in Java language implementing object-oriented programming concepts
- compose programs in Java using some annotations
- design and implement a business application with the JEE platform
- choose a service development strategy and implement it

- manipulate XML and JSON structured data
- develop a program requesting one or more services
- deploy a business application in the cloud

Description of the skills acquired at the end of the course
C1.4 Specify, design, implement and validate a whole or part of a complex system
C3.7 Make pragmatic and informed choices with the aim of producing tangible results
C3.8 Conceive, design, implement and reach the stage of industrialization

2EL5030 – Programming efficiently in C++

Instructors: Frederic PENNERATH
Department: CAMPUS DE METZ
Language of instruction: ENGLISH
Campus: CAMPUS DE METZ
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : No

Description

Knowing how to code an algorithm effectively in a given programming language requires a prior understanding of the associated calculation model and how the instructions in that language are translated into machine instructions. Too many students still approach programming in a superficial and risky way, lacking the basic knowledge necessary to write elegant and effective code.

The unique strength of the C++ language is to allow the production of compiled codes close to the optimal machine code while offering different high-level programming approaches such as strong typing, object programming, functional programming and meta-programming (automatic code generation at compilation). For this reason, C++ has become the essential language for developing optimized algorithms. Its only disadvantage is its richness, which has continued to grow in its most recent versions (C++11/14/17/10) and which makes it difficult to understand the language in its entirety without adequate training.

This course is intended for students, including beginners, who want to master the different aspects of C++ programming in order to be able to write code that combines performance and elegance. The course adopts a bottom-up approach starting from the mechanisms of elementary program execution and gradually moving towards the most advanced language functionalities.

The objective is to transmit to the students a real know-how of programming, on the one hand by illustrating the concepts through relevant examples of use, and on the other hand by devoting a significant part of the hourly volume to laboratory work.

Quarter number
SG8

Prerequisites (in terms of CS courses)
No specific requirements are expected, but a basic experience of programming.

Syllabus
Lectures:

- Preliminary: terminal, compilation string, makefile (1h30)
- The basics of C programming '(1/2): typing, execution thread, stack, heap, functions, struct, pointers (1h30)
- The basics of C programming (2/2): typing, execution thread, stack, heap, functions, struct, pointers (1h30)
- The basics of object programming in C++: classes and inheritance (1h30)
- Advanced notions of object programming: polymorphism, multiple inheritance,... (1h30)
- Advanced notions of memory management: references (lvalue, rvalue), constness, smart pointers (1h30)
- Functional programming: lambda functions, callable types, exceptions,... (1h30)
- Generic programming based on templates (1h30)
- Generic versus object-oriented programming (1h30)
- Standard library: design and content (1h30)
- Advanced notions of generic programming (1h30)
- Exam (2h)

Labworks :

- TP on memory manipulation (3h)
- Inheritance TP (3h)
- TP on functional programming (3h)
- TP on generic programming and STL (1,5h + 2 x 3h)

Class components (lecture, labs, etc.)

- Courses based on code examples
- Significant part (50%) devoted to practical programming work

Grading
The assessment will be based on a single examination scheduled at the end of the course. The written examination of 2 hours will be done without any

document. It will include a MCQ and small programming exercises.The modalities of remedial examination will be identical to the ones of the initial examination.

Course support, bibliography

- Website provided by teachers
- Effective Modern C++, Scott Meyers, 2014
- Professional C++, Marc Gredoire, 2014
- A Tour of C++, Bjarne Stroustrup, 2013

Resources

- Two teachers: Hervé Frezza-Buet and Frédéric Pennerath
- No tutorials but only practical work on the machine
- One workstation per student
- One or two labwork groups of 15 students maximum each.
- The labwork will be carried out in the Linux environment and will be based exclusively on free software (g++, CMAKE, etc.).

Learning outcomes covered on the course

- To know how to write a program in C++ using different programming paradigms such as object programming, functional programming and generic programming.
- To know certain aspects of the C++ language that have a decisive influence on the performance of programs during their execution.
- To know the functionalities offered by the most recent specifications of the C++ language (C++11, C++14, C++17 and soon C++20).
- To know how to use a C++ compilation and debugging environment

Description of the skills acquired at the end of the course

- C6.3: Conceive, design, implement and authenticate complex software.
- C6.4: Solve problems through mastery of computational thinking skills.

2EL5040 – Big Data: data gathering, storage and analysis on clusters and Clouds

Instructors: Stephane VIALLE
Department: CAMPUS DE METZ
Language of instruction: ENGLISH
Campus: CAMPUS DE METZ
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

Decrease of sensor price make easier their usage in various environments (inside factories, cities, transports…) and generate many raw data flows. A similar increase can be observed with structured data available on the web or in private archives of companies. Some "Big Data" technologies have appeared and quickly evolved to manage and analyse these data sources.

- This course presents the Big Data environments that have emerged to store and interrogate these new Big Data: in particular NoSQL BdD and distributed environments like Hadoop and Spark.These environments were born in the innovative web industries, and have brought new programming paradigms like Map-Reduce (implemented in several variants).
- An important part of the course is devoted to the design of algorithms for filtering, enriching and analyzing data stored in Big Data environments. Most of these algorithms are based on the Map-Reduce programming paradigm and will be tested during labs. Performance metrics and criteria for scaling up distributed systems will also be presented and used in labs.
- The last part of the course presents Machine Learning algorithms, used to process and analyze data sets, and which sometimes require the use of massive parallel computing on GPUs.

Quarter number

SG8

Prerequisites (in terms of CS courses)

- SG1 common course "*Systèmes d'Information et Programmation*" (1CC1000)
- ST2 common course "*Algorithmique & Complexité*" (1CC2000)
- ST4 common course "*Statistique et Apprentissage*" (1CC5000)

Syllabus

- **Introduction and terminology (1CM - 1h30):** Data Engineering vs Data Science, distributed hardware and software architectures, high performance data analysis, SMPD vs Map-Reduce parallelization.

- **Hadoop environment and technology (1CM - 1h30):** Distributed file system (HDFS), Hadoop Map-Reduce principle, resource manager version 1 with scale limit, and optimized version 2 (YARN).

- **Spark environment and technology (3CM - 4h30):** Spark performance-oriented architecture and mechanisms, simple Map-Reduce algorithm, Map-Reduce algorithm for graph analysis, Spark-SQL libraries and stream processing.
    - **Tutorial courses 1 & 2 (3h00)**
    - **Labs 1 & 2 (6h00)** on PC clusters

- **Metrics and scaling limits (1CM - 1h30): acceleration and efficiency metrics, scaling criteria.**

- **Data exploration and preparation (1CM - 1h30):** classic problems encountered with data, need for data exploration and preparation

- **NoSQL data bases (2CM – 3h00):** Emergence of NoSQL databases, NoSQL technologies, use of MongoDB
    - **Lab 3 (3h00)**

- **Introduction to Machine Learning (ML) technologies (3CM : 4h30):** classification of ML algorithms, clustering algorithms, examples of ML libraries in Python
    - **Lab 4 (3h00)**

- **Written examination (1h30)**

Class components (lecture, labs, etc.)

Theoretical issues introduced during the different lectures will be experimented during some labs on Big Data clusters of

CentraleSupelec *Data Center for Education.* These experimental plateforms will allow to request Spark and MongoDB environments, distributed on PC clusters and managing large volumes of data. During the last part of the course, some computing servers will allow to efficiently run Machine Learning libraries. Some performance measurements will complete the evaluation of the different solutions developped during the labs.

Composition of the course: lectures 18h00 (12 x 1h30), tutorials 3h00 (2 x 1h30), labs 12h00 (4 x 3h00) and a final written exam (1h30)

Possible schedule of the course:

- 3 courses, 1 tutorial course, 1 lab, 1 course, 1 tutorial course, 1 lab, 6 courses, 1 lab, 2 courses, 1lab
- Written exam (1h30)

Grading

Relative weights of the different examinations:

- 40%: lab reports. Any unjustified absence at labworks will result in a score of 0. A justified absence at a labwork will neutralize the score of this labwork and will increase the weight of the others.
- 60%: final written exam of 1h30, with documents.

Evaluation of the different learning objectives:

- The first set of learning outcomes (AA1*) will be evaluated based on the consistency of the Big Data solution designed in the final examination.
- The second set of learning outcomes (AA2*) will be evaluated based on the reports of the different labs.

Remedial examination: If a remedial exam is necessary, 100% of the score will depend on a written exam of 1h30, with same modalities than the initial wrtitten exam.

Course support, bibliography

Documents supplied to the students:

- Slides et notebook of the teachers.

Suggested books:

- Pirmin Lemberger, Marc Batty, Médéric Morel et Jean-Luc Raffaëlli. *Big Data et Machine Learning*. Dunod. 2015 (in french).
- Eric Biernat et Michel Lutz. Data Science : *Fondamentaux et études de cas*. Eyrolles. 2015 (in french).
- Bahaaldine Azarmi. Scalable Big Data Architecture. Apress. 2016.
- Kristina Chorodorw. MongoDB. The Definitive Guide. 2nd edition. O'Reilly. 2013.
- H. Karau, A. Konwinski, P. Wendell and M. Zaharia. Learning Spark. O'Reilly. 2015.
- Rudi Bruchez. Les bases de données NoSQL et le Big Data. 2ème édition. Eyrolles. 2016.
- Tom White. Hadoop. The definitive Guide. 3rd edition. O'Reilly. 2013.
- Donald Miner and Adam Shook. MapReduce Design Patterns. O'Reilly. 2013.
- Matthew Kirk. Thoughtful Machine Learning with Python. O'Reilly. 2017.

Resources

- 18h00 of lectures about Data Engineering including: the introduction to standard and distributed Big Data environments, and the design of fast and scalable solutions.
- 3h00 of tutorials about architecture sizing and Map-Reduce algorithmics.
- 12h00 of labs about experimentation of standard and Opensource Big Data software (Hadoop HDFS, Spark, MongoDB, Machine Learning libraries), on high performance computing servers and clusters (resources of the *Data Center for Education* of CentraleSupelec).

Learning outcomes covered on the course

When finishing the course, the students will be able:

- **[Learning Outcomes 1* (AA1*)]** To specify and to design a complex and consistent system for large scale data analysis (core skill **C1.4**):
  - to specify and to set the size of a Big Data hardware architecture
  - to choose a Big Data environment adapted to the use case (ex: Spark and some of its libraries, or some kind of NoSQL dtabases...)

- to design a Map-Reduce based software architecture and algorithm, function of the available Map-Reduce variant (in order to clean, to prepare, to filter and to request large data)
- to optimize a Map-Reduce based algorithm to improve its performances and scalability
- to specify and to set the size of a Machine Learning hardware architecture (ex: CPU, CPU cluster, GPU, GPU cluster...)

- **[Learning Outcomes 2* (AA2*)]** To evaluate performances and strength of a Big Data architecture (core skill **C3.6**):
    - to define a metric and a scaling benchmark adapted to the use case
    - to identify the bottlenecks of the hardware and software architectures (when increasing the data volume)
    - to identify the single points of failure of the global architecture
    - to identify the kind of incorrect data disturbing the analysis

Description of the skills acquired at the end of the course

- **C1.4 :** Design, detail and corroborate a whole or part of a complex system. (Learning Outcomes **AA1***).
- **C3.6 :** Evaluate the efficiency, feasibility and strength of the solutions offered (Learning Outcomes **AA2***).

2EL5050 – Estimation methods and introduction to the modern coding theory

Instructors: Michel BARRET
Department: CAMPUS DE METZ
Language of instruction: FRENCH
Campus: CAMPUS DE METZ
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

This course presents two key issues of decision theory: pure estimation and detection. More precisely, the following notions will be presented and implemented numerically: formalization of estimation and detection problems, influence of cost function, Bayesian / non-Bayesian point of view, prior information. The problems of estimating power spectral density and prediction, with finite and infinite past, of a second-order ergodic time series will be studied in detail. Finally, the four fundamental coding theorems for discrete memoryless systems will be presented with their proofs.

Quarter number

SG6

Prerequisites (in terms of CS courses)

- Probability 1A (CIP-EDP, 1SL1000),
- Signal processing ST4 (1CC4000)

It is advisable to have also followed:

- Statistics, Machine learning and Data processing ST4 (1CC5000),
- Digital environment, computer and programming SG1 (1CC1000).

Syllabus

1. Fundamentals of estimation (6h of course)
   1.1 Introduction (goals of estimation, model, bayesian / non-bayesian point of view, examples)

1.2 Bayesian estimation (Hilbert space, orthogonal projection theorem, mean square estimations with linear constraint)
   1.3 Elements of non-Bayesian estimation (Cramer-Rao inequality, maximum likelihood estimator)
2. Estimation of a signal in an additive noise (3h of tutorials)
3. Power spectral density estimation (non-parametric methods) (3h of tutorials)
4. Detection (3h of course)
   4.1 Test of hypotheses (problem presentation, Bayesian theory, Neyman-Pearson strategy, ROC curves)
   4.2 Application to the detection of a signal in a noise (Karhunen-Loève decomposition, detection of a deterministic signal in a Gaussian noise)
5. Detection (3h of tutorials)
6. Linear statistical filtering (1h30 of course)
   6.1 Introduction and preliminaries
   6.2 Wiener filtering
7. Wiener filtering with linear contraint (3h of tutorials)
8. Prediction with infinite past (3h of courses)
   8.1 Case of a signal whose power spectral density is bounded and admits a strong factorization
   8.2 General case, Wold's decomposition
9. Interpolation of a stationary signal (3h of tutorials)
10. Prediction with finite past (1h30 of course)
11. Primitives of the Information theory (3h of course)
   11.1 Introduction (discrete source of information, discrete channel, message)
   11.2 Four key coding issues (channel coding, channel approximation, distributed source coding, random extraction)
   11.3 Fundamental theorems (random coding, random binning)
12. Exercises on the four key coding issues (2h of tutorials)

Class components (lecture, labs, etc.)
18h of courses + 17h of tutorials + homeworks

Grading
Evaluation of homeworks and some tutorials an evaluation in binomial (or trinomial) in the form Homework + Tutorials (spectral analysis) + reportan individual evaluation (short qcm)an individual evaluation (short qcm) the absence not excused at an individual evaluation gives the grade 0the absence not excused in tutorials gives the standard penalties of the studies rule final grade = 1/2* grade1 + 1/4*(grade2 + grade3) resit: an oral exam

Course support, bibliography
M. Barret, *Traitement Statistique du Signal*, ELLIPSES, 2009.

M Bloch et J. Barros, *Physical-Layer Security,* Cambridge University Press, 2011.

Resources

Some of the tutorials will be done with a computer (using Matlab or Python)

Learning outcomes covered on the course

At the end of this course, students will be able to deal with a wide range of concrete problems of estimation and detection, encountered in a scientific or industrial context. Starting from such a problem, they will be able:

- to model it by introducing a suitable cost function;
- to propose an adequate solution (adapted to the information a priori)
- to prove the optimality of the solution under certain conditions that they will be able to explain;
- to implement the method on data;
- to criticize the results.

In addition, at the end of the course, students should have acquired basic knowledge of the modern theory of coding for discrete memoryless systems (channel, source with side information to the decoder), where the above estimation and detection methods are applied.

Description of the skills acquired at the end of the course

Skills developed by the course

- C1.2: Select, use and develop modelling scales, allowing for appropriate simplifying hypotheses to be formulated and applied towards tackling a problem;
- C1.3: Apply problem-solving through approximation, simulation and experimentation

2EL5060 – Analysis and processing of audio data (speech and music)

Instructors: Stephane ROSSIGNOL
Department: CAMPUS DE METZ
Language of instruction: ENGLISH
Campus: CAMPUS DE METZ
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

The aim of this course is to present the corpus of non-parametric and parametric spectral analysis methods, as part of the analysis of musical and speech sound signals.

Spectral analysis is one of the elements of signal processing chains; therefore, it is not just the visualization of spectra. The main objective is to decide and/or estimate. Some examples: What was the original score? Or what instruments are present in the orchestra? What is the fundamental frequency of this or that sound? What does this person say? Where is this person or this other one? Etc. The choice of this or that spectral analysis method is crucial, depending on the current problem.

The focus is put on the different concepts underlying each method, and the performance of these methods are compared. This last approach also highlights the concept of modeling (physical modeling/signal modeling/...), inherent in an efficient engineering approach.

Moreover, the various tools are studied in the context of the observation of the human being, who communicates with his fellow beings and his environment through his senses. Of these, sight and hearing are the best known, and only they allow a remote approach to the environment. Communication systems (human-to-human, human-to-machine or machine-to-human) are designed to acquire and reproduce these perceptions as faithfully as possible. It is therefore useful to know and be able to model in detail on the one hand the system of human perception, that is to say the receiver (the ear, here), but also the system of production of the signal concerned by the perception (human speech, music, various sounds), that is, the transmitter.

The sound platforms of the Metz campus (holophony room and anechoic room) are used for the practical aspects of this course.

This course has many areas of application: in-depth analyzes of time series; sound analysis for recognition and coding; phonetic coders for telephony; tools for the arts.

Quarter number
SG6

Prerequisites (in terms of CS courses)
Signal processing (1CC400).
Statistics and machine learning (1CC5000)
Programming experience (1CC1000)

Syllabus

- 1. Non-parametric spectral analysis methods (mainly based on the Fourier transform)
    - 1.1. Further information on these methods, already known
    - 1.2. Review of their limits
    - 1.3. Statistical means used to make the most of these methods
- 2. Parametric spectral analysis methods
    - 2.1. Introduction to some of them
    - 2.2. Contributions, compared to non-parametric methods
    - 2.3. Cost of parametric methods
- 3. The sounds
    - 3.1. Models of perception (ear) and production (voice, mainly)
    - 3.2. Sound localization
    - 3.3. Virtualization of sound sources (holophony)

Class components (lecture, labs, etc.)

18h Lecture

9h Tutorials. (3 hours for each part of the lecture; sequencing Lecture/Tutorials: 6h L; 3h T; 6h L; 3h T; 6h L; 3h T)

8h Labs. A single topic.

Grading
Continuous monitoring (50%, 2/3 MCT at the beginning of the tutorials; individual score) and oral presentation at the very end of the labs (50%). Labs : grading by pair; differentiated in the event of an anomaly in a pair.

Course support, bibliography
Slides.

Resources

- Teacher : Stéphane Rossignol
- Room size for tutorials : 34
- Max room size for labs : 34
- Software : Matlab (34 licences)/Octave (Python)
- Rooms for labs : rooms on Metz campus

Learning outcomes covered on the course

- Design a complete signal processing chain.
- Compare the performances of the various tools at our disposal for the analysis of complicated time series, in order to choose the one which will be best suited for this or that signal to be analyzed.
- Program in an interpreted computer language (matlab/octave/python/...).
- Mastering the basic and advanced principles of analog signal processing and digital signal processing.
- Mastering the basic principles of sound perception (cognitive perception).

Description of the skills acquired at the end of the course

- C1.1 : Examine a problem in full breadth and depth, within and beyond its immediate parameters, thus understanding it as a whole. This whole weaves the scientific, economic and social dimensions of the problem.

- C2.3 : Rapidly identify and acquire the new knowledge and skills necessary in applicable domains, be they technical, economic or others.
- C3.6 : Evaluate the efficiency, feasibility and strength of the solutions offered.
- C9.4 : Demonstrate rigour and critical thinking in approaching problems from all angles, be they scientific, social or economic.

2EL5070 – Image processing

Instructors: Jean-Luc COLLETTE
Department: CAMPUS DE METZ
Language of instruction: FRENCH
Campus: CAMPUS DE METZ
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

Image processing meets many areas of activity, such as medical imaging, satellite or robotics for localization in an environment. The preliminary step to image processing is its acquisition. The modeling of image sensors is therefore crucial to make the best use of the information that can be extracted. The images can also come from a reconstruction process such as that implemented in a scanner. The transmission and the compression of the images intervene in the quality of the results of their analyzes. We must understand its principles to take them into account in these analyzes. The different treatments that can be considered are then presented. Many applications will illustrate this course to have an overview on how to exploit the information in the image.

Quarter number

SG6

Prerequisites (in terms of CS courses)

- Signal Processing : 1CC4000
- Programmation and Information System : 1CC1000

Syllabus

1. **Photometry, colorimetry, visual perception**
    1.1. Radiometric and photometric quantities
    1.2. Perceptual models of the eye
    1.3. Additive and subtractive synthesis
2. **Color image sensors and rendering devices**
    2.1. Physical modeling
    2.2. Geometric modeling
    2.3. Calibration

2.4. Gamma correction

3. Other types of image

3.1. Multi and hyper spectral imaging
3.2. SAR imaging
3.3. LIDAR imaging
3.4. Overview of tomographic reconstruction techniques (scanner)

4. Coding and compression

4.1. Overview of orthogonal transformations
4.2. Overview of wavelet transformations
4.3. Still image coding
4.4. Image sequence coding

5.Improvement, image restoration

5.1. Improved contrast
5.2. Noise attenuation
5.3. Filtering from Wiener

6. Elements of mathematical morphology

6.1. Basic operators
6.2. Watershed

7. Geometric transformations and image registration

7.1. Nature of transformations
7.2. Metrics for registration
7.3. Specific optimization methods

8. Image segmentation and characterization of shapes

8.1. Region or edge approach
8.2. Extraction of features
8.3. Unsupervised classification

Class components (lecture, labs, etc.)

15h of lecture, 6h of tutorials and 14h of labs.
35 students for tutorial/labs groups

Grading

A written report will be requested on Laboratory Work (TP) and an oral presentation on this activity will also be organized (scheduled during labs). Any unjustified absence from a TP session will result in a zero mark. The final mark will be the equal average of the individual mark of the oral presentation and the mark of the laboratory work report.
The catch up exam will take place in the same way as the initial examination, with additional work requested in TP and an oral presentation of this work.

Course support, bibliography

"Digital Image Processing", William K. Pratt

Resources

Lectures will be given to present the main concepts.
Applications will be tested on computer during tutorial courses.

Learning outcomes covered on the course

• Knowing how to identify imperfections and limitations of operation of an image acquisition system.
• Knowing how to model and characterize this system in the optical domain.
• Knowing how to program or use basic processing algorithms (filtering, transformations) on digital images by mastering their complexity.
• Having an overview of how to use the information in the image.

Description of the skills acquired at the end of the course

• C3.6: Evaluate the efficiency, feasibility and strength of the solutions offered. / proposed solutions
• C6.4: Solve problems through mastery of computational thinking skills.

2EL5080 – Robust electronic and embedded systems

Instructors: Jean-Louis GUTZWILLER
Department: CAMPUS DE METZ
Language of instruction: FRENCH
Campus: CAMPUS DE METZ
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

Many electronic systems are called embedded because they are part of a larger whole by interacting with the world around them. The use of such systems is so widespread that the fields of application are very varied and the economic stakes are significant. These systems require, for their operations, to study the interactions with their environment, not only because of their function, but also because they can be disturbed by external influences. It is therefore essential to consider supply and autonomy issues (for battery operation for example), temperature, size, reliability or component lifespan. These issues are to be managed both in terms of hardware design and software design.
In addition, electronic disturbances have become an important issue, so that regulations require marketing approval.
This course will mainly focus on two points:

- programming microcontrollers for an application that must interact with its environment in real time,
- the resistance of systems to electromagnetic disturbances according to regulation: not being destroyed by unexpected powerful events, and functioning normally in the presence of usual disturbing events.

Quarter number

SG8

Prerequisites (in terms of CS courses)

Signal processing course of the ST4 (1C4000). Having followed the 1st year elective course of Electronic Systems (1EL8000) can be a plus.

Syllabus

Taking the example of a data acquisition system, this course addresses the following concepts:

- Issues, economic context, regulation

• Theoretical aspects of signal acquisition and reconstruction, Shannon and Nyquist theorems, out-of-band acquisition, I / Q acquisition
• Analog electronics for acquisition processing (amplifiers, multiplexers, filters, converters)
• Basic digital processing and associated components; programming for real-time processing
• Fragility of the components and solutions considered
• Disturbances and proposed solutions

Class components (lecture, labs, etc.)
18h of lecture, 15h of tutorials, 2h of exam in case of a presentation (see : méthodes d'évaluation).

Grading
Depending on the number of students registred in this course, the evaluation wil consist in:
- An individual presentation addressing the themes of this course for a particular component (if it is possible to organize the session)
- An individual report addressing the themes of this course for a particular component (if there are too many students to organize the session).
Components will be proposed by the teacher, but students may choose other components than those proposed (the approval of the teacher will be required). The same component can only be presented by one student.

In case of insufficient initial examination, a remedial examination will be proposed which will take the form of an individual report to be drawn up (therefore the second form envisaged above for the initial examination).

Course support, bibliography

« Fonctions, composants et perturbations », Jean-Louis Gutzwiller, Handout.

Resources
Lectures will be given to present the main concepts.
Applications will be tested on electronic cards during tutorial courses.

Tutorial groups size : 24 students

Learning outcomes covered on the course

- To know the disturbance mechanisms that can interfere with the operation of embedded systems
- To know the classical solutions used to limit the effects of disturbances
- To choose between these different solutions to solve a given case
- To design embedded systems to be resistant to disturbances
- To specify a system with the people in charge of the design of the electronic cards

Description of the skills acquired at the end of the course

- C3.4 : Take decisions in an environment that may not be fully transparent, embracing the unexpected and calculating risk (step 2)
- C7.4 : Persuade by working on communication techniques. Master spoken, written and body language as well as basic communication techniques (step 2)

2EL5090 – Design of complex electronic systems: from component to heterogeneous system

Instructors: Yves HOUZELLE
Department: CAMPUS DE METZ
Language of instruction: FRENCH
Campus: CAMPUS DE METZ
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : Yes

Description

For a decade, French electronics has invested in high value-added areas and advanced sectors such as aeronautics, defense, medical, smart card payment, fiber optic telecommunications ..., discarding consumer products such as televisions and telephones.
Electronic systems cover a wide range of applications, ranging from analog electronics, with the amplifier as a basic function, to digital electronics, which implements the "smart" part of systems. In addition, the frequency range extends over a very broad spectrum ranging from low frequency applications such as audio processing to very high frequency applications such as radio communications.
The very different constraints related to this wide variety of themes impose different design tools that are adapted to each problem.
This course will provide students with basic concepts and knowledge of the tools used to design both analog and digital electronic systems.

Quarter number

SG6

Prerequisites (in terms of CS courses)

Automatic course of ST5. Having followed the 1st year elective course of Electronic Systems (1EL8000) can be a plus.

Syllabus

The course will present the components and methods of synthesis using the different tools (and understanding their limits) in order to give the future engineers the means to take part in the design of heterogeneous electronic systems.

The concepts will be implemented during the tutorials and labs which will be dedicated to the following two applications :
- design a fiber-optic videophone,
- carry out a digital radio transmission with pulse width modulation.

Class components (lecture, labs, etc.)
Class components (lecture, labs, etc.): 15h of lecture + 6h of tutorials + 12h of labs.

Grading
A written report will be requested on Laboratory Work. The final written exam will count for 70% of the final grade. The Laboratory Work report will count for 30% of the final grade.The catch-up session will be in the form of an oral examination.
An unjustified absence in Laboratory Work will be penalized with a 0 for the session.

Course support, bibliography
- Documentations of components available on the internet.
- Électronique radiofréquence – Georges Seignier – 10114.
- Introduction à l'électronique analogique – Gilles Tourneur – 17189/01.
- Systèmes logiques et électronique associée – Volume 1 – Jacques Oksman, Jean-Philippe Szlowicz, Philippe Bénabès – 11121/01.

Resources
Teacher : Yves Houzelle.
TD and TP group size : 24 students.

Learning outcomes covered on the course

- Know the concepts of analog, digital and radiofrequency electronics: component modeling, polarization, linearization, large signal analysis, loopback and feedback, impedance matching, synchronous sequential logic, frequency behavior.
- Master the main tools of CAD, simulation and validation.
- Be able to analyze electronic functions using the appropriate models.
- Know how to design and dimension electronic functions by taking into account the interfaces between components and with external interfaces.
- Know how to specify an electronic system, and write specifications.

Description of the skills acquired at the end of the course

- C1.2: Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when addressing a problem.
- C1.3: Solve problems using approximation, simulation and experimentation.

2EL5110 – Light to understand matter

Instructors: Ninel KOKANYAN
Department: CAMPUS DE METZ
Language of instruction: ENGLISH
Campus: CAMPUS DE METZ
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

There are many different characterization techniques that use *light*. Optical characterization techniques are generally non-destructive, fast and simple to implement, requiring very little sample preparation. These methods explore the change of intensity, energy, phase, direction or polarization of the light wave after interaction with the object under study. These techniques are now in great demand in the industrial world (quality control, surface characterization, atmospheric studies, food, biomedical and pharmaceutical analyzes, etc.).
The main purpose of this lecture is to address the most relevant examples of optical techniques with a focus on their applicability, usefulness and limitations. During the lecture will be presented different techniques that can be used in a complementary way and the obstacles that are frequently noticed during their use. Examples of practical and real applications will illustrate these points, offering suggestions on how it is possible to avoid obstacles as much as possible.

Quarter number

SG6

Prerequisites (in terms of CS courses)

1SL3000 - Lecture of quantum physics 1A

Syllabus

- Introduction
- Light scattering
- UV-VIS-NIR spectrophotometry
- Ellipsometry
- Interferometry
- Reflectometry

- Photoluminescence
- Infrared spectroscopy and Fourier transform infrared spectroscopy (FTIR)
- Raman spectroscopy
- Applications of optical techniques
- Examples of applications in industry, biology, medicine, nanomaterials,...

Class components (lecture, labs, etc.)

20h of lectures, 6h of tutorials and 8h of practical work

Grading

Continuous assessment: QUIZ (25%), project (25%), final written exam (50%). In case of a justified absence to one of the intermediary examinations, the grade of this latter is replaced by the grade of the final examination.

Course support, bibliography

Mauro Sardela, *Practical Materials Characterization*, Springer-Verlag New York (2014)
Jin Zhong Zhang, *Optical Properties and Spectroscopy of Nanomaterials,* World Scientific (2009)
Peter Lasch and Janina Kneipp, *Biomedical Vibrational Spectroscopy,* A JOHN WHILEY & SONS, INC. (2007)

Resources

LMOPS Laboratory equipments
Teaching team : Ninel Kokanyan, Thierry Aubert

Learning outcomes covered on the course

17. To be aware of different optical techniques
18. To be aware of the operating principles of different spectroscopic components
19. Design and realize a device for optical measure
20. Be able to interpret obtained spectroscopic results
21. Identify the characterization technique suited for given material as well as for studied parameter

Description of the skills acquired at the end of the course

C1.2 : Develop and use appropriate models, choosing the correct modeling scale and simplifying assumptions when addressing problem

C2.1 : Thoroughly master a domain or discipline based in the fundamental sciences or the engineering sciences

C3.4 : Take decisions in an environment that may not be fully transparent, embracing the unexpected and calculating risk.

2EL5120 – Smart Photonics Systems

Instructors: Delphine WOLFERSBERGER
Department: CAMPUS DE METZ
Language of instruction: ENGLISH
Campus: CAMPUS DE METZ
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : No

Description

In the context of new technologies, light is increasingly used as a support for calculating, transporting or storing information. The objective of this course is to present recent developments in "photonics", including lasers and their applications in different fields: ultra-fast optics, telecommunications, all optical information processing.

After a few notions of wave physics, the different types of laser sources will be discussed as well as the different components of a typical optical information transmission channel: from emitters (LEDs and laser diodes) to receivers (photodiodes) . A practical experiment on the transmission of sound will be set-up to validate the course. We will then discuss about different applications that we carry out in our laboratories using light: chaos in lasers, random numbers generation, holography for storing light, slow light... Some visits of labs will be organized to allow students to discover the world of research and innovation.

Quarter number

SG8

Prerequisites (in terms of CS courses)

none

Syllabus

Physical properties of lasers:

Laser basics principles, Fabry-Pérot cavity, threshold conditions, laser dynamics, modulation bandwidth.

Ultra-Fast Optics:

Generation of ultra-short pulses: femto-second lasers (Laser Ti: Sapphir), Optical Parametric Oscillator (OPO), Pulse measurement (auto-correlation).

Telecommunications basics

Network structure: access, transport, popular models – Traffic regulation: guided and free space propagation – Resources accessibility: TDMA, FDMA, CDMA – Different ways of communications: concurrency or complementarities.

Guided propagation, optical fibers

Guided wave theory: geometrical and wave approach of the optical fibers, attenuation and dispersion – Temporal Multiplexing – Wavelength Division Multiplexing: WDM, DWDM – Interconnects.

Components and optoelectronic interfaces

Light emitters: Electro luminescent diodes (DEL), Laser diodes, Emitting optical interface (modulation, noise, coupling, laser-fiber) – Photo detectors: PIN photodiodes, Avalanche photodiode, Reception optical interface.

Non-linear Optical Components

Non-linear propagation and solitons: non-linear Schrödinger equation, stability – Electro-optic effect – Optical parametric amplification.

Towards all optical network

Multiplexing – Amplification – Optical routing and commutation: micro-mirrors, liquid crystals, and spatial solitons.

Class components (lecture, labs, etc.)
30,5h lecture, 3h00 practical laboratory work

Grading
Oral evaluation (1h30) at the end of the course based on an oral presentation of 2-3 students : the mark will be individual.

Course support, bibliography

Les Composants Optoélectroniques, François Cerf, Hermes Science Publications, Paris 2000.

Fundamentals of photonics, E.A. Saleh, M.C. Teich (ISBN : 978-0-471-35832-9).

Resources

Educational team : Delphine Wolfersberger - Nicolas Marsal

Learning outcomes covered on the course

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

- understand basics of lasers and their applications: holography, laser-based cryptography, optical buffering, optical memories ...
- understand the physical phenomena that are at the origin of lasers emission: threshold, resonance, ...
- become familiar with the ultra-fast optics: femto-second laser, optical parametric oscillator
- design and realize practically an optical communication for optical video/sound transmission
- understand notions of nonlinear optics used for the development of novel optoelectronic components.

Description of the skills acquired at the end of the course

C1.1 Examine problems in their entirety and beyond their immediate parameters. Identify, formulate and analyse the scientific, economic and human dimensions of a problem

C1.2 Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when addressing a problem

C1.3 Apply problem-solving through approximation, simulation and experimentation. / Solve problems using approximation, simulation and experimentation

2EL5130 – Chaos, Fractals and complexity

Instructors: Damien RONTANI
Department: CAMPUS DE METZ
Language of instruction: ENGLISH
Campus: CAMPUS DE METZ
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

Neural networks, electronic or optical oscillators, or even chemical reaction are various examples of dynamical systems, where the state variable describing their spatiotemporal evolution evolve in a nonlinear fashion. From the intrinsic nonlinearity present in these systems stems rich dynamical behaviors, which allows for the observation of novel phenomena of interest for scientists and engineers. We can cite chaotic dynamics for example, explaining the impossibility to provide accurate long-term weather forecasting or collective phenomena, such as synchronisation, with multiple applications in neurosciences.

This lecture will provide to the student with the fundamental tools and framework of science of complexity. It will be illustrated by multiple example from recent research articles with application in the field of engineering. The student will use analytical and numerical techniques form the resolution of problems.

Quarter number

SG8

Prerequisites (in terms of CS courses)

Basics in Linear Algebra and real analysis (level L2)
Classical Physics (Electricity, mechanics, Fluid dynamics...) (level L2)
Modeling (1CC3000 : Theory and analysis of linear dynamical systems, ordinary differential equations, and partial dérivative equations).

Syllabus

Context and Introduction (1.5h)
Discovery of Chaos theory : from H. Poincaré to E. Lorenz
B. Mandelbrot and discovery of Fractals
Examples of complex phenomena in physics, chemistry, and biology

General introduction to nonlinear systems and chaos theory (10h)
Introduction to the mathematical framework (Map, ODE, stability analysis)
Notion of attractors : fixed points, limit cycles, Torus, strange attractors
Bifurcations
Route to Chaos and strange attractors. Bifurcation diagrams. Notion of Lyapunov Exponents.

Special case of nonlinear time-delay systems. Mathematical description with delay differential equations (DDE). Significance in Biology and Physics. Application of time-delay systems in photonics .

Introductions to Fractals (1.5h)
Introduction to the theory of fractals. Self-similarity and fractal dimension (Hausdorff). Cantor, Mandelbrot, and Julia sets.

Complex phenomena – Introduction to network physics (11.5h)
Definition of complex physical networks. Examples in biologie (metabolism, genetic, neurosciences) and in engineering (transportation and power grids)
Collective and emergent phenomena. Notion of synchronization.
Examples of synchronization in Biology and Physics
Presentation of the Kuramoto Model.

Small classes (3h):
Stability analysis of nonlinear systems (1.5h)
Synchronization in networks of nonlinear oscillators (1.5h)

Labs (7.5h):

Numerical simulations of fractals (1.5h)
Numerical simulation and analysis of nonlinear dynamical system (3h)
Analysis and simulation of a network of phase d'oscillators and observation of synchronisation (3h)

Class components (lecture, labs, etc.)
Lectures with emphasized interactions with numerical and experimental demonstration. Priority given to physical interpretation and examples from current research. The presentation of mathematical tools is ilimted to essential notions necessary for the understanding of concepts seen in class.
Small class: (x2) will be organized for the assimilation of key notions

Labs: (x3) will be organized for the experimenting with concepts seen in class and will focus on example from current research topics.

Hourly volume:
Lectures: 24.5h
Small class: 3h
Labs: 7.5h

Grading

Evaluation (Modalities and weight of each quiz / evaluation in the final grade) :

12. Small Project on numerical simulations with a small written report (10-15 pages) - 50% of total grade. If the report is missing : the grade 0 is attributed to the project section.
13. Lab Reports - 50% of total grade. Unjustified absences during Lab session and/or missing Lab report : the grade 0 is given to the corresponding Lab session.

Course support, bibliography

1. S. H. Strogatz, « Nonlinear Dynamics and Chaos : with Applications in Physics, Biology, Chemistry, and Engineering », Westview Press (2001), ISBN 978-0738204536
2. A. Pikovsky, M. Rosenblum, J. Kurths, « Synchronization: a Universal Concept in Nonlinear Sciences», Cambridge University Press, 2003, ISBN 978-0521533522

Resources

Teaching staff /faculty : Damien Rontani, Marc Sciamanna

Computing Ressources with Matlab and/or Python for laboratories and small classes

Learning outcomes covered on the course

To know the scientific context and multi-disciplinary aspects of nonlinear sciences and network theory.

To identify / recognize situations where is formalism can be applied to solve a problem.

To know and master a few basic methods for the analysis of nonlinear dynamical systems and nonlinear networks.

To perform numerical simulations of dynamical systems and dynamical networks

Description of the skills acquired at the end of the course

C1.2 : Develop and use appropriate models, choising the correct modelling scale and simplying assumptions when addressing a problem

C1.3 : Apply problem-solving through approximation, simulation and experimentation. / Solve problems using approximation, simulation and experimentation

C1.5 : Bring together broad scientific and technical concepts in a core structure contained within the framework of aninterdisciplinary approach

2EL5140 – Modeling for Systems Engineering

Instructors: Virginie GALTIER
Department: CAMPUS DE METZ
Language of instruction: FRENCH
Campus: CAMPUS DE METZ
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : Yes

Description

Complex systems involve many heterogeneous elements (mechanical, software, economic...). Systems engineering is an interdisciplinary approach allowing us to design, verify, and develop them in a controlled way. According to INCOSE (International Council on Systems Engineering), *research shows effective use of Systems Engineering can save 10-20% of the project budget. It is not hard to know when Systems Engineering fails, because when something important goes wrong it usually makes the news fast. People get hurt, programs are delayed and over budget*: from the problems encountered by the Hubble Space Telescope, to the crashes of Boeing's 737 Max airplane, and the construction of the Channel Tunnel which came 80% over-budget. *But when Systems Engineering goes right, no-one notices- which is just how it should be.* This course focuses on modeling, on which rely systems engineering methodologies and tools.

The challenges of modeling are best grasped in action; and experience contributes a considerable amount in the success of this activity. Therefore, a significant part of the course will be dedicated to practical implementation, notably on the basis of the ST5 project.

Quarter number

SG6

Prerequisites (in terms of CS courses)

- Modeling Systems Core Course
- ST5 Project

Syllabus

Introduction

- definition(s) of a model
- system lifecycle
- objective and fundamentals of MBSE (Model-Based Systems Engineering)
- introduction to SysML

Requirements modeling

- stakeholder identification
- use case definition
- requirements diagram

Structural modeling

- basis for structural decomposition, notions of interfaces
- block and package definition diagrams

Dynamic modeling

- functional decomposition and composition
- activity and state diagrams
- model animation

Transverse modeling

- parametric diagram
- allocation and traceability
- matrix-based structural complexity management
- trade-off

Class components (lecture, labs, etc.)
The course is composed of a succession of sequences made of:

- a presentation of general concepts that can be reused by students in many contexts,
- an MCQ to check that the students have understood the key points,
- a guided practice exercise based on a common example,
- an application to a project developed in small groups, using ST5 projects as basis.

Grading

Individual continuous assessment (50%) and project final group presentation (50%, which would be made personal in case the contributions are too different from one student to the next)

Re-take exam: oral examination including a practical exercise on a computer

Course support, bibliography

Guide to the SEBoK (*https://www.sebokwiki.org/wiki/Main_Page*)

INCOSE SE Vision 25 (*https://www.incose.org/docs/default-source/aboutse/se-vision-2025.pdf?sfvrsn=b69eb4c6_4*)

SysML Distilled, Lenny Delligatti, Addison-Wesley, 2014 (*https://app.ute.edu.ec/content/4915-114-4-1-6-19/SysML%20Distilled_%20A%20Brief%20Guide%20-%20Lenny%20Delligatti.pdf*)

Resources

Teaching staff: Virginie Galtier

Software: students are asked to install Cameo Systems Modeler on their PC according to the instructions and license provided in the first class; occasional use of other open-source and free tools

Note: Written material is mostly in English.

Learning outcomes covered on the course

At the end of this course, students:

- will be able to imagine a system modeling approach (observation, definition of the system, proposal of a formal model, analysis and exploitation of the results),
- will know the concepts of systems modeling (notion of components and interactions, different hierarchies used in modeling, principles of decomposition),
- will be able to deploy a system model based on the different SysML diagrams,
- will be familiar with an industrial modeling tool (Cameo Systems Modeler),
- will be able to exploit some behavioral modeling techniques of a system in order to predict its behavior.

Description of the skills acquired at the end of the course

Core Skills C1.4 – Design, detail and corroborate a whole or part of a complex system.

Core Skills C2.1 – Thoroughly master a domain or discipline based on the fundamental sciences or the engineering sciences

2EL6010 – Model based design of critical embedded control systems

Instructors: Nabil SADOU
Department: CAMPUS DE RENNES
Language of instruction: ENGLISH
Campus: CAMPUS DE RENNES
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : No

Description

Critical embedded control systems are present in various industrial fields (factory 4.0, Avionics, Railways...) but also in our daily live (home automation, automotive, medical...).

These systems, which are often critical, are subject to robustness, operational reliability and qualification constraints. This requires the use of specification methods that optimize the design process and formally guarantees all properties, particularly safety ones. The development of certified languages and tools reduces project certification costs by simplifying critical control applications design and automating verification, qualifiable/certified code generation, and documentation generation.

The objective of this course is to present the different processes of critical systems design. Based on the skills acquired in the system modeling course (ST5), the different activities will illustrate the use of formal methods and models in the different stages from specification to solution design and code generation.

The courses also illustrate how the generated code is embedded on a hardware platform taking into account execution performance (time performance, sizing...). Integration, verification and validation processes will be also presented.

Quarter number

SG6

Prerequisites (in terms of CS courses)

None

Syllabus

Introduction (critical systems, design, qualification, control systems, system development processes...)
Model-driven modeling and model transformation
Real time systems
System modeling and specification
Formal languages, synchronous languages,
Implementation of a control (Control of a Railways system) (see : https://youtu.be/BxieOtRYb9U)

Class components (lecture, labs, etc.)

lecture (12h), labs (21h), examen (2h)

Grading

written examination (30%) project evaluation (70%) writing exam (2h)

Course support, bibliography

M. Klein, "A Practioners's Handbook for Real-Time Analysis : Guide to Rate Monoto-nic Analysis for Real-Time Systems", Kluwer Academic, Boston, 1993, ISBN 0-7923-9361-9.

Sanford Friedenthal , Alan Moore, Rick Steiner. « A Practical Guide to SysML, Second Edition: The Systems Modeling Language » (The MK/OMG Press), 2012

C. Bonnet et I. Demeure, "introduction aux systèmes temps réel", Hermes sciences. Paris 1999.

Richard Zurawski (Editor). Embedded Systems Handbook, Second Edition 2-Volume. June 25, 2009 by CRC Press Reference - 837 Pages - 225 B/W Illustrations ISBN 9781439807613

Resources

- lecture, labs.

This course contains few lectures. The design of a railway network system project will be used to implemente the theorical elements defined in the differents lectures.

Learning outcomes covered on the course

By the end of this course students will be able :

- to identify the real time aspects of an application, specify it and propose a design solution.
- propose software structures and implementation.
- to conduct performance analysis to demonstrate that the system can successively meet constraints and requiremennts.
- to perform the different phases of the design cycle
- to use a model based design approach.
- design project management

Description of the skills acquired at the end of the course

- identify the real time aspects of an application, specify it and propose a design solution is part of C1.1Examine a problem in full breadth and depth, within and beyond its immediate parameters, thus understanding it as a whole. This whole weaves the scientific, economic
  and social dimensions of the problem.
- propose software structures and implementation is part of C1.2Select, use and develop modelling scales, allowing for appropriate simplifying hypotheses to be formulated and applied towards tackling a problem.
- conduct performance analysis to demonstrate that the system can successively meet the system constraints is part of 3.6 Evaluate the efficiency, feasibility and strength of the solutions offered.
- perform the different phases of the design cycle is part of C1.4 Design, detail and corroborate a whole or part of a complex system and 3.6 Conceive of, design, implement and authenticate complex software.
- use a model based design approach C6.3 Conceive of, design, implement and authenticate complex software.
- design project management is part of C8.1 Work collaboratively in a team.

2EL6020 – Computer Architecture

Instructors: Ruben SALVADOR PEREA
Department: CAMPUS DE RENNES
Language of instruction: FRENCH
Campus: CAMPUS DE RENNES
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

This elective course is part of the InfoSec track but remains accessible to any interested second-year student. Microprocessors are omnipresent in today's society, so their design and construction are major challenges. The way microprocessors are designed and built largely affect the overall security of computing systems.

The main objective of this course is to give students all necessary basic knowledge to understand how modern processors work. We will lay out the fundamental concepts and techniques in computer architecture, with a focus on the hardware/sofware interface and a bottom-up approach to understand how computers work and how they can be actually designed.

This course is largely inspired by Patterson and Hennessy's book "Computer Organization and Design, The Hardware/Software interface, RISC-V Edition, Morgan Kaufmann, 2018", and it will be used as the main book for the course. Both did pioneering work on computer architecture, specifically in "Reduced Instruction Set Computer" (RISC) architectures. David Patterson coined the term RISC, while John L. Hennessy was the inventor of the MIPS microprocessor. Both won the 2017 Turing Award for their work in RISC architectures.

Quarter number

SG6

Prerequisites (in terms of CS courses)

- Digital systems/electronics fundamentals
- Information systems and programming
- Algorithms & complexity fundamentals

Syllabus
Digital circuit design using a Hardware Description Language (HDL) (6h lectures + 6h tutorials)

- Combinational logic circuits design
- Sequential logic circuits design, Finite State Machines (FSM), análisis temporal
- Reconfigurable circuits: the Field-Programmable Gate Array (FPGA)
- HDL design flow for FPGAs (HDL description, simulation, synthesis)

Computer architecture and RISC-V (10.5h lectures + 10.5h labs)

- The Von Neumann model of computer architectures
- RISC/CISC architecture paradigms
- RISC-V instruction set architecture (ISA), addressing modes
- Processor components: datapath, register file, arithmetic logic unit (ALU), control unit, memory, peripherals
- Interrupts and exceptions
- Performance: pipeline, memory hierarchy and caches, branch prediction, out-of-order execution
- Notions on processor architecture security

Tutorials and Labs

- VHDL design flow for FPGAs
- RISC-V assembly programming
- VHDL design of (a subpart of) a RISC-V processor

Class components (lecture, labs, etc.)
Lectures : 16.5h
Tutorials : 6h
Labs : 10,5h

Grading
Final exam (project defense): 50%
Lab exam (technical realization and demonstration): 50%

Course support, bibliography

- **Slides** provided to students

- **Main books for the course**
  - D. A. Paterson, J. L. Hennessy, Computer Organization and Design: The Hardware/Software Interface, RISC-V Edition, Morgan Kaufmann, 2018. [CA]

- S. L. Harris, D. M. Harris, Digital Design and Computer Architecture (MIPS or ARM Edition), Morgan Kaufmann. [DDCA]

- **Other books**
  - W. J. Dally, R. C. Harting, T. M. Aamodt, Digital Design Using VHDL: A Systems Approach, First Edition, Cambridge University Press, 2016 [DD]
  - B. J. LaMeres, Introduction to Logic Circuits & Logic Design with VHDL, Second Edition, Springer, 2019 [DD]
  - M. M. Mano, C. R. Kime, T. Martin, Logic and Computer Design Fundamentals, Fifth edition, Pearson, 2015 [DDCA]
  - P. J. Ashenden, J. Lewis, The Designer's Guide to VHDL, Third Edition, Morgan Kaufmann, 2008 [DD]
- **Freely available PDFs**
  - B. Mealy, F. Tappero, Free Range VHDL : http://www.freerangefactory.org [DD]
  - P. J. Ashenden, The VHDL Cookbook : https://tams.informatik.uni-hamburg.de/vhdl/doc/cookbook/VHDL-Cookbook.pdf [DD]

Legend:
[CA] : Computer Architecture
[DD] : Digital Design
[DDCA] : Digital design and computer architecture

Resources

- Teaching staff: Rubén Salvador, Amor Nafkha, Jacques Weiss, Guillaume Hiet
- Maximum enrollment: 25
- Software, number of licenses required: Xilinx Vivado (25 licences)
- Board Xilinx Pynq-Z1
- Equipment-specific classrooms : Rennes Campus Level 3 and 5 lab rooms, 25 students

Learning outcomes covered on the course
At the completion of the course, students will be able to :

- explain the fundamental design principles of modern microprocessors architectures
- design some blocs of a simple microprocessor corresponding to the RISC-V instruction set architecture
- simulate and synthesize this microprocessor on an FPGA
- develop programs in assembly language using RISC-V instruction set

Description of the skills acquired at the end of the course
C1.4 - Design, detail and corroborate a whole or part of a complex system.

2EL6030 – Operating systems

Instructors: Frederic TRONEL
Department: CAMPUS DE RENNES
Language of instruction: FRENCH
Campus: CAMPUS DE RENNES
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

This teaching is part of the infosec course. It is highly recommended to follow the Computer Architecture course, and the Compilaton course in order to profit from the Operating System course. At this point of the year, the student should understand how a CPU works, and know the tools that produce an executable for this processor. The objective of this course is to give all knowledges required to realise a real micro-kernel that is able to manage the process memory, the interruptions (and consequently the system calls), and is able to perform basic inputs-outputs.

Quarter number

SG8

Prerequisites (in terms of CS courses)

Information System and Programming (SIP), Algorithmic and Complexity, Computer Architecture, Compilation

Syllabus

The course is organised as follows:
I Lesson 1 and 2 :
- History of operating systems
- Process Management
- Scheduling algorithms
- Process Synchronisation

II Lesson 3 :
- Virtual Memory management

III Lesson 4 :
- Interruption management
- Protection mechanism
- System calls

IV Lesson 5 :

- Input/Output management
- File System management

V Lesson 6 et 7 :

- Présentation of several systems (Linux, Windows, Mac OS X, Android). Comparison.

VI Lesson 8 :

- Virtualisation/Virtual Machine/Emulation

Class components (lecture, labs, etc.)

Course Operating System CM 12h TD 3h Homework 3h
Implementation of an OS micro-kernel TP 20h Homework 21h

Grading

final exam (oral presentation of the project) : weight 0,5Micro kernel evaluation (evaluation of the result of the realisation of the micro kernel): weight 0,5

Course support, bibliography

- Andrew Tanenbaum, " Systèmes d'exploitation ", 3eme Edition, Pearson.
- Russinovich, Mark, Solomon, David, Ionescu, Alex, "Windows Internals", 6eme edition, Microsoft Press.
- Daniel Bovet, Marco Cesati, "Understanding the Linux Kernel", 2nd Edition, O'Reilly.
- Love, Robert , "Linux Kernel Development: A thorough guide to the design and implementation of the Linux kernel (Developer's Library) ", Addison-Wesley.

Resources

a FPGA card running a RISC-V processor, or an emulator (.e.g., qemu)

Learning outcomes covered on the course

Understand the concepts, structure and design of operating Systems
Understand the impact of the operating system on application system design and performance
Programme how to implement simple OS mechanisms

Description of the skills acquired at the end of the course

C2.1 Thoroughly master a domain or discipline based on the fundamental sciences or the engineering sciences.
C2.5 Master the skillset of a core profession within the engineering sciences (at junior level).
C3.7 Make pragmatic and informed choices with the aim of producing tangible results.
C8.1 Work collaboratively in a team.

2EL6040 – System programming under linux and windows

Instructors: Alexandre DANG
Department: CAMPUS DE RENNES
Language of instruction: FRENCH
Campus: CAMPUS DE RENNES
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

This elective is part of the InfoSec track, but is nonetheless open to any 2nd year student willing to attend it.
The C language is still one of the most widely used languages to program low-level software applications in operating systems or application layers closeby. In particular, it is widely used for background services in GNU/Linux and Microsoft Windows systems (web servers, database servers, e-mail servers, file servers, and so on). Although designed a long time ago (in the 1970s) this state of things is due to the unchallenged performance of C programs, thanks to the continuous progress of available compiler toolchains. The drawbacks of writing in such a concrete language are therefore (partially) balanced by near-optimal performance, at the cost of a substantial effort for program design.
This course is therefore oriented towards students willing to strengthen their programming skills through experience with the C language, by writing applications close to the OS using standard UNIX interfaces (POSIX standard, I/O management, inter-process communication, multiprocess / multithread programming, system signal handling, debugging and application design and implementation) and their Microsoft Windows cousins with the Win32/Win64 APIs.
This course will also be the opportunity to realise the intrinsic difficulties of programming in C (especially the explicit memory management and the consequences of arguable design decisions in the implementations of arrays and strings) and the safety and security problems they incur.
We will use this experience to introduce a new programming language (Rust), which allows to guarantee both more security and safety (by language design, especially thanks to its rich type system) and achieves high performance just like C programs. To the best of our knowledge, this is the first language in programming languages history that reconciles security/safety with performance (previous attempts always sacrificed either security or performance). The Rust language is already currently used by Mozilla developers for the web browser Firefox.

Quarter number
SG8

Prerequisites (in terms of CS courses)
Systèmes d'information et programmation, Algorithmique & Complexité, réalisation préalable d'un projet de développement logiciel (1A)

Syllabus
Part 1 : The C language
Part 2 : The Rust language
Part 3 : System APIs in Unix and Windows, POSIX standard

Class components (lecture, labs, etc.)
50% courses, 50% practical work, mini-project

Grading
Final exam (oral presentation of the project) : 50%Lab exam : 50%

Course support, bibliography
- Le langage C - 2e édition - Norme ANSI (August 20, 2014) , Brian W. Kernighan and Dennis M. Ritchie.
- The Rust Programming Language, May 2018, Steve Klabnik and Carol Nichols.
- Programming Rust (August 2016), Jim Blandy.
- La norme POSIX.
- Windows System Programming, (4th Edition) (Addison-Wesley Microsoft Technology) by Johnson M. Hart (2015-10-01).

Resources
A Linux and Windows environment

Learning outcomes covered on the course
Create efficient C and Rust programs on the Linux and Windows platforms.
Select and make use of the OS kernel functions and their APIs.

Description of the skills acquired at the end of the course
C2.1 Thoroughly master a domain or discipline based on the fundamental sciences or the engineering sciences.
C6.3 Conceive of, design, implement and authenticate complex software.

2EL6050 – Modelica and bond graph: multi-domain modeling, analysis and simulation

Instructors: Pierre HAESSIG
Department: CAMPUS DE RENNES
Language of instruction: ENGLISH
Campus: CAMPUS DE RENNES
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : No

Description

Context: technical systems are usually made by **assembling components** (ex. in a car: engine, starter, brakes…) which behavioral models come from **different technical fields** (electrical, mechanical, thermal…). As a result, these components are often mastered by **different people**. The engineering of complex systems therefore raises difficulties in **exchanging and building up models**. This elective aims to learn two commonly used modeling tools to meet these needs: Modelica and bond graphs.

The bond graph is a graphical description of energy links between the components of a system. This representation is based on analogies between physical domains (e.g. mechanical inertia ~ electrical inductance). The main interest of the bond graph is in the existence of systematic approaches for the structural analysis of the modeled system, in particular through the central notion of *causality*.

Modelica is a non-proprietary language* used to address these industrial needs:

- Model systems spanning several physical domains
- Easily build structured models using reusable components
- Collaborate effectively and build up models within a team

In the end, Modelica allows simulating the dynamics of complex systems (a few thousand variables).

*unlike Simulink/Simscape for example

Quarter number

SG6

Prerequisites (in terms of CS courses)

none

Syllabus

Course schedule:

Bond graph (5 h + 2 h personal work)

- Principles of the bond graph formalism, analogies between domains
    - procedure for assigning causality
- Analysis of structural properties
- Extraction of the state-space equations

Modelica (14 h + 6 h personal work)

- Introduction to Modelica: brief history, use in industry, principles
- Getting started with Modelica
    - First practical examples: ODE, electrical circuit, mechanics.
    - Analogies between variables: flow and potential
    - Hybrid systems, discontinuity, events (example of a diode rectifier)
- Structuring of models
    - Inheritance and composition
    - Packages
    - Creation of a customized physical component

Versioning (2 h + 1 h personal work, as required)

Depending on students' needs, there will be exercises to help people get started with Git (versioning software) and GitLab (collaborative development platform).

Modeling project (9 h + 18 h personal work)

(*"M³ project": Multiphysics Modeling with Modelica*) in groups of 3–4.

- Examples of project subjects: tidal power plant, drone, fuse, electromagnetic switch

Final evaluation (2 h, see §Evaluation methods)

Class components (lecture, labs, etc.)

For bond graph, teaching is done through interleaved lectures and exercises.

For Modelica, teaching is done through practical computer-based exercises with concise lectures to introduce key concepts.

In order to enable a practical mastery of these two tools, the focus is on practice through small exercises in the classroom, small exercises in self-study between classes and finally with the final project.

Grading

The evaluation of the elective is based on two activities that take place during a final 2-hour session:

- theoretical quiz without documents on bond graph and Modelica fundamentals (1/2 of the grade)
- final modeling project (1/2 of the grade)
    - A sheet detailing the project's objectives is given at the start of the project. In relation to these objectives, the evaluation criteria are listed in detail.
    - the project grade can be individualized within a group

Course support, bibliography

Material of the Modelica course: http://éole.net/courses/modelica/

- including an extended list of references: http://éole.net/courses/modelica/90-references.html

Michael M. Tiller *"Modelica by Example"*, online book, first published in 2014 an continuously updated since. URL: mbe.modelica.university.

Geneviève Dauphin-Tanguy et al. *"Les bond graphs"*, livre Hermès, 2000.

Resources

Teacher : Pierre Haessig

Computer sessions using the free software OpenModelica

Please note that installing the software under macOS is difficult. It may be necessary to work with a Linux virtual machine.

Learning outcomes covered on the course

For bond graph, the course is about learning the concepts of this representation to be able, on simple examples, to:

- model the system by a bond graph
    - including the application of the causality assignment procedure
- analyze the structural properties of the system
- extract the state-space equations

For Modelica, the course objectives are:

- use the Modelica language and the OpenModelica development environment to model and simulate dynamic systems
- know how to reuse standard Modelica models
- structure a complex model into reusable components
- work in a team on a common complex model, with a versioning system (git)

Description of the skills acquired at the end of the course

The skills described above make it possible to validate the following CentraleSupélec engineering skills:

- C1.2 Use and develop appropriate models, select the appropriate modeling scale and relevant simplifying assumptions to address the problem
- C1.3 Solve the problem with approximation, simulation and experimentation
- C1.4 Specify, design, build and validate all or part of a complex system

2EL6060 – Serious Game

Instructors: Catherine SOLADIE
Department: CAMPUS DE RENNES
Language of instruction: ENGLISH
Campus: CAMPUS DE RENNES
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

What if you save the world from your console?

The game, and especially the video game, is a fascinating medium. You have certainly experienced a maximum concentration, facing a screen or a board, hours that we no longer feel, challenges and limits that are crossed and exceeded. The game does not announce its ideas, it makes them live. The game does not explain, it implies.

Today, this strength of the game shows us that it is possible to go beyond mere entertainment: more and more, it allows to transmit knowledge, know-how, ecological or social awareness, ... In short, the game becomes seriously useful, from industry to classrooms.

In this elective, you will discover how the serious game has transformed the transmission of ideas in many areas, from learning to read to car repair, through education to gestures of care. These examples will allow you to become a designer of your own serious game, because your ideas also deserve to be playable.

Highlights

Discover and analyze several use cases and their effectiveness
Introduce one of the major themes of the serious game by making a YouTube popularization video
Build and develop as a group project your own serious game using a video game development platform such as *Unity*

Quarter number

SG8

Prerequisites (in terms of CS courses)
Computer science :

- Algorithms
- Programming language (basis)

Syllabus

Background (10%)

- Introduction to the elective and major issues around the serious game.
- Discoveries of industrial problems and specific cases throughout the elective.
- DragonBox: How do 5-year-olds learn algebra in 50 minutes?

YouTube popularization video (25%)

- Subject choice among several proposed themes (game design vs gameplay, role of the score, interaction loop, ...)
- Creation of a YouTube video explaining the issues of the chosen theme (1 production per student).
- Share and watch videos on the Youtube channel dedicated to the elective.

Realization of a proof of concept of serious game (65%)

- In groups of 3 to 5 people.
- Accompanied by a professional in the video game industry.
- On a subject of your choice.
- The design, as well as the supervision will be done in two distinct but complementary sets:
  - the serious aspect, the useful objective to reach, the message or the knowledge to be transmitted;
  - the game aspect, the mechanics of the game implemented so that the interaction with the player works.
- Test your creation with your classmates and your entourage, and make it evolve in iterative mode!

Class components (lecture, labs, etc.)

- Presence course: 10% (6 HEE)
- PW and evaluation: 40% (24 HEE)
- Project and YouTube video : 50% (30 HEE)

Grading
Youtube video on a theoretical aspect of the serious game: 1/4 of the noteMCQ of theoretical knowledge about serious games: 1/4 of the noteDefense of the project of realization of a serious game: 1/2 of the note

Course support, bibliography
Introduction au Serious Game, de Julian Alvarez et Damien Djaouti
Concevoir un serious game pour un dispositif de formation, de Béatrice Lhuillier
Les serious games. Une révolution, de Yasmine Kasbi
La Gamification: Ou l'art d'utiliser les mécaniques du jeu dans votre business, de Clément Muletier et Guilhem Bertholet
Serious Game : Révolution pédagogique, de Valérie Lavergne Boudier et Yves Dambach

Resources
Teaching team:

- Catherine SOLADIE
- Pierre Haessig
- Renaud SEGUIER
- Externals

Size of PW (default 35 students): <= 50

Software tools and number of licenses needed:

- Unity (free for students): https://unity3d.com/en/unity

PW rooms:

- 251 and 252, Rennes Campus (up to 30 students in each room / 15 posts per room)

Learning outcomes covered on the course
At the end of this lesson, you will be able to:

- Define the main concepts related to serious games (C2.3)
- Argue the practices implemented in existing serious games (C2.3)
- Implement a video game (C2.3)

- Combine your software development skills with new skills (such as pedagogy or medicine) in a multidisciplinary approach (C1.5)
- Imagine and design a serious game (C3.5)
- Be proactive and get involved in the creation of a YouTube video and a POC (C3.1)
- Take into account the game play and the UX in the creation of a serious game (C6.7)
- Use the expertise and personal knowledge of at least one member of the group (eg music, art, science, ecology) to design a serious game (C8.3)

Description of the skills acquired at the end of the course

- C2.3 : Rapidly identify and acquire the new knowledge and skills necessary in applicable domains, be they technical, economic or others.
- C3.5 : Put forward new tools with either continual progress or disruptive solutions as the goal
- C6.7 : Understand information transmission.
- C8.3 : Engage outside expertise, to go the extra mile. Identify and develop strengths and talents.

We also expect :

- C3.1 : Be proactive and involved.
- C1.5 : Bring together broad scientific and technical concepts in a core structure that is nestled in an interdisciplinary approach.
- C6.6 : Understand the digital economy.

2EL6070 – Virtual and augmented reality

Instructors: Catherine SOLADIE
Department: CAMPUS DE RENNES
Language of instruction: ENGLISH
Campus: CAMPUS DE RENNES
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

Mixed realities: beyond reality.

Beyond the physical and tangible reality, new worlds have emerged since a few decades: data, and more generally all digital contents, have their own reality. If we can talk about virtual worlds, it is because the interactions that bind us to these new pouch of reality have become as important as their background. And if today, these interactions remain focused on screens with variable sizes associated with tactile surfaces, the boundary between the physical world and the virtual worlds calls to scramble for more "natural" relationships to digital and what he has to offer.

We will then seek to plunge into virtual worlds to leave reality aside, or conversely, stick to our reality more practical information, more relevant, hitherto hidden. We do not want to know that data exist, we must be able to touch them, turn around, enter them. How to imagine these new interactions? What to see, and with what material? How far can we deceive our senses before digital indigestion?

In this elective, you will discover the main principles that underlie mixed realities - this continuum whose virtual and augmented realities are representatives. Behind these new modes of reality, you will understand the technological issues that lock or open the way to new exchanges between user and system. Finally, you will have the opportunity to put your new knowledge into practice through a project on a topic of your choice - go to the (inter)action!

Highlights

- Discover the challenges of several industries in terms of mixed realities
- Raise your skills in image analysis and critical user tracking at RA

- Try to win a 3-day PASS for the World RV Show in Laval

Quarter number
SG8

Prerequisites (in terms of CS courses)
Computer science :

  - algorithms
  - Programming language (bases)

Skills in image processing and synthesis would be a plus non essential.

Syllabus
Background (15%)

  - Introduction to elective and major issues around virtual and augmented reality.
  - Discoveries of industrial problems and specific cases throughout the elective.
  - Cave Immersia visit

YouTube popularization video (25%)

  - Subject choice among several proposed themes (the first VR headset, haptic interaction, ..)
  - Creation of a YouTube video explaining the issues of the chosen theme (1 production per student).
  - Share and watch videos on the Youtube channel dedicated to the elective.
  - The best video will receive a 3-day student PASS for the VR & A Laval Virtual show.

Analysis and synthesis of images for virtual and augmented reality (20%)

- Alternation theory / practice in the form of BE (Bureau d'étude)
  - SLAM
  - Object detection
  - Camera relocation

Realization of a virtual or augmented reality application (40%)

  - In groups of 2 to 4 people.
  - On a subject of your choice.

- Test your creation with your classmates and your entourage, and make it evolve in iterative mode!
- Apply project management methods that are appropriate to the situation.

Class components (lecture, labs, etc.)

- Class: 17% (10 HEE)
- Cave Immersia: 5% (3HES)
- Consulting and evaluation: 28% (17 HEE)
- Project and YouTube video: 50% (30 HEE)

Grading
MCQ of theoretical knowledge on virtual reality, augmented reality, mixed reality: 1/3 of the noteDefense of the project of realization of a system of virtual or augmented reality: 1/3 of the noteYoutube video: 1/3 of the note

Course support, bibliography
Interaction et collaboration en réalité virtuelle et augmentée, de Samir Otmane
Les casques de réalité virtuelle et de jeux vidéo, de Philippe Fuchs
Comment la réalité augmentée est en train de révolutionner le monde de la consommation, de Aleks IGNJATOVIC
L'Interaction en Réalité Mixte: Une étude de l'interaction en réalité virtuelle et réalité augmentée appliquée à l'archéologie sous-marine, de Mahmoud Haydar
La réalité augmentée avec Unity - Guide du développeur (exemples et solution complète avec C#), de Stéphane DORLAC
Le traité de la réalité virtuelle, de Philippe Fuchs et Guillaume Moreau

Resources
Teaching team:

- Catherine SOLADIE
- Renaud SEGUIER
- Externals

Size of PW (default 35 students): <= 30 for BEs

Software tools and number of licenses needed:

- Unity (free for students): https://unity3d.com/unity RV and RA Helmets (available at the Cave)

PW rooms:

- 251 and 252, Rennes Campus (up to 30 students in each room / 15 posts per room)

Learning outcomes covered on the course

- Quote and explain several fields of application of virtual, augmented or mixed reality (C6.6)
- Describe the impact of these new technologies in the world of tomorrow (C6.6)
- Identify issues related to tracking and interaction with users (C6.7)
- Compare different algorithms useful for virtual and augmented reality (C3.6)
- Design an application using virtual or augmented reality (C6.7)
- Choose the appropriate project management methods to achieve such an application (C8.4)
- Work autonomously to make a Youtube video (C3.1)

Description of the skills acquired at the end of the course

a. C3.1 : Be proactive and involved.
b. C6.6 : Understand the digital economy.
c. C6.7 : Understand information transmission.
d. C8.4 : Work using project management techniques appropriately tailored to the situation.

We also expect :

- C2.2 : Transfer knowledge and methodology across multiple disciplinary fields.
- C2.3 : Rapidly identify and acquire the new knowledge and skills necessary in applicable domains, be they technical, economic or others.

2EL6090 – Artificial Intelligence and Deep Learning

Instructors: Catherine SOLADIE
Department: CAMPUS DE RENNES
Language of instruction: ENGLISH
Campus: CAMPUS DE RENNES
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

DNA or line of code?

Homo Sapiens is cut to walk on two feet, yet he must learn a year before getting up. Underwater creatures can move in total darkness, and their species have evolved over millions of years to achieve this result. Adaptation to a milieu, to a problem, or intelligence, are not static notions but the result of a constant effort: learning.

Thus, the emergence of technological systems capable of prediction, of expertise, quickly raises the question of learning. How can a program acquire, assimilate, organize knowledge? On this point, taking inspiration from the living is a rather fruitful starting point. How to mimic the behavior of our neurons? That of evolution and natural selection? What results to expect?

In this elective, you will discover the principal methods of Artificial Intelligence and how they work. You will be able to take in hand the most recent algorithm on concrete cases, and you will have the opportunity to push the study on a subject of your choice. It's up to you to learn how to learn!

Highlights

Artificial life: cellular automata, neural networks, genetic algorithms
Deep Learning:
  Convolution networks and the importance of knowledge bases
  Temporal processing of data: RNN, LSTM
  Generative models like VAE or GAN

Quarter number

SG6

Prerequisites (in terms of CS courses)
Statistics and learning.

Syllabus

Background (5%)

- Introduction to the subject
- Historical context.
- Link with the subjects of the program.

Artificial life (15%)

- Alternation theory / practice in the form of BE (*Bureau d'étude*)

- Artificial Life
    - Cellular automata and emergence concept
    - Genetic algorithms
    - Multi-agent systems
    - Reinforcement Learning

Machine Learning and Deep learning (40%)

- Alternation theory / practice in the form of BE (*Bureau d'étude*)

- Machine Learning
    - Neural networks
    - Backpropagation
    - Non-negative matrix factorization
- Deep Learning
    - Auto-encoders
    - Recurrent neural networks
    - Convolutionnal neural network and transfer learning
    - Deep generative models

Project to build a BE (40%)

- Individual project
- Deepening of a subject chosen freely
- Presentation in the form of a *bureau d'étude*
    - 15m of theory
    - 1h of PW

Class components (lecture, labs, etc.)

2. Course: 13% (8 HEE)
3. Consulting and evaluation: 37% (22 HEE)
4. Online courses: 20% (12 HEE)
5. Project to build a *bureau d'étude* : 30% (18 HEE)

Grading

MCQ of theoretical knowledge on AI and Deep Learning: 1/3 of the note
Defense of the project of realization of a BE: 1/3 of the note
BE content and justification: 1/3 of the note

Course support, bibliography

Tutoriels de Yann Lecun
Machine Learning avec Scikit-Learn - Mise en oeuvre et cas concrets, Aurélien Géron
Deep Learning with Python, Francois Chollet
Pattern Recognition and Machine Learning, Christopher Bishop, Springer, 2006. The best book on Machine Learning, it covers a lot of topics! Freely available online.
Deep Learning, Ian Goodfellow et al., MIT Press, 2016. A reference book on Deep Learning. Freely available online.
Dive into Deep Learning, Aston Zhang et al., 2019 An interactive deep learning book with code, math,...

Resources

Teaching team:

4. Catherine SOLADIE
5. Renaud SEGUIER
6. Simon LEGLAIVE

Size of PW (default 35 students): <= 30 for BEs

Software tools and number of licenses needed:

- Pytorch or equivalent (free)

PW rooms:

- 251 and 252, Rennes Campus (up to 30 students in each room / 15 posts per room)

Learning outcomes covered on the course

- Know a wide range of machine learning and deep learning tools for data processing, including massive data (C2.1, C6.5)
- Know the basics of machine learning (C2.1)
- Know how to list and give examples of different machine learning families (C2.1)
- Test, analyze and evolve different machine learning and deep learning algorithms (C1.3, C3.2, C6.4, C6.5)
- Evaluate the performance of a machine learning algorithms (C3.6)
- Design and propose a data processing software illustrating a specific concept or a specific algorithm of machine learning or deep learning (C2.3)

Description of the skills acquired at the end of the course

- C2.1 : Thoroughly master a domain or discipline based on the fundamental sciences or the engineering sciences.
- C3.6 : Evaluate the efficiency, feasibility and strength of the solutions offered.
- C6.4 : Solve problems through mastery of computational thinking skills.
- C6.5 : Operate all types of data, structured or unstructured, including big data.

We also expect :

- C3.2 : Problematise assumptions and givens, overcome failure and make decisions.
- C6.3 : Conceive of, design, implement and authenticate complex software.
- C1.3 : Apply problem-solving through approximation, simulation and experimentation.

2EL6100 – Communication Systems Engineering

Instructors: Haïfa FARES
Department: CAMPUS DE RENNES
Language of instruction: ENGLISH
Campus: CAMPUS DE RENNES
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

All communications today (mobile communication, satellites, local area networks, ADSL wired networks, etc.) offer higher bit rates thanks to digital processing whose fundamentals have been stated from the information theory of *Claude Shannon* (1948) based on the the two following principles:

- Source Coding trying to remove unnecessary redundancies in the transmitted messages and to gain in information rates.
- Channel coding to protect the transmission of the compressed information toward the receiver aiming to minimize errors for the detected signal.

For ideal transmission over a Gaussian channel, joint source / channel coding is the appropiate way to approach the theoretical limit of the maximum achievable date rate predicted by information theory.

On the other hand, for a wide spectrum of applications, the channel can be much more restrictive with phenomena such as selectivity, multi-path transmission, the Doppler effect ... However, even for this type of channel, there are, fortunately, other ways of protecting the information (besides channel coding) mainly using the notion of diversity (temporal, spectral, spatial ...)

Quarter number

SG6

Prerequisites (in terms of CS courses)

- Notions of probabilities
- Digital Signal Processing (Fourier Transform, Spectral Analysis)

These knowledges are learned from signal processing (1CC4000) and modelisation (1CC3000) courses.

Syllabus

Part 1 : Information theory

- What is information? Mutual information? Entropy?
- Channel capacity
- Shannon 's theorems (channel and source coding)

Part 2 : Source coding

- Codes with fixed and variable lengths
- Huffman codes
- Applications (JPEG, MPEG, MP3, H264)

Part 3 : Channel coding

- Block codes
- Convolutional codes
- Viterbi decoding
- Applications: video broadcasting, mobiles communications, etc.
- To go further: LDPC codes, turbo codes, polar codes, ….

Part 4 : Channel selectivity and diversity

- Multi-path channel and frequency selectivity
- Diversity concept (temporal, spectral, spatial, of polarisation)
- Channel equalization
- Performance (Bit error rate, spectral efficiency)

Class components (lecture, labs, etc.)

The fundamentals are presented in lectures with specific examples. Exercices ensure a good understanding of the course and correct the misinterpretations of the course. Personal works are additional courses requested from students (applications and extensions).

Grading

Final exam : coefficient 0,5Laboratory exam : coefficient 0,25Personnal work : coefficient 0,25 In case of a justified absence to one of the intermediary examinations, the grade of this latter is replaced by the grade of the final examination.

Course support, bibliography

- Lectures notes provided to students
- G. Battai, "*Théorie de l'information - Application aux techniques de communication*", Ed. Masson, 1997.
- W. Peterson, E. Weldon, "*Error corrcting codes*", Ed. MIT Press, 1972.
- S. Lin, D. Costello, " *Error control coding: Fundamentals and Applications*", Ed. Prentice Hall, 1983.
- G. Cohen, J. L. Dornstetter, P. Godlewski, "*Codes correcteurs d'erreus*", Ed. Masson, 1992.
- J. Proakis, "*Digital communications"*, 4e édition, Ed. McGraw-Hill, 2001.
- J. C. Bic, D. Duponteil, J. C. Imbeaux, "*Eléments de communications numériques*", Ed. Dunod, 1986.
- R.Boite, M. Kunt, "*Traitement de la parole*", Ed. Polytechniques et Universitaires Romandes, 1987.
- J. Deller, J. Hansen, J. Proakis, "*Discrete time processing of speech signals*", Ed. IEEE Press, 1999.
- T. M. Cover, J. A. Thomas, "*Elements of Information Theory*", Wiley New York, 1991.

Resources

- Teaching staff (instructor(s) names): Amor Nafkha, Georgios Ropokis, Haïfa Farès, Yves Louët
- Maximum enrollment (default 35 students): 20
- Software: MatLab
- Equipment-specific classrooms

Learning outcomes covered on the course

The first objective of this elective is to provide elements regarding the information theory by covering channel and source coding. The second objective is to detail what a digital transmission is and what are the different requirements to target expected performance.

For instance, the students will be able to:

- understand a digital communication chain
- understand the different chain blocks
- understand the metrics of performance evaluation of a digital transmission
- optimize the dimensioning of a transmission chain under constraints (performance trade-offs)

- generate, analyze, process digital signals with Matlab

Description of the skills acquired at the end of the course
In terms of skills:

- The first three course outcomes aim to acquire the C1.2 skill "**Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when addressing a problem**"
- The outcomes 4 and 5 contribute to the core of C1.3 skill "**Apply problem-solving through approximation, simulation and experimentation. / Solve problems using approximation, simulation and experimentation**"
- The outcome 5 adresses the C1.4 skill "**Design, detail and corroborate a whole or part of a complex system**"
- Tutorials and personal work contribute to develop both C8.1 skill **"Work collaboratively in a team**" and C3.1 skill "**Be proactive and involved, take initiatives**"
- The personal work, for instance, helps to deepen the C7.1 skill **"Persuade at core value level; to be clear about objectives and expected results. To apply rigour when it comes to assumptions and structured undertakings, and in doing so structure and problematise the ideas themselves. Highlight the added value**"

2EL6110 – New network paradigms

Instructors: Bernard JOUGA
Department: CAMPUS DE RENNES
Language of instruction: FRENCH
Campus: CAMPUS DE RENNES
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : Yes

Description

This elective course is part of the InfoSec Track, but is accessible to any 2nd year student. It aims to present advanced concepts of Computer Networks architecture and is based on the fundamental concepts presented in the elective course "Network and Security " of 1st year.
The classic paradigms of Computer Networks related to the creation of Internet (layered models, TCP/IP protocols, client/server model, etc.) have become widely adopted. However, changes in user needs in terms of data availability and volumetrics as well as the emergence of new applications and new services (support of "heavy" applications as Wep Apps, Cloud Computing, cryptocurrency, etc.) lead to significant changes in traditional architectures of Information Systems. These architectural evolutions, as well as the rise of associated technologies, can also be explained by two current trends:

- The outsourcing of network and hosting infrastructures, and even of applications themselves;
- The optimisation of the use of these infrastructures.

This implies in particular:

5. Dynamic, on-demand adaptation capabilities, including the ability to distribute storage and processing but also to quickly reconfigure infrastructures;
6. Resource sharing capabilities (compute, storage and network), generally based on the virtualization of infrastructures;
7. The use of decentralized, peer-to-peer models;
8. Scalable resource allocation models, etc.

Quarter number
SG6

Prerequisites (in terms of CS courses)
1CC1000 – Information Systems and Software Development
1EL6000 – Computer Networks and Security

Syllabus

4. Lessons 1 to 5 (7,5h):
    1. Cloud Computing
    2. Data Center Networks
    3. Software-Defined Networking (SDN)
5. Lessons 6 and 7 (3h):
    - IPv6
6. Lessons 8 and 9 (3h):
    - LDAP Directories
7. Lessons 10 and 11 (3h):
    - Distributed Architectures (Cluster)
    - Distributed File Systems
    - Cluster Management, 0rchestration
    - Load Balancing
8. Lessons 12 and 13 (3h):
    - Peer-to-peer (P2P) Architecture
    - Blockchain
9. Laboratory study (15,5h): implementation of a software network and a distributed service with OpenStack

Class components (lecture, labs, etc.)
A large place is left to practical aspects.
The lectures are punctuated with demonstrations and manipulations.
A long-term laboratory study, including a part of homework, makes it possible to gradually implement the technologies presented in classroom.

Grading
Final written exam: coefficient 0.5 Defence of the laboratory study: coefficient 0.5. Controlled attendance at laboratory study: 0.2 penalty points per not justified absence.

Course support, bibliography

- Teachers Slides

- Paul Goransson, Chuck Black, Timothy Culver, « Software Defined Networks A Comprehensive Approach”, 2nd Edition, Morgan Kaufmann
- William B. Norton, The 2014 Internet Peering Playbook: Connecting to the Core of the Internet

Resources

- Teaching staff (teachers' names of lectures): Bernard Jouga, Guillaume Piolle
- Software tools and number of licenses required: VirtualBox, OpenLDAP, OpenStack, HAProxy, Open vSwitch, OpenDaylight
- Material resources: cluster of several dedicated machines for installing and setting up a private cloud
- Laboratory study rooms (department and capacity): Rennes campus level 5, 25 people in laboratory study

Learning outcomes covered on the course
At the end of this course, students will be able to:

- design a distributed network architecture offering load balancing and high disponibility;
- design an architecture based on an Infrastructure as a Service;
- use an LDAP directory within an architecture;
- explain the principles of elasticity and resource management in Cloud Computing;
- explain the principles and pro & cons of resource virtualization;
- explain the principles of peer-to-peer networks for data exchange or Blockchain management.

Description of the skills acquired at the end of the course

- C1.1- Examine a problem in full breadth and depth, within and beyond its immediate parameters, thus understanding it as a whole. This whole weaves the scientific, economic and social dimensions of the problem
- C1.4 - Design, detail and corroborate a whole or part of a complex system

2EL6120 – Intelligent Wireless Access & Experimentation

Instructors: Georgios ROPOKIS
Department: CAMPUS DE RENNES
Language of instruction: ENGLISH
Campus: CAMPUS DE RENNES
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : Yes

Description

The scope of the course is to present the essential knowledge necessary to understand the characteristics of wireless communications systems and standards. To this end, the course focuses on some of the several aspects of communications systems including:

- transmission technologies used in current and future standards, including 4G and 5G
- Multiple Access technologies used in current and future standards (starting from 2G and moving to 5G and beyond 5G),
- the basics and characteristics of telecommunications hardware including the architecture of computing equipment used in communication and the behavior of RF chains,
- architectures of mobile processors
- the process of experimentation and prototyping for wireless communications systems.

The course covers all the technical essentials for students that are interested in understanding the fundamentals of wireless communications and its applications, and can serve as a first step for those interested in taking further studies in wireless communications engineering. Moreover, as the course exposes students to several aspects of wireless communications engineering, it serves as an excellent opportunity for those of them interested in pursuing a career in project/team management in the broad area of Communications Engineering. The course will help students familiarising with the most significant aspects of Wireless engineering including wireless communications standards and their characteristics, wireless hardware and prototyping. The presentation of the material will follow a standard oriented approach such as to cover students interested both in the fundamentals of Wireless Communications as well as students mostly interested in a more applied approach to Wireless Communications.

Quarter number
SG8

Prerequisites (in terms of CS courses)

- Notions of probabilities
- Digital Signal Processing (Fourier Transform, Spectral Analysis)
- Basic programming skills

These presrequisites correspond to signal processing (1CC4000),modelisation (1CC3000) and programming (1CC1000) courses.

Syllabus
Part 1: Fundamentals of Wireless transmission

- Physical modelling of wireless channel
- Detection in a fading channel
- Digital Single Carrier and Multicarrier modulation
- Diversity techniques

Part 2: Multiple Access Schemes and Standards : (Multiple Access Schemes for 2G, 3G, 4G, 5G and Beyond 5G networks).

- TDMA, FDMA, CDMA, SDMA
- FDD, TDD, half duplex and full duplex
- Interference management
- Applications in GSM/UMTS/4G/5G network standards
- Other wirless access standards: WLAN, WPAN and LPWAN
- IoT standards and connected objects

Part 3: Computing architectures for wireless communications

- Adaptable wireless communications architecture: the Software-Defined Radio (SDR)
- Analog/Digital front-ends and ADC/DAC data converters
- Embedded computing architectures: from mobile ARM processors to DSPs, FPGAs and GPUs
- Embedded computing platforms for wireless communications

Part 4: Hardware implementation fon wireless systems using GNU Radio and USRP platforms

- Tutorial on GNU Radio
- Implementation of a simple FM receiver
- Implementing a file transfer application on GNU Radio and USRP with QPSK based modulation and demodulation

Class components (lecture, labs, etc.)

Course layout, course organization (CM, TD, EL / TP sequencing) in hours:
Fundamentals of Wireless Communications Lectures: 4.5h
Multiple Access Schemes and Standards Lectures: 6h
Practical work on Fundamentals of Wireless Communications and Multiple Access Schemes: 3h
Computing Architectures for Wireless Communications CM: 9h
GNU Radio tutorial CM: 1.5h
Experimentation/Practical work using GNU Radio and USRPs : 9h
Exam: 2h
Total (HPE): 35h

Grading

Final (written or oral) exam and evaluation of practical/laboratory work

Course support, bibliography

- Handout provided to students
- Tse, D., & Viswanath, P., "Fundamentals of Wireless Communication". Cambridge: Cambridge University Press, 2005.
- Holma H., & Toskala A., "LTE for UMTS: OFDMA and SC-FDMA Based Radio Access", Wiley Publishing, 2009.
- Vaezi M., Ding Z., & Poor H. V., "Multiple Access Techniques for 5G Wireless Networks and Beyond", Springer 2018.
- Yannick Bouguen, Eric Hardouin, François-Xavier Wolff, "LTE et les réseaux 4G", Eyrolles, 2012
- A. Elnashar, M. A. El-saidny, M. Sherif, K. Abdulla, "Design, deployment and performance of 4G networks", Wiley-Blackwell 2014,
- Fattah Hossam, "5G LTE narrowband Internet of Things (NB-IoT)", CRC Press in 2019.
- A. Pacaud, "Électronique radiofréquence", Ellipses, 2000,B. Razavi
- "RF microelectronics, communication electronics", Prentice Hall, 1997
- P.L.D. Abrie, "Design of RF and microwave amplifiers and oscillators", Artech House, 1999,
- S.C. Cripps, "RF power amplifiers for wireless communications", Artech House, 2006,
- Gernot Hueber, Robert Bogdan Staszewski "Multi-Mode/Multi-Band RF Transceivers for Wireless Communications: Advanced Techniques, Architectures, and Trends" , John Wiley & Sons, Inc, 2010
- Peter B. Kenington, " RF and Baseband Techniques for Software Defined Radio ", Artech House, 2005.

- Collins, T.F.; Getz, R.; Pu, D.; Wyglinski, A.M. Software-Defined Radio for Engineers; Artech House: Norwood, MA, USA, 2018.

Resources

- Teaching staff (nales of professors delivering lectures): Haïfa Farès, Amor Nafkha, Georgios Ropokis, Ruben Salvador
- Size of TD (by default 35 students): 20
- Software tools and number of required licences: MATLAB and GNU radio for practical and personal work
- Practice rooms (deparment and capacity):

Learning outcomes covered on the course

At the end of the course, the students should be able to:

- understand the basics of digital transmission and multiple access schemes used in existing standards
- understand how a complete wireless communications RF chain works (Radio, Analog and Digital domains)
- become familiar with several different digital processing platforms available for building wireless communications systems and their impact on system requirements (cost, performance, lifetime, energy efficiency etc)
- understand the terminology, structure and characteristics of modern wireless and mobile communications standards
- experiment on building a real wireless communication system

Description of the skills acquired at the end of the course

The course addresses the folowing skills

- C1.2 skill "Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when addressing a problem"
- Tutorals and practical work address:
    - The C1.4 skill "Design, detail and corroborate a whole or part of a complex system"
    - Core Skills "C3.1-Be proactive and involved" and "C8.1-Work collaboratively in a team"

2EL6130 – Embedded systems and internet of things

Instructors: Jean-Francois LALANDE
Department: CAMPUS DE RENNES
Language of instruction: FRENCH
Campus: CAMPUS DE RENNES
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : Yes

Description

This elective course is part of the Infosec track, but can be taken by any second year student. The goal of this elective course is to discover the specificities of the development of applications that are executed on embeded systems or IoT objects.

The constraints for developing these connected objects are multiple: energy limits, computing capacities, network connectivy, data overloading, real time, etc. Indeed, this elective course will focus on general principle that are shared by these devices, ofr example, the data upload to the cloud, the optimization of the software computing, the network connectivity.

In a second part, the elective course illustrates these principles by selecting real embedded systems on which we study the software ecosystem. From the language point of view, the course shows how can be used the C language or languages using virtual machines and in both cases, how these languages are used in embedded systems. For the data, the course presents the solutions for storing locally or using programming API which enables to upload these data in cloud infrastructures.

This course may be enriched by industrial partners that can provide their expertise for specific embedded devices.

Quarter number

SG8

Prerequisites (in terms of CS courses)

Information system and programming, Algorithms and complexity, 1st year elective Network and security

Syllabus

Chapter : Principles: embedded systems and IoT

2. The specificity of embedded OS
3. The network protocols for IoT (z-wave, zigbee)
4. The languages for embedded systems
5. Real time systems (WCET)

Chapter : RIOT OS

3. Discovering RIOT
4. Development language
5. Lab: manipulating sensors

Chapter : Developing Android mobile applications

- Specificities of Android development
- Graphical User Interfaces
- Client Serveur applications
- Labs: discovering Android, requesting a server

Chapter : Javacard for smartcards

- Specificities of smartcards
- Developping applets for Javacard enabled smartcards

Class components (lecture, labs, etc.)

12h of course
15h of labs

Grading

Continuous control: Evaluation of RIOT and Android labs (0.5)
Continuous control: Presentation of advanced topics (0.5)

Resources

- 13 Arduino

- 13 MKRFox1200
- Smartcard readers

Learning outcomes covered on the course

- Know the specificities and the constraits of embedded systems et internet of things
- Develop software with such systems

Description of the skills acquired at the end of the course

C6.3 Specify, develop et realize and validate a software

2EL6140 – Microgrids : components and control

Instructors: Pierre HAESSIG
Department: CAMPUS DE RENNES
Language of instruction: ENGLISH
Campus: CAMPUS DE RENNES
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : Yes

Description

The supply of electricity to isolated sites such as islands has some specific characteristics due to the small size of their power grid. This leads to a high risk of instability and therefore the control of a microgrid, including all its electrical components, is crucial for its proper operation.

This elective proposes to study this issue from two perspectives:

- **Electrical engineering**: presentation of the key electrical components of an alternating microgrid
- **Automatic control**: implementation of control techniques on these components and introduction to the control of large-scale systems (i.e. how to go beyond the “classical” control theory which only deals with 2–3 variables).

Note: the electrical engineering program of this elective is close to the “Energy Conversion” elective offered in Paris-Saclay. The automatic control part is unique to this elective.

Quarter number

SG8

Prerequisites (in terms of CS courses)

Power systems concepts you need to know (e.g. by having taken the first-year elective “Electrical Energy (ENE)”):

- Power in AC regime: P (active), Q (reactive) and S (apparent)
- **Three-phase** electric power system: phase-to-neutral and phase-to-phase voltages

Control theory concepts you need to know (e.g. by having followed the ST5 common course on automatic control):

- Modeling a system by a transfer function
- Regulation of a linear system by a PID controller

Having taken the ST7 “Smart grids and energy challenge: energy management in isolated sites” would be a plus, but is not a prerequisite, as the topics addressed are very different:

- ST7 “Renewable energies and microgrids” course: high level modeling (energy flows), with economic optimization.
- this elective: voltage/current modeling and more detailed analysis of electrical components and their low-level regulation.

Syllabus

This elective belongs to both *electrical engineering* and *automatic control*, with extra *transversal and practical* skills on the analysis and control of systems thanks to the intensive use of a modeling and simulation software.

For the electrical part, the aim is to understand the operation and modeling of the *energy conversion components* of a microgrid:

- power electronics converters (choppers and inverters)
- AC electric machines (synchronous and asynchronous)

This knowledge is presented through lectures and exercise sessions.

For the automatic control part, the aim is to understand the *control and regulation* strategies of microgrid components, in particular the power electronics converters. In addition, this part includes an introduction to the control of large-scale systems (the microgrid with its many components).

This automatic control part is mainly conducted as hands-on sessions on computers. These sessions are an opportunity to *intensively practice* a modeling and simulation tool (Simulink/Simscape). One of the issues addressed is the choice of a level of details in the model adapted to the objective (compromise between simplicity, speed, fidelity…). This transversal skill is meant to be transposable to other engineering fields.

Note: the optimization of power flows (power dispatch) to ensure the economically optimal operation of a microgrid is not addressed. Indeed, this issue is part of the ST7 optimization project. “Smart grids and the energy challenge: energy management in isolated sites”.

Class components (lecture, labs, etc.)

Lecture sesssions aim at acquiring basic knowledge in the field of power systems. These sessions include exercises on paper.

The practical sessions are done on computers (Matlab/Simulink). Computer work can be done in pairs. The time devoted to these sessions is substantial to allow the students to become fully comfortable with the simulation tool.

Lectures: 9 hours, Tutorials: 9 hours, Laboratories: 15 hours, Evaluation (written exam): 2 hours.

Grading

The evaluation of the lecture sessions is one final written exam.

The evaluation of the computer lab sessions is done by checking the progress along the sessions and by a final synthesis report.

The weighting between the lecture part and the practical part is 50%, 50%.

Course support, bibliography

Course site on Edunao:
https://centralesupelec.edunao.com/course/view.php?id=1494

Resources

Course staff:

- Pierre Haessig: course supervisor
- Alexandros Charalampidis: computer lab sessions
- Loïc Matel: electric machines & power electronics lectures

Required software: Matlab, with Simulink and the Simscape Electrical toolbox. Academic licenses for those products are free for all CentraleSupélec students.

Learning outcomes covered on the course

At the end of the lectures, students will be able to:

- *Describe the operation* and *perform simple theoretical analyses* of the electrical machines and power electronic converters covered in the course

At the end of the practical part, students will be able to:

- *Implement* models of electronic converters in a simulator (Simulink) with a complexity adapted to the phenomena to be studied.
- *Describe* the control structure of an electronic converter and *adjust* some control loops of this structure.
- *Evaluate/analyze* the proper operation of the regulation through well-selected simulations

Description of the skills acquired at the end of the course

The learning outcomes of this course allow validating the following CentraleSupélec engineer core skills:

- C1.2 Use and develop appropriate models, select the appropriate modeling scale and relevant simplifying assumptions to tackle a problem
- C1.3 Apply problem-solving through approximation, simulation and experimentation
- C1.4 Specify, design, build and validate all or part of a complex system

2EL6150 – Model-based predictive control

Instructors: Romain BOURDAIS
Department: CAMPUS DE RENNES
Language of instruction: ENGLISH
Campus: CAMPUS DE RENNES
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Engineering Sciences
Advanced level : Yes

Description

Model Predictive Control (MPC) is the advanced control technic the most used for engineering systems. Its industrial use is booming because it optimizes the operation of an industrial process, its energy efficiency while integrating operating constraints. However, it is still the subject of a large number of scientific publications, even if the last concerns of the scientific community remain very theoretical.

This course presents the main principles of the predictive control in a precise, readable and intuitive mathematical formalism and which is not reserved for the automation engineers - *The predictive control will be treated in depth and in all the aspects of the automatic in the mention of 3rd year "Control Engineering"* - After an introduction to the basic concepts of the MPC, this course is built around many case studies, where they will be applied both in simulation and in practice for different industrial processes. In this course, it is therefore a question of providing decision and control tools that exploit a model of the system in order to improve its efficiency. Expectations in terms of efficiency are translated into a mathematical multicriteria that must be minimized. The model can be derived from a mathematical representation of the considered system, in which case conventional methods (deterministic, linear programming for example, or explicit resolution) of optimization can be used. The optimization process can also use a simulator of the studied system, which must then use heuristic techniques.

The applications will focus on energy management in an eco-district and the exploitation of such techniques for the sizing of energy production or storage systems.

Quarter number

SG8

Prerequisites (in terms of CS courses)

Control Science Course
Optimisation Course

Syllabus
An Introduction to Model Predictive Control (6h lecture, 6h de TD, 9h of Laboratory Work, including 1 hour of exam)

- Basis concepts
    - Prediction model
    - Receding horizon principle
    - Specifications and mathematical translation of objectives
    - Optimization problem solving and closed-loop behavior
    - Tuning
    - Explicit and Implicit solving
- Economic MPC
- Constraints Integration

Case Study 1: Energy management in Residential Houses (1h lecture, 4h laboratory work, 9h Homework, 1 hour of exam). Group work of 3/5 students. This first case study aims at integrating a set of complex heterogeneous systems into an energy manager.

- Data analysis and bibliographic analysis
- Design of a power management system, integrating energy and power constraints
- Integration of mixed processes: continuous and with decision variables
- Development of a performance evaluation simulator
- Written exam

Case Study 2: Dimensioning and predictive management of a solar production and an electrical storage for the energy independence of an isolated site (1h lecture, 5h laboratory work, 18h homework, 1 oral presentation of the results). This second case study incorporates an economic dimension coupled with risk-taking in the management of uncertainties.

- Data analysis and bibliographic analysis
- Integration of uncertainty (weather phenomena, random consumption)
- Compromise search: investment in infrastructure and strong active management capability
- Return on investment calculation
- Assessment of the comforts (satisfaction of the requests)

- Risk analysis
- Team Challenge - Presentation and Peer Review

Class components (lecture, labs, etc.)

This module is built on very few theoretical courses. Practical work is at the heart of this module, which combines both model experiments (industrial wind tunnel) and technical-economic studies where theoretical content is used as a basis for decision-making.

Grading

Written exam of part 1 (0.25) Written exam of part 2 (0.25)Oral presentation of part 3 (0.5)

Course support, bibliography

- Model-based Predictive Control – A practical approach, J.A. Rossiter, CRC Press, 2003
- Model Predictive Control: Theory and Design, J. Rawlings and D. Mayne, Nob Hill Pub, 2009
- Model Predictive Control, E. Camacho and A. Bordons, Springer-Verlag London, 2007

Resources

6. Teaching staff (instructor(s) names): Romain Bourdais, Pierre Haessig
7. Maximum enrollment (default 35 students): 25 students
8. Software, number of licenses required: Matlab/Simulink/Optimization Toolbox
9. Equipment-specific classrooms: 25 students, Model Wind tunnel (available on Rennes Campus)

Learning outcomes covered on the course

At the end of this course, the student will be able to

- Specify the technical and economic stakes of the control-command problem under a Model Predictive Control formalism:
    - Choose an optimization criterion
    - Integrate operating and usage constraints

- Choose and use an appropriate optimization tool to solve the predictive control problem under consideration.
- Tune the parameters adapted to the situation and argue about these choices through simulation.
- Master scientific and technical communication (during reports or oral presentations).

Description of the skills acquired at the end of the course

- "Specifying the stakes of the control-command problem under a predictive command formalism" is part of **C1.1 "Examine a problem in full breadth and depth, within and beyond its immediate parameters, thus understanding it as a whole. This whole weaves the scientific, economic and social dimensions of the problem.".**
- "Choosing and using a suitable optimization tool for solving the predictive control problem under consideration" is part of **C1.2 "Select, use and develop modelling scales, allowing for appropriate simplifying hypotheses to be formulated and applied towards tackling a problem".**
- "Mastering scientific and technical communication" is part of **C7.1 "Persuade at the level of core values; to be clear about objectives and expected results. To apply rigour when it comes to assumptions and structured undertakings, and in doing so structure and problematise the ideas themselves. To make the added value known.".**
- Teamwork in the 2 case studies is part of **C8.1 "Work collaboratively in a team".**

2EL6160 – Economics of innovation

Instructors: Romain BOURDAIS
Department: CAMPUS DE RENNES
Language of instruction: FRENCH
Campus: CAMPUS DE RENNES
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Business Sciences
Advanced level : No

Description

The objective of this intervention is twofold. The first step is to address the general issue of market innovation from the perspective of economic theory, with particular attention to the foundations for the introduction of intellectual property tools as mechanisms to address market failures. The approach used to do this is micro-based, and is based on the presentation and resolution of well-known theoretical models of industrial economics in order to identify the conditions under which the use of these tools is to be recommended, in a context of strategic interactions - competitive and/or cooperative - on the markets.

A second part of this course aims to present conceptual models of innovation from a manager's point of view. It consists of addressing concrete points for activating innovation strategies based on recent models of their implementation within the organization. Specifically, an effort is being made to better understand the paradigm shift from a so-called closed innovation model to a new so-called open innovation model, by exposing the breaking points between them. Through use cases, an essential question is based on a better understanding of current intellectual property strategies, in a context in which cooperative dynamics can mingle with traditional competitive relationships. This creates new growth opportunities, which require the construction of new business models based in some cases on a discretionary relaxation of strict intellectual property rights. New business models (platform models, crowdsourcing, etc.) are finally presented, underlining the role of market innovations as a complement to usual technological innovations.

Quarter number

SG6

Prerequisites (in terms of CS courses)

none

Syllabus

- Innovation(s) and decision-making in an uncertain environment: A general introduction to the innovation economy
- Market failure and intellectual property
    - Definitions and highlights
    - The patent: a corrective tool?
    - A model of innovation race
    - A dormant patent model
    - A licensing model
- Innovation and R&D: From competition to cooperation?
    - Knowledge externalities
    - A model of competition and cooperation in R&D with externalities of knowledge
- Innovation: Modern managerial practices
    - The "problem" of the manager
    - The closed innovation model
        - Conceptual presentation
        - A case study: Xerox
    - Towards a new paradigm: the open innovation model
        - Conceptual presentation
        - A case study: Intel
- Towards new business models
    - Platform models
    - Crowdsourcing as a use of the "crowd
    - Outlaw activities as a new source of income
    - Innovative business models in the software industry: free software business models

Class components (lecture, labs, etc.)
This course consists of different lectures and the applications will be studied during tutorial sessions.

Grading
A written exam will be held during the last course

Resources
The course will be taught by Thomas Le Texier, assistant professor at the University of Rennes 2

Learning outcomes covered on the course
At the end of this course, the student will be able

- to present the different instruments of intellectual property, their strategic definition and their effects on the firm and the market (performance and regulation)
- to build theoretical models in the broader industrial economy, and in the industrial economy of innovation, intellectual property and digital markets in particular
- define and exploit recent managerial models in innovation management as well as new business models

Description of the skills acquired at the end of the course

- C1.2 Select, use and develop modelling scales, allowing for appropriate simplifying hypotheses to be formulated and applied towards tackling a problem.
- C6.6 Understand the digital economy.

2EL6170 – Production and flow management

Instructors: Romain BOURDAIS
Department: CAMPUS DE RENNES
Language of instruction: FRENCH
Campus: CAMPUS DE RENNES
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Business Sciences
Advanced level : No

Description

The aim of this course is first of all to introduce students to the main concepts of production and flow management, in order to

- better understand current issues and the role of production management in organizations
- get the same language as business leaders

Its second objective is to familiarize students with the methods and tools applicable to production and flow management, mainly :

- flow and stock control methods
- methods for improving industrial performance (lean manufacturing, etc.).

Quarter number

SG8

Prerequisites (in terms of CS courses)

None

Syllabus

- Products and resources, flows and capacity in the company
    - Manage products and resources in the company
        - Managing products: flow decisions
        - Managing resources: capacity decisions

        - Ensure synchronization of flows and capacities over time
    - Data associated with products and resources
        - Technical data
        - Activity data
- Flow and stock control
    - Inventory management
        - Inventory Management Models for Independent Demand
        - Choosing a model
    - Flow planning
        i. Comprehensive planning: development of ICP
        ii. Detailed planning: developing the PDP
    - Flow programming
        - MRPO Logic
        - MRP1 logic: load-capacity matching
    - Flow scheduling
        - Centralized Scheduling
        - Decentralized Scheduling (Kanban...)
    - Demand Driven approaches - a credible synthesis?
- Improvement of industrial performance (lean logic)
    - Measuring industrial performance
        - Calculation criteria
        - SRTs and other indicators
    - The Just-A-Time (lean logic)
        - Actions at the product level
        - Resource actions
        - Actions at the level of relations with partners - link with Supply Chain Management and partnership methods (GPA, GMA, CPFR...) + new tools (Blockhain)

Class components (lecture, labs, etc.)
The course alternates between lectures and tutorials.

Grading
This module will be evaluated by a written exam.

Resources
The course (a mix of lectures and working classes) is given by a team of professors from the Institut de Gestion de Rennes.

Learning outcomes covered on the course
By the end of this course, students will be able to:

- Establish the links between the Production Management function and, in the broadest sense of the word, logistics with the different departments of the company.
- Identify the main problems of logistics (especially industrial logistics) in organizations.
- Use the main methods of stock management and flow control and analyse their consequences for the company.
- Identify the methods of stock management and flow control best suited to a given environment.
- Using some productivity indicators in industrial logistics (TRS...)

Description of the skills acquired at the end of the course

C1.1 Examine a problem in full breadth and depth, within and beyond its immediate parameters, thus understanding it as a whole. This whole weaves the scientific, economic and social dimensions of the problem

C2.5 Master the skillset of a core profession within the engineering sciences (at junior level)

C3.7 Make pragmatic and informed choices with the aim of producing tangible results.

2EL6180 – Digital marketing

Instructors: Romain BOURDAIS
Department: CAMPUS DE RENNES
Language of instruction: FRENCH
Campus: CAMPUS DE RENNES
Workload (HEE): 60
On-site hours (HPE): 35
Quota :
Elective Category : Business Sciences
Advanced level : No

Description

The objective of this course is to present the marketing approach and its challenges, and to show the impact of digital transformation on the company and more precisely on the marketing function.

Quarter number

SG6

Prerequisites (in terms of CS courses)

None

Syllabus

Introduction

1. The short history of marketing
2. What is marketing?
3. The key role of perceived value
4. Marketing in a context of digital transformation and globalization

I. The fundamentals of marketing

1. Establish a marketing strategy
a. Strategic diagnosis
b. The marketing study
2. Implementing the marketing strategy: the marketing mix

II. The impact of digital on marketing

1. From digitisation to digital transformation: definitions and representations of the digital transformation of companies
2. The impact of digital on managerial issues
3. The use of new technologies to optimize the marketing approach
a) Digitisation and marketing research
b) Digitisation and marketing mix

The modification of spaces and places
The modification of social relations
Modification of the offer
The modification of the role of the actors of the company

4. Illustrated typology of companies' digital strategies

Conclusion

Class components (lecture, labs, etc.)
The various courses are taught by professors and lecturers from the University of Rennes. The concepts seen in class will be illustrated and put into perspective during a company visit (2 or 3 hours) and an "interview" meeting with a digital marketing practitioner (3 hours of intervention by Marianne Auffrey, former marketing manager of the Rennes stadium on digital communication)

Grading
An individual written file will be requested at the end of the module.

Course support, bibliography
Ferrandi F., Lichtlé M.C. (2014), Marketing, Dunod, 352p.

Aurélie Dudezert A. (2018), La transformation digitale des entreprises. Paris, La Découverte, « Repères ». URL : https://www.cairn.info/la-transformation-digitale-des-entreprises--9782348036019-page-57.htm
Hagberg J., Sundstrom M., Egels-Zandén N., (2016) "The digitalization of retailing: an exploratory framework", International Journal of Retail & Distribution Management, 44, 7, 694-712

Resources
The teaching team consists of Maud Daniel and Jacques Diouf, professors at the University of Rennes 2.

Learning outcomes covered on the course
At the end of this course, students will be able to:

- Establish the strategic diagnosis/marketing of a brand/brand
- Know how to build and implement a marketing action plan
- To know how to situate a company's strategy in a context of digital transformation
- Optimize the use of new technologies in the implementation of marketing strategy

Description of the skills acquired at the end of the course

C4.1 : Think in client terms, identify and analyse customer needs, the constraints of other stakeholders as well as include societal challenges.
C7.4 : Master spoken, written and body language, as well as basic communication techniques.

2EL6190 – Bayesian methods for machine learning

Instructors: Simon LEGLAIVE
Department: CAMPUS DE RENNES
Language of instruction: FRENCH
Campus: CAMPUS DE RENNES
Workload (HEE): 0
On-site hours (HPE): 35
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

Bayesian modeling, inference and prediction techniques have become commonplace in machine learning. Bayesian models are used in data analysis to describe, through latent factors, the generative process of complex data (medical images, audio, documents, etc.) The discovery of these latent or hidden variables from observations is based on the notion of posterior probability distribution, the calculation of which corresponds to the Bayesian inference step.

Let's take the example of a technique called "Latent Dirichlet Allocation" or LDA. This is a Bayesian method, which in particular is used to discover hidden topics in a set of observed documents. If we apply this technique to analyze a set of 1102 abstracts of scientific articles on Bayesian machine learning, the following topics emerge:

Topic #1: model models data process latent bayesian dirichlet hierarchical nonparametric inference
Topic #2: features learn problem different knowledge learning image object example examples
Topic #3: method neural bayesian using linear state based kernel approach model
Topic #4: belief propagation nodes local tree posterior node nbsp given algorithm
Topic #5: learning data bayesian model training classification performance selection prediction sets
Topic #6: inference monte carlo markov sampling variational time algorithm mcmc approximate
Topic #7: function optimization algorithm optimal learning problem gradient methods bounds state
Topic #8: learning networks variables structure network bayesian em paper distribution algorithm

Topic #9: bayesian gaussian prior regression non estimation likelihood sparse parameters matrix
Topic #10: model information bayesian human visual task probability sensory prior concept
(credits: Rémi Bardenet, https://github.com/rbardenet/bml-course/blob/master/notebooks/00_topic_modelling_for_Bayesian_ML_papers.ipynb)

Recognizable topics stand out, such as *Topic #6* on approximate Bayesian inference methods or *Topic #8* on learning in Bayesian networks.

The Bayesian machine learning approach has the advantage of being interpretable, and it makes it easy to include expert knowledge through the definition of priors on the latent variables of interest. In addition, it naturally offers uncertainty information about the prediction, which can be particularly important in certain application contexts, such as medical diagnosis or autonomous driving for example.

After an introduction and a few reminders, we will first study the Bayesian decision theory. We will then focus on models with latent variables and exact inference techniques such as the expectation-maximization algorithm. As exact inference is not always possible, we will move on to approximate techniques, more precisely variational and Markov chain Monte Carlo (MCMC) methods. We will also study recent variational inference methods based on stochastic gradient descent optimization techniques, which scale for large datasets or for high-dimensional data. We will end with Bayesian deep learning approaches, which are of great interest for current challenges in artificial intelligence.

Theoretical concepts will be applied on concrete data, in particular during lab sessions (based on Python). Different models of supervised and unsupervised Bayesian learning will be implemented. In particular, these applications will allow the students to study the influence of the prior on the parameters of the model and on the obtained prediction compared to a non-Bayesian approach.

Prerequisites (in terms of CS courses)

Basics of statistics and probabilities. Fundamentals of machine learning: empirical risk minimization, maximum likelihood approach, supervised learning (linear models for regression and classification), unsupervised learning (dimensionality reduction, clustering). The 1st-year course "statistics and learning" provides all these requirements.

Syllabus

Courses:

- Introduction and reminders
- Bayesian decision theory
- Latent variable models and exact inference
- Variational inference
- Markov chain Monte Carlo methods
- Models and inference for sequential data
- Bayesian deep learning

Lab sessions:

- Probabilistic principal component analysis
- Bayesian linear regression
- Bayesian Gaussian mixture model
- Bayesian deep learning

Class components (lecture, labs, etc.)

The course is organized in 7 lectures of 3 hours, and 4 lab sessions of 3 hours (on Python). Some lectures may also include practice on a computer. Students may also be asked to do theoretical preparatory work before the lab sessions.

Grading

Students will be evaluated through lab session reports (Jupyter notebooks) for 30% of the final grade, and through a final exam of 2 hours, for 70% of the final grade.

Course support, bibliography

Course materials (slides, Jupyter notebooks, Python code and teaching activities) will be made available on Edunao.

References:

8. Christopher M. Bishop, "Pattern Recognition and Machine Learning"
9. Kevin P. Murphy, "Machine Learning, A Probabilistic Perspective"

Resources

Teaching team: Simon Leglaive

Software tools: Anaconda (Python package manager).

Learning outcomes covered on the course
At the end of the course, students are expected to:

- know when it is useful or necessary to use a Bayesian machine learning approach;
- have a view of the main approaches in Bayesian modeling and inference;
- know how to identify and derive a Bayesian inference algorithm from the definition of a model;
- be able to implement standard supervised or unsupervised Bayesian learning methods.

Description of the skills acquired at the end of the course
C6.4 Solve problems using a computational thinking process.
C6.5 Use all types of data, structured or not, including massive.

SCIENCE AND ENGINEERING CHALLENGE N°5 COURSES

ST5 – 51– PILOTAGE ET CONTROLE DE VOL DANS LE TRANSPORT AERONAUTIQUE ET SPATIAL

Dominante : GSI (Grands Systèmes en Interaction) et CVT (Construction, Ville et Transports)
Langue d'enseignement : Français
Campus où le cours est proposé : Paris-Saclay

Problématique d'ingénieur

Cette séquence aborde la problématique de la conception de lois de pilotage et du contrôle dynamique de vol de véhicules (avion, satellite et lanceur). Elle vise à donner aux élèves les notions de base associées à la conception de systèmes de contrôle d'un objet volant autour de ses 6 degrés de liberté afin de garantir une stabilité de fonctionnement et les performances requises. Les technologies dans les domaines de l'aéronautique et du spatial étant en constante évolution (propulsion, structure, matériaux, etc.), les lois de pilotage doivent s'adapter pour garantir les meilleures performances tout en tenant compte des nouvelles contraintes, notamment règlementaires, environnementales et économiques.

L'enseignement d'intégration permet de mettre en œuvre les compétences et connaissances acquises dans le cas d'un avion, d'un nanosatellite et/ou d'un lanceur. Ces véhicules connaissent un engouement ces dernières années du fait de la réduction du coût associé à la construction et au fonctionnement. Cependant, il soulève de nouvelles problématiques notamment pour le contrôle d'attitude et des performances dus à la miniaturisation des composants et donc de la réduction de leurs capacités d'action et leur efficacité.

L'intervention d'industriels du secteur de l'aéronautique et du spatial dans cette séquence permet de mieux appréhender les enjeux associés à la conception et l'exploitation de systèmes de plus en plus contraints.

Prérequis nécessaires

Deux grandes thématiques sont abordées dans cette séquence : la modélisation d'objets indéformables et la modélisation de systèmes linéaires (fonctions de transfert, représentation d'état, équations différentielles) pour le contrôle. Ces prérequis font partie du cours commun de Modélisation (ST2) et de l'électif Mécanique et milieux continus. Le reste des compétences nécessaires s'appuie sur une capitalisation des connaissances de CPGE et l'autoformation

Modules contexte et enjeux : L'introduction de la séquence s'organise autour de quatre demi-journées de formation visant à présenter la séquence, l'enseignement d'intégration et à introduire les enjeux des différents secteurs du spatial et de l'aéronautique, selon les actions :

1. Présentation de la séquence thématique et introduction aux enseignements d'intégrations
2. Conférence sur les missions spatiales scientifiques (intervenant : CNES) et Table Ronde avec les acteurs scientifiques et économiques du secteur (CNES, Thalès Alinea Space, Airbus Defense and Space, ESA et Safran Tech)
3. Conférence Aéronautique : de la conception des avions de ligne jusqu'à l'exploitation et la gestion du trafic (intervenant : Air France) et Table Ronde avec les acteurs du secteur (Air France, Parrot, Safran, ASTECH).
4. Lanceur (intervenant : ArianeGroup enjeux commerciaux) et table ronde (ArianeGroup, CNES, ESA).
5. Conférence d'introduction au Droit des activités spatiales (intervenant : Institut du Droit de l'Espace et des Télécommunications, IDEST). Conférence d'introduction aux notions de responsabilités et assurances (intervenant : ArianeGroup).

Cours spécifique (60 HEE) : Performances et trajectoires de vol

– **Brève description :** Le cours spécifique de la séquence a pour objectifs :

- modéliser le comportement d'un engin en vol dans le cadre de la mécanique des corps rigides,
- décrire la dynamique des véhicules dans le cas de vols dans et hors de l'atmosphère (trajectoire, modes propres, instabilités),
- choisir et déployer des stratégies de contrôle et pilotage.

Il est organisé en deux temps. Premièrement, en s'appuyant sur le cours de mécanique proposé en première année, la mécanique de corps rigides est introduite pour donner les outils nécessaires à la construction de modèles d'avion, de lanceur, satellites, drône… Dans un deuxième, le cours décrira la dynamique et les stratégies de contrôle d'un avion, d'un satellite et d'un lanceur
Le cours fait intervenir plusieurs acteurs des secteurs de l'aéronautique et du spatial. Les séances permettent de comprendre les modèles utilisés et les stratégies de contrôle à utiliser. Les étudiants prendront en main les outils de contrôle sur un système de leur choix et pourront mettre en place une stratégie de pilotage dans une phase d'avant-projet.

Enseignement d'intégration :
Les trois enseignements d'intégration sont construits de la même façon et couvrent les mêmes objectifs d'apprentissage. Il s'agit de partir d'un cahier des charges de performances pour un avion, un nanosatellite ou un lanceur

et d’opérer des choix d’architecture et de pilotage pour assurer les performances attendues. Les objectifs communs sont donc :

- Comprendre les contraintes des systèmes volants, et les différents niveaux de modélisation du comportement dynamique
- Choisir les solutions techniques pertinentes pour le contrôle de trajectoire, de stabilité et d'orientation (capteurs/actionneurs...)
- Concevoir un système complet par modélisation, y compris des actionneurs et des capteurs, dimensionnement des actionneurs, génération d’énergie et capacité de calcul de CPU
- Implémentation d'une loi de commande optimale, avec prise en compte des aspects économiques
- Validation de la loi de commande sur un modèle réaliste

Enseignement d’intégration n°1 : Stratégie de contrôle d’un nanosatellite

- **Partenaire associé :** Thalès Alenia Space via le Centre spatial de CentraleSupélec
- **Lieu :** Campus Paris-Saclay

Enseignement d’intégration n°2 : Définition et conception de mission d’un lanceur

- **Partenaire associé :** CNES Direction des Lanceurs
- **Lieu :** Campus Paris-Saclay

Enseignement d’intégration n°3 : Conception d’un avion/Aircraft design

- **Partenaire associé :** OAD SPRL (aircraft design company)
- **Lieu :** Campus Paris-Saclay

2SC5110 – Performance and flight paths

Instructors: Sihem TEBBANI
Department: AUTOMATIQUE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 34,5
Quota :

Description

The course provides the skills and knowledge needed to model and control flying vehicles (in and out of the atmosphere) to improve system performance. It is divided into two parts.

The first part of this course is a core curriculum whose objectives are to provide a common basis of knowledge and skills. This common core is organized into three parts. First, solid mechanics is introduced to give the necessary tools for the modeling of airplanes, launchers, satellites, UAVs... In a second step, the course describes the dynamics and control strategies of an aircraft. Finally, space mechanics is introduced to give the necessary tools to describe movement, disturbances, and maneuvers of a spacecraft.

The objectives of the second part of the course are to provide new knowledge and skills to reinforce those seen in the core curriculum of this course. It will focus on the design and control of three systems: an aircraft, a launcher, and a satellite. It will provide specific knowledge and skills necessary for the topics of the challenge week.

Numerous experts in aeronautics and aerospace fields are involved in this course.

Quarter number

ST5

Prerequisites (in terms of CS courses)

There is no specific prerequisites.

Syllabus

Core curriculum:

1. General mechanics :
This course will provide the basic notions in solid mechanics. It will address the following points:

- Equation of motion of a rigid body. Fundamental Principles of Dynamics
- Tutorial 1: Measurement of the parameters of inertia of a mricosatellite.
- Mechanical linkage between rigid bodies.
- Tutorial 2: movement of a Cubli.
- Aerospace actuators (stability of rotation around the main axis of inertia, gyroscopic effect, application to gyroscopic actuators, reaction wheels).
- TD 3: attitude of a satellite

2. Flight Mechanics :
This part of the course will illustrate the dynamic stability through the stability study of an airplane in flight. The objective is to identify the movements induced by small disturbances around a state of equilibrium and to determine the damping or the amplification of these movements according to the properties of the aircraft. The lecture part gives all the mathematical modeling tools that will be used in the stabilization study. It will address the following points:

- Definition of Euler angles. Matrix formulation
- Linearized dynamic equations of motion
- Solving linearized equations
- Presentation of the representative modes: phugoid, incidence oscillation, Dutch roll, Roll subsidence mode and spiral divergence.

3. Space mechanics
This course introduces the fundamentals of space mechanics, focusing on the study of free motion in gravity field, orbital manoeuvres and space environmental perturbations. Some insights on inter-planetary missions are given.

Elective course (One course depending on the chosen topic of the challenge week)

In the second part of the course, three courses are proposed, corresponding to an introduction to the projects of the challenge week.

1. Control of an airplane

This course aims to detail the modeling and control of an airplane. It will address the following points:

22. Presentation of the specification for the flight performance of an airplane
23. Modeling forces acting on the aircraft (including thrust, lift and drag)
24. Coefficients and ratio for the study of the trajectory performance.

2. Control of a launcher

The course aims to address the fundamentals of attitude control of a launcher, in both propelled and ballistic phases. The requirements to be met by the control system as well as the physical disturbances to be managed during the flight will be addressed. Command synthesis principles will be presented, as well as aspects relating to the actuators.

3. Control of a satellite

This course aims to detail the modeling and control of a satellite. It will address the following points:

- Architecture of a AOCS
- Typical missions, families of AOCS, types of orbits, disturbing couples,
- Sensors and actuators for a satellite
- control modes and algorithms, contribution of the AOCS
- Specifications for a AOCS system (stability, performance, robustness, different developped controllers).

Class components (lecture, labs, etc.)

Lectures and tutorials.
Several examples of real aircraft and aerospace systems will be presented.

Grading

The specific course will be evaluated individually by a final examination lasting 1 hour 30 minutes. This evaluation will be done by MCQ. Ten questions per section on the first part of the course (core curriculum), i.e., 30 questions in total. These questions can include small exercises of application.

Course support, bibliography

14. Orbital Mechanics for Engineering Students, H. D. Curtis, Butterworth-Heinemann. 2013.
15. Practical Methods for Aircraft and Rotorcraft Flight Control Design: An Optimization-Based Approach, Mark B. Tischler, Tom Berger, Christina M. Ivler, Mohammadreza H. Mansur, Kenny K. Cheung and Jonathan Y. Soong. ISBN: 978-1-62410-443-5.
16. Advances In Aircraft Flight Control, M B Tischler, CRC Press, 28 jun. 1996.
17. Aircraft Control and Simulation: Dynamics, Controls Design, and Autonomous Systems Brian L. Stevens, Frank L. Lewis, Eric N. Johnson, John Wiley & Sons, 2 oct. 2015 - 768 pages
18. Performance, Stability, Dynamics and Control of Airplanes, Third Edition 2015, Bandu N. Pamadi, ISBN: 978-1-62410-274-5.

Resources

- Teaching team: G. Puel, E. Bourgeois, F. Richecoeur, Ch. Betrancourt, F. Farago, J. Geoffroy, P. Samson, A. Garus, S. Tebbani (coordinator)
- Maximum of 35 students in each tutorial group.
- Software tools: Matlab

Learning outcomes covered on the course

The objectives are to acquire skills and knowledge to:

- Model the behavior of a flight vehicle in the framework of solid mechanics, flight mechanics, and space mechanics.
- Describe the dynamics of flying vehicles into and out of the atmosphere (trajectory, modes, instabilities).

- Choose and develop control strategies.

This course will also provide a global view of control systems for flying vehicles, as well as performance requirements and associated constraints.

Description of the skills acquired at the end of the course

At the end of the course, students will acquire an operational understanding of the design tools of a flying vehicle in flight through the acquisition of:

- basic concepts in solid mechanics, flight mechanics and space mechanics
- good knowledge of the requirements and constraints of the control of a flying system
- good knowledge of different aerospace systems and vehicles (aircraft, UAV, satellite, launcher).

They will be able to:

- model vehicle dynamics in the case of flights in and out of the atmosphere (trajectory, modes, instabilities).
- Choose and develop control strategies.
- Evaluate the flight performance of the flight of a vehicle and to propose effective and economical solutions to improve it.

2SC5191 – Control strategy of a nanosatellite

Instructors: Giorgio VALMORBIDA, Sihem TEBBANI, Christopher BETRANCOURT
Department: DOMINANTE - GRANDS SYSTÈMES EN INTERACTION, DOMINANTE - CONSTRUCTION VILLE TRANSPORTS
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description
This module is developed in partnership with Thalès Alenia Space. The main goal is to introduce the main tasks on the design of a nanosatellite. For a satellite mission, the participants will propose a satellite orbit, choose sensors and actuators, design the mission modes, propose a dynamical model, design a control laws, simulate the trajectories and assess the resulting performances.

Quarter number
ST5

Prerequisites (in terms of CS courses)
Course "Cubesat design and control: attitude and orbit control systems" of the specific course "performance and flight trajectories".

Syllabus
Traceability matrix : methods for the validation and verification of requirements. Proposal of mission modes, hardware selection. Definition of pointing, mass and power budgets. Disturbance torque assessments. Selection, layout and sizing hardware components.
Dynamics modeling, and simulation including torque disturbances. Writing the technical notice.

Class components (lecture, labs, etc.)
The group will be split into teams of 5 students, which will work independently from the other teams. Each day, a part of the satellite design will be proposed and a document of requirements will be provided.

Each team has to deliver either a short report or software, and to give a short talk by the end of the day.

Grading
The evaluation will include a final report, the developed software, and the final oral presentation. At the end of each session, the teams will also present the results of the day, which will be accounted for in the final mark.

Course support, bibliography
Course handouts "Guidage et Pilotage d'un Satellite"

Resources
• Document of requirements in an industrial format
• Orbit simulation software, satellite instrumentation software.
• Supervision by Thalès e Alenia Space engineers and CentraleSupélec Professors

Learning outcomes covered on the course
The main goals are

- Understand aspects and constraints in satellite design, develop models for each design stage and understand the dynamical behavior of the satellite
- Choose a satellite orbit to satisfy the requirements
- Design the hardware by choosing sensors, actuators and energy generators
- Propose a set of operational modes and the control laws to satisfy the performance requirements.

Validate each step of the design with simulation (GMAT, VTS Timeloop, Matlab/Simulink)

At the end of the module, the participants will have completed the main steps in the desing of a AOCS : the choice of the orbit, the choice of harware components and the AOCS architecture as well as the design and validation of control laws.

Description of the skills acquired at the end of the course

- Analyze, design and implement complex systems made up of scientific, technological, social and economic dimensions. (C1)
- Acquire and develop broad skills in a scientific or academic field and applied professional areas. (C2)
- Act, engage, innovate within a scientific and technological environment. (C3).

- Persuade by working on communication techniques Master spoken, written and body language, as well as basic communication techniques. (C7.4).
- Work collaboratively in a team. (C8.1).
- Engage outside expertise to go the extra mile. Identify and develop strengths and talents. (C8.3).
- Work using project management techniques appropriately tailored to the situation. (C8.4).
- Demonstrate rigour and critical thinking in approaching problems from all angles, be they scientific, social or economic. (C9.4).

2SC5192 – Definition and design of a launcher mission

Instructors: Christopher BETRANCOURT, Sihem TEBBANI
Department: DOMINANTE - CONSTRUCTION VILLE TRANSPORTS, DOMINANTE - GRANDS SYSTÈMES EN INTERACTION
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description

In this challenge week, the student will experiment the multidisciplinary sizing and design of a launcher.
It consists in the understanding the interactions between the different technical fields involved in this design.
Another issue is also to understand the associated challenges of each involved technical field and adopt the different sizing methods for a first sizing procedure.
For this propose, the challeng week is organized in several modules of a realistic sizing loop for which students will be supported by CNES DLA engineers.

Quarter number

ST5

Prerequisites (in terms of CS courses)

The course "Guidance and control of a launcher" of the specific course "performance and flight trajectories".

Syllabus

This Challenge Week will be structured around the following modules:

- Mission analysis - launcher staging
- Trajectory
- Liquid propulsion
- Solid Propulsion
- Aerodynamics and mechanical loads
- Sizing of structures
- Launcher control

Each module will be the subject of a dedicated session (half a day per module) during which the students, working in pairs, will design and consolidate a launcher ,meeting specific specifications.

Class components (lecture, labs, etc.)
Engineers from CNES DLA will supervise this Challenge Week.
They will provide a detailed work plan with questions to the students in order to help them to make design choices while ensuring a good understanding of the challenges (technical, programmatic) and the related physical problems.
Analytical and numerical tools should be used by students to address the issues raised.
The hypotheses and data considered should be questioned in order to understand the issues of a multi-disciplinary design loop; these elements will lead students to iterate on their design choices in order to obtain relevant technical solutions.

Grading
The evaluation will include a final report, project progress notes at the end of each module, and an oral presentation.

Course support, bibliography

- Detailed workplan structuring the developments to be carried out by the students.
- Simplified preliminary sizing tools (under WINDOWS 10).

Resources

- Specifications and a workplan of the developments to be carried out by the students.

- Simplified preliminary numerical sizing tools
- Teaching team : engineers of CNES - Direction des Lanceurs.
- Working in pairs.

Learning outcomes covered on the course
At the end of this project, the student will have an operational understanding of the design tools of a launcher via:

- good knowledge of the requirements and constraints for the design of a launcher,

- good knowledge of different systems constituting a launcher,
- understanding the interactions between the different technical disciplines involved in the design of a launcher and the associated challenges.

He will be able to:

- Model the trajectory of a launcher and implement launcher sizing methods,
- Choose and deploy launcher control strategies,
- Evaluate the launcher's flight performance and propose efficient and economical solutions to improve it.
- Know how to meet the requirements of a launcher's multi-disciplinary design.

Description of the skills acquired at the end of the course

- Analyze, design and implement complex systems made up of scientific, technological, social and economic dimensions. (C1)
- Acquire and develop broad skills in a scientific or academic field and applied professional areas. (C2)
- Act, engage, innovate within a scientific and technological environment. (C3).
- Persuade by working on communication techniques Master spoken, written and body language, as well as basic communication techniques. (C7.4).
- Work collaboratively in a team. (C8.1).
- Engage outside expertise to go the extra mile. Identify and develop strengths and talents. (C8.3).
- Work using project management techniques appropriately tailored to the situation. (C8.4).
- Demonstrate rigour and critical thinking in approaching problems from all angles, be they scientific, social or economic. (C9.4).

2SC5193 – Design of an electric airplane

Instructors: Christopher BETRANCOURT, Sihem TEBBANI
Department: DOMINANTE - CONSTRUCTION VILLE TRANSPORTS, DOMINANTE - GRANDS SYSTÈMES EN INTERACTION
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description

The goal of this training is to let you discover the different stages of an aircraft design process in both a theoretical and a practical perspective. You will be introduced to the typical methods used in an aircraft design office, and apply this knowledge by doing the preliminary design of your own aircraft After completing this training course, you will have acquired knowledge and skills that will enable you to work out the main aircraft characteristics and layout in a very short time frame.

Quarter number

ST5

Prerequisites (in terms of CS courses)

Have to follow the elective course "Airplane control".

Syllabus

When a team commits to design a new aircraft or to modify an existing aircraft, the project will always follow the same pattern. The process starts by analyzing the market and existing products. Next is the conceptual design which is followed by the preliminary design and detail design before sending the drawings to the workshop which will build a prototype. Obviously, at each stage, several iterations are made as necessary before proceeding to the next stage. In the process, we will begin by a more global or synthetic approach of aircraft design before getting into more and more detail. We will go from a basic concept into full optimization, from using parameters derived from simple statistical data to using sophisticated algorithms.

Grading
Evaluation will take place the last day of the course and include : an oral presentation to present your project and followed by a question and answer session.

Resources
Teacher: Didier Breyne
ADS . Aircraft Design Software

Learning outcomes covered on the course
Student will learn how to:
- Define the layout and configuration of the new aircraft.
- Work out estimates for empty weight and maximum take-off weight.
- Compute wing loading.
- Work out estimates for lift and drag ✧ Work out performance estimates (take-off, climb, cruise, landing).
- Make an analysis of the aircraft's stability and control.
- Compute the applied loads ✧ Select the structural materials.
- Estimate the costs (design, manufacturing, operational).

Of course, the general concepts are not only valid for aircraft design but can equally be applied to the development of any other conceivable product or service.

Description of the skills acquired at the end of the course
Analyze, design and implement complex systems with scientific, technological, human and economic components (C1).
Develop in-depth skills in a scientific or sectoral field and a family of professions (C2).
Act, undertake and innovate in a scientific and technological environment (C3).
Master spoken, written and body language. Master basic communication techniques (C7.4).
Work in a team/collaboration (C8.1).
Use the expertise of others and push one's own limits. Identifying and exploiting wealth and talent. (C8.3)
Work in project mode using project management methods appropriate to the situation. (C8.4)
Demonstrate rigour and critical thinking in approaching problems from all angles, scientific, human and economic (C9.4).

ST5 – 52 – COMMANDE DE (BIO)PROCEDES POUR PRODUIRE DURABLE

Dominante : VSE (Vivant-Santé-Environnement) et GSI (Grands Systèmes en Interaction)
Langue d'enseignement : Français
Campus où le cours est proposé : Paris-Saclay

2SC5210 – Chemical Engineering: application to environment and sustainable production

Instructors: Julien COLIN, Cristian-Felipe PUENTES MANCIPE
Department: PROCÉDÉS
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 34,5
Quota :

Description

Process Engineering consists in **designing, operating and optimizing environmentally friendly processes** for the **development of various products and services** in many traditional and high-tech sectors (agri-food, biotechnology, cosmetics, fine chemicals, materials, oil, pharmaceuticals, water and waste treatment, etc.) and for the **production of** traditional (nuclear, thermal, etc.) and renewable **energies**. Its methodologies are widely used to ensure the **recycling and recovery** of many products and the **purification** of liquid and gaseous effluents, thus becoming a key tool in the global **sustainable development** strategy. The challenges associated with this environmental dynamic are multiple: reduction of energy and raw material consumption, costs, waste, risks and dangers. Process intensification turns out to be the major lever to address them. Bioprocesses have developed very strongly in the last decades for two reasons: (i) the use of living organisms, acting as processing plants, to transform matter, purify polluted systems (liquid, solid), (ii) the use of biomass to replace fossil resources.

This course is an introduction to Process Engineering and its methodologies, allowing students to acquire general tools that can be easily transposed to multiple fields, such as biotechnology and environment. It is fully in support of the current environment, energy and health challenges.

Quarter number

ST5

Prerequisites (in terms of CS courses)

None

Syllabus

1. Introduction to Process Engineering for Sustainable Development; steady state material balance

Case study: Process for the manufacturing of 1st generation bioethanol (*conversion of renewable raw materials by white biotechnologies*)

2. Flow models (perfectly agitated and plug flow)

Case study:

- Valorization of whey (*valorization of residues from the agrifood industry by white biotechnology*)
- Designing biological treatment basin of an urban wastewater treatment plant (*process in the service of the environment, reduction of reactor volumes and water footprint*)

3. Thermal balances: calorific / enthalpic

Case study: Designing a reactor Production of brewer's yeast in batch mode (*optimisation of the reactor geometry and its thermal regulation*)

4. Liquid-vapour equilibria, single and multi-stage distillation

Case study: Flash distillation of ethanol-water mixture; Multi-stage distillation of bioethanol (*alternative to fossil fuels*)

5. Mass Transfer: Diffusion and Convection

Case study: Raceway production of Spirulina microalgae (*sustainable production of nutrients for food and feed*)

6. Mass Transfer: Permanent Contact Technologies

Case study:

- Treatment of a gaseous effluent. Removal of a pollutant (*environmental process*)
- Biogas purification for biomethane production by membrane technology (*production of a renewable energy carrier for conventional uses*)

Class components (lecture, labs, etc.)

The course module is organized in lectures (15 h), to introduce knowledge and methodological tools, which will be then applied through case studies (18 h).

Grading

- Homework: Presentation, by group, of a bibliographic project whose topic is an extension of the course (30 % of the grade); these oral presentations take place during the last class session.
- Intermediate written exam by group: 3-hour case study (30 % of the grade).

- Individual final written exam: 1.5-hour case study (40 % of the grade).

Course support, bibliography

• Slideshows

• Techniques de l'ingénieur :

+ Charpentier J., Génie des procédés, développement durable et innovation – Enjeux et perspectives, 2013
+ Moulin J.P., Pareau D., Rakib M., Stambouli M., Transfert de matière – Méthodologie, 2000
+ Moulin J.P., Pareau D., Rakib M., Stambouli M., Isambert A., Transfert de matière – Distillation compartimentée idéale, 2001
+ Moulin J.P., Pareau D., Rakib M., Stambouli M., Transfert de matière- Autres opérations compartimentées, 2002
+ Buch A., Rakib M., Stambouli M., Transfert de matière- Cinétique du transfert de matière entre deux phases, 2008
+ Sun L.M., Thonnelier J.Y., Perméation gazeuse, 2004
+ Vuillermaux J., Réacteurs chimiques – Principes, 1994
+ Boulinguiez B., Le Cloirec P., Purification de biogaz – Élimination des COV et des siloxanes, 2011

• General Books: Perry Chemical Engineer's Handbook, 8th edition, 2007, McGraw-Hill, New York

• Specific books:

- *Reactor and bioreactor engineering*
  + Coulson and Richardson’s Chemical Engineering – Volume 3A: Chemical and Biochemical Reactors and Reaction Engineering, 4th Edition, 2017, Elsevier. Oxford
  + Fogler H.S., Elements of chemical reaction engineering, 5th Edition, 2016, Pearson Education, Englewood Cliffs
  + Levenspiel O., Chemical Reaction Engineering, 3rd edition, 1999, John Wiley and Sons, New York
  + Villadsen J., Nielsen J., Lidén G., Bioreaction Engineering Principles, 3rd Edition, 2011, Springer, New York
- *Heat and mass transfer*
  + Bergman T.L., Lavine A.S., Incropera F.P., Dewitt F., Fundamentals of Heat and Mass Transfer, 7th Edition, 2011, John Wiley and Sons, New York
  + Coulson and Richardson’s Chemical Engineering – Volume 1B: Heat and Mass Transfer: Fundamentals and Application, 7th Edition, 2018, Elsevier, Oxford
  + Cussler E.L., Diffusion Mass Transfer in Fluid systems, 3rd Edition, 2009, Cambridge University Press, Cambridge

+ Treybal R., Mass Transfer Operations, 4th Edition, 1982, McGraw Hill, New York

- *Bioethanol production*

+ Cardona C.A., Sanchez O.J., Gutierrez L.F, Process synthesis for fuel ethanol production, 2010, CRC Press, Boca Raton

+ Naik S.N., Goud V.V., Rout P.K., Dalai A.K, Production of first and second generation biofuels: A comprehensive review, Renewable and Sustainable Energy Reviews 14, 2010, 578–597

+ Vohra M., Manwar J., Manmode R., Padgilwar S., Patil S. Bioethanol production: Feedstock and current technologies, Journal of Environmental Chemical Engineering 2, 2014, 573–584

Resources

• Teaching staff (instructor(s) names): Julien COLIN, Cristian PUENTES
• Maximum enrolment (default 35 students): 30 to 40
• Software, number of licenses required: Excel, Python, Matlab
• Equipment-specific classrooms (specify the department and room capacity): None

Learning outcomes covered on the course

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

- List the type of mass transfer and its coupling to heat transfer,
- Identify the different mass transfer mechanisms (diffusion / convection) working in a given configuration and the potential coupling between heat and mass transfer,
- Write mass balances, taking into account, if necessary, chemical or biochemical reaction kinetics,
- Simplify a seemingly complicated problem, where several transfer phenomena coexist, by taking into account only the main ones,
- Formalize phenomena into equations through elemental balances,
- Design conversion and separation technologies based on thermodynamic and kinetic considerations.

Description of the skills acquired at the end of the course

- C1.1 : Examine problems in their entirety and beyond their immediate parameters. Identify, formulate and analyse the scientific, economic and human dimensions of a problem. **Milestone 1**

- C1.2 : Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when addressing a problem. **Milestone 1**
- C1.3 : Apply problem-solving through approximation, simulation and experimentation. **Milestone 1B**
- C7.1 : Persuade at core value level; to be clear about objectives and expected results. To apply rigour when it comes to assumptions and structured undertakings, and in doing so structure and problematise the ideas themselves. Highlight the added value. **Milestone 1**

2SC5291 – Optimized biological treatment of urban wastewater

Instructors: Sihem TEBBANI, Julien COLIN, Cristian-Felipe PUENTES MANCIPE
Department: DOMINANTE - VIVANT, SANTÉ, ENVIRONNEMENT, DOMINANTE - GRANDS SYSTÈMES EN INTERACTION
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description

In urban wastewater treatment plants, biological processes are designed to eliminate carbon and nitrogen pollution through the action of microorganisms that grow spontaneously in aerobic or anaerobic environments.
The pollutants removed are concentrated in the form of aqueous suspensions or sludge, which constitutes bulky waste containing fermentable and toxic materials. The sludge management is therefore an important phase of treatment systems aiming to ensure the reduction of their volume and odour nuisance. One of the processes used for this treatment is anaerobic digestion, which produces liquids with a high concentration of nitrogen that must be re-treated. The amount of nitrogen contained in these effluents can represent up to 20% increase in the nitrogen load to be eliminated by the plant. There are two solutions to address this problem: (1) a so-called classical one, in which these concentrated effluents are directly returned to the primary plant, or (2) the anaerobic ammonium oxidation process, or Anammox, an innovative alternative to traditional nitrification/denitrification processes, allowing the direct transformation of nitrite and ammonium into gaseous dinitrogen.
The objective of this ‘challenge week’ is to develop control strategies for the two solutions mentioned in order to meet the minimum treatment requirements of the treated water and to compare their performance in terms of operating costs and biogas production as a vector for sludge energy recovery.

Quarter number

ST5

Prerequisites (in terms of CS courses)

There are no specific prerequisites.

Syllabus

– Introduction on pollution, wastewater and sludge treatment technologies.

– Simulation of the classical process with constant and variable feed rate. Understanding of the functioning of unit processes, simulation model, microbial population dynamics.

– Bibliographical synthesis on the Anammox process.

– Simulation of the Anammox process with constant and variable feed rate. Understanding of: operation of the unit process, simulation model, microbial population dynamics.

– Development of PID control strategies in order to comply with the imposed depollution specifications. Evaluation of the regulation quality (static error, response time, overshoot, disturbance absorption).

– Comparison of the two processes on the basis of operating costs (additional carbon input and electricity consumption for aeration needs), sludge production and biogas production by anaerobic digestion.

Class components (lecture, labs, etc.)

The teaching team and the industrial partner will hold a first introductory session on the problem. Then, the students will be divided into teams. All the teams will work on the same specifications, so that they can deal with the process engineering and automation aspects of the teaching. For the understanding of the Anammox process, each team will make in parallel a synthesis of an article proposed by the teaching team. Finally, each team will propose a unique regulation strategy to the partner, which will include the comparison and critical analysis of the two processes.

Grading

The evaluation is based on: continuous assessment, a written report, an oral evaluation.

Course support, bibliography

PDF support from the industrial partner

Reference books on control of bioreactors:

– Bastin G., Dochain D., On-line Estimation and Adaptive Control of Bioreactors, Elsevier, 1990.

– D. Dochain (éditeur). Automatic Control of Bioprocesses, Wiley-ISTE, 2008.

Documentation from Techniques de l’ingénieur:

– BOEGLIN J.C., Traitement biologique des eaux résiduaires, Techniques de l’Ingénieur, J3942 V1, Décembre 1998.
– BOEGLIN J.C., Traitements et dispositions finales de boues résiduaires, Techniques de l’Ingénieur, J3944 V1, Septembre 2000.
– GAÏD A., Traitement des eaux résiduaires, Techniques de l’Ingénieur, C5220 V1, Février 2008.
– SPERANDIO M., HERAN M., GUILLOT S., Modélisation biologique des procédés biologiques de traitement des eaux, Techniques de l’Ingénieur, W6500 V1, Août 2007.

Papers on Anammox process:
– NSENGA KUMWIMBA M., LOTTI T., SENEL E., LI X., SUANON F. Anammox-based processes: How far have we come and what work remains? A review by bibliometric analysis, Chemosphere 238 (2020) 1-17.
– VAN DER STAR W.R.L., ABMA W.R., BLOMMERS D., MULDER J.W., TOKUTOMI T., STROUS M., PICIOREANU C., VAN LOOSDRECHT M.C.M., Startup of reactor for anoxic ammonium oxidation: Experiences from the first full-scale anammox reactor in Rotterdam, Water Research 41 (2007) 4149– 4163.
– TAO C., HAMOUDA M.A., Steady-state modeling and evaluation of partial nitrification-anammox (PNA) for moving bed biofilm reactor and integrated fixed-film activated sludge processes treating municipal wastewater, Journal of Water Process Engineering 31 (2019) 1-9.
– LACKNER S., GILBERT E.M., VLAEMINCK S.E., JOSS A., HORN H., VAN LOOSDRECHT M.C.M., Full-scale partial nitritation/anammox experiences – An application survey, Water Research 55 (2014) 292-303.
– BIASE A., KOWALSKI M.S., DEVLIN T.R., OLESZKIEWICZ J.A., Moving bed biofilm reactor technology in municipal wastewater treatment: A review, Journal of Environmental Management 247 (2019) 849–866.
– VEUILLET F., LACROIX S., BAUSSERON A., GONIDEC E., OCHOA J., CHRISTENSSON M., LEMAIRE R. Integrated fixed-film activated sludge ANITATMMox process – a new perspective for advanced nitrogen removal, Water Science and Technology 69.5 (2014), 915-922.

Resources

– Complete simulator of the classical treatment plants
– Software tools: SUMO/MatLab
– Documentation describing the unitary treatment processes (wastewater and sludge)
– Supervision: Teacher-researchers of the school and industrial partner
– Teamwork

Learning outcomes covered on the course

At the end of the Challenge Week, the student will be able to:

– Simulate an urban wastewater treatment plant with treatment of secondary effluents or sludge.
– To understand the operation of the Anammox process as an alternative to the traditional treatment of nitrogen pollution.
– Design PID control loops to maintain the system at desired operating conditions (regulatory requirements on nitrogen and carbon concentration).
– Determine and critically analyze the best solution for the treatment of effluents with high ammonia concentration in terms of operating costs and sludge energy recovery.

Description of the skills acquired at the end of the course
– Analyze, design and implement complex systems made up of scientific, technological, social and economic dimensions. (C1).
– Acquire and develop broad skills in a scientific or academic field and applied professional areas. (C2).
– Act, engage, innovate within a scientific and technological environment. (C3).
– Persuade by working on communication techniques Master spoken, written and body language, as well as basic communication techniques. (C7.4).
– Work collaboratively in a team. (C8.1).
– Engage outside expertise to go the extra mile. Identify and develop strengths and talents. (C8.3).
– Work using project management techniques appropriately tailored to the situation. (C8.4).
– Demonstrate rigor and critical thinking in approaching problems from all angles, be they scientific, social or economic. (C9.4).

2SC5292 – Strategies for optimizing a biotechnology plant: application to sourdough production.

Instructors: Sihem TEBBANI, Cristian-Felipe PUENTES MANCIPE, Julien COLIN
Department: DOMINANTE - VIVANT, SANTÉ, ENVIRONNEMENT, DOMINANTE - GRANDS SYSTÈMES EN INTERACTION
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description

On an industrial scale, fermentation can be conducted in a continuous or discontinuous way. When designing or optimizing a plant, this choice is crucial, especially as it determines the productivity of the process, its control method, the logistical organization and the inherent costs.
Although more capital-intensive (specific reactors, increased instrumentation and automation), the continuous design has the advantage of smoothing production and thus limiting storage and handling steps. Therefore, it receives particular attention.
The Soufflet Group has a factory close to Caen dedicated to the production of sourdoughs. This symbiotic mixture of lactic acid bacteria and yeast is used for the production of bread, to which it gives specific characteristics: taste, better digestibility and longer shelf life. The production of each batch of sourdough lasts one week and is currently using a succession of batch reactors of increasing size.
The objective of the Challenge Week is to support the company in the optimization of the existing plant and in the design of a new continuous plant, implementing various strategies: flow management, dimensioning of the reactors and implementation of a robust control.

Quarter number

ST5

Prerequisites (in terms of CS courses)

There are no specific prerequisites.

Syllabus

Students will first need to understand symbiotic growth of two populations of microorganisms, the modeling of this growth, and the related simplifying

assumptions. After identifying the parameters, they will have to implement this model in a standard bioreactor simulator to simulate a single process (unit operation) for the production of sourdough, in continuous (Continuous Stirred Tank Reactor) and then discontinuous mode (Batch Stirred Tank Reactor).
The students will then duplicate the model of this unit operation to simulate the existing batch process.
From this reference, an optimized solution for continuous production will be investigated, according to two strategies:

- Part of the groups will work on maximizing the production through an optimized management of the existing installation,
- The other part of the groups will have to design a new continuous production line to reach the performance level of the existing site while minimizing investment costs.

Finally, each group will draw up a simplified (control) model of the process and will propose a regulation to ensure the performance of the production system – from a quality point of view – despite changes in the composition of the growing medium. Different approaches will be implemented (e.g. PID, feedback control, pole placement, linearising control). The performance of different correctors will be compared for different bioreactor operating scenarios.

Class components (lecture, labs, etc.)
Students will be divided into groups. The project will be carried out by organizing the internal work of each group in order to address the different themes of the specifications.
Analytical and numerical tools will have to be developed by the students in order to address the problems raised.
The hypotheses and data considered must be questioned; these elements will lead the students to iterate on their design choices in order to obtain relevant solutions.

Grading
The evaluation will include a continuous assessment, a final report, and an oral presentation.

Course support, bibliography

- Perry Chemical Engineer's Handbook, 8th Edition, 2007, McGraw-Hill, New York
- Dawes E.A., Quantitative problems in biochemistry, 6th Edition, 1980, Longman, London

- Coulson and Richardson’s Chemical Engineering – Volume 3A: Chemical and Biochemical Reactors and Reaction Engineering, 4th Edition, 2017, Elsevier. Oxford
- Villadsen J., Nielsen J., Lidén G., Bioreaction Engineering Principles, 3rd Edition, 2011, Springer, New York
- Thiele C., Grassl S., Gänzle M., 2004, Gluten Hydrolysis and Depolymerization during Sourdough Fermentation, Journal of Agricultural and Food Chemistry, 52 (5):1307-1314
- Gänzle M.G., Ehmann M., Hammes W.P., 1998, Modeling of Growth of Lactobacillus sanfranciscensis and Candida milleri in Response to Process Parameters of Sourdough Fermentation, Applied and Environmental Microbiology, 64 (7):2616-2623
- Neysens P., De Vuyst L., 2005, Kinetics and modelling of sourdough lactic acid bacteria, Trends in Food Science & Technology, 16(1-3):95-103

- G. Bastin, D. Dochain, On-line Estimation and Adaptive Control of Bioreactors, 1990, Elsevier
- D. Dochain, Automatic Control of Bioprocesses, 2008, Wiley-ISTE

- Database from measurements on industrial sites

Resources

- Simulator of a standard bioreactor (Matlab/Simulink)
- Database from measurements on industrial sites
- Bibliography on the studied industrial bioprocess and biological phenomena
- Supervision: teacher-researchers CentraleSupélec, with regular contact with an industrialist.
- Work in group

Learning outcomes covered on the course

At the end of the Challenge Week, the students will be able to:

- Model a bioprocess for the culture of a microorganisms for industrial application
- Simulate the operation of a process chain, including different types of reactors
- Optimize and size industrial bioreactors

- Design control laws to maintain the system at desired operating conditions (pH, concentrations, etc.) to ensure bioprocess performance despite external disturbances
- Analyze the proposed solution (including economic analysis) and be critical of the results obtained

Description of the skills acquired at the end of the course

- Analyze, design and implement complex systems made up of scientific, technological, social and economic dimensions (C1)
- Acquire and develop broad skills in a scientific or academic field and applied professional areas (C2)
- Act, engage, innovate within a scientific and technological environment (C3)
- Persuade by working on communication techniques Master spoken, written and body language, as well as basic communication techniques (C7.4)
- Work collaboratively in a team (C8.1)
- Engage outside expertise to go the extra mile. Identify and develop strengths and talents (C8.3)
- Work using project management techniques appropriately tailored to the situation (C8.4)
- Demonstrate rigor and critical thinking in approaching problems from all angles, be they scientific, social or economic (C9.4)

2SC5293 – Advanced supervision of biogas production from waste

Instructors: Julien COLIN, Cristian-Felipe PUENTES MANCIPE, Sihem TEBBANI
Department: DOMINANTE - VIVANT, SANTÉ, ENVIRONNEMENT, DOMINANTE - GRANDS SYSTÈMES EN INTERACTION
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description

Anaerobic digestion is a natural process of degradation of organic substances by micro-organisms (bacteria and archaea) in the absence of oxygen (anaerobic conditions).
This process makes it possible to recover a fraction of the energy contained in the waste in the form of biogas, a mixture of methane and $CO2$.
The widespread use of these technologies would on the one hand considerably reduce the energy demand necessary to treat waste (10% of the energy used on the planet) but could in the long term constitute a source of energy.

However, the anaerobic digestion process is complex and involves several hundred species of microorganisms. Moreover, it is unstable, and intermediate compounds (volatile fatty acids) can, under certain conditions, accumulate and lead to the total shutdown of the reactor. To avoid this, very precise and costly monitoring is necessary.

The objective of the Challenge Week is to propose and develop monitoring and control strategies to reduce the risk of reactor acidification and to optimize energy production from waste.

Quarter number

ST5

Prerequisites (in terms of CS courses)

There are no specific prerequisites.

Syllabus

Students will first need to understand an anaerobic digestion model that will be provided and simulate it for different conditions.

In particular, they will need to simulate reactor acidification under conditions of overloading the reactor.
They must propose a simulator with a simplified model for this complex system, for the purpose of implementing control and estimation strategies.
In a second step, they will have to develop observers to evaluate certain intermediate compounds, and in particular volatile fatty acids. It is desirable that a self-calibration dynamic is introduced to take into account the slow drifts of certain model parameters.
Other groups will use the models to develop control strategies. Different approaches will be implemented (e.g. PID, feedback control).
In the end, a supervisor will be proposed by associating an observer(s) to a control law. The performances of the different supervisors will be compared for different reactor operating scenarios.

Class components (lecture, labs, etc.)
Students will be divided into groups. The project will be carried out by organizing the internal work of each group in order to address the different themes of the specifications.
Analytical and numerical tools will have to be developed by the students in order to address the problems raised.
The hypotheses and data considered must be questioned; these elements will lead the students to iterate on their design choices in order to obtain relevant solutions.

Grading
The evaluation will include a continuous assessent, a final report, and an oral presentation.

Course support, bibliography

- Anaerobic Digestion Model No. 1, PWA Publishing, 2002.
- Dynamical Model Development and Parameter identification for an anaerobic wastewater treatment process, O. Bernard et al., *Biotechnology and bioengineering*, *75*(4), 424-438, 2001.

- On-line Estimation and Adaptive Control of Bioreactors, G. Bastin, D. Dochain, Elsevier, 1990.

- Automatic Control of Bioprocesses, éditeur D. Dochain. Wiley-ISTE, 2008.

Resources

- Simulator of the bioprocess to be studied,
- State-of-the-art and a description of the studied bioprocess.

- Supervision: Teacher-researchers of the CentraleSupélec, with regular contact with an industrial.
- Work in group.

Learning outcomes covered on the course

At the end of the Challenge Week, the students will be able to:

- Model a bioprocess for the culture of a microorganism for environmental application
- Design software sensors to reconstruct variables not available online
- Design control laws to maintain the system at desired operating conditions (pH, temperature, concentrations, etc.) to maximize the productivity of the bioprocess.
- Analyse the proposed solution (including economic analysis and ecological footprint) and be critical of the results obtained.

Description of the skills acquired at the end of the course

- Analyze, design and implement complex systems made up of scientific, technological, social and economic dimensions. (C1)
- Acquire and develop broad skills in a scientific or academic field and applied professional areas. (C2)
- Act, engage, innovate within a scientific and technological environment. (C3).
- Persuade by working on communication techniques Master spoken, written and body language, as well as basic communication techniques. (C7.4).
- Work collaboratively in a team. (C8.1).
- Engage outside expertise to go the extra mile. Identify and develop strengths and talents. (C8.3).
- Work using project management techniques appropriately tailored to the situation. (C8.4).
- Demonstrate rigour and critical thinking in approaching problems from all angles, be they scientific, social or economic. (C9.4).

ST5 – 53 – VEHICULE AUTONOME ET CONNECTE

Dominante : SCOC (Systèmes Communicants et Objets Connectés)
Langue d'enseignement : Français
Campus où le cours est proposé : Paris-Saclay

2SC5310 – Architecture and technologies of smart and communicating vehicles

Instructors: Caroline LELANDAIS PERRAULT
Department: SYSTEMES ELECTRONIQUES
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 34,5
Quota :

Description

The objective of this course is to familiarize students with the architectures and technologies used for the autonomous and connected vehicle (ACV) and their means of development.
To do this, it is necessary to define what is a mobility system in which the vehicle is embedded and then to understand the functional architecture of the ACV. As the functions of the ACV are essentially composed of electrical and electronic systems, the electrical and electronic hardware architecture is presented as well as its specificities and constraints due to the environment in which the automobile operates. Also at the hardware level, intelligent sensors and real-time embedded aspects of processing are studied. At the processing level, traditional or more advanced control laws, image processing for localization and mapping, artificial intelligence and data fusion techniques are discussed. At the communication level, the "vehicle-to-vehicle/vehicle-to-infrastructure" (V2X) technologies, the associated protocols, the characteristics and constraints of the communication channels for the application are studied. Finally, at the level of vehicle validation, the development process as it is carried out by manufacturers is presented.

Quarter number

ST5

Prerequisites (in terms of CS courses)

To follow this thematic sequence, it is recommended to have taken one of the elective courses in Electronic Systems (two occurrences in SG1 and two occurrences in SG3) and one of the elective courses in Networks and Security (one occurrence in SG1 and two occurrences in SG3). The Modeling course given in ST2 is also a prerequisite.

Syllabus

The course is divided into four parts, as follows:

I System definition and development methods

- Definition of the mobility system (infrastructure/vehicle) and architecture of the autonomous and connected vehicle (perception, processing, communication, actuation, and propulsion and energy conversion)
- AD/ADAS development process

II On-board electronics

- The electrical and electronic architecture of the vehicle (power supply network, ECUs, communications bus)
- Hardware specificities in automotive electronics (physico-chemical environment, EMC, reliability, card manufacturing process, operating safety)
- Intelligent sensors (LIDAR, RADAR, cameras, smart sensors)
- Real-time embedded in the automobile (real-time constraints depending on the function, ECUs, processors, FPGAs, etc.)

III On-board algorithms and processing

- Control laws for the autonomous vehicle (LQR, Kalman filtering, neural networks, fuzzy logic...)
- Artificial intelligence for autonomous vehicles
- Heterogeneous data fusion techniques

IV Communication of the vehicle with its environment

- V2X Technologies
- Channel access, traffic, and performance

Note: this outline does not reflect precisely the chronology of the course

Class components (lecture, labs, etc.)

21 HPE of lectures + 12 HPE of practical work

Grading

The evaluation will be a written exam of one hour and a half.

Resources

The courses will be taught by CentraleSupélec professors and by industrial experts from automotive manufacturer or automotive electronics companies.

For the 2020 edition, more interactive sessions in the form of practical work will be introduced.

Learning outcomes covered on the course

At the end of this course, the student will be able to understand the electrical and electronic architecture of an autonomous and connected vehicle and the communication technologies between the vehicle and its environment. The student will be able to model and simulate a vehicle communicating at the functional and physical level by detailing the constraints and limitations related to the environment and technologies.

Description of the skills acquired at the end of the course

C1.5: Bring together broad scientific and technical concepts in a core structure contained within
the framework of an interdisciplinary approach
C2.3: Rapidly identify and acquire the new knowledge and skills necessary in applicable /
relevant domains, be they technical, economic or others
C2.5: Master the skillset of a core profession within the engineering sciences (at junior level)
C9.4: Demonstrate rigour and critical thinking in approaching problems from all angles, be they
scientific, social or economic

2SC5390 – Urban delivery by autonomous and connected vehicles

Instructors: Morgan ROGER
Department: DOMINANTE - SYSTÈMES COMMUNICANTS ET OBJETS CONNECTÉS
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description

The challenges of autonomous and connected vehicles do not only concern the automotive sector. The integration teaching offered here allows you to understand on the one hand the approach of designing a complex and critical system, and on the other hand the plurality of problems of the autonomous and connected vehicle, through an industrial scenario in an adapted context.

The chosen scenario is that of a so-called “last mile” delivery. The cost and delivery time of a parcel by carrier is strongly impacted by the last mile, especially in urban areas. Due to traffic jams and parking, delivery trucks could advantageously be picked up at the entrance to major cities by lighter means of transport adapted to the urban environment. Using bikes is too expensive; the carriers consider in the short term a fully automated delivery on the last mile. The solution consists in managing a fleet of autonomous and connected robots carrying out deliveries, based on arrival times, delivery addresses and characteristics of the robots.

You work in a team in charge of designing such a delivery system. In this context, you follow a model-oriented system engineering process to specify the functionality of the system. You adopt a modeling methodology to develop the necessary algorithms (control / command, sensor fusion, data fusion, decision making and telecommunications) to meet the specifications. A reduced-scale test platform allows you to assess the quality of the delivery system obtained and improve the algorithms.

Quarter number

ST5

Prerequisites (in terms of CS courses)

1st-year elective module "Electronic systems"

1st-year elective module "Network security"
Specific teaching module "Architecture and technologies for smart and connected vehicules"

Syllabus
The following technical aspects are implemented in this integration teaching:

- functional needs analysis, system specifications
- system modeling
- state machines
- control law
- telecommunications
- communications protocol
- image processing
- sensor fusion
- embedded and real-time processing
- mixed hardware-software computation

Class components (lecture, labs, etc.)
The objective is to complete a technical proof of concept on a reduced-scale platform made up of robots rolling on an adapted support schematically representing the urban environment. Teams of 5 or 6 students are formed beforehand so as to present a broad spectrum of skills. After an initial functional analysis of the system based on brainstorming, the teams decide on their internal organization in order to deal with the various aspects in parallel and with consistency: hardware, modeling, embedded intelligence, connectivity. Each team is given a robot and can access the test rooms to validate the behavior of the system in a physical environment and refine its functionality. The last day of the week is devoted to the preparation of the evaluation and to the evaluation itself.

Grading
The grading is team-based through an oral presentation describing the design choices and the innovations of the system, followed by a demonstration of its performance on the test platform, in front of a panel of teachers and industrial experts.

Resources
Human resources: a team of teachers specializing in the various engineering fields concerned (electronics, telecommunications, modeling, signal processing) present 100% of the time; automotive (Renault) and modeling (Mathworks) industrial experts visiting during the week and present for the evaluation.

Logistical resources: working rooms for student teams, large rooms for test and evaluation platforms, a teachers' HQ.
Material resources: rolling robots (including 4 driving wheels, an Arduino board, a Raspberry Pi nanocomputer, a camera and several other on-board sensors, batteries).
Software resources: Matlab / Simulink, Linux, Python, C ++, OpenCV, ...

Description of the skills acquired at the end of the course
C1.1 Study a problem in its entirety, the situation as a whole. Identify, formulate and analyze a problem in its scientific, economic and human dimensions
C1.2 Use and develop suitable models, choose the right modeling scale and relevant simplifying hypotheses to deal with the problem
C1.3 Solve the problem with a practice of approximation, simulation, and experimentation
C1.4 Specify, design, build and validate all or part of a complex system
C1.5 Mobilize a broad scientific and technical base within the framework of a transdisciplinary approach
C6.1 Identify and use the necessary software for your work on a daily basis (including collaborative work tools). Adapt your "digital behavior" to the context
C8.1 Work in a team / in collaboration.
C8.3 Call on the expertise of others and push your own limits. Identify and exploit wealth and talents.
C8.4 Work in project mode by implementing project management methods adapted to the situation

ST5 – 54 – L'ECO-QUARTIER, UN SYSTEME COMPLEXE. AMENAGEMENT DURABLE & MANAGEMENT DE PROJET COMPLEXE

Dominante : CVT (Construction, Ville, Transport) et GSI (Grands Systèmes en Interaction)
Langue d'enseignement : Français
Campus où le cours est proposé : Paris-Saclay

2SC5410 – Sustainable urban planning

Instructors: Frédérique DELMAS-JAUBERT
Department: MÉCANIQUE GÉNIE CIVIL
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 34,5
Quota :

Description

The specific course entitled Planning and Sustainable Urbanization - AMUD - will provide the basic knowledge of the real estate and construction value chain, the emergence of smart cities and how traditional models of value creation are upset. , the relationship between the circular economy, the city, and the environment, and its impacts on natural resources.

Quarter number

ST5

Prerequisites (in terms of CS courses)

none

Syllabus

Human beings evolve in a framework that they help to shape: built environment, landscaped natural areas, transport infrastructures and public spaces are the ingredients of the living environment that we propose to study. These amenities and the behaviors of the men and women who live there have an impact on the natural resources of water, air and energy. All of these practices are today shaken by the rise of the digital economy.

What is an eco-neighborhood?
• Sustainability criteria
• Planning; SCOT, PLU
• what kind of things are build

Who builds what?
- Residential real estate
- Shops

- Offices
- Public spaces

Introduction to the value chain and management of a construction operation
- Real estate development
- Urban scale
- Designers, contractors and other service providers: who does what?
- Economic value and environmental value

Circular economy applied to building processes

In situ course: visit of an eco-district
- Architecture
- Urban form
- Services and equipment

Smart city: GIS and user data
- Urban geography, a discipline that articulates spatial, temporal, human data ...
- The tools of Geographic Information Systems
- Graphic representation, dynamics and decision support
- Data property and digital business model

Smart city and Transports
- Maas: mobility as a service, an example of a digital paradigm shift
- New modes of individual and collective transport: technical and urban innovations and infrastructures
- Planning and the role and responsibilities of policies and carriers
- New urban economic models

Urban resilience and risk management
- Natural risks and the exposure of populations
- Prevention works, benefits and ecological costs
- project risk management

Impact on the water resource
- Effects of urbanization on the water resource
- Traditional and innovative techniques: industrial installations and alternative management
- Urban resilience and water risk management

Waste
- History of waste collection and associated professions

- Technological innovations: pneumatic networks
- Industrial installations for the treatment of waste and cohabitation with the city: risk management, nuisance management

Energy
- Consumptions of buildings and new digital uses
- The question of scale and pooling: heat networks <> individual boilers
- Natural resources and their limits

Class components (lecture, labs, etc.)
This teaching includes:
- Lectures, delivered by different teachers on the campus of Gif
- In situ courses, delivered by teachers or temporary staff, traveling through a project area
- Thematic research to go deeper into a topic

22,5 hours of course
10,5 hours of tutorials

Grading
- Visit report (15%)
- thematic research (35%)
- written control (1H30) (50%)

Resources
The teaching team includes urban and architecture specialists as Frédérique Delmas, François Cointe, Olivier Ledru and Arnaud Lafont, teachers-researchers as Franck Marle, Yann Leroy and François Cluzel.

Learning outcomes covered on the course
Three main purposes about stakeholders, issues and digital transformation of the city:
- By the end of the course, the student is able to identify stakeholders in real estate and urban project (C1.1), to analyse an urban project from different point of view, comparing the positions avec different stakholders (C4.1), to list social and environmental responsibilities of everyone, beyond their economic model (C9.2).
- By the end of the course, the student is able to link together the main economic, environmental, technical and human issues of an urban operation (C1.1) and to compare different kind of solutions (C3.6 et C9.4).
- By the end of the course, the student is able to report on the transformations of the urban services economy with the rise of the digital

economy (C6.6).

Description of the skills acquired at the end of the course

C1.1 Examine a problem in full breadth and depth, within and beyond its immediate parameters, thus understanding it as a whole. This whole weaves the scientific, economic and social dimensions of the problem.

C2.1 Thoroughly master urban development domain, within every discipline involved and every scale.

C3.6 Evaluate the efficiency, feasibility and strength of the solutions offered.

C4.1 Think in client terms, identify and analyse customer needs, the constraints of other stakeholders as well as include societal challenges.

C6.6 Understand the digital economy applied to smart city concept and upheaval for traditional economic city actors

C9.2 Identify, within a given structure, the scope of liability as well as socio-ethical and environmental responsibilities.

C9.4 Demonstrate rigour and critical thinking in approaching problems from all angles, be they scientific, social or economic.

2SC5490 – Eco-district design project

Instructors: Frédérique DELMAS-JAUBERT, Franck MARLE
Department: DOMINANTE - GRANDS SYSTÈMES EN INTERACTION, DOMINANTE - CONSTRUCTION VILLE TRANSPORTS
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description

The purpose of integration education is to design an eco-district.
Students are organized in groups (about thirty students per group), broken down into 6 to 8-student teams.
Several deliverables are expected, like:
- A diagnosis of the territory and of the existing urban project
- Specific domain-oriented deliverables (energy, water, waste management, ...)
- Justification of choices made
- A virtual model of the project .

Quarter number

ST5

Prerequisites (in terms of CS courses)

Specific module : sustainable urban planning

Syllabus

(if the case is confirmed)

The ZAC Corbeville: what future in the short, medium and long term for the space around the interchange of the N118 on the plateau of Moulon? A ZAC project was submitted by the EPAPS to a public inquiry in the spring of 2019. For the needs of the case study, we will modify one or more major parameters of the studies already carried out (political orientation, mobility solutions, ambition of density, ...) and it is proposed to study the consequences on the urban project.
All the disciplines of the urban project are to be taken into account:
- Mobility strategy: what transitional and definitive means awaiting the

arrival of the metro? In particular public transport: tramway, cable car, bus with high level of service ...
- Public spaces: the functions of public spaces (circulating, walking, walking, sitting, playing ...) must they be modified? Are the urban links to existing heavy transports to be strengthened?
- Water treatment: questioning public spaces is the opportunity to further improve the rainwater treatment strategy of the area.
- Real estate development: the land charges expected by the developer can be realized? Are the expected types of programs likely to be realized under the conditions originally planned?
- If the real estate development is modified, are the public facilities due under the ZAC affected?
- Urban form: the urban form crystallizes the choices made for public spaces and real estate programs. It is a major factor of attractiveness of the territory. How is it impacted?
- City and agriculture: this modification is an opportunity to question the relationship between city and agriculture. The question of neighborhood supply is raised, with a strong political demand to support local agricultural development.

Input data :
- Historical aerial photo
- Maps available on geoportal (in particular IGN with topography, watercourse, and existing building)
- Insee data available online
- Program and guide EPAPS of the district of Moulon

Class components (lecture, labs, etc.)
Sprint-based project (3 sprints of 1,5 day each).
Self-organized and connected teams withing the group, sprint reviews with each group supervisor.
Opportunity to get specific expertise during some sessions.

Grading
Continuous assessment, based on team (for local deliverables) and group (for global deliverables) results and team organization. Individual contribution to collective teamwork is also assessed.

Resources
Teachers are professors, architects, urbanists, engineers, researchers, ...
Franck Marle, Arnaud Lafont, Ulysse Vizzardi, François Cointe, François Cluzel, Frédérique Delmas

Learning outcomes covered on the course
Upon completion of this module, students will progress in :

- developing a transdisciplinary approach to eco-districts and urbanism
- using scientific, technological, social and economic knowledge to design and validate such a complex system
- applying a collaborative project management approach to attain desired results

Description of the skills acquired at the end of the course

C1.4 Design, detail and corroborate a whole or part of a complex system.

C1.5 Bring together broad scientific and technical concepts in a core structure that is nestled in an interdisciplinary approach.

C3.6 Evaluate the efficiency, feasibility and strength of the solutions offered.

C7.1 Persuade at the level of core values; to be clear about objectives and expected results. To apply rigour when it comes to assumptions and structured undertakings, and in doing so structure and problematise the ideas themselves. To make the added value known.

C8.4 Work using project management techniques appropriately tailored to the situation

C9.4 Demonstrate rigour and critical thinking in approaching problems from all angles, be they scientific, social or economic.

ST5 – 55 – LUMIERE ET MATIERE : DEVELOPPEMENT D'INSTRUMENTS DE HAUTE TECHNOLOGIE

Dominante : PNT (Physique et NanoTechnologie)
Langue d'enseignement : Français
Campus où le cours est proposé : Paris-Saclay

2SC5510 – Physics of matter

Instructors: Pietro CORTONA
Department: PHYSIQUE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 34,5
Quota :

Description

Aim of the course is to give to the students a basic knowledge of solid-state physics. Some examples of applications in nanoscience and opto-electronics will also be given. The ultimate goal is that the students realize that understanding and controlling the great variety of material properties pave the way to a wide range of very interesting applications.

Quarter number

ST5

Prerequisites (in terms of CS courses)

Quantum and Statistical Physics course

Syllabus

Course syllabus:
• Order in solids: the crystal lattice.
• Scattering of waves by the crystals: diffraction.
• Phonons and thermal properties.
• Metals and conductivity: Drude and Sommerfeld models.
• Band structure: electrons in bulk crystals and in nanostructures.
• Semiconductors – Quantum wells: applications in optoelectronics.
• Defects in crystals and their consequences on the physical properties of materials.

Class components (lecture, labs, etc.)

Lectures (13 hours and half), tutorials (18 hours) and one seminar (one hour and half).

Grading

Written exam (1h30) without documents (if it will be held in the classrooms of Centralesupelec)

Written exam (1h30) with documents otherwise

Course support, bibliography
Handout
Solid-state physics, Ashcroft and Mermin

Resources
Teaching staff: P. Cortona, H. Dammak, C. Paillard for three tutorial groups

Learning outcomes covered on the course
At the end of the course, the students are supposed to know:
• Take advantage of the crystal symmetry in the study of the crystal properties;
• Determine the interatomic distances from the results of X-rays diffraction experiments;
• Distinguish a conductor from an insulator on the basis of the specific heat behavior at low temperature;
• Distinguish conductor, semiconductor and insulator on the basis of their band structure;
• Establish the semiconductor conductivity dependence on temperature and doping;
• Estimate the point defects (vacancies, interstitiels,...) concentration in a cristal in function of the temperature.

Description of the skills acquired at the end of the course
C2.1 : "Thoroughly master a domain or discipline based on the fundamental sciences or the engineering sciences."
C2.4 : "Create knowledge within a scientific paradigm."
C1.3 : "Apply problem-solving through approximation, simulation and experimentation."

2SC5591 – Synchrotron X-ray Beamline design

Instructors: Pierre-Eymeric JANOLIN
Department: DOMINANTE - PHYSIQUE ET NANOTECHNOLOGIES
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description

This is a multidisciplinary course. Teams of about 20 students are challenged with understanding, designing and scaling the physical, mechanical, heating and materials aspects of key technological components of a synchrotron beamline.

This is a multidisciplinary course. Teams of about 20 students are challenged with understanding, designing and scaling the physical, mechanical, heating and materials aspects of key technological components of a synchrotron beamline. The use of CAD tools is encouraged.

Each team shall be supported by experts working in French and European synchrotrons, through daily video interviews.

One of the team shall design a beamline able to perform angiography on a human patient and the other team shall design a beamline able to detect the presence of a cancer-inducing isotope of Chromium in a frog ovarian cells.

Quarter number

ST5

Prerequisites (in terms of CS courses)

Basic knowledge in modern physics and heat transfer. Mechanical engineering skills will be useful

Syllabus

This module is a project-based learning activity, with emphasis on the following topics:

- Crystallography, radiation by an accelerated particule, fluorescence, absorption, scattering, diffraction of short wavelength radiation

- Heat transfer: convection, radiation, conduction, fluid mechanics
- Computer-Aided Design (CAD), numerical modeling, design pre-project, pre-scaling of mechanical systems.
- Selection of materials, standard mechanical properties, strength of materials in an extreme environment, surface states, elaboration and shaping processes
- Experiencing teamwork under time pressure, chairing a meeting, oral expression

Class components (lecture, labs, etc.)

Students will work in project mode during the one-week module and will attend preparation and debrief sessions on prior and subsequent weeks.

The students enrolled in this course must attend the final defense, at synchrotron SOLEIL; it is followed by a visit of the SOLEIL facility.

Grading
Méthodes d'évaluation en ENGLISH :1/3 on the involvment during the week (evaluated by the profs as well as the other team members)1/3 on the final presentation (one presenter per group, everybody in the group gets the same grade)1/3 on the final report (common grade for the entire team)

Course support, bibliography
Reference textbooks and databases. ShareDoc (asynchroneous collaborative platform), Adobe Connect (video-conferencing and synchroneous collaborative work platform), Spaceclaim (CAD) and Comsol (heat transfer).

Resources
The use of CAD tools (e.g. SPACECLAIM or SOLIDWORKS) is encouraged. Students who wish to learn these tools will be given access to a license of SPACECLAIM and will be provided with online tutorial sessions. Alternate design tools (drawings, models,...) are also very useful, in particular for the design of specific components of the beamline.

Learning outcomes covered on the course

- apply design concepts using basic notions of modern physics
- identify the key heat transfer modes to model and design systems. Use Comsol.
- know the key points for a pre-project study in a multidisciplinary context

- master the use of Ashby diagrams for materials selection
- understand orders of magnitude for mechanical and physical properties of usual materials
- develop teamwork abilities, know and identify different roles in a team (on the basis of Belbin tools); manage a workgroup, collect and share information, shape and defend the results of the work in front of an audience / a jury.

2SC5592 – Quantum cascade lasers

Instructors: Thomas ANTONI
Department: DOMINANTE - PHYSIQUE ET NANOTECHNOLOGIES
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description

The aim of this course is to learn new concepts in modern maths and physics and to realize how they enable technological breakthroughs that can be industrialized. This course is also a first opportunity to tackle the basic principles of nanotechnologies. In addition to scientific knowledge, it will also develop the soft skills of the engineer job through teamwork, written and oral communications.

Quantum cascade lasers are nanodevices invented twenty years ago. Engineering miracle their operation is possible because of the lattest advances in quantum mechanics, optics and thermics. In a team work, the students will get familiar with these concepts and implement an engineer approach to turn them, numerically, in an object reality-constrained.

Quarter number

ST5

Prerequisites (in terms of CS courses)

Quantum and Statistical Physics , Partial Differentieal Equations

Syllabus

- quantum physics (electronic transport, band structures, semiconductors)
- optics (mode guiding, cavities, emission)
- lasers
- basics of nanotechnologies
- partial differential equations
- numerical simulations through MATLAB or Python

Class components (lecture, labs, etc.)

This course is open to fourty students and will take place over a full week.

The students will be divided into two teams of twenty people, each team having to deliver a numerical quantum laser. The teams will be composed of four groups of five students, each group being more specifically responsible for developing a basic unit of the device.

Grading

Oral presentation, report, personal contribution, MCQ.

Course support, bibliography

A list of books available at the documentation center will be given dureing the first session.

Resources

- Exchanges with engineers who are experts in the various fields covered
- Bibliographic Resources
- Use of MATLAB or Python

Learning outcomes covered on the course

- turn a theoretical concept into an actual object
- pose the problem
- estimate orders of magnitude and iterate
- criticize a result
- know how to tackle multi-physics systems

Description of the skills acquired at the end of the course

- Specify, design, build and validate all or part of a complex system
- Mobilizing a broad scientific and technical base in the framework of a transdisciplinary approach
- Transpose to other disciplinary fields, generalize knowledge
- Identify and rapidly acquire new knowledge and skills needed in relevant technical, economic and other fields

- Evaluate the effectiveness, feasibility and robustness of proposed solutions
- Choose solutions and act pragmatically, with a view to achieving tangible results
- Making complex content intelligible. Structure one's ideas, one's argumentation.
- Synthesize and take a step back
- Building buy-in and ownership
- Master scientific and technical communication. Be precise, relevant.
- Gather relevant and reliable information to support an argument.
- Teamwork/collaboration

ST5 – 56 – SYSTEMES MULTI-ENERGIES

Dominante : ENE (Energie) et GSI (Grands Systèmes en Interaction)
Langue d'enseignement : Français
Campus où le cours est proposé : Paris-Saclay

2SC5610 – Introduction to energy production

Instructors: Maya HAGE HASSAN, Amir ARZANDE
Department: ENERGIE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 34,5
Quota :

Description

To reduce energy consumption and polluting emissions it's necessary to use energy systems that includes sources whose efficiency and characteristics are complementary. This is true for electricity generation systems, where the growth of intermittent renewable generation requires more flexibility from conventional means of production, and also from the transport sector, where the electric and thermal powertrains complement each other advantageously.
These multi-energy systems require advanced control modes to take advantage of the complementarity of energy sources, and satisfy user needs and economic, technical and environmental constraints.

Quarter number

ST5

Prerequisites (in terms of CS courses)

Transport Phenomena, Electric energy

Syllabus

1. Thermal energy conversion
Turbomachines (turbojets, turboalternators)
Internal combustion engines
Introduction to the physics of nuclear reactors

2. Electrical energy conversion
Structure of AC machines, motor / generator operation
Electronic converters.
Principles for speed variation of machines (machine system and converters)

Class components (lecture, labs, etc.)
Thermal energy conversion : CC1, CC2, CC3, CC4 + T1, T2

Electrical energy conversion : CC5, CC6, CC7, CC8 , CC9,+ T3, T4

CC : Core Curriculum
T : Tutorial

Grading
Exam at the end of the course for 1 hour and a half.

Course support, bibliography
lecture notes

Resources
Teaching staff: Amir Arzandé, Maya Hage Hassan, Antoine Renaud, Pierre Duquesne (Centrale Lyon), Pascal Yvon (CEA)
Size of tutorial classes (default 35 students): 25
Tutorials in classical auditorium and computer rooms

Learning outcomes covered on the course
At the end of this course students will be able to
Understand the basics of energy conversion systems in mechanics and electrical.
Understand different ways of converting thermal energy into mechanical one (internal combustion engine, turbomachine, nuclear core).
Identify the strengths and constraints of these different modes of energy production as well as to propose first elements of pre-sizing.
Propose a fast modeling of synchronous and asynchronous machines and converters and also to identify some machine / converter systems for hybridization applications, with regards to the electrical portion of the course.

Description of the skills acquired at the end of the course
Examine problems in their entirety and beyond their immediate parameters. Identify, formulate and analyse the scientific, economic and human dimensions of a problem
Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when addressing a problem
Apply problem-solving through approximation, simulation and experimentation. / Solve problems using approximation, simulation and experimentation

Design, detail and corroborate a whole or part of a complex system
Create knowledge within a scientific paradigm
Master the skillset of a core profession within the engineering sciences (at junior level)
Be proactive and involved, take initiatives
Act ethically, with integrity and respect for others
Demonstrate rigour and critical thinking in approaching problems from all angles, be they scientific, social or economic

2SC5691 – Regulation and control of energy production and conversion systems

Instructors: Guillaume SANDOU
Department: DOMINANTE - ENERGIE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description

This "Challenging Week" entitled "Energy production and conversion" aims to tackle the regulation issues of several electrical energy production units, linked to the transport or distribution network. The considered systems to be studied will be for instance an hydroelectric production unit, a wind farm or a photovolatic production unit.
The work to be done will be divided into few main steps:
- development of a model of the energy production unit based on given documents and data
- design of a control law for the production unit in face with specifications well suited to the considered problem
- Validation based on simulations of the regulation law.

These studied will be carried out in collaboration with EDF and in particular with the "Centre d'Ingénierie Hydraulique" located in Bourget-du-Lac. Depending on the considered case, the work will consist in reproducing the observed behaviour of the controlled production unit, enhancing the performance of the regulation, or investigating an innovative operating mode for the production unit.

Quarter number

ST5

Prerequisites (in terms of CS courses)

- Control (Second year core module, ST5)
- Introduction to energy production (module in the Engineering Challenge Term ST5 "Multi-energy systems")

Syllabus

Outline of the Challenging Week :

- First half-day: presentation and choice of the projects
- Half-days 2 to 8 : project completion
    - Handling of the proposed issue and corresponding available documents and data
    - Design of a nonlinear simulator for the open-loop production unit
    - Determination of a model well suited to control purposes
    - Computation of the control law in face with dedicated specifications for the considered unit
    - Definition, if possible, of an innovative control law strategy
    - Validation based one the nonlinear simulator
- Last half-day: oral presentation of the results

Class components (lecture, labs, etc.)

Project, made by groups of 4 or 5 students.
Supervision by teachers from CentraleSupélec.

Grading

Each group of 4 or 5 students should provide:
- a full simulator of the work done, including a non linear simulator of the system, control law and validation files;
- a report explaining the proposed approach and in particular the way to use the simulator and the codes;
- an oral presentation of the work

Course support, bibliography

N. Gionfra, H. Siguerdidjane, G. Sandou, D. Faille, and P. Loevenbruck. Combined Feedback Linearization and MPC for Wind Turbine Power Tracking. 2016 IEEE Multi-Conference on Systems and Control, International Conference on Control Applications, Buenos Aires, Argentina, September 19th-22nd, 2016.
Boubekeur Boukhezzar and Houria Siguerdidjane. Nonlinear Control of a Variable-Speed Wind Turbine Using a Two-Mass Model. IEEE Transactions on Energy Conversion, vol. 26, no. 1, Mars 2011.
Morten Hartvig Hansen and Lars Christian Henriksen. Basic DTU Wind Energy controller. DTU Wind Energy E-0018. January 2013.
Gérard Robert, Frédéric Michaud. Reduced Models for Grid Connected Hydro Power Plant Application to Generation Control. International Conference on Communications, Computing and Control Applications. 3-5 March 2011. Hammamet, Tunisia
Nicola Femia, Giovanni Petrone, Giovanni Spagnuolo, and Massimo Vitelli. Optimization of Perturb and Observe Maximum Power Point Tracking Method. IEEE Transaction on Power Electronics, Vol. 20, No. 4, July 2005
Rae-Young Kim, and Jih-Sheng Lai. Seamless Mode Transfer Maximum

Power Point Tracking Controller For Thermoelectric Generator Applications. IEEE Transaction on Power Electronics, vol. 23, no. 5, September 2008

Resources

- Teachers from the Control Department and Energy Department;
- Contacts and meetings with research engineers from EDF;
- Documents and data about electricity production units;
- Use of students' laptops

Learning outcomes covered on the course

At the end of this module, students will be able to

- Model a physical and industrial system for control purposes;
- Capture the impact of a production unit regulation ob the global operation of the electrical system;
- Model a system, from a functional point of view , so as to determine the control strategy;
- Develop a control law in face with some specifications;
- Take into account the specificities of some energy production units;
- Validate the behaviour of a controlled electricity production unit.

Description of the skills acquired at the end of the course

C1.1 Examine problems in their entirety and beyond their immediate parameters. Identify, formulate and analyse the scientific, economic and human dimensions of a problem

C1.2 Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when addressing a problem

C1.3 Apply problem-solving through approximation, simulation and experimentation. / Solve problems using approximation, simulation and experimentation

C1.4 Design, detail and corroborate a whole or part of a complex system

C2.1 Thoroughly master a domain or discipline based on the fundamental sciences or the engineering sciences.

C3.6 Evaluate the efficiency, feasibility and strength of the solutions offered. / proposed solutions

C3.7 Make pragmatic and informed choices with the aim of producing tangible results.

C7.1 Persuade at core value level; to be clear about objectives and expected results. To apply rigour when it comes to assumptions and structured undertakings, and in doing so structure and problematise the ideas themselves. Highlight the added value

C8.1 Work collaboratively in a team

2SC5692 – Hybrid power train

Instructors: Amir ARZANDE, Maya HAGE HASSAN
Department: DOMINANTE - ENERGIE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description

The objective is to be able to propose a hybrid powertrain model and combine the practical part on a characterization bench and the modeling part.

Quarter number

ST5

Prerequisites (in terms of CS courses)

Electric energy

Syllabus

1. Presentation of the different elements of the hybrid power train :
Introduction to the environmental, economic constraints
Presentation of ways to increase the overall efficiency of the powertrain and the structure of a hybrid drive train
Presentation of the combustion engine, structure of the automotive industry
Control of electrical machines (choice between MCC and synchronous machine), for integration in a system model
2. Application and development of a numerical model :
Presentation of the hybrid system model in Simulink :
Implementation of the different parts of the block diagram: car model, combustion engine, gearbox, electric motor coupling, batteries.
Presentation of a flow management strategy on WLTP consumption cycle.

Class components (lecture, labs, etc.)

Project

Grading

final defense

Resources
Modeling on Matlab
Papers

Learning outcomes covered on the course
- Implementing a systemic model of the electric powertrain and then a hybrid powertrain
- Implementing digital processing tools under matlab/Simulink
- Implementing a control approach for the entire hybrid chain from driver to wheels
- Introduction to cycle dimensioning: complexity of the system and contradiction of several objectives to be achieved

2SC5693 – Hybrid aeronautical propulsion

Instructors: Antoine RENAUD
Department: DOMINANTE - ENERGIE
Language of instruction: FRENCH
Campus:
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description

The electrification of aviation is a topical issue, given the challenges of reducing polluting emissions to which the air transport community has committed itself: by the middle of the 21st century, the aim is to halve CO2 emissions from all air traffic. At the same time, it is estimated that the volume of passengers carried will almost double.

In this context, it is legitimate to focus on electrically-powered aircraft, which raises the problem of energy storage: batteries are still very heavy and are barely sufficient to move light aircraft with two passengers over a few hundred kilometers.

During this challenge week, we will focus on a light aircraft of the high-end ultralight class. For this category of aircraft, we can already consider electrification of the propulsion with existing technologies. We will consider a hybrid architecture combining a battery with a hydrogen fuel cell.

Quarter number

ST5

Prerequisites (in terms of CS courses)

Transport phenomena or Electrical energy courses

Syllabus

A general Simulink template of the model will be provided, with a number of blank sub-templates that will need to be completed. Validation tests will then have to be carried out on each of the sub-systems.

1. Fuel Cell

- Battery core electrochemistry
- Thermal management
- Sequencing logic

2. Electrical distribution and motorization

- Engine and its regulation
- Battery and its management system
- Power regulation

3. Airframe

- Flight mechanics and taxiing
- Control loops and piloting

4. Preparation of the test procedure

- Definition of mission profiles
- Pre- and post-processing

In a second part, the groups will be redistributed into three teams and the models of the sub-systems will be shared. Each team will be in charge of assembling its aircraft and testing it.

Class components (lecture, labs, etc.)
The work will be supervised by speakers from SafranTech as well as CentraleSupélec teachers. Students will be divided into groups and sub-groups according to the different tasks to be accomplished. Reconfigurations will take place during the week according to the progress of the work.

Grading
The evaluation is based on attendance, motivation and efficiency throughout the week as well as on two group presentations, one in the middle of the week and the second on the last day.

Resources
The whole activity will take place using Matlab/Simulink software to simulate the problem.

Learning outcomes covered on the course
By the end of the week, students will have learned about flight mechanics, how to fly an airplane, and how electric motors and fuel cells work. Most importantly, they will have learned how to manage the constraints

associated with these different elements when they are assembled in a complex system. Finally, the scope and complexity of the problem necessarily require teamwork with different core businesses, replicating real-life work situations.

Description of the skills acquired at the end of the course

C1.3: Apply problem-solving through approximation, simulation and experimentation.

C1.4: Design, detail and corroborate a whole or part of a complex system.

C2.3: Rapidly identify and acquire the new knowledge and skills necessary in applicable/relevant domains, be they technical, economic or others.

C7.1: Persuade at core value level; to be clear about objectives and expected results. To apply rigour when it comes to assumptions and structured undertakings, and in doing so structure and problematise the ideas themselves. Highlight the added value.

C8.1: Work collaboratively in a team

ST5 – 57 – CONTROLE DE LA POLLUTION ACOUSTIQUE ET ELECTROMAGNETIQUE

Dominante : MDS (Mathématique, Data Science) et Info&Num (Informatique et Numérique)

Langue d'enseignement : Français

Campus où le cours est proposé : Paris-Saclay

2SC5710 – Theory and algorithmics for wave control

Instructors: Anna ROZANOVA-PIERRAT
Department: MATHÉMATIQUES
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 34,5
Quota :

Description

Acoustic pollution is today considered a major annoyance by the population, while electromagnetic pollution raises many questions and questions related to health problems. Practical achievements to control this pollution represent a major technical and industrial challenge, but do not yet benefit from the new developments that mathematical analysis, numerical simulation and computer science can bring to it.

This course focuses on the design of innovative products (acoustic or electromagnetic coating) intended to control acoustic / electromagnetic pollution.
Having introduced the physical context in the "Context and challenges" module, it aims to give students the concepts in mathematics and computer science associated with the design and manufacture of such products. This course offers two training paths:

1) Theoretical analysis path, directed by Ms. Rozanova-Pierrat: a path based on mathematical theory (EDPs, functional analysis, derived from Fréchet) associated with numerical methods (finite elements, finite differences) to master the control of waves to define the form of an acoustic or electromagnetic coating. In particular, in this way are treated the EDPs on the irregular edges (fractals) and is developed the method of optimization of the forms and the concept of the derivative compared to the edge.

2) Digital analysis path, numerical and algorithmic methods, directed by M. Magoulès: this path aims to deepen the numerical methods used in the theoretical analysis path, it is oriented towards scientific calculation. In particular, in this way are treated the numerical methods and the implementation of these for the propagation of the waves and the method of optimization of the forms.

The two tracks prepare for the three EIs proposed subsequently. More precisely, they study the methods (theoretical or numerical) which are useful for the themes of the three EIs: for controlling external acoustic waves (near motorways, airports, construction sites) or internal (sound insulation in offices by perforated panels or acoustic liners in aircraft reactors for example), as well as in the control of electromagnetic pollution (anechoic chambers).

Quarter number
ST5

Prerequisites (in terms of CS courses)

Knowledge of SG courses of the 1st year: Algorithmics and complexity (for the Scientific Computing track) and EDPs (for the Mathematical Methods track)

Elective course "Wave Physics" is recommended for the EI "Electromagnetic pollution control"

Syllabus
The control problems described by partial differential equations (observability, controllability, controllability) are developed in the course of the "Automatique et Contrôle" of the ST, which is further explored in the context of the control of the dissipation of the wave energy. The observability in this case depends on the geometry of the absorbing edge. To illustrate the reasons for requiring geometric irregularity, we introduce the notions of fractal geometry with known results in physics (for two tracks) and mathematics (for the track "Theoretical analysis"). In particular, we present the phenomena of localization and absorption of waves (acoustic or electromagnetic) which are connected by the spectral analysis of the model. To better understand the environmental and sociological issues of acoustic barrier development, we present some psychoacoustic aspects, which show the importance of the dissipation of certain frequencies. The course studies in particular, for a fixed frequency, obtaining an optimal form for a frequency model on the Helmholtz equations in order to allow its use in the IE on two types of controls: geometric and topological. We then consider the main difficulty of having an "almost optimal" shape over a wide band of frequencies, important from a psychoacoustic point of view and industrial interests. In this context are also presented the most suitable numerical methods (thoroughly for the track "Scientific computing") in order to quickly and robustly determine the optimal shape or the "almost optimal" shape of the geometry on a frequency band by numerical simulation.

Course outline per session: 1) Course/TD on the common theme of two tracks with adapted levels of presentation:
EDPs introduction: Delta operators, nabla, div, edge of a domain, an external normal, integration by parts. Wave propagation models.
2) Course/TD a) Theoretical Analysis track: Traces, extensions, compact sets, compact operators. Poisson equation.
b) Numerical Analysis track: Poisson equation, finite element method, finite difference method, numerical implementation.
3) Course/TD a) Theoretical Analysis track: Fractal boundary. Analysis of the Poisson problem with mixed boundary conditions and the associated spectral problem.
b) Numerical Analysis track: Pre-fractal boundary. Spectral problem and associated numerical methods, implementation of the different boundary conditions, numerical error.
4) Course/TD a) Theoretical Analysis track: Helmholtz model with an absorbing edge, its theoretical resolution and dependence on the acoustic energy of the frequencies
b) Digital Analysis track: Advanced numerical methods in the context of waves
5) Course/TD on the common theme in two ways: Numerical resolution of the Helmholtz problem with edge dissipation and the associated spectral problem
6) Machine and TP tutorials: Launch of the eigenmode localization project for two tracks
7) Course/TD a) Theoretical Analysis track: Parametric optimization (existence of an optimal form)
b) Digital Analysis track: Introduction of parametric, algorithmic and associated digital optimization
8) Course/TD a) Theoretical Analysis track: Fréchet derivative and the derivative with respect to a parameter
b) Numerical Analysis track: Concept of the Fréchet derivative. Numerical implementation of parametric optimization
9) Course/TD a) Theoretical Analysis track: Optimization of forms. Shape derivative.
b) Digital Analysis track: Introduction to optimizing shapes. Numerical implementation of shape optimization
10) Course with an adaptation to the two paths: Numerical algorithm of the optimization of the forms and the optimality on a range of frequencies. Wave control, link with th commun "Automatic" course.

Class components (lecture, labs, etc.)

Cours 12*1h30, TD 8*1h30, TP 3*1h (TDs on a computer, computations on a cluster), project (not included in TDs), handbook of the course adapted to the track Theoretical Analysis, computations on a cluster, solutions of exercises

Grading
Final exam 1h30 evaluated as 70% in the final note and the project evaluated as 30% in the final note.

Course support, bibliography

- *Frédéric Magoulès, Thi Phuong Kieu Nguyen, Pascal Omnes, Anna Rozanova-Pierrat. Optimal absorption of acoustical waves by a boundary , SIAM SICON, to appear, 2020.*
- *Kevin Arfi, Anna Rozanova-Pierrat. Dirichlet-to-Neumann or Poincaré-Steklov operator on fractals described by d-sets. Discrete and Continuous Dynamical Systems - Series S, American Institute of Mathematical Sciences, 2019, 12 (1), pp.1-26.*
- *G. Allaire Conception optimale de structures, Springer.*
- *A. Henrot, M. Pierre Variation et optimisation de formes. Une analyse géométrique. Springer.*
- *M. Filoche and S. Mayboroda, Universal mechanism for Anderson and weak localization, Proceedings of the National Academy of Sciences of the USA 109, 14761 (2012).*
- *M. Filoche and S. Mayboroda, The landscape of Anderson localization in a disordered medium, Contemporary Mathematics, 601 (2013), 113-121*

Resources
Students are divided into two groups corresponding to two mentioned tracks before the start of the specific course. Each group has courses intended to introduce concepts used in TDs and in the longer term in IE (the three IEs offered). There will be some courses on numerical methods in the mathematical way and there will be some basic theoretical courses (such as multidimensional integration) in the numerical way. It is planned to have a session of TPs (TDs on the computer) of 3h common for 2 channels at the end of which there is a digital project to render (the influence of the geometry of the wall on the localization of the eigen modes and dissipation of wave energy). Students will perform modeling, simulation, visualization and rendering of the phenomenon. The two tracks provide for two different test subjects. The Mathematical Analysis track is based on the course handout, which will be made available to everyone. Students of two tracks also have at their disposal all the subjects of the TDs with the corrections. Numerical calculations will be performed on a

CentraleSupélec calculation cluster by connecting to Jupyter.

Learning outcomes covered on the course
Theoretical Analysis track:
-understand the theoretical and numerical techniques of acoustic / electromagnetic wave control
-Validate theoretical and numerical techniques of acoustic / electromagnetic wave control (shape optimization)
Numerical Analysis track, numerical and algorithmic methods :
- numerical techniques of acoustic / electromagnetic wave control
-Implement numerical methods to simulate acoustic wave propagation phenomena of large dimensions (external / internal problems and problems for a wide band of frequencies)
-Validate numerical techniques of acoustic / electromagnetic wave control

Description of the skills acquired at the end of the course
C1.1, C2.1, C6.1, C7.1, C9.4

Theoretical Analysis track (functional analysis, shape optimization):
To be able to deal with the control problems described by the PDEs.
Know how to deal with edge irregularity including fractal to show the well-posed nature of a problem described by PDEs.
Knowing how to apply the method of optimizing shapes and deriving an energy functional from the edge of the domain.
To be able to deduce from the application objectives the constraints of control and the fact of an existence / non-existence of an optimal form.
Target the geometric scales of interest in relation to the wavelengths to be dissipated.
Being able to deal with digital aspects.

Numerical Analysis track (Scientific Computing, numerical and algorithmic methods):
To be able to deal with the control problems described by the PDEs.
To be able to deduce from the application objectives the constraints of control and the importance of an optimal form.
Target the geometric scales of interest in relation to the wavelengths to be dissipated.
Master the finite element method and finite differences and their implementation.
Knowledge of resolution methods related to the simulation of wave propagation.
Mastery of numerical difficulties related to simulation.

2SC5791 – Control of external acoustic pollution

Instructors: Frédéric MAGOULES, Anna ROZANOVA-PIERRAT
Department: DOMINANTE - MATHÉMATIQUES, DATA SCIENCES
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description

We are positioning ourselves on the industrial stakes which impose the economic constraints and the technological constraints necessary for the improvement of the existing products of the market, to design innovative coatings to absorb the noise of the planes, trains, cars. The aim is to develop these innovative products in an optimal way by controlling the energy of the waves by the geometry of the wall while taking into account the economic constraints. For example, COLAS and École Polytechnique have developed an anti-noise wall called "Fractal Wall" TM, which was designed empirically with complex geometry to dissipate different wavelengths. However, this wall even if it is four times more efficient than conventional walls for low frequencies, is almost not sold ... The explanation is that its construction, being by demolding, may break the wall, this which results in a high cost of manufacture. This IS proposes to find by wave control methods optimal forms that are as absorbent as possible (in decibels) that satisfy the constraints imposed by the manufacturer, for example, the least expensive manufacturing cost with the greatest reduction. important decibels. First numerical results in this context show the existence of optimal "not too complex" forms capable of improving the performance of the "Fractal wall" by a factor of 6.

Quarter number

ST5

Prerequisites (in terms of CS courses)

The courses of ST5 and in particular the course "Theory and algorithmics for wave control" (one of two proposed tracks)

Syllabus

Teamwork simulated an "industrial company", definition of issues, bibliographic research, physical understanding and practical interest, mathematical modeling of the problem, development of the corresponding mathematical theory if necessary (the problem well or badly posed, regularity of the solution , derivation of acoustic energy with respect to the geometry of the wall, influence of choice of chosen porous material on the absorption of energy, ...), development / implementation of the numerical method, numerical analysis of the results , the analysis of their relevance, possible improvement, obtaining an effective shape for a large band of frequencies.

Class components (lecture, labs, etc.)
Teamwork, project, dialogue with various specialists in the field.

Grading
Report, final and intermediate deliverables, defense.

Resources
Connection to a cluster at the distance

Students will perform modeling, simulation, visualization and rendering of the chosen phenomenon. They will study the simulation chain with a goal of performance and precision under economic constraints (manufacturing cost) and environmental (gain in decibel or potential).

Deliverables: report, software, transparencies and defense

Learning outcomes covered on the course
Understand the contribution of geometry in the design and development of new products
To understand the theoretical and numerical techniques of acoustic wave control
Implement numerical methods to simulate acoustic wave propagation phenomena of large dimensions (external problems and problems for a wide band of frequencies)
Validate the theoretical and numerical techniques of acoustic wave control
Confront students with the realization of a complex product using numerical simulation techniques

Description of the skills acquired at the end of the course
C1.1 Study a problem in its entirety, the situation as a whole. Identify, formulate and analyze a problem in its scientific, economic and human dimensions: study of the industrial, psychoacoustic and environmental interest for the determination of the constraints of the control problem, their implementations in the numerical method and the analysis of their sufficiency of theoretical point of view for the existence of optimal control.

C2.1 To have deepened a field or a discipline related to the basic sciences or sciences of the engineer: understanding and application of a mathematical methodology in the context of development of an innovative product engineer.

C3.5 Propose new solutions / tools either in disruption or in continuous progress: by using the scientific advancement of fundamental disciplines such as mathematics and physics and an efficient IT implementation, propose a new solution to design the existing noise barriers .

C4.1 Thinking customer. Identify / analyze the needs, issues and constraints of other stakeholders, including societal and socio-economic: study of industrial, psychoacoustic and environmental interest for the determination of the constraints of the control problem.

C6.1 Identify and use the software necessary for his work on a daily basis (including collaborative work tools). Adapt your "digital behavior" to the context: use and development of a numerical code based on existing parts.

C7.1 Convince on the merits. Be clear about the objectives and the expected results. Be rigorous about the assumptions and the approach. Structure your ideas and your argumentation. Highlight the created value. To convince while working on the relation to the other: by working in team the strategic choice is crucial to have good results of the project, to do it it is necessary to be able to convince the others; teamwork itself; the final defense before a multi-disciplinary jury.

C8.1 Teamwork / Collaboration: This is the principle of IS.

C9.4 Demonstrate rigor and critical thinking in approaching problems from all angles, scientific, human and economic: validation and analysis of results obtained digitally with critical thinking.

2SC5792 – Indoor noise pollution control

Instructors: Anna ROZANOVA-PIERRAT, Frédéric MAGOULES, Éric SAVIN
Department: DOMINANTE - MATHÉMATIQUES, DATA SCIENCES
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description

We focus on the industrial issues that impose the economic constraints and the technological constraints necessary to improve existing products on the market, in order to design interior coatings to absorb the noise inside the buildings and also acoustic liners in jet engines. In this context we are interested in three key applications: (i) the design of coatings in anechoic chambers (until now acoustic anechoic chambers have been empirically designed based on geometries using different scales), (ii)) the design of perforated absorbent panels (absorbent materials are fibers that have very good acoustic absorbency properties, and are usually covered with wooden panels for aesthetic reasons, which unfortunately hampers their effectiveness) and finally (iii)) absorbent insulations perforated in jet engines. In the last application it is important to optimize the diameter and positioning of the holes in the material. The objectives are to better control the waves by analyzing the optimal shape of the surface of these coatings in order to improve the sound absorption in decibels by taking into account the stakes and industrial constraints.

Quarter number

ST5

Prerequisites (in terms of CS courses)

The courses of ST5 and in particular the course "Theory and algorithmics for wave control" (one of two proposed trackes)

Syllabus

Teamwork simulated an "industrial company", definition of issues, bibliographic research, physical understanding and practical interest, mathematical modeling of the problem, development of the corresponding mathematical theory if necessary (the problem well or badly posed, regularity of the solution , derivation of acoustic energy with respect to the geometry of the wall, influence of choice of chosen porous material on the absorption of energy, ...), development / implementation of the numerical method, numerical analysis of the results , the analysis of their relevance, possible improvement, obtaining an effective shape for a large band of frequencies.

Class components (lecture, labs, etc.)
Teamwork, project, dialogue with various specialists in the field.

Grading
Report, final and intermediate deliverables, defense

Resources
Connection to a cluster at the distance

Students will perform modeling, simulation, visualization and rendering of the chosen phenomenon. They will study the simulation chain with a goal of performance and precision under economic constraints (manufacturing cost) and environmental (gain in decibel or potential).

Deliverables: report, software, transparencies and defense

Learning outcomes covered on the course
Understand the contribution of geometry in the design and development of new products
Apprehend the theoretical and numerical techniques of acoustic wave control
Implement numerical methods to simulate acoustic wave propagation phenomena of large dimensions (internal problems and problems for a wide band of frequencies)
Validate the theoretical and numerical techniques of acoustic wave control
Confront students with the realization of a complex product by numerical simulation techniques

Description of the skills acquired at the end of the course

C1.1 Study a problem in its entirety, the situation as a whole. Identify, formulate and analyze a problem in its scientific, economic and human dimensions: study of the industrial, psychoacoustic and environmental interest for the determination of the constraints of the control problem, their implementations in the numerical method and the analysis of their sufficiency of theoretical point of view for the existence of optimal control.

C2.1 To have deepened a field or a discipline related to the basic sciences or sciences of the engineer: understanding and application of a mathematical theory in the context of development of an innovative product engineer.

C3.5 Propose new solutions / tools either in disruption or in continuous progress: using the scientific advancement of fundamental disciplines such as mathematics and physics (the use of the course) to propose a new solution to the defects of the existing noise barriers (present new findings and their analyzes of relevance and effectiveness).

C4.1 Thinking customer. Identify / analyze the needs, issues and constraints of other stakeholders, including societal and socio-economic: study of industrial, psychoacoustic and environmental interest for the determination of the constraints of the control problem.

C6.1 Identify and use the software necessary for his work on a daily basis (including collaborative work tools). Adapt your "digital behavior" to the context: use and development of a numerical code based on the existing parts.

C7.1 Convince on the merits. Be clear about the objectives and the expected results. Be rigorous about the assumptions and the approach. Structure your ideas and your argumentation. Highlight the created value. To convince while working on the relation to the other: by working in team the strategic choice is crucial to have good results of the project, to do it it is necessary to be able to convince the others; teamwork itself; the final defense before a multi-disciplinary jury.

C8.1 Teamwork / Collaboration: This is the general principle of IS.

C9.4 Demonstrate rigor and critical thinking in approaching problems from all angles, scientific, human and economic: validation and analysis of results obtained numerically.

2SC5793 – Control of electromagnetic pollution

Instructors: Frédéric MAGOULES, Anna ROZANOVA-PIERRAT, Dominique PICARD
Department: DOMINANTE - MATHÉMATIQUES, DATA SCIENCES
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description

We are positioning ourselves on the industrial stakes which impose the economic constraints and the technological constraints necessary to improve the existing products of the market, this in order to absorb the electromagnetic waves. As fields of application, we aim at the design / optimization of electromagnetic anechoic chambers. It is noted that the absorbent materials (there will be an anechoic chamber visit in the Bréguet building and eventially of Thales-Limours) for the electromagnetic waves are different dissipative materials for acoustic waves.

Quarter number

ST5

Prerequisites (in terms of CS courses)

The course "Engineering of waves" of the 1st year will be a plus.

The courses of ST5 and in particular the course "Theory and algorithmics for wave control" (one of two proposed trackes).

Syllabus

Team work "company", definition of issues, bibliographic research, physical understanding and practical interest, mathematical modeling of the problem, development of the corresponding mathematical theory if necessary (the problem well or badly posed, regularity of the solution , derivation of the electromagnetic energy with respect to the geometry of the wall, influence of the choice of the chosen porous material on the absorption of the energy, ...), development / implementation of the numerical method, the numerical analysis of the results , the analysis of their relevance, possible improvement, obtaining an effective form for a broad band of frequencies.

Class components (lecture, labs, etc.)
Teamwork, project, dialogue with various specialists in the field.

Grading
Report, final and intermediate deliverables, defense

Resources
Computer room

Students will perform modeling, simulation, visualization and rendering of the chosen phenomenon. They will study the simulation chain with a goal of performance and precision under economic constraints (manufacturing cost) and environmental (gain in decibel or potential).

Deliverables: report, software, transparencies and defense

Learning outcomes covered on the course
◦ Understand the contribution of geometry in the design and development of new products
◦ Understand the theoretical and numerical techniques of controlling electromagnetic waves
◦ Implement numerical methods to simulate phenomena of propagation of large electromagnetic waves (problems for a wide band of frequencies)
◦ Validate the theoretical and numerical techniques of the control of the electromagnetic waves
◦ Confront students with the realization of a complex product by numerical simulation techniques

ST5 – 58 – SYSTEMES COMPLEXES INDUSTRIELS ET CRITIQUES A LOGICIELS PREPONDERANTS

Dominante : Info&Num (Informatique et Numérique)
Langue d'enseignement : Français
Campus où le cours est proposé : Paris-Saclay

2SC5810 – Design and verification of critical systems

Instructors: Idir AIT SADOUNE
Department: INFORMATIQUE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 34,5
Quota :

Description

This course aims to address both the design and verification of complex and critical systems using techniques from Software Engineering. As the components of such systems are heterogeneous (i.e. both continuous for physical and discrete for software), the methodologies and tools presented in this course will be multiple and integrated into a development cycle framework. The idea is to start the analysis phase by using semi-formal tools (UML, SysML,...), often used in systems engineering to describe the structure of the system and its interactions, then to address in a scientific way the design and validation phases using formal techniques of software engineering (timed, stochastic and hybrid modeling, temporal logic, model-checking). The main objective of such an approach is to show, through the formal models obtained, that the system does what is expected of it while respecting the constraints imposed by the specifications and by the environment, or in the opposite case, to extract the states of the system that may call into question its correct functioning. In the latter case, the economic gain is very interesting and appreciable by the engineers who can correct the problems detected by the verification of the model before going to the stage of the implementation (programming).

Quarter number

ST5

Prerequisites (in terms of CS courses)

6. Information systems and programming
7. Algorithmics and complexity
8. Model representations and analysis

Syllabus

- Chapter 1 - Presentation of temporal logics: LTL, CTL (3h lectures and 6h tutorials).
- Chapter 2 - Timed Automata: Modeling and Verification (3h lectures and 6h tutorials).
- Chapter 3 - Stochastic Models: Modeling and Verification (3h lectures and 3h tutorials).
- Chapter 4 - Opening on Modeling and Verification of Hybrid Systems (1.5h lectures and 1.5h tutorials).
- Practical sessions (2 x 3h)

Class components (lecture, labs, etc.)

- 10,5h lectures
- 16,5h tutorials
- 6h Practical sessions

Grading

Final exam (1H30)

Resources

The contributors (speakers):

- Marc Aiguier, (Department of Computer Science)
- Idir Ait Sadoune, (Department of Computer Science)
- Paolo Ballarini, (Department of Computer Science)
- Lina Ye (Department of Computer Science)

Learning outcomes covered on the course

At the end of this course, the student will be able to:

- Model a critical software system by using different formal approaches (temporal logic, automata, timed automata, stochastic models, hybrid automata).
- Model a critical software system by taking into account different types of constraints (functional, non-functional, temporal, ...)

- Analyze in a scientific way the model of a critical software system using the techniques from Software Engineering (formal verification technique: model checking).
- Extract the states of a critical software system that can call into question its correct functioning.
- Validate the model of a critical software system (the system does what is expected of it).

Description of the skills acquired at the end of the course

- C1.1 - Examine a problem in full breadth and depth, within and beyond its immediate parameters, thus understanding it as a whole. This whole weaves the scientific, economic and social dimensions of the problem.
- C1.2 - Select, use and develop modelling scales, allowing for appropriate simplifying hypotheses to be formulated and applied towards tackling a problem.
- C1.4 - Design, detail and corroborate a whole or part of a complex system.
- C3.2 - Problematise assumptions and givens, overcome failure and make decisions.
- C3.6 - Evaluate the efficiency, feasibility and strength of the solutions offered.
- C6.3 - Conceive of, design, implement and authenticate complex software.

2SC5891 – Design of a safe signaling system for the railways

Instructors: Idir AIT SADOUNE
Department: DOMINANTE - INFORMATIQUE ET NUMÉRIQUE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description

The aim is to discover critical systems modeling activities in railway systems, by using the CLEARSY Safety Platform and by proving some safety properties.
During this project, several safety functions will be developed, implemented and improved, mainly using Boolean expressions. Such a system usually has hundreds or thousands of equations, it is understood that this project addresses only a subset of them.
Signaling system control is a risky activity since an error could allow:
- a train derailing.
- two trains colliding.
We will focus on the logical functions that allow a train to make a safe trip for the chosen route topology.

Quarter number

ST5

Prerequisites (in terms of CS courses)

- Design and verification of critical systems (the specific course of the ST)
- Modeling by using B method (to be done at the first day of this ST)

Syllabus

- - Modeling a critical system by using the B formal method, the Atelier B tool, and the Clearsy Safety platform.
- - Modeling a railway system.
- - Modeling and Verification of the safety properties of a railway system.

- - Generating a source code to be embedded in an electronic card from a B formal model.

Class components (lecture, labs, etc.)
Project over a week (9 half days)

Grading
- Students will be evaluated after a presentation of the obtained results (15 or 20 minutes).

Resources

- Atelier B, a tool enabling the operational use of B method. (https://www.clearsy.com/outils/atelier-b/)
- Clearsy Safety Platform (https://www.clearsy.com/outils/clearsy-safety-platform/).

Learning outcomes covered on the course

6. - Modeling a critical system using the B formal method.
7. - Modeling Safety properties in the railway systems.
8. - Verification of Safety properties by using theorem proving.
9. - Generating a source code to be embedded in an electronic card from a B formal model.

Description of the skills acquired at the end of the course

2. C1.1 - Examine a problem in full breadth and depth, within and beyond its immediate parameters, thus understanding it as a whole. This whole weaves the scientific, economic and social dimensions of the problem.
3. C1.2 - Select, use and develop modelling scales, allowing for appropriate simplifying hypotheses to be formulated and applied towards tackling a problem.
4. C1.4 - Design, detail and corroborate a whole or part of a complex system.
5. C3.6 - Evaluate the efficiency, feasibility and strength of the solutions offered.
6. C6.3 - Conceive of, design, implement and authenticate complex software.

2SC5893 – Intelligent system for automated control of air traffic

Instructors: Lina YE
Department: DOMINANTE - INFORMATIQUE ET NUMÉRIQUE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description

Safety-critical systems in the avionics field are subject to strict time and reliability constraints. Their development therefore requires engineering techniques that take these characteristics into account as early as possible in their life cycle. This EI is therefore interested in the design of models of intelligent systems to control air traffic and the verification of certain safety properties on these models. These systems are composed of highly interacting components that are parallel and synchronous. All these subsystems are subject to verification and testing to ensure their own functionality. For example, it is essential to demonstrate the absence of deadlock and the possibility for each to ensure correct operations compatible with their own time constraints.

Quarter number

ST5

Prerequisites (in terms of CS courses)

ST5: Industrial complex and critical systems with preponderant software

Syllabus

Based on the informal description of the safety-critical system, the students are asked to use a semi-formal modelling approach to capture and structure safety requirements and then to transform into a formal model (e.g., timed automata) before applying model-checking techniques for the formal verification purposes. An optional part is dedicated to develop a tool to detect a type of unrealistic scenarios in models, which can very often disturb the results of model checkers like UPPAAL.

Class components (lecture, labs, etc.)

One-week project integrating ST5 course content with demonstrative, active and discovery methods.

Grading
report and defense

Course support, bibliography

- Alur. Alur, R., Dill, D.L. A theory of timed automata. Journal of Theoretical Computer Science 126(2), page: 183–235, 1994
- Christel Baier and Joost-Pieter Katoen, Principles of Model Checking (Representation and Mind Series). TheMIT Press, 2008.
- Gerd Behrmann, Alexandre David, Kim Guldstrand Larsen. A Tutorial on Uppaal. Formal Methods for the Design of Real-Time Systems, International School on Formal Methods for the Design ofComputer, Communication and Software Systems, SFM-RT, page:200-236, 2004.
- Patricia Bouyer, Uli Fahrenberg, Kim Guldstrand Larsen, Nicolas Markey, Joël Ouaknine, James Worrell,Model Checking Real-Time Systems. Handbook ofModel Checking, page:1001-1046, 2018.
- Patricia Bouyer, François Laroussinie, Nicolas Markey, Joël Ouaknine, James Worrell, Timed Temporal Logics.Models, Algorithms, Logics and Tools, page: 211-230, 2017.
- Nicolas Navet and Stephan Merz, Modeling and Verification of Real-Time Systems (1st ed.). Wiley-IEEE Press, 2008.

Resources
WIFI, PROJECTOR
UPPAAL

Learning outcomes covered on the course
Students need to know and understand how to design a safety system with informal and formal approaches by ensuring safety requirements.

Description of the skills acquired at the end of the course
Students must be able to exploit their resources (e.g. their own knowledge), master the work environment, achieve goals by producing results and also develop self-help and sharing with others in the group.

2SC5894 – Production systems for "smart factories"

Instructors: Paolo BALLARINI
Department: DOMINANTE - INFORMATIQUE ET NUMÉRIQUE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description

Recent developments in manufacturing engineering lead to the formulation of dedicated new paradigms such as Industry 4.0 (Germany) and smart manufacturing (USA). The main idea behind these novel paradigms is that future production systems shall be capable to fullfil individual customer requirements by flexibly adapting the production outcome so to yield product variants in very small lot size. To this aim manufacturing systems must become "smart" hence consisting of intelligent machines, pieces and infrastuctures able to exchange and process information so that the production process adapts itself to the specific customer requirements. In this context modelling and performance analysis of production processes becomes fundamental. In this course we are going to focus on formal modelling and performance analysis of production processes whereby a number of fault-prone machines are arranged in a given topology to yield a given final product. We are going to analyse how relevant performance indicators are affected by different aspects of the production systems and so to study the impact that system's (re)configuration has on productivity.

Quarter number

ST5

Prerequisites (in terms of CS courses)

Students must have attended the course "Systèmes critiques" of ST5

Syllabus

Class components (lecture, labs, etc.)

Grading
Seminar

Resources
A tutorial room with WiFi connection

Learning outcomes covered on the course
Students will learn how to apply formal methods to the problem of modelling and performance analysis of a production system, i.e. a system composed by a network of fault-affected, repairable manufacturing machines that can be configurated adaptibly in response to market needs.

- developping stochastic models of production systems starting from a informal specifications
- taking into account fault injections in the production system model
- conception of relevant key performance indicators for analysing the performances of the production system (fault tolerance, availability, throughput, etc)
- execution of a complete performance analysis study based on model checking approaches

Description of the skills acquired at the end of the course
see "learning outcomes"

ST5 – 59 – ASSISTANCE ET AUTONOMIE DE LA PERSONNE

Dominante : VSE (Vivant-Santé-Environnement) et ENE (Energie)
Langue d'enseignement : Français
Campus où le cours est proposé : Metz

2SC5910 – Control of a motorization chain

Instructors: Jean-Louis GUTZWILLER
Department: CAMPUS DE METZ
Language of instruction: FRENCH
Campus: CAMPUS DE METZ
Workload (HEE): 60
On-site hours (HPE): 34,5
Quota :

Description

This course covers the necessary concepts to control a motorization chain in its electronic aspects (converters, power, power supply), servo control (modelling, observers, regulators) and digital (analog-digital conversion, programming, real-time). The practical aspects will be tested on microcontroller cards to concretely implement a speed control system of a DC motor.

Quarter number

ST5

Prerequisites (in terms of CS courses)

None

Syllabus

- DC motor
- DC-DC converters
- Mechanical modelling
- Synthesis of control laws (analog regulation and digital regulation)
- Non-linear regulation
- Microcontroller programming

Class components (lecture, labs, etc.)

12h of lecture, 6h of tutorials, 15h of labs and 1h30 for the final exam.
24 students for tutorial/labs groups

Grading

A written report on the practical work, to be given on the date indicated by the teacher, will be requested and a one-and-a-half hour individual exam will take place at the end of the course. The score of the individual examination will count for 60% and the score of the practical work report will count for 40% of the final grade. In case of absence, the standard penalty according to the regulations will be applied.

If the exam fails, a remedial exam will take place in the form of a one-and-a-half hour individual written exam.

Course support, bibliography
« Commande des entraînements à vitesse variable », handout.

Resources
Lectures will be given to present the main concepts.
Applications will be tested on electronic cards during tutorial courses.

Tutorial groups size : 24 students
Lab groups size : 24 students

Learning outcomes covered on the course
- Understanding how motors work
- Choose the characteristics and performances adapted to the problem
- Develop the command laws
- Mastering the servo systems

Description of the skills acquired at the end of the course

- C3.4 : Take decisions in an environment that may not be fully transparent, embracing the unexpected and calculating risk
- C3.6 : Evaluate the efficiency, feasibility and strength of the solutions offered. / proposed solutions
- C7.4 : Persuade by working on communication techniques. Master spoken, written and body language as well as basic communication techniques

2SC5990 – Motorized wheelchair for disabled person

Instructors: Jean-Louis GUTZWILLER
Department: DOMINANTE - VIVANT, SANTÉ, ENVIRONNEMENT, DOMINANTE - ENERGIE
Language of instruction: FRENCH
Campus: Metz
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description

This integration teaching, which is part of the thematic sequence "Assistance and autonomy of the person", deals with the concepts of how to operate an electric wheelchair for a paralyzed person. Such a chair has a joystick for controlling motors that actuate the wheels. The function of the chair must be as accurate and as fast as possible to respond to the users inputs. The mechanics, the electronics and the algorithms used for the control participate together to obtain the desired performances.

Quarter number

ST5

Prerequisites (in terms of CS courses)

Control of a motorization chain

Syllabus

Different topics will be proposed as:
- study and design of an electronic control board for electrical motors,
- study and design of the computer program to put in the microprocessor,
- study and design of connectivity with other objects (smartphone, internet),
- simulation of the mechanical behavior of the system in order to optimize the control ...

Class components (lecture, labs, etc.)

The students will choose, in groups of 3 to 5, one of the proposed topics. These topics will be dealt with during the project time (from Monday to Thursday) and an evaluation will be done on the last day (Friday).

Grading

Students will be required to provide a written report by group and will have to support their work with an oral presentation. The mark of the report will be 50% in the final mark for all the members of the group and the individual mark obtained at the oral presentation will also be 50% of the final mark.

Resources
Teaching will be in the form of a project during which students will have access to computer, electronic and mechanical equipment (depending on the subject of the project).

Learning outcomes covered on the course
At the end of this course, students will be able to:
- design a part of a motor control chain (depending on the chosen subject),
- pilot the realization of the device (give the manufacturer clear instructions for the realization of the device),
- write and test the computer programs necessary for the operation of the device.

Description of the skills acquired at the end of the course
C2.3 : Rapidly identify and acquire the new knowledge and skills necessary in relevant domains, be they technical, economic or other
C6.3 : Conceive, design, implement and authenticate complex software (level 2)
C7.1 : Persuade at core value level; be clear about objectives and expected results. Apply rigour when it comes to assumptions and structured undertakings, and in doing so, structure and problematise the ideas themselves. Highlight the added value (level 2)

ST5 – 60 – NAVIGATION SEMI-AUTONOME DE DRONES

Dominante : MDS (Mathématiques et Data Sciences)
Langue d'enseignement : ENGLISH
Campus où le cours est proposé : Metz

2SC6010 – Autonomous Robotics

Instructors: Jeremy FIX
Department: CAMPUS DE METZ
Language of instruction: ENGLISH
Campus: CAMPUS DE METZ
Workload (HEE): 60
On-site hours (HPE): 34,5
Quota :

Description

This course will present the field of autonomous robotics (driving of vehicles, robot of exploration and inspection, etc ...) by showing how this problem integrates very diverse technologies (localization (SLAM), clouds of points, planning, shape recognition) and how this integration is achieved at the system level (illustrations with ROS). The laboratory works associated with the course will be carried out on the robots at the disposal of the smartroom of the Metz campus and with a simulator. This work will be an opportunity to integrate different techniques of machine learning and signal processing on robots moving in their environment. The course and the practical applications will allow to discover these techniques in real cases, with the prospect of preparing for the more in-depth courses taught in the third year in the Science of Data and Information.

Quarter number

ST5

Prerequisites (in terms of CS courses)

1C1000 : Information systems and programming
1C4000 : Signal processing

Knowledge in probability theory will be helpful.

Syllabus

- Lecture 1 (1h30) : Introduction to autonomous robotics
- Lecture 2 (1h30) : Introduction to ROS and simulation, experiment on real robot
- *Introductory Lab (6h00) : Simulator, ROS and ROS advanced*
- Lecture 3 (1h30) : Reminders on probability
- Lecture 4 (1h30) : State estimation

- Tutorial1 (1h30) : Kalman Filter and state estimation
- Lab2 (1h30) : Kalman Filter and state estimation
- Lecture 5 (1h30) : Localization
- Tutorial2 (1h30) : Localization (Markov and Monte Carlo)
- Lab3 (3h00) : Localization (Markov and Monte Carlo)
- Lecture 6 (1h30) : Mapping and SLAM
- Lab4 (3h00) : Mapping and SLAM
- Lecture 7 (1h30) : Motion planning
- Lab 5 (3h00) : Deterministic and stochastic planning
- Lecture 8 (1h30) : Navigation
- Lab 6 (3h00) : Trajectory tracking and obstacle avoidance
- Lecture 9 (1h30) : Architecture and interaction
- Lab 7 (3h00) : Integration on a real robot

Class components (lecture, labs, etc.)

The course is organized around lectures complemented with tutorials and lab works for practicing the concepts. The lab works, with real or simulated robotic platforms, will specifically be the opportunity to implement the various concepts seen in the class. In order for the practicals to be as profitable as possible, they will be prepared in advance by the students with the help of a worksheet that will be sent to them. This implementation will heavily rely on ROS, which will be presented in details at the beginning of the course. Programming will be done in Python and all the experiments will run on Linux.

Grading

Written exam of 1h30 in duration.

Course support, bibliography

- Latombe, **Robot Motion Planning**, Kluwer Academic Publishers, 1991.
- Thrun et al., **Probabilistic Robotics**, MIT Press, 2005.
- Lavalle, **Planning Algorithms**, Cambridge University Press, 2006.
- Siegwart et al., **Introduction to Autonomous Mobile Robots**, MIT Press, 2011.
- Siciliano et al., **Springer Handbook of Robotics**, Springer, 2016.

Resources

Instructor : Francis Colas (INRIA)
Teacher assistant : Francis Colas, Jeremy Fix
Tutorial classes : 30 students, 1 teacher
Labworks : 2 x 15 students, 2 teachers
Softwares : Only open source softwares (Linux, Python, ROS, Gazebo)
Hardware : Turtlebots equiped with a LIDAR (x6)

Lab works : The computers in the labs will have all the softwares pre-installed

Learning outcomes covered on the course

- Know the different components of an autonomous robotic system
- Conduct robotics experiments with ROS on simulated or real robots
- Mathematically stating a state estimation problem
- Implement and test algorithms for state estimation, localization, navigation, planning

Description of the skills acquired at the end of the course

C1.3, Jalon 2B : Apply problem-solving through approximation, simulation and experimentation. Solve problems using approximation, simulation and experimentation

C1.4, Jalon 2 : Design, detail and corroborate a whole or part of a complex system.

C3.6 : Evaluate the efficiency, feasibility and strength of the solutions offered/proposed solutions

2SC6090 – Semi autonomous UAV indoor navigation

Instructors: Jeremy FIX, Herve FREZZA-BUET
Department: DOMINANTE - MATHÉMATIQUES, DATA SCIENCES
Language of instruction: ENGLISH
Campus: CAMPUS DE METZ
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description

The students will work on issues related to the technical inspection of indoor environments by UAVs (visual and thermal diagnosis). They will thus provide answers to needs in terms of improving energy performance and detecting possible damage, in particular allowing significant savings for the considered sites.

During this week of practicals, the focus is on helping a human operator by automating drone control as much as possible and providing the operator with a high level of logical control. The students will have implemented servoing techniques with the particularity of including a human operator in the control loop. They will also have integrated machine learning and pattern recognition techniques for the interpretation of information flows from the embedded sensors (mainly video). This is a first contact, through the application and experimental side, with the field of machine learning.

Through this experience, they will have acquired a more general competence in the design of robotic systems with ROS.

Quarter number

ST5

Prerequisites (in terms of CS courses)

Students should be comfortable with Linux/Ubuntu, ROS and OpenCV.
These prerequisites will be taught during the thematic sequence with which this practical is associated.

Syllabus

The practical is divided into three main modules. The first module deals with 1) the low level control loop regulating roll/pitch angles and upward and rotational speeds and 2) some higher level controls (U-turn, translation along an axis). The second module focuses on the management over time of direct behaviors (linear/angular speeds) and logical behaviors (taking the door to the left, moving into the corridor). The third module includes all the image processing functionalities (detection of vanishing lines, calculation of optical flow, etc.). These three modules are further divided with a finer granularity so that the students can parallelize the work.

Class components (lecture, labs, etc.)
- Presentation of case studies by industrial partners
- Designing solutions to proposed problems
- Development of proposed solutions in a real environment
- Implementation on real drones and possible adjustment of solutions
- Presentation/Demonstration of solutions to industrial partners

Grading
Students will present their work during an oral presentation with the opportunity to demonstrate their solutions. A mini-report, a collection of experimental results, accompanies the presentation. The grade will be half based on the work of the group and half based on the individual work. The grade of the group will consider the overall results obtained by the group and the defense. The individual grade will consider the involvement and the progress of each student individually on the assigned subtasks.

Resources
Instructor : Hervé Frezza-Buet, Jérémy Fix
Student groups: 5 students
Softwares : Only open source softwares (Linux, Python, ROS, Gazebo-Sphinx)
Hardware: Each group of students will have one bebop2 (lent by Parrot), a joystick, and a laptop
Lab works : The computers in the labs will have all the softwares pre-installed

Learning outcomes covered on the course
- Be able to carry out an ambitious project from start to finish
- Working as a team
- Split the work of a project into subtasks
- Experiment with real robotics platform
- Carry out a software project combining robotics, signal processing and computer science

Description of the skills acquired at the end of the course
C1.3, Jalon 2B : Apply problem-solving through approximation, simulation and experimentation. Solve problems using approximation, simulation and experimentation
C1.4, Jalon 2 : Design, detail and corroborate a whole or part of a complex system.
C3.6 : Evaluate the efficiency, feasibility and strength of the solutions offered/proposed solutions

ST5 – 61 – SMART PHOTONICS SYSTEMS FOR CONTROL AND MEASURE

Dominante : PNT (Physique et NanoTechnologie), SCOC (Systèmes Communicants et Objets Connectés)
Langue d’enseignement : ENGLISH
Campus où le cours est proposé : Metz

2SC6110 – Photonics for the control of physical systems

Instructors: Nicolas MARSAL
Department: CAMPUS DE METZ
Language of instruction: ENGLISH
Campus: CAMPUS DE METZ
Workload (HEE): 60
On-site hours (HPE): 34,5
Quota :

Description

This course will teach the basic knowledges of the measurement and exploitation of the physical quantities of optical electromagnetic waves, in the context of the exploitation of photonics for the observation and control of physical systems.
It will focus on:

- Optical metrology
- Photonic technologies including semiconductor materials and optical fibers, phase and intensity modulation
- Signal analysis exploiting in particular the non-linear dynamics of a physical system
- Properties and regulation of non-linear systems

Quarter number

ST5

Prerequisites (in terms of CS courses)

Basic knowledge of electromagnetism, materials, electricity and electronics.

Syllabus

- Optical measurement and instrumentation: generalities in metrology and error analysis, photometry, and optical detectors, holographic metrology, velocimetry, interferometry.
- Laser source technologies: additions to solid state physics, materials and semiconductors.
- Modeling and control of sources: analysis and non-linear dynamics of laser sources.
- Generation of optical signals: spatial and temporal modulation techniques of optical signals; engineering and optical beam design.

Class components (lecture, labs, etc.)
30h00 lectures and 3h00 practical exercices

Grading
Oral presentation at the end of the course on the basis of a group presentation of 2 to 3 students (the mark will be individual). 1.5h.

Resources
Lecturers: Delphine Wolfersberger, Marc Sciamanna, Nicolas Marsal, Damien Rontani

Learning outcomes covered on the course
Thanks to this course, students will learn the physical quantities and tools which allow to spatially characterize optical beams, to analyze their frequencies, to modulate their intensities, their phases to guide them in different physical systems (fiber, waveguide ...)
They will see the linear and non-linear dynamics associated with those beams when they propagate in different materials and / or physical systems.
Thanks to this course and in addition to the EI, the student will be able to physically design a LIDAR, to test its performance and to compare it with other equipment used in optical metrology.

Description of the skills acquired at the end of the course

C1.1 Examine problems in their entirety and beyond their immediate parameters. Identify, formulate and analyse the scientific, economic and human dimensions of a problem
C1.2 Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when addressing a problem
C1.3 Apply problem-solving through approximation, simulation and experimentation. / Solve problems using approximation, simulation and experimentation

2SC6190 – Laser remote sensing (LIDAR)

Instructors: Marc SCIAMANNA, Delphine WOLFERSBERGER
Department: DOMINANTE - PHYSIQUE ET NANOTECHNOLOGIES
Language of instruction: ENGLISH
Campus: Metz
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description

This EI is based on the use of lasers as tools to control the infinitely small and the ultra-fast for, in particular, applications in the field of optronic surveillance and target detection. It is proposed to develop an innovative control-command solution for the generation of ultrashort laser pulses and the implementation of a photonic system whose intended application is laser telemetry (LIDAR: laser radar). These "lidars" have enormous potential for defense, the environment, security: mobile identification, gas detection, active imaging, ... The detection and identification of danger or targets is a key element of the defense and security systems , and are key elements for example devices developed by AIRBUS for civil aviation or simulation of laser shooting for the training of the armed forces.

Quarter number

ST5

Prerequisites (in terms of CS courses)

None

Syllabus

The students will be divided into different groups each performing 4 practical works.
Practical Work Proposal:
1 / a session on the emitting laser: realization and characterization of a laser transmitter regulated in temperature so as to maintain its constant power
2 / a session on the generation of a laser pulse: study of the generation of a laser pulse via the use of an optical feedback loop
3 / a session on the shaping of the laser beam: shaping of the laser beam via the appropriate optics and / or via the use of a spatial light modulator (SLM) allowing ultimately the use of beams not Conventional (ex bundles of

Airy)
4 / a session on the receiver: development of the device for receiving and analyzing the optical signal
These 4 sessions will be followed by a session on the synthesis of the different experiments for the realization of a telemetry device and possibly the development of the servo system necessary for the laser signal to reach the target.

Class components (lecture, labs, etc.)
Experimental and digital realization in team in the form of a challenge

Grading
Oral presentation in front of CS professors and industrial partner Airbus GDI Simulation

Resources
optical set-ups
Pedagogical Team : Delphine Wolfersberger - Marc Sciamanna - Nicolas Marsal - Damien Rontani

Learning outcomes covered on the course
Recent advances in the generation of unconventional optical beams will make it possible to explore new beam topologies (eg Airy beams: non-diffracting, curvilinear trajectory, self-regenerating in the event of obstacles) that pave the way for an improvement. performance (spatial resolution, speed, etc.). Through this EI, students will apply:
i / understanding of essential physical quantities related to an optical electromagnetic wave
ii / design and realization of a photonic slave system
iii / numerical simulation of the optical system
iv / innovative optical beam engineering by exploiting spatial and temporal modulation techniques of signals
v / to be able to make a choice of devices to answer an economic problem of sizing and energy consumption.

Description of the skills acquired at the end of the course
C1 Analyze, design and build complex systems with scientific, technological, human and economic components
C2 Develop in-depth competence in a scientific or sectoral field and a family of trades
C8 Leading a project, a team

ST5 – 62 – INTELLIGENCE ENERGETIQUE ET SMART BUILDING

Dominante : GSI (Grands Systèmes en Interaction) et SCOC (Systèmes Communicants et Objets Connectés)
Langue d'enseignement : ENGLISH
Campus où le cours est proposé : Rennes

2SC6210 – High energy performance communications

Instructors: Yves LOUET
Department: CAMPUS DE RENNES
Language of instruction: ENGLISH
Campus: CAMPUS DE RENNES
Workload (HEE): 60
On-site hours (HPE): 34,5
Quota :

Description

ICT (Information and Communication Technologies including base stations, data centers, user equipment's, etc.) field is responsible of 6 to 10% of the worldwide electrical consumption what corresponds to 4% of the greenhouse gases emissions. With an early growth of 7% especially with the coming 5G and the expected increase of billions of connected "things", it is urgent to reduce this footprint by finding new ways of transmitting, processing and saving data. That is to say spectral efficiency (ie transmit the maximum data in a given bandwidth) have to be joined with the objectives to increasing the energy efficiency of the links. To do so the milestones of this courses are:

- Make the audience aware of the ICT footprint
- Explain with is power consuming in ICT and where are the potential gains
- Draw the communications chain (transmitter, channel, receiver) with the key parameters which come into play (bandwidth, data bit rate, power, link budget, etc.). Explain the role of the key components (coding, modulation, filtering, etc.).
- Put in light one of the most dimensional factor : constant or no-constant envelope signal Continuous Phase Modulation (CPM) modulation format with constant envelope (MSK, GMSK, FSK, OQPSK, ….) and their associated receivers
- The associated standards (mobile communications, Bluetooth, IoT, aeronautical communications, etc.).
- compare the linear and non linear modulations

Quarter number
ST5

Prerequisites (in terms of CS courses)
Most of the prerequisites of this course fit with the topics covered in the 1A course entitled "Signal Processing" (1CC4000). In particular :

- deterministic modelisation of signals
- power, energy, correlation
- Fourier transform and spectral representation of signals
- spectral analysis
- filtering and convolution
- sampling of signals and aliasing
- Discrete Fourier Transform

Syllabus
Syllabus:

1. Introduction : ICT footprint

a. The networks
b. The user equipment’s

2. Linear modulations

a. Bit to symbol coding
b. Symbol to signal coding : waveform filtering : intersymbol interferences
c. Spectrum density
d. Examples of standards

3. Linear modulations

a. CPM (FSK, MSK, GMSK, OQPSK, etc.)
b. Receivers architectures
c. Examples of standards

4. Comparison between linear / non linear modulations

a. Spectrum sefficiency
b. Energy efficiency
c. Bit error rate performance on AWGN channel

Class components (lecture, labs, etc.)
Regarding the HPE (Heures Présentiel Elèves), the course is divided into three part:

- 18 hours of lectures
- 4,5 hours of tutorials classes
- 10,5 hours of laboratory classes

Furthermore, 25,5 hours of personnal works are scheduled. This course will be evaluated by a 1,5 hours exam. The Professors are Yves Louët (head of the course), Haïfa Fares and Georgios Ropokis.

Grading
This course will be evaluated by :a score related to laboratory classes reports (weighted 0.2)a score of a 1h30 exam duration (weighted 0.8)

Course support, bibliography
[1] J. B. Anderson, T. Aulin, and C.-E. Sundberg, Digital Phase Modulation. New York: Plenum Press, 1986.
[2] L. H. J. Lampe, R. Tzschoppe, J. B. Huber, and R. Schober, “Noncoherent Continuous- Phase Modulation for DS-CDMA,” in Communications, 2003. ICC ’03. IEEE International Conference on, vol. 5, pp. 3282–3286 vol.5, May 2003.
[3] M. Mouly and M.-B. Pautet, The GSM System for Mobile Comm.. Telecom Publishing, 1992.
[4] M. K. Simon, Bandwidth-Efficient Digital Modulation with Application to Deep-SpaceCommunications. John Wiley & Sons, 2005.
[5] Reducing the Energy Consumption of Photonics Hardware in Data Center Networks Authors: Richard Penty, Jonathan Ingham, Adrian Wonfor, Kai Wang, Ian White Richard Penty, Core Switching and Routing Working Group Adrian Wonfor, Green Touch, 2012

Resources
Regarding the HPE (Heures Présentiel Elèves), the course is divided into three part:

- 18 hours of lectures
- 4,5 hours of tutorials classes
- 10,5 hours of laboratory classes

Furthermore, 25,5 hours of personnal works are scheduled. This course will be evaluated by a 1,5 hours exam. The Professors are Yves Louët (head of the course), Haïfa Fares and Georgios Ropokis.

Learning outcomes covered on the course
At the end of this course, the student will be able to:

- evaluate the carbon footprint of the ICT (Information and Communication Technology) domain
- identify the most energy consuming processings and devices to transmit information
- argue about the most appropriate choice of parameters for a transmission according to the needs
- simulate a high energy efficiency radio transmission and establish its performance
- evaluate the trade-off between spectral efficiency (for high bit rate) and energy efficiency (energy saving) for a given transmission
- justify the use of high energy efficiency waveforms in some contexts (Internet of Things, low bit rate transmissions, autonomy, ...)

Description of the skills acquired at the end of the course
C1.1 Examine a problem in full breadth and depth, within and beyond its immediate parameters, thus understanding it as a whole. This whole weaves the scientific, economic and social dimensions of the problem
C1.3 Apply problem-solving through approximation, simulation and experimentation
C2.4 Create knowledge within a scientific paradigm.
C6.1 Identify and use the necessary software for one's work (including collaborative tools) and adapt digital responses as appropriate to the context.
C6.6 Understand the digital economy
C9.3 Act ethically, with integrity and respect for others.
C9.4 Demonstrate rigour and critical thinking in approaching problems from all angles, be they scientific, social or economic.

2SC6290 – Hierarchical control of thermal comfort

Instructors: Hervé GUEGUEN, Romain BOURDAIS
Department: DOMINANTE - SYSTÈMES COMMUNICANTS ET OBJETS CONNECTÉS, DOMINANTE - GRANDS SYSTÈMES EN INTERACTION
Language of instruction: ENGLISH
Campus: Rennes
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description

The building must no longer be considered as a simple consumer but as a real energy actor perfectly integrated into its ecosystem. It must be fully integrated into a renewed vision of society, where comfort and health are in harmony with energy management. This requires rethinking the systems through new steering functions and stronger interactions with occupants. The "building" ecosystem is complex, because it consists of a heterogeneous set of systems: local production, storage, supply, sale, and the various equipment, which must be coordinated for optimized management.
The challenges facing the engineers are first the analysis of needs and the specification of intelligent control systems. This design is based on the integration of control algorithms deployed on communicating systems to achieve an optimal compromise between technology - cost - efficiency, such as closed loop performance, communication frequency and protocol, sensor autonomy and actuator life.

The objective is to define a modular system, allowing to implement hierarchical control strategies between a local regulation of comfort by zone and a supervisor managing the intermittency of the occupation, the limitation of available power in order to minimize the consumption related to thermal comfort. The challenges induced by this project are the consideration of societal issues (human, comfort and energy efficiency), technical constraints (power limitation, ease of implementation and robustness of the solution) and technologies allowing implementation. The different groups will have to work together to address the different aspects of the project and result in a proof of concept implementation.

Quarter number
ST5

Prerequisites (in terms of CS courses)
Automatique (commun course 2A)

One of the 2 courses:

- High Energy Performance Communications
- System Architecture and Modeling

Syllabus
This course is built from a simulator/emulator of the thermal behaviour of a building, whose meteorological data and conditions of use are taken from data from the city of Rennes.

The energy manager that the students will have to build will have to be implemented and validated in the simulator.

Class components (lecture, labs, etc.)
The pedagogical activity alternates between working together and working in mini-groups to arrive at a collective proposal at the end of the week.

Grading
The activity will be evaluated during the various daily points and during the final presentation.

Resources
A room, equipped with different computers, input/output acquisition cards, is available for students. Arduino cards and various communication objects will be provided by the digital communication research team of the campus. This integration teaching is supervised by 3 teacher-researchers from the school with complementary skills (System modeling, control system and digital communications).

Learning outcomes covered on the course
At the end of this teaching, the students will be able:
- to implement a collaborative control law and to validate it by simulations
- to design a communication protocol between connected objects and to experimentally validate it
- to present a technological solution and to valorize it from a technical-economic point of view

Description of the skills acquired at the end of the course

C1.1 : Examine a problem in full breadth and depth, within and beyond its immediate parameters, thus understanding it as a whole. This whole weaves the scientific, economic and social dimensions of the problem.

C1.4 : Design, detail and corroborate a whole or part of a complex system.

C3.6 : Evaluate the efficiency, feasibility and strength of the solutions offered.

C8.1 : Work collaboratively in a team.

ST5 – 63 – SYSTEMES INTELLIGENTS ET EMBARQUES POUR LA SANTE

Dominante : GSI (Grands Systèmes en Interaction), VSE (Vivant-Santé-Environnement) et SCOC (Systèmes Communicants et Objets Connectés)
Langue d'enseignement : Français
Campus où le cours est proposé : Rennes

2SC6310 – System Architecture and Modeling

Instructors: Hervé GUEGUEN, Nabil SADOU
Department: CAMPUS DE RENNES
Language of instruction: FRENCH
Campus: CAMPUS DE RENNES
Workload (HEE): 60
On-site hours (HPE): 34,5
Quota :

Description

Modern systems are becoming more and more complex. This complexity results from the interaction between their components, the increase and complexity of the exchanged data, the heterogeneity of concepts, substances, trades, standards, but also from human complexity (organization, ergonomics, psychology, sociology ...).
To better handle this complexity, it is often necessary to model the different artifacts of the system. This modeling allows stakeholders at different phases of the system's life to better understand its objectives, to structure its architecture, to make analyses to predict its behavior, and thus to make a justified choice between alternatives. The various models constitute a reference for all stakeholders involved in the system design.
Thus, the objective of this course is to provide students techniques and tools for modeling and structuring system architectures. Technological systems will be privileged with fields such as avionics, railway, industry, energy, or health. Moreover, the emphasis will be made in identifying system performance attributes (critical SPI system performance indicators) that need to be monitored to design, implement, operate, or manage complex systems.

Quarter number

ST5

Prerequisites (in terms of CS courses)

none

Syllabus

1. Introduction to system modeling
2. Stakeholders' needs and requirements modeling
3. System architecture structuring and modeling
4. Behavioral modeling and composition

5. Choice of structure
6. Technical solutions modeling and trade-off

Class components (lecture, labs, etc.)
Lectures, exercises, case study

Grading
written exam (1h30) (50%) and regular testing (50%)

Resources
lectures, exercises, case study

Learning outcomes covered on the course
By the end of this course, students will be able to :
- Design and implement system modeling (Observe, Define the system, Propose a formal model, Analyze and Exploit the results)
- Understand the concepts of system structure (components, hierarchies, and decomposition principles) with a particular focus on the interactions between the elements of a system (causal or non-causal, synchronous, or asynchronous, information or energy exchange interfaces, etc.).
- Understand and analyze interactions to accurately organize the architecture of a system to facilitate its modularity and future evolutions.
- Deploying the various techniques of behavioral modeling of a system to predict its behavior.

Description of the skills acquired at the end of the course

- C1.1Examine a problem in full breadth and depth, within and beyond its immediate parameters, thus understanding it as a whole. This whole weaves the scientific, economic, and social dimensions of the problem.
    - C1.1 Study a problem as a whole, the situation as a whole. Identify, formulate and analyze a problem in its scientific, economic and human dimensions
    - C1.2Select, use, and develop modeling scales, allowing for appropriate simplifying hypotheses to be formulated and applied towards tackling a problem.
- C8 Leading a project, a team
    1. C8.1 Work collaboratively in a team.

2SC6390 – Smart system for personalized blood glucose control

Instructors: Marie-Anne LEFEBVRE
Department: DOMINANTE - VIVANT, SANTÉ, ENVIRONNEMENT, DOMINANTE - SYSTÈMES COMMUNICANTS ET OBJETS CONNECTÉS, DOMINANTE - GRANDS SYSTÈMES EN INTERACTION
Language of instruction: FRENCH
Campus: CAMPUS DE RENNES
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description

The objective is to offer a blood glucose regulation support system for diabetic patients;

This system must address various issues: operational safety and ease of use for the patient, digital integration of control algorithms, ability to interact with control elements (subcutaneous blood glucose sensor, micro insulin delivery pump,...) via various communication protocols and low energy cost;

It must allow local interaction with the patient and remote interaction with a doctor for the monitoring of biomedical data.

Quarter number

ST5

Prerequisites (in terms of CS courses)

Modeling
Information systems and programming

Syllabus

Understanding the issue
Definition of requirements (safety, comfort,...)
Definition of the functional and physical architecture of the control system
Modeling and study of a corrector
Study of the embedded integration of the corrector

Study of the aspects of patient interface and communication with the embedded controller
Integration and Validation
Synthesis

Class components (lecture, labs, etc.)
Work in groups of 5-6 students

Grading
Summary notes, Final defense and demonstration

Learning outcomes covered on the course
Students will be able to:

- Apply the principles of a system analysis methodology

- analyze and carry out the integration of a real time regulation

- have programming bases for the sofware components dedicated to embedded systems, and for their inter-communication

Description of the skills acquired at the end of the course
C1.2 Identify, formulate and analyse a problem in its scientific, economic and human dimensions
C3.7 Evaluate the effectiveness, feasibility and robustness of the proposed solutions
C6.4 Specify, design, build and validate complex software
C8.1 Teamwork / Collaboration

ST5 – 64 – MODELISATION ET CONCEPTION D'UN SYSTEME DE SUPERVISION DE CAPTEURS

Dominante : Info&Num (Informatique et Numérique) et SCOC (Systèmes Communicants et Objets Connectés)
Langue d'enseignement : Français
Campus où le cours est proposé : Rennes

2SC6410 – Data models and design schemas

Instructors: Jean-Francois LALANDE
Department: CAMPUS DE RENNES
Language of instruction: FRENCH
Campus: CAMPUS DE RENNES
Workload (HEE): 60
On-site hours (HPE): 34,5
Quota :

Description

This course allows to discover the necessary notions for building software that manipulate large quantities of data. It learns the object oriented programming using two languages, Java and Scala. It then present the methologie of software design with a link with the course of system modeling that introduce the different activity diagrams (activities, sequence, blocks, etc.). The course helps students to wonder about the structure of software when using different design patterns.

In a second part, the course forcuses on the data manpulation. The goal is to learn the basic about database software and the theoritical problems behing them (data structuration, requests). Finally, if times allows, this part concludes with a presentation of software that helps to implement object-relation mapping.

Quarter number

ST5

Prerequisites (in terms of CS courses)

10. Information System and Programming
11. Algorithms and complexity

Syllabus

Object oriented programming (Java/Scala)

- Inheritance, encapsulation, polymorphism, dynamic dispatch
- Generiity, covariance, contravariance, invariance

- Fonctions and anonymous classes
- Types and type inference

Lab: discovering of the languages and illustrating the course notions
Personal work: go further with reflexivity, serialisation, Java NIO, JNI, Garbage collector

Software engineering

- Historical methods: V cycle, spiral circle, tests
- UML diagrams: using diagrams seen in "System Models" (use case, sequence, classes, state transition)
- Test and continuous integration

Relational databases

- Relational algebra
- Database design, normalization
- SQL language, requests, indexing
- Optimizing requests

Introduction to design patterns

Class components (lecture, labs, etc.)
34.5 HPE: 12h of course, 3h of exercices, 18h of practical labs, 1,5 Exam

Grading
Final exam: 1h30 : 50 % Continuous control: TL software engineering, by pairs of students: 15 min of presentation, 10 minutes of questions : 50%. In case of a justified absence to one of the intermediary examinations, the grade of this latter is replaced by the grade of the final examination.

Resources
Computer labs;

- Eclipse, IntelliJ
- Database software

Learning outcomes covered on the course

- Do object oriented programming
- Choose correctly the adequate design patterns
- Know how to manipulate data in a database
- Modelise with an object-relation mapping

Description of the skills acquired at the end of the course

C1.2 Use and develop adapted models, chose the righ model scale and the hypothesis for tackle the problem

C6.4 Specify, develop, and validate a complex software

2SC6490 – Development of a sensor monitoring system

Instructors: Jean-Francois LALANDE
Department: DOMINANTE - SYSTÈMES COMMUNICANTS ET OBJETS CONNECTÉS, DOMINANTE - INFORMATIQUE ET NUMÉRIQUE
Language of instruction: FRENCH
Campus: CAMPUS DE RENNES
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description

In partnership with a company (for example, an ESN present locally) and in collaboration with the students of the "Smart Building" and "Health" STs, the objective is to develop the information system that will enable the collection and processing of data from sensors, and to provide services for the regulation. The industrial partner will provide expertise on the appropriate technological choices for the development of the system on the one hand, and on the other hand, guide the students in setting up an AGILE organization. The educational objective is to perceive the interest of design choices to facilitate the software evolution, and the benefits of an AGILE organization.

Quarter number

ST5

Prerequisites (in terms of CS courses)

- Information System and Programming
- Algorithm and complexity

Syllabus

From a technical point of view, we will aim to develop by a team a complete infrastructure for collecting, processing and displaying data from sensors. Data from other project groups in other STs will pushed and hosted on a local server but will then be pushed onto a cloud-like infrastructure. At this stage, no treatment is performed. The data is then re-extracted and can be processed to be projected into a final data model suitable for presentation. This data will be stored in a database to be implemented by the development team. This data is then presented via a REST API to the part of the team developing the application frontend.

Class components (lecture, labs, etc.)
Students will be divided into a project team organized around a project leader (which can change every day). At the beginning of the day, each project team will be given features to be provided at the end of the day. In addition, every day, minor improvements will have to be made in order to respond as quickly as possible to the needs expressed by students from other STs during a meeting bringing together all the ST students concerned.

To support the EI, it is expected:

- a computer room that can accommodate up to 25 people
- access to a Cloud Computing infrastructure
- possible VPNs to connect the different software components

Grading
Oral presentation

Resources

- computers
- sensors for testing and from other STs

Learning outcomes covered on the course

- Understand and model the client requests
- Implement as a team a solution answering the client requests

Description of the skills acquired at the end of the course

- C4.1 Think in client terms, identify and analyse customer needs, the constraints of other stakeholders as well as include societal challenges.
- C8.4 Work using project management techniques appropriately tailored to the situation.

SCIENCE AND ENGINEERING CHALLENGE N°7 COURSES

ST7 – 71 – MODELISATION MATHEMATIQUE DES MARCHES FINANCIERS ET GESTION DES RISQUES

Dominante : MDS (Mathématiques, Data Sciences)
Langue d'enseignement : ENGLISH
Campus où le cours est proposé : Paris-Saclay

2SC7110 – Stochastic Finance and risk modelling

Instructors: Loane MUNI TOKE
Department: MATHÉMATIQUES
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 34,5
Quota :

Description

This course is an introduction to financial mathematics in discrete time, with a focus on derivatives pricing/hedging and risk measures in a discrete-time stochastic framework.

Quarter number

ST7

Prerequisites (in terms of CS courses)

1st year Mathematics and Computer Science courses (CIP, EDP, Algo et complexité, Statistiques)

Syllabus

Stochastic calculus in discrete time. Introduction to financial derivatives. Financial market modelling in discrete time. Towards continuous time and the Black-Scholes model. Risk measures. Porfolio optimization.

Class components (lecture, labs, etc.)

Lectures (18h), tutorials (9h) and labs (6h)

Grading

Labs (25%) and final exam (75%). In case of a justified absence to one of the intermediary examinations, the grade of this latter is replaced by the grade of the final examination.

Course support, bibliography

Jacod, J., & Protter, P. (2012). *Probability essentials*. Springer.
Föllmer, H., & Schied, A. (2011). *Stochastic finance: an introduction in discrete time*. Walter de Gruyter.
Shreve, S. (2005). *Stochastic calculus for finance I: the binomial asset pricing model*. Springer.
Lamberton, D., & Lapeyre, B. (2000) *Introduction to Stochastic Calculus Applied to Finance*. Chapman and Hall.

2SC7190 – Risk Management on financial markets

Instructors: Loane MUNI TOKE
Department: DOMINANTE - MATHÉMATIQUES, DATA SCIENCES
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 80
On-site hours (HPE): 48
Quota :

Description

Students enrolled in this course are asked to solve an optimization problem in a financial risk management setting. Subjects are proposed by an industrial or academic partner.

Quarter number

ST7

Prerequisites (in terms of CS courses)

Stochastic Finance and Risk Modelling (ST7 MDS)

Syllabus

Each project includes the study of a research article on risk management, e.g., pricing or hedging of a financial product, or management of an investment portfolio. Real market data is provided by the project partner. Each project requires the coding of the proposed solution.

List of 2020 subjects (may differ in 2021):

- Optimal portfolio allocation (in partnership with BNP Paribas)
- Optimization for insurance products (in partnership with Generali)
- Hybrid portfolio optimization (in partnership with Volga Technologies)

Class components (lecture, labs, etc.)

Project with regular supervision. Short lectures if needed.

Grading

Source code, technical report and oral presentation

ST7 – 72 – OPTIMISATION DE L'INFRASTRUCTURE DES RESEAUX POUR LES VILLES INTELLIGENTES

Dominante : SCOC (Systèmes Communicants et Objets Connectés)
Langue d'enseignement : ENGLISH
Campus où le cours est proposé : Paris-Saclay

2SC7210 – Optimization of network infrastructures

Instructors: Mohamad ASSAAD
Department: TÉLÉCOMMUNICATIONS
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 34,5
Quota :

Description

This course gives an overview of the emerging problems in telecommunications networks to answer the problematic of smart cities (e.g. information gathering and routing, traffic offload in the network, etc.). This course hence explains concepts related to the optimization of the network infrastructure and presents the required mathematical tools. In particular, the course focuses on the fundamental principles of Game Theory and explains how it can be used to optimize the performance and functions of network infrastructures in smart cities.

Quarter number

ST7

Prerequisites (in terms of CS courses)

Signal processing, communication networks, optimization.

Syllabus

- General introduction
    - smart cities and game theory
    - Game theory: normal and extensive form
    - Decision and solution concepts (rationality, Nash equilibrium, etc)
    - Correlated Equilibria
- Different Game types and application to the problems of smart cities
    - Zero sum and non zero sum games
    - Finite games and mixed strategies
    - Routing games

    - Revolutionary games
    - Repeated games
    - Stable Matching: stable marriage games
- Case Study: Application to smart charging problems, application to frequency allocation in wireless networks

Class components (lecture, labs, etc.)

Organization of the lectures

- General Introduction: 6h CM + 1.5 TD
- Different types of games (zero sum, routing, etc.): 9h CM + 7.5h TD
- Case study: 3h CM

Grading

- Homework (25%) - Final Exam (75%) - 1.5h

Course support, bibliography

- Rida Laraki, Jérôme Renault, Sylvain Sorin, Bases Mathématiques de la Théorie des Jeux, Ecole Polytechnique, 2013.

-E. Altman, Advances in Dynamic Games and Applications, 2013

- D.Bertsekas and J. Tsitsiklis, Parallel and Distributed : Numerical Methods, athena scientific, 2015.

- D. Bertsekas and R. Gallager, Data Networks, Prentice Hall.

- Chen, C., Zhu, S., Guan, X., Shen, X.S, Wireless Sensor Networks : Distributed Consensus Estimation, Springer, 2014.

- G. Ferrari, Sensor Networks : Where Theory Meets Practice, Springer-Verlag, 2009.

- Recent papers on IoT, smart cities and wireless networks.

Resources

Lecturers: Mohamad Assaad (CS), Mikael Touati (Orange Labs)

Exercices sessions (TD): 25 students per classroom

software to use: Matlab

Learning outcomes covered on the course
At the end of the course the student will be able to :

1- know the emerging problems in telecommunications networks for smart cities
2- model a network in the context of smart cities with its main functions
3-formulate emerging problems in smart cities using distributed optimization and tools from Game Theory
4-know the tools of games theory used in optimizing the performance and function of network infrastructures in smart cities
5-implement game theory algorithms in Matlab

Description of the skills acquired at the end of the course
C1.1: "be able to make the list of parameters that impact the studied system, the list of elements with which it is in relation" and "know how to identify the important parameters with respect to the problem posed"
C1.2: "Know how to use a model presented in class in a relevant way. Make the choice of simplifying assumptions adapted to the studied problem"
C1.3: "Solve a problem using an approach based on approximation", "Make a relevant simulation choice for a given problem" and
"Know the limitations of numerical simulations and what one can expect from; know how to criticize results of numerical simulations"

2SC7290 – Smart cities: connected cities

Instructors: Mohamad ASSAAD
Department: TÉLÉCOMMUNICATIONS
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 80
On-site hours (HPE): 48
Quota :

Description

The projects are centered around practical applications of optimization (combinatorial, convex) and game theory to the current problems of smart cities and telecommunication networks. The projects will be multidisciplinary and will serve to put into perspective the courses of ST7 and to introduce students to scientific research in the field of Connected Systems (SCOC).

Quarter number

ST7

Prerequisites (in terms of CS courses)

signal processing, communication networks, optimization, Matlab

Syllabus

Example of projects: optimization of services in a smart city taking into account network constraints (network capacity, bit rate, signaling, energy consumption, etc.) and economic gains and benefits for citizens.
The practical context of the project is related to a precise service in smart cities (information gathering from sensors, temperature regulation, video surveillance as well as other services with low latency and high reliability requirements) and it will be given as a complement to the courses. Students will propose and implement (collaboratively) algorithms to optimize the transport of information in the network (link with the notions of optimization, game theory, and routing of information seen in the courses). Students will test their approaches on real data, if possible. Each group will propose to the rest of the students a solution among those tested, arguing their choice by criteria of performance, cost, equity and operational risk. The optimal solution is chosen by a consensus of all students.

Class components (lecture, labs, etc.)
Each project is assigned on average to five students and is mainly supervised by a professor. Some projects are jointly proposed with some industrial partners and are hence co-supervised by engineers from these companies. A room dedicated to the projects will be available to students. The supervisors will follow up regularly (one meeting / group / week at the beginning and one daily meeting per group during the final week). Inter group collaboration will be encouraged (whenever it is possible), and students will be assessed on their ability to work in teams (leadership, tasks' sharing, communication).

Grading
report to write+defense (per group).

Resources
software to use: Matlab

Learning outcomes covered on the course
At the end of the project the student will be able to :

1- know emerging problems in telecommunications networks for smart cities
2- model a network in the context of smart cities with its main functions
3- formulate emerging problems in smart cities as optimization frameworks
4-implement optimization algorithms (convex, combinatorial) and game theory methods in Matlab .

Description of the skills acquired at the end of the course
C1 : Analyse, design and implement complex systems made up of scientific, technological, social and economic dimensions.
C1.1 : Examine problems in their entirety and beyond their immediate parameters. Identify, formulate and analyse the scientific, economic and human dimensions of a problem
C1.2 : Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when addressing a problem
C1.3 : Apply problem-solving through approximation, simulation and experimentation. / Solve problems using approximation, simulation and experimentation
C1.4 : Design, detail and corroborate a whole or part of a complex system.
C1.5 : Bring together broad scientific and technical concepts in a core structure contained within the framework of an interdisciplinary approach.

C2 : Acquire and develop broad skills in a scientific or academic field and applied professional areas
C2.1: Thoroughly master a domain or discipline based on the fundamental sciences or the engineering sciences.
C2.3 : Rapidly identify and acquire the new knowledge and skills necessary in applicable / relevant domains, be they technical, economic or others.
C3 : Act, engage, innovate within a scientific and technological environment
C3.1 : Be proactive and involved, take initiatives
C3.2 : Question assumptions and givens. Overcome failure. Take decisions
C6 : Thrive in an international and multicultural environment
C6.1 : Identify and use the necessary software for one's work (including collaborative tools) and adapt digital responses according to the context.
C8 : Lead a team, manage a project
C8.1: Work collaboratively in a team.
C8.2 : Train and motivate a group, demonstrating effective leadership.
C8.4 : Work using project management techniques appropriately tailored to the situation.
C9 : Think and act as an accountable ethical professional
C9.2 : Identify, within a given structure, the scope of liability as well as socio-ethical and environmental responsibilities.
C9.4 : Demonstrate rigor and critical thinking in approaching problems from all angles, be they scientific, social or economic.

ST7 – 73 – ECONOMIE CIRCULAIRE ET SYSTEMES INDUSTRIELS

Dominante : GSI (Grands Systèmes en Interaction), VSE (Vivant-Santé, Environnement), CVT (Construction, Ville et Transports)
Langue d'enseignement : Français
Campus où le cours est proposé : Paris-Saclay

2SC7310 – Circular economy and industrial ecology methods

Instructors: Yann LEROY, François CLUZEL
Department: DOMINANTE - GRANDS SYSTÈMES EN INTERACTION
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 34,5
Quota :

Description

According to ADEME (French environmental protection agency), Circular Economy aims at shifting the current paradigm based on linear economy, by limiting the waste of resources and environmental impacts, and by increasing the efficiency at all stages of products economy. It is composed of 7 pillars: sustainable procurement, eco-design, industrial and territorial ecology, functional economy, responsible consumption, longer duration of use, recycling and waste recovery.

Industrial Ecology is an approach whose objective is to limit the impacts of industry on the environment. It aims at considering an industrial system as a whole to identify, model and optimize material and energy flows, as well as associated environmental impacts. It aims at reproducing a natural system in the human activities, where all material and energy flows are reused, where the notion of waste does not exist anymore. All economic sectors are concerned.

The course’s objective is to cover the different dimensions of circular economy to provide to the students a global vision of the field. Then the focus will be made on the operational industrial ecology tools, which students will learn to manipulate (MFA (Material Flow Analysis, tool to map material and energy flows) and LCA (Life-Cycle Assessment, tool to calculate environmental impacts) software) to drive industrial ecology projects. These tools will be directly used for the project of the engineering challenge term.

Quarter number

ST7

Prerequisites (in terms of CS courses)
None

Syllabus
The course is structured into 11 3-hours sessions.

1. Introduction to Circular Economy and environmental impacts (Yann Leroy and/or François Cluzel)

A. The Pillars of Circular Economy
The sessions 2-6 are built on the following format: lecture and workshop on an industrial case study. These sessions go through the 7 pillars of Circular Economy according to the ADEME's definition.
2. Product End-of-life (Yann Leroy and/or François Cluzel)
3. Ecodesign, extension of product lifespan and responsible consumption (Yann Leroy and/or François Cluzel)
4. Sustainable procurement (Yann Leroy and/or François Cluzel)
5. Functional economy and responsible consumption (Patrice Vuidel, ATEMIS)
6. Industrial and Territorial Ecology (Yann Leroy and/or François Cluzel and/or Andreas Hein)

B. Methods and tools for Industrial Ecology
The sessions 7-11 (Yann Leroy and/or François Cluzel) are dedicated to Material Flow Analysis (MFA), Life Cycle Assessment (LCA) and Circularity and Sustainability Indicators (lectures and workshops). These three approaches will be applied on a case study in group.

12. Final exam : duration 1h30

Class components (lecture, labs, etc.)
According to specific needs, the sessions will alternate lectures and tutorials on industrial case (case study and or serious games), and tutorials on MFA and LCA professional software (used during the project of the Engineering Challenge Term). Some sessions may be organized as flipped classrooms.

Grading
Final written exam on sessions 1 to 6 (50%) + evaluation of tutorials (per group) for sessions 7-11 (50%)

Course support, bibliography

25. Adoue, C., 2007. Mettre en œuvre l'écologie industrielle. PPUR, Lausanne.

26. Buclet, N., Barles, S., 2011. Écologie industrielle et territoriale : Stratégies locales pour un développement durable. Presses Universitaires du Septentrion, Villeneuve d'Ascq, France.
27. Erkman, S., 2004. Vers une écologie industrielle, 2e éd. ed. Charles Léopold Mayer, Paris.
28. Hawken, P., Lovins, A., Lovins, L.H., 1998. Natural Capitalism: Creating the Next Industrial Revolution, 1st edition. ed. US Green Building Council, Boston.

Resources

Teachers: François Cluzel, Yann Leroy, Flore Vallet, Andreas Hein, Michael Saidani, Yasmine Salehy (all members of the Industrial Engineering Research Department) and some other external speakers
Software: Life-Cycle Assessment (OpenLCA) and Material Flow Analysis (Stan)

Learning outcomes covered on the course

- Be aware of major environmental stakes
- Know the 7 pillars of circular economy
- Master the main industrial ecology tools: Material Flow Analysis, Life-Cycle Assessment, Circularity and Sustainability Indicators
- Be able to model and simulate an industrial system in a circular economy perspective
- Be able to optimize an industrial system in a circular economy perspective

Description of the skills acquired at the end of the course

19. C1 Analyse, design and implement complex systems made up of scientific, technological, social and economic dimensionsC1.1 Examine problems in their entirety and beyond their immediate parameters. Identify, formulate and analyse the scientific, economic and human dimensions of a problem
    a. C1.2 Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when addressing a problem
    b. C1.3 Apply problem-solving through approximation, simulation and experimentation. / Solve problems using approximation, simulation and experimentation

c. C1.5 Bring together broad scientific and technical concepts in a core structure contained within the framework of an interdisciplinary approach

20. C2 Acquire and develop broad skills in a scientific or academic field and applied professional areas
    - C2.1 Thoroughly master a domain or discipline based on the fundamental sciences or the engineering sciences
    - C2.5 Master the skillset of a core profession within the engineering sciences (at junior level)
21. C6 Advance and innovate in the digital world
    - C6.2 Engage in design thinking using classic and agile conception and prototyping tools (CAD, 3D printing etc.)
    - C6.5 Operate all types of data, structured or unstructured, including big data.
22. C9 Think and act as an accountable ethical professional
    - C9.1 Understand and analyse the consequences of one's choices and actions.
    - C9.2 Identify, within a given structure, the scope of liability as well as socio-ethical and environmental responsibilities.
    - C9.4 Demonstrate rigor and critical thinking in approaching problems from all angles, be they scientific, social or economic.

2SC7391 – Biorefinery : optimization of flows and/or associated processes

Instructors: Julien LEMAIRE, Yann LEROY, François CLUZEL
Department: DOMINANTE - GRANDS SYSTÈMES EN INTERACTION, DOMINANTE - VIVANT, SANTÉ, ENVIRONNEMENT
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 80
On-site hours (HPE): 48
Quota :

Description

The project Biorefinery was proposed to the students on the year 2019-2020 for the first edition of this ST7. A similar or close project will be proposed on the year 2020-2021 but could be subject to change compared with the description below, that nevertheless allows to well illustrate engineering challenges, subjects, methods and tools that will be used in such a project.

The project "**Biorefinery : optimization of flow or associated processes**" is one of the projects concluding the ST7 "Circular Economy and Industrial Systems". It aims at applying specific and common course tools to carry out an Industrial Ecology project by modelling material and energy flows and measuring environmental impacts. In particular, students will be able to use two key tools from the specific courses to scale and define circular economy approaches and understand the multi-criteria nature of environmental issues: Material Flow Analysis, which consists of mapping and quantifying the flows of material and energy transiting a site; and Life Cycle Analysis, which consists of quantifying the environmental impacts of a product or system over all stages of its life cycle. These tools will enable them to model the industrial system as a whole in order to identify and then deploy ways of optimizing it, for example by enhancing the value of certain flows.

A biorefinery can be defined as an industrial ecosystem that enables biomass (animal or plant by-products or waste) to be used in the form of various food and non-food products (energy, chemical intermediates, materials, cosmetics, health, etc.). France is a world leader in this field, thanks in particular to the Bazancourt-Pomacle biorefinery, which processes more than 4 Mt of plant biomass per year. The biorefinery is one of the credible industrial tools to support the ecological transition, both to meet climate and societal challenges and to relocate the industry, particularly within agricultural or forest production basins. It thus meets the triple objective of sustainable development (environmental, social and economic).

Although its raw materials are largely renewable, this is not enough to guarantee the sustainability of its activities. Sober use of resources remains essential, both in terms of reducing the consumption of atoms and energy and limiting waste production and cost management. This requires optimization of processes, their integration into the site and flows within and between production workshops.

The objective of this project is, at the scale of the industrial site, to understand the organization of processes and flows in order to then identify optimization opportunities. Through a multidisciplinary approach (data sciences, modeling-simulation-optimization, process engineering, etc.), students will work in groups to identify, develop and present an operational solution that generates added value for the industrialist and at the same time contributes to reducing the environmental impact of the biorefinery.

Quarter number
ST7

Prerequisites (in terms of CS courses)
None

Syllabus
The project will be spread over 6 to 8 weeks with 16 "project" slots of 3 hours at the beginning, interspersed with the slots for specific and common courses, then 6 hours during the last 2 weeks.
After the first presentation session of the 2 projects (VSE or CVT), students will have to choose one of the projects and quickly form groups of 5. Before the day of the biorefinery visit, preferably scheduled during the third session, the groups will have to get acquainted with the subject and the stakes, and start a bibliographical work.
The visit of the biorefinery (CEBB, ARD and Cristanol) and the presentation of this ecosystem by two of its actors: Jean Marie Chauvet (project manager of the BRI platform) and Christian Beloy (Head of the Environment Department of the ARD company), will enable them to define a study perimeter and objectives to be achieved. The students will have to divide the tasks and roles within the groups but also between the groups, which will have to be complementary to each other in order to study this complex ecosystem.
Throughout the sessions, students will therefore have to work in groups, in coordination with the other groups, with the support of the teaching team, and with the possibility of soliciting the industrial partner at various stages.

The last session will be devoted to oral presentations of the work of the different groups in the presence of the industrial partner. 2 additional weeks will then be left to the students to report on their work and their deliverables, taking into account any remarks raised during the presentations.

Class components (lecture, labs, etc.)

Project-based learning
8 interdependent groups of 5 students with a relevant breakdown of the biorefinery study
Group work with support from supervisors
Several scheduled exchanges with the industrial partner
Use of Teams to facilitate exchanges and group work

Grading

Students are evaluated on the quality of their oral presentation and deliverables, including a writen debriefing (individual and group grade). Their grade will be based in particular on a handout specifying the specific tasks and roles of each student in each group.
Oral presentation: 35%.
Report and deliverables: 65%.

Course support, bibliography

Slideshows and ST7 specific course materials
Slides of the different presentations
Bioraffinerie 2030 : Une question d'avenir, Pierre-Alain SCHIEB, Honorine LESCIEUX-KATIR, Maryline THÉNOT and Barbara CLÉMENT-LAROSIÈRE, L'Harmattan, 2014.
Previous years' reports and deliverables
Documents and data provided by the company ARD

Resources

Teaching staff : Julien LEMAIRE (LGPM - Chair of Biotechnology), Yann LEROY (LGI)
Enrolment size: 40 students maximum
Software tools and number of licenses required: 40 licenses (LCA software (OpenLCA) and MFA software (Stan))
Computer rooms (40 posts)
1 day visit to the Bazancourt-Pomacle biorefinery

Learning outcomes covered on the course

1) Be aware of major environmental issues
2) Mastering the main tools of industrial ecology: MFA and LCA
3) Know how to model and simulate an industrial system in a circular economy perspective
4) Knowing how to optimize an industrial system in a circular economy perspective
5) Knowing how to organize in interdependent teams and manage a project
6) To know how to define a study perimeter and precise objectives to meet industrial needs.
7) Knowing how to reduce the complexity of a problem in a relevant way
8) Dealing with uncertainty or lack of data
9) Take a critical look at data and models

Description of the skills acquired at the end of the course

C1.1, milestone 1: Know how to list the parameters influencing the system under study and the elements with which it is related. Identify those that are important in relation to the problem at hand.
C1.1, milestone 2: Know how to conduct a questioning process to address the different aspects of the problem and highlight its interactions with the outside world, based on a scientific and economic culture.
C1.2, milestone 1: Know how to use a model presented in class in a relevant way (model describing a phenomenon, without couplings). Choose simplifying hypotheses adapted to the problem studied.
C1.2, milestone 2: Know how to choose the right model for a given problem, choose the modeling scale.
C1.2, milestone 3: Knowing how to choose, enriching models describing phenomena involving several scales or couplings.
C1.3, milestone 1B: Solving a problem with approximation practice
C1.3, milestone 2B: Know the limitations of numerical simulations and what can be expected from them, know how to criticize the results of numerical simulations.
C1.5, milestone 2: Knowing how to mobilize knowledge in order to solve an engineering problem (Mobilizing a broad scientific and technical base in the framework of a transdisciplinary approach)

C2.1 : To know how to respond to an engineering problem with the adequate tools (i.e. with scientific methods of a sufficiently high level, corresponding to the state of the art - engineer level).
C2.5 : Master the skills of one of the basic engineering professions (at junior level)

C3.1, Milestone 1: Be proactive, take initiative, get involved - Maintain contact with and check alignment with stakeholders.

C3.1, milestone 2: Be proactive in relation to the request formulated, anticipating difficulties where necessary.
C3.3, milestone 1: Undertake ambitious high-impact projects and quantify this impact - behave professionally (punctuality, respect for stakeholders...), have a personal requirement.

C6.1, milestone 1: Use content creation tools (texts, spreadsheets, videos, mindmap, storyboard, web pages, maps, ...), Use collaborative work tools, Install the software necessary for your work.
C6.2, milestone 1: Practice collaborative design through product design and prototyping tools (CAD, 3D printer...) - Have a collaborative experience of designing a hardware or software object and if possible prototyping (depending on the context)
C6.3, milestone 1: Specify, design, build and validate software
C6.5, Milestone 1: Ability to implement a data processing method (recovery, cleaning, transformation, analysis, interpretation, visualization)
C6.5, milestone 2: Know how to choose a data processing method for heterogeneous data (format, quality, producer) in large quantities (i.e. cannot be processed by a spreadsheet)

C7.1, Milestone 2: Convince on the merits. Be clear on objectives and expected results. Be rigorous about assumptions and approach. Structure your ideas and arguments. Highlight the value created

C8.1, milestones 1 to 3: Working in a team/collaboration - Actively listen to your teammates - Know how to position yourself in a team, identify what you can bring to a group - Try to involve each team member according to his or her strengths - Work in an autonomous and interdependent way towards a common team objective - Contribute to the cohesion and motivation of your teammates whatever the difficulties encountered
C8.4, Milestones 1 and 2: Work in project mode by implementing project management methods appropriate to the situation.

C9.1, milestone 1: Understand and analyse the possible consequences of one's choices and actions - Situate one's action in an organisation and in the temporality of the activity
C9.2, Milestones 1 to 3: Perceive the scope of responsibility of the structures to which you contribute, integrating environmental, social and ethical dimensions.
C9.4, Milestone 1: Demonstrate rigour and critical thinking in approaching problems from all angles, scientific, human and economic.

2SC7393 – Construction sites of Grand Paris

Instructors: Yann LEROY, François CLUZEL, Frédérique DELMAS-JAUBERT
Department: DOMINANTE - CONSTRUCTION VILLE TRANSPORTS, DOMINANTE - GRANDS SYSTÈMES EN INTERACTION
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 80
On-site hours (HPE): 48
Quota :

Description

The project Grand Paris was proposed to the students on the year 2019-2020 for the first edition of this ST7. A similar or close project will be proposed on the year 2020-2021 but could be subject to change compared with the description below, that nevertheless allows to well illustrate engineering challenges, subjects, methods and tools that will be used in such a project.

The project "**Construction sites of Grand Paris**" is one of the projects concluding the ST7 "Circular Economy and Industrial Systems". It aims at applying specific and common course tools to carry out an Industrial Ecology project by modelling material and energy flows and measuring environmental impacts. In particular, students will be able to use two key tools from the specific courses to scale and define circular economy approaches and understand the multi-criteria nature of environmental issues: Material Flow Analysis, which consists of mapping and quantifying the flows of material and energy transiting a site; and Life Cycle Analysis, which consists of quantifying the environmental impacts of a product or system over all stages of its life cycle. These tools will enable them to model the industrial system as a whole in order to identify and then deploy ways of optimizing it, for example by enhancing the value of certain flows.

"200 km of automatic lines, equaling the actual metro network, and 68 stations: Grand Paris Express is the biggest urban project in Europe! More than a transportation network, it opens new horizons and offers numerous opportunities. With it, the metropolis becomes larger and more unified. 90% of the futur Grand Paris Express network will be underground, which requires to excavate huge amounts of clay from the ground, during gigantic construction works using around 20 tunnel boring machines. Wastes of the building and civil engineering works sector in Île-de-France represent around 30 million tons per year. The construction sites of Grand Paris

Express will represent en increase of waste from 10 to 20% per year. Société du Grand Paris, in charge of the construction of Grand Paris Express, is strongly involved on traceability, the removal modes (avoid trucks on roads), and the reusing of excavated clays. The evoked reusing modes are in particular reusing as materials: concrete, road undercoat, embankment, cement, plaster; but also reusing as volume: quarry filling, urban parks... SGP is also searching for innovative solutions, like the creation of fertile lands, building materials...

The objective of this project is to develop technico-economic scenarios for reusing the clay from the Grand Paris Express sites, in a Circular Economy perspective. In a first phase, in partnerships with the company Spie batignolles valérian, the students will gain knowledge and will characterize the available clay deposits from the Grand Paris Express construction sites. In a second phase, the students will work on one of these two clay reusing subjects:

- Reuse of excavated clay as embankment slopes for the future CDG Express train line, that will connect Roissy-Charles de Gaulle airport to Paris in 2025, subject proposed by Spie batignolles valérian;
- Reuse of excavated clay as innovative building materials in raw clay, subject proposed par the project Cycle Terre and CRAterre.

Quarter number
ST7

Prerequisites (in terms of CS courses)
None

Syllabus
The project will be spread over 6 to 8 weeks with 16 "project" slots of 3 hours at the beginning, interspersed with the slots for specific and common courses, then 6 hours during the last 2 weeks (4 full days).
After the first presentation session of the 2 projects (VSE or CVT), students will have to choose one of the projects and quickly form groups of 10 to 12. During the second session, the industrial partner(s) will present in detail the subject. The students will sign a non-disclosure agreement and will work in close link with their client all along the project. The client will transmit the necessary data, and could propose complementary talks or give access to adapted experts. The students may also have the opportunity to into the field, at list for a half-day of visit at the beginning of the project.
Students will apply agile project management thanks to a tutoring by a teacher in project management. Throughout the sessions, students will therefore have to work in groups, possibly in coordination with the other

groups, with the support of the teaching team, and with the possibility of soliciting the industrial partner at various stages. At the middle of the project (session 8/16), the students will give a intermediary presentation of their work, which will allow the teachers and client to make a feedback, give advices, identify the lacking data and possibly redirect the work.
The last session will be devoted to oral presentations of the work of the different groups in the presence of the industrial partner. 2 additional weeks will then be left to the students to report on their work and their deliverables, taking into account any remarks raised during the presentations.

Class components (lecture, labs, etc.)
Project-based learning
8 groups of 10 to 12 students
Group work with support from supervisors, in agile mode
Several scheduled exchanges with the industrial partner
Use of Teams to facilitate exchanges and group work

Grading
Students are evaluated on the quality of their oral presentation and deliverables (intermediary and final reports, presentations, and all the files justifying the process and the results). Their grade will be based in particular on a handout specifying the specific tasks and roles of each student in each group.

Course support, bibliography
Slideshows and ST7 specific course materials
Slides of the different presentations
Documents and data provided by the industrial partners

Resources
Teaching staff : Frédérique DELMAS-JAUBERT (Engineer, Architect, teacher in Sustainable Urban Planning at CentraleSupélec), François Cluzel (LGI), Franck Marle (LGI)
Industrial partner(s): the students will interact directly with one or several industrial partners who will play the role of client.
Enrolment size: 50 students maximum
Software tools: LCA software (OpenLCA) and MFA software (Stan)
At least a half-day of visit on site

Learning outcomes covered on the course
1) Be aware of major environmental issues
2) Mastering the main tools of industrial ecology: MFA and LCA

3) Know how to model and simulate an industrial system in a circular economy perspective
4) Knowing how to optimize an industrial system in a circular economy perspective
5) Knowing how to organize in interdependent teams and manage a project
6) To know how to define a study perimeter and precise objectives to meet industrial needs.
7) Knowing how to reduce the complexity of a problem in a relevant way
8) Dealing with uncertainty or lack of data
9) Take a critical look at data and models

Description of the skills acquired at the end of the course
C1.1, milestone 1: Know how to list the parameters influencing the system under study and the elements with which it is related. Identify those that are important in relation to the problem at hand.
C1.1, milestone 2: Know how to conduct a questioning process to address the different aspects of the problem and highlight its interactions with the outside world, based on a scientific and economic culture.
C1.2, milestone 1: Know how to use a model presented in class in a relevant way (model describing a phenomenon, without couplings). Choose simplifying hypotheses adapted to the problem studied.
C1.2, milestone 2: Know how to choose the right model for a given problem, choose the modeling scale.
C1.2, milestone 3: Knowing how to choose, enriching models describing phenomena involving several scales or couplings.
C1.3, milestone 1B: Solving a problem with approximation practice
C1.3, milestone 2B: Know the limitations of numerical simulations and what can be expected from them, know how to criticize the results of numerical simulations.
C1.5, milestone 2: Knowing how to mobilize knowledge in order to solve an engineering problem (Mobilizing a broad scientific and technical base in the framework of a transdisciplinary approach)

C2.1 : To know how to respond to an engineering problem with the adequate tools (i.e. with scientific methods of a sufficiently high level, corresponding to the state of the art - engineer level).
C2.5 : Master the skills of one of the basic engineering professions (at junior level)

C3.1, Milestone 1: Be proactive, take initiative, get involved - Maintain contact with and check alignment with stakeholders.
C3.1, milestone 2: Be proactive in relation to the request formulated, anticipating difficulties where necessary.

C3.3, milestone 1: Undertake ambitious high-impact projects and quantify this impact - behave professionally (punctuality, respect for stakeholders...), have a personal requirement.

C6.1, milestone 1: Use content creation tools (texts, spreadsheets, videos, mind map, storyboard, web pages, maps, ...), Use collaborative work tools, Install the software necessary for your work.
C6.2, milestone 1: Practice collaborative design through product design and prototyping tools (CAD, 3D printer...) - Have a collaborative experience of designing a hardware or software object and if possible prototyping (depending on the context)
C6.3, milestone 1: Specify, design, build and validate software
C6.5, Milestone 1: Ability to implement a data processing method (recovery, cleaning, transformation, analysis, interpretation, visualization)
C6.5, milestone 2: Know how to choose a data processing method for heterogeneous data (format, quality, producer) in large quantities (i.e. cannot be processed by a spreadsheet)

C7.1, Milestone 2: Convince on the merits. Be clear on objectives and expected results. Be rigorous about assumptions and approach. Structure your ideas and arguments. Highlight the value created

C8.1, milestones 1 to 3: Working in a team/collaboration - Actively listen to your teammates - Know how to position yourself in a team, identify what you can bring to a group - Try to involve each team member according to his or her strengths - Work in an autonomous and interdependent way towards a common team objective - Contribute to the cohesion and motivation of your teammates whatever the difficulties encountered
C8.4, Milestones 1 and 2: Work in project mode by implementing project management methods appropriate to the situation.

C9.1, milestone 1: Understand and analyse the possible consequences of one's choices and actions - Situate one's action in an organisation and in the temporality of the activity
C9.2, Milestones 1 to 3: Perceive the scope of responsibility of the structures to which you contribute, integrating environmental, social and ethical dimensions.
C9.4, Milestone 1: Demonstrate rigor and critical thinking in approaching problems from all angles, scientific, human and economic.

ST7 – 74 – OPTIMISATION DE SYSTEMES DE TRANSPORT PASSAGERS

Dominante : GSI (Grands Systèmes en Interaction), Info&Num (Informatique & Numérique)
Langue d'enseignement : Français
Campus où le cours est proposé : Paris-Saclay

2SC7410 – Decision Support : Models, algorithms and implementation

Instructors: Vincent MOUSSEAU
Department: SCIENCES ENTREPRISE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 34,5
Quota :

Description

Decision making is an intrinsic activity in the engineering profession and often leads to optimize one or more aspects of a system. But these decisions are also based on the judgments/preferences of a decision-maker/user. Preferences have therefore played a key role in many computer applications and modern information technologies. This is the case of computer marketing, recommendation systems, adaptive user interfaces,... Decisions can be strategic, tactical or dynamic, in complex, competitive, uncertain, optimize or find a compromise between conflicting criteria ... To solve the complex decision problems between them, they must be confronted, the engineers must implement the concepts and methods and algorithms to formalize a problem of decision.

Quarter number

ST7

Prerequisites (in terms of CS courses)

none

Syllabus

- Introduction to decision making, basic concepts,
- Modeling of decision problems using mathematical programming.
Presentation of modeling and resolution tools (modelers and solvers),
- Implementation using Julia JUMP,
- Decision in the presence of risk, decision in the uncertain, utility theory, decision trees,
- Multi-criteria decision and modeling of preferences, aggregation models,
- Empirical analysis of decision behavior,

- Learning preference models from data, incremental learning,
- Metaheuristics for combinatorial problems,
- Multiobjective optimization,

Class components (lecture, labs, etc.)
lectures: 13.5h
exercises: 10,5h
lab: 9h
this distribution may slightly vary

Grading
Final exam (1h30): 70% Lab evaluation: 30%

Course support, bibliography
Lecture slides and exercices will be provided.
Labs will beorganized using a Jupyter notebook

Bibliography:
D. Bouyssou, T. Marchant, M. Pirlot, P. Perny, A. Tsoukiàs, P. Vincke “Evaluation and Decision models: A critical perspective”, Kluwer, 2000.
W. Cooper, L. Seiford, and K. Tone, “Introduction to Data Envelopment Analysis and its use”, Springer, 2006.
C. Guéret, C. Prins, M. Sevaux. "Programmation linéaire, 65 problèmes d’optimisation modélisés et résolus avec Visual Xpress", Eyroles, 2003
C. Kwon, "Julia programming for operations research", 2019, second edition, http://www.chkwon.net/julia
P. Vallin, D. Vanderpooten, “Aide à la décision, une approche par les cas”, 2e édition, Ellipses. 2002.
H.P. Williams. "Model building in mathematical programming". J. Wiley, New York, 2013. 5ème édition,

Resources
Equipe enseignante (V. Mousseau + chargés de TD/TP à valider)
Software: jupiter hub + julia + jump + CPLEX + metaheuristiques libraries
TD: ~30 students
TP: ~20 students
Wifi ABSOLUTELY REQUIRED for TD and TD

Learning outcomes covered on the course
This course aims to develop students' abilities to develop and implement models and algorithms relevant to a decision-making situation.
At the end of the course, students will master some methods / models for decision support. They will be able to manipulate models, use them in an

operational way and implement them efficiently. They will also have the necessary elements to take a step back and have a critical sense in relation to these methods, and thus to distinguish their performances and their limits of application.

Description of the skills acquired at the end of the course

C1 (all sub-competences): Analysis, design and implementation of complex systems made up of scientific, technological, social and economic dimensions.
C2.1: Thoroughly master a domain or discipline based on the fundamental sciences or the engineering sciences.
C2.3: Rapidly identify and acquire the new knowledge and skills necessary in applicable / relevant domains, be they technical, economic or others.
C6.3: Conceive, design, implement and authenticate complex software.
C6.4: Solve problems through mastery of computational thinking skills.
C6.5: Operate all types of data, structured or unstructured, including big data.

2SC7491 – Optimizing the operations of an airline

Instructors: Asma GHAFFARI
Department: DOMINANTE - GRANDS SYSTÈMES EN INTERACTION, DOMINANTE - INFORMATIQUE ET NUMÉRIQUE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 80
On-site hours (HPE): 48
Quota :

Description

The work, which will be done in groups of 4 to 5 students, consists of examining a problem of optimisation of one or more resources necessary for the operations of the Air France company. The problem will be presented and detailed by people from Air France's Operations Research department. The objective will be to pose the problem in the form of a mathematical model and to develop a computer program to translate the model and solve it in order to optimize the decision to be recommended to the professions concerned. Representatives of Air France decision-makers involved in the issue will be present throughout the project to shed light on the challenges of the situation and explain the expectations of stakeholders.

Quarter number

ST7

Prerequisites (in terms of CS courses)

Student should have an overview of the basic optimization models, namely mathematical programming based models. He or she should also master some coding environment.

Grading

Project pedagogy with support from professors and professionals from the professions concerned by the problem and the operational research profession.

Learning outcomes covered on the course

Learn to :

- on the challenges of airline operations

- modeling a real and complex optimization problem through mathematical programming
- translate a mathematical model into a computer program with specific optimization tools
- Choose a solution method adapted to a given optimization problem
- Translating and using theoretical optimization methods in a computer language
- Interact with experts in the aviation industry and operational research

2SC7492 – Optimization of aircraft paths when approaching an airport

Instructors: Oualid JOUINI
Department: DOMINANTE - GRANDS SYSTÈMES EN INTERACTION, DOMINANTE - INFORMATIQUE ET NUMÉRIQUE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 80
On-site hours (HPE): 48
Quota :

Description

Air traffic flow management (ATFM) is an air transportation problem that considers a network of airports and the airspace sectors connecting them, where a pre-defined set of flights traverses (Agustín et al., 2012; Bertsimas and Gupta, 2015; Bertsimas and Patterson, 1998). ATFM problem aims to balance the available airport and airspace sector capacities with the demand of flights through different decisions such as ground delays, airborne delays, and rerouting to avoid congested airspace sectors (Agustín et al., 2012). An airport capacity is controlled by the number and the layout of the available runways and an airspace sector capacity depends on its open configuration.

In this regard, airspace sector can be either one basic sector (an indivisible airspace portion) or a combination of basic sectors. Each of the different combinations of basic sectors resulting in operational sectors corresponds to a unique sector configuration. Figure 1 shows an example of basic sectors (Malmö Sectors, Sweden). Figure 2 shows some of the possible combinations (configurations/collapse sectors). Depending on operational conditions, such as weather or traffic flows, basic sectors can be combined differently resulting in different airspace volumes known as operational sectors, which are controlled by a team of air traffic controller (ATCOs), each of the teams occupying an operational position inside the air traffic control centres (ATCC) operations room (Treimuth, 2018).

This project aims to link the traffic flow management problem with the airspace configuration problem in order to minimize air traffic flow costs and minimize the unused airspace capacities. This can be achieved by developing a bi-objective mixed integer linear programming model. These two objectives are expected to be conflicting as minimizing delays requires having more airspace capacity and thus selecting elementary sectors, while minimizing the unused capacity will come at cost of delay some flights.

Quarter number
ST7

Prerequisites (in terms of CS courses)
No prerequisite.

Syllabus
The developed model is expected to produce an optimal flight schedule and an optimal selection of sector configurations (elementary and/or collapse) with their opening schemes.
Project data and collaboration

- This project is in collaboration with the Swedish Civil Aviation Administration (LFV).
- The models will be developed for Sweden and the capacity data obtained from LFV will be used. Other flights data will be obtained from DDR2 of EUROCONTROL.

The proposed model shall obey the following operational constraints
1- Airport departure capacities and arrival capacities shall not be exceeded.
2- Airspace capacities of the selected sectors shall not be exceeded
3- Flight path connectivity: a flight cannot enter its next sector unless it has spent at least the minimum time required in its current sector
4- During the day of operation, each elementary or collapse sector if selected shall be kept open for a duration that is at least equal to a pre-defined value.
5- During the day of operation, each elementary or collapse sector can be re-opened multiple times if necessary but does not exceed a pre-defined value.

Expected Results
1- Comparative analysis between the given sectors and their opening scheme with the optimized schedule.
2- Comparative study on the developed heuristic performance

Class components (lecture, labs, etc.)
Project-based teaching method : conducting meeting with the groups involved to disucss the project progress and to answer any questions

Grading
3 evaluations : 2 intermediate and one final.

- Phase 1:

o Extending the basic air traffic flow management model to account for rerouting and testing it using basic data

o Developing an advanced air traffic flow management model for a given set of configurations and their opening scheme and testing it using real data.

- Phase 2:

o Modifying the model developed in Phase 1 to optimize the configurations selection and their opening scheme in a bi-objective formulation.

o Comparing the results of Phase 1 with the results of Phase 2

- Phase 3:

o Developing a heuristic in order to solve the model developed in Phase 2.

Course support, bibliography

Agustín, A., Alonso-Ayuso, A., Escudero, L. F., & Pizarro, C. (2012). On air traffic flow management with rerouting. Part I: Deterministic case. European Journal of Operational Research, 219(1), 156–166.

Bertsimas, D., & Gupta, S. (2015). Fairness and Collaboration in Network Air Traffic Flow Management: An Optimization Approach. Transportation Science, 50(1), 57–76.

Bertsimas, D., & Patterson, S. S. (1998). The Air Traffic Flow Management Problem with Enroute Capacities. Operations Research. https://doi.org/10.1287/opre.46.3.406

Treimuth, T. (2018). Dynamic optimization of airspace sector grouping (Institut National Polytechnique de Toulouse).

Resources

1- Optimization solvers (Cplex, Groubi, etc)

2- Programming softwares (Python, Julia,..etc)

Learning outcomes covered on the course

1- To make students familiar with mixed integer models and their applications in aviation

2- To enhance the students understanding about multiobjective models and Pareto optimal solutions

3- To practice heuristic development as solution approach for complex problems

Description of the skills acquired at the end of the course

1- Modeling skills : translating real-life problems into mathematical models

2- Optimization skills : dealing with optimization solvers to solve the proposed models

3- Programming skills : developing heuristic for specific problems

2SC7493 – Organization of on-demand transport systems

Instructors: Jakob PUCHINGER
Department: DOMINANTE - INFORMATIQUE ET NUMÉRIQUE, DOMINANTE - GRANDS SYSTÈMES EN INTERACTION
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 80
On-site hours (HPE): 48
Quota :

Quarter number

ST7

ST7 – 75 – OPTIMISATION ET GESTION DE FLUX DE SYSTEMES COMPLEXES

Dominante : GSI (Grands Systèmes en Interaction) et VSE (Vivant-Santé, Environnement)
Langue d’enseignement : Français
Campus où le cours est proposé : Paris-Saclay

2SC7510 – Managing and optimizing industrial flows

Instructors: Guillaume LAMÉ
Department: SCIENCES ENTREPRISE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 34,5
Quota :

Description

Production flows in factories, patient flows in hospitals, customer flows in supermarkets: understanding and managing flows is an issue in all industrial activities. Beyond specific issues, flow management is an overarching approach that can be adapted in many industrial situations.

Understanding and controlling flows is a major component of industrial performance. This module provides an introduction to industrial flow management and tools to tackle these issues.

Quarter number

ST7

Prerequisites (in terms of CS courses)

none

Syllabus

- Principles of discrete-event simulation of systems of industrial flows.
- Use of Simul8 for discrete-event simulation.
- Optimisation of flow systems.
- Use of OptQuest coupled to Simul8 for simulation-optimisation.
- Perspectives on the industrial implementation of these techniques.
- Industrial case studies.

Class components (lecture, labs, etc.)

The module will comprise lectures, either presential or as videos and reading assignments to prepare individually, and study cases and exercises.

Grading

- 90 minutes written exam.
- Assignment.
- The overall mark will be 50% for the final exam and 50% for the assignment.

Course support, bibliography

Exercises and study cases, lecture notes.

Resources

Discrete-event simulation software Simul8, and the extension OptQuest for simulation-optimisation.

Simul8 only exists for Windows. Students using Mac OS will need to install a virtual machine, which may slow down the simulation software and compromise its general usability.

Lectures, videos, exercises and industrial study-cases.

Learning outcomes covered on the course

After this module, students will be able to use simulation and optimisation approaches to understand and improve the performance of a flow system.

Description of the skills acquired at the end of the course

Use of discrete-event simulation for modelling industrial systems, and implementation on Simul8.

2SC7591 – Flow management in the gas cylinder supply chain

Instructors: Guillaume LAMÉ, Loïc PINEAU
Department: DOMINANTE - VIVANT, SANTÉ, ENVIRONNEMENT, DOMINANTE - GRANDS SYSTÈMES EN INTERACTION
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 80
On-site hours (HPE): 48
Quota :

Description

Students will apply the tools provided in the associated course on an industrial case study proposed by a partner. In particular, they will be able to implement discrete event simulation on a long and in-depth case study.

Quarter number

ST7

Prerequisites (in terms of CS courses)

none

Syllabus

In parallel with the associated ST7 course, students will progressively apply the techniques taught in the course on a real complex industrial problem.
Course reminders will be provided as needed.

Class components (lecture, labs, etc.)

Industrial case study.

Grading

Group project.

Course support, bibliography

Contents from the ST7 course.
Data from the industrial case study.

Resources
Industrial case study, with data and information on the context and the industrial challenge, supervised by a tutor.

Discrete-event simulation software Simul8, and the extension OptQuest for simulation-optimisation.

Simul8 only exists for Windows. Students using Mac OS will need to install a virtual machine, which may slow down the simulation software and compromise its general usability.

Learning outcomes covered on the course
Implementation of discrete event simulation.

Description of the skills acquired at the end of the course
Implementation of discrete event simulation on a real case-study.

ST7 – 76 – SIMULATION A HAUTE PERFORMANCE POUR LA REDUCTION D’EMPREINTES

Dominante : MDS (Mathématiques, Data Science) et INFONUM
Langue d’enseignement : ENGLISH
Campus où le cours est proposé : Gif

2SC7610 – Parallel Computing Methods and Algorithms, and Optimization Methods

Instructors: Stephane VIALLE, Frédéric MAGOULES
Department: INFORMATIQUE
Language of instruction: ENGLISH,FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 34,5
Quota :

Description

Simulation is today at the heart of many design and optimization approaches, to reduce the impact of the products created: reducing the carbon footprint, the sound footprint ... Such problems are often complex systems, whose simulation requires specific skills in high performance and large scale simulations.

In this course, students will learn to develop models and simulations without limit on the size of the problem, without sacrificing the accuracy of computations. For this purpose:

- They will design models based on blocks of operations which can be run in parallel.
- They will design distributed algorithms that can be deployed on a growing number of processors as the size of the problem increases, without sacrificing accuracy of results.
- They will identify mathematical optimization methods adapted to the problem.
- They will experiment parallel programming for optimization.

Quarter number

ST7

Prerequisites (in terms of CS courses)

- SG1 common course « Systèmes d'Information et Programmation » (1CC1000)
- ST2 common course « Algorithmique et complexité » (1CC2000)

- Basic knowledge in linear algebra

Syllabus

Architectures and Programming Models

- Introduction to computer architectures (types of architecture and parallelism)
- Sequential and parallel programming (Python) calling an external program (FORTRAN/C/C++) of high performance computing on multi-cores and on clusters
- Introduction to parallel computers

Parallel and distributed algorithms

- Introduction to parallel models and environments with message passing (MPI)
- Introduction to gradient algorithms
- Methodology of parallelization for the gradient algorithm
- Implementation on parallel computers

Domain decomposition methods

- Introduction to minimization algorithms in the context of optimization
- Partitioning techniques and methodology of parallelization
- Parallel Domain decomposition methods (Primal Schur method, Dual Schur method, Schwarz method, FETI method, optimized interface conditions)
- Minimization of communications

Genetic algorithm and meta-heuristics

- Introduction to optimization with meta-heuristics calling parallel kernels
- Parallelization of meta-heuristics based on local research (simulated annealing, tabu search, variables neighborhood search)
- Parallelization of meta-heuristics based on population estimation (genetic algorithms and colony optimization algorithms)
- Optimal allocation of resources with meta-heuristics calling parallel kernels

Performance criteria

- Efficiency, strong and weak scalability, Amdhal's law, Gustafson's law, load balancing, granularity
- Illustration of performance losses and of code optimization

Class components (lecture, labs, etc.)

Lectures (25,5 hours) and tutorials (7,5 hours) with written final exam (1,5 hours).

Grading

Evaluation 100% with a written final exam split between : AA.1 and AA.3 evaluated by the first part of the exam, and AA.2 and AA.3 evaluated by the second part of the exam

Course support, bibliography

- Frédéric Magoulès, François-Xavier Roux, Guillaume Houzeaux. Parallel Scientific Computing. Wiley & Sons, Inc., 2015. Hardcover 354 pages (in English). This course support is also available in other languages: in French (Dunod, 2017), in Spanish (CIMNE, 2014), in Japanese (Morikita Publishing Co Ltd, 2015), in Hungarian (Pollack Press, 2018).
- Frédéric Magoulès, Stéphane Vialle. Parallel and Distributed Computing, Numerical Methods: Slides of the lectures

Resources

- Teachers : Filippo GATTI et Frédéric MAGOULES et Stéphane VIALLE
- Lectures and tutorials composed on group of 25 students working on computers.
- Access to various clusters (Data Center for Education of CentraleSupelec, and Mésocentre de CentraleSupelec-ENS Paris Saclay).
- Validation with standards languages: C/C++/Python, message passing interface library (MPI).

Learning outcomes covered on the course

AA.1 At the end of the lectures, students will be able to parallelize computation kernels, through domain decomposition methods, involved in optimization techniques (core skills C2.1 and C3.6).

AA.2 At the end of the lectures, students will be able to parallelize optimization methods based on genetic algorithms, and heuristics methods (core skills C1.3 and C3.6).

AA.3 At the end of the lectures, students will be able to implement parallelization techniques allowing to solve a problem in a limited time and where the sequential solution is not possible in a limited time (core skills C3.6).

Description of the skills acquired at the end of the course

C1.3 Apply problem-solving through approximation, simulation and experimentation. / Solve problems using approximation, simulation and experimentation

C2.1 Thoroughly master a domain or discipline based on the fundamental sciences or the engineering sciences.

C3.6 Evaluate the efficiency, feasibility and strength of the solutions offered. / proposed solutions

2SC7691 – Optimization of a seismic exploration campaign for infrastructure protection

Instructors: Stephane VIALLE, Filippo GATTI
Department: DOMINANTE - MATHÉMATIQUES, DATA SCIENCES, DOMINANTE - INFORMATIQUE ET NUMÉRIQUE
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 80
On-site hours (HPE): 48
Quota :

Description

Project of the ST7 "High Performance Simulation for Footprint Reduction",
Project topic in partnership with CEA-DAM.
Majors: Computer Science (INFONUM) & Math, Data Sciences (MDS).

After the accident in Fukushima (Japan), the use of high-performance computing has become increasingly common in estimating the seismic risk associated with nuclear power plants. These tools are of strategic importance not only in the context of the design of new installations, but also in order to study the performance of existing power plants in the face of extreme vents, not anticipated during their design. In this context, the SEISM Institute (of which CentraleSupélec and CEA are founders) was founded in 2012. It is a French scientific grouping, comprising academic and industrial partners (including CEA and EDF), with the 'objective of bringing together the various know-how in seismology and earthquake engineering to improve the prediction of the seismic response of critical sites and structures in France, as well as the assessment of the associated risk.
In this context, this project concerns the optimization of a geophysical exploration campaign on an experimental site, using its digital twin, built using a wave propagation code (SEM3D) in development between CentraleSupélec, CEA and the Institute of Globe Physics. SEM3D simulates the propagation of seismic waves over large 3D domains, with domain decomposition on a Cartesian (or spherical) mesh. It also integrates the site topography and complex geological structures. The project therefore consists of solving an inverse problem in order to optimize - using SEM3D - the geological configuration of the site of interest. This optimization is based on the *Reverse Time Migration* method (i.e. resolution by adjoint problem). The optimization strategy provides for many realistic simulations, from source to sensors (forward) and back-propagation of the

misfit (backward) in order to be able to update iteratively the mechanical properties of the subsoil. Indeed, given the size of the site of interest (~10 km wide) and the spatial resolution sought (~100m), although SEM3D is parallelized and distributed on supercomputers, each wave propagation simulation can last several hours on many shared computing cores. For this, at each iteration, the *Forward* and *Backward* steps must be properly chained with an appropriate job scheduling strategy (launch of batch calculations). Finally, the number of sensors for in situ recordings must be reduced, given the associated costs, in terms of sensors, acquisition campaigns and storage of the data obtained.

The objective of this study is therefore threefold:

1. propose a geology model minimizing the difference between simulation and records,

2. minimize the number of sensors required to arrive at a model at a reasonable financial cost (considering their spatial layout),

3. manage to design this solution over the duration of the project with high-performance computers and with a limited quota of computing hours.

For this purpose, an optimization loop will be developed using the wave propagation simulation code as efficiently as possible: by sparingly exploring the space of possible configurations, to economically find a good solution.

Technical details of the system:
The studied system consists of a sedimentary basin surrounded by outcropping bedrock, possible candidate for the construction of a new nuclear power plant. To evaluate the seismic response of the site and to propose possible earthquake scenarios, one needs to know:

- the 3D geometry of the geological layers,
- the mechanical properties of these layers.

This information is fundamental for the definition of site effects on seismic energy radiated by an active fault.

Quarter number
ST7

Prerequisites (in terms of CS courses)
First year courses:

- SG1 common course "Systèmes d'Information et Programmation" (1CC1000)
- ST2 common course "Algorithmique et complexité" (1CC2000)

Courses of the ST:

- ST7 common course "Optimisation" (2CC3000)
- ST7 specific course "Méthodes et algorithmes parallèles pour l'optimisation" (2SC7610)

Others prerequisites:

- Parts of common course "CIP - Convergence, Intégration et Probabilités" (1SL1000)
- Parts of common course "EDP - Equations aux dérivées partielles" (1SL1500)
- Knowledge of linear algebra will also be needed

Syllabus
Main tasks of the study:

- Presentation of the subject at the beginning of the first part of the project (intervention of CEA-DAM):
    - presentation of theoretical fundamentals in wave propagation in complex configurations,
    - presentation of scientific issues related to design earthquake-resistant nuclear power plants, to the evaluation of the seismic response of the site and the estimation of the associated risk.
- Formalization of the problem (and of its characteristic sizes) represented by the geophysical investigation to characterize the seismic response of a nuclear site. Choice of an optimization method adapted to problem. Development of the algorithm on a verification case, supported by the analytical solution.
- Identification of SEM3D code parameters and their respective impacts on its parallel execution time, handling of computing resources of the Moulon Mesocentre.
- Conception and implementation in Python of an optimization code calling SEM3D. The optimization code will itself be parallelized if its algorithm allows it (we would then have a parallel master code calling on request a parallel code).
- Test and debugging of the complete parallel optimization code on the Moulon Mésocentre supercomputers, on small and medium problems (low frequency and / or small size of the domain).
- Application to a real case (in terms of the size of the area studied, and maximum frequency):

    - test larger problems on a larger number of nodes and CPU cores (approach of scaling),
    - analysis of the quality of the solution found and of the performance of calculations,
    - code optimization to improve the solution found AND, if required, the performance of calculations,
- Estimate the minimum number of sensors needed to find a workable solution based on available resources and maximum duration of the study.
- The study will conclude with the submission of a report and a presentation to be evaluated: the quality of the solution found, the effectiveness and the possible extensions of the crafted optimization code, and the management of the computational resources and quota during the project.

Rmk : Different student groups will experiment different optimization methods, but they will test all several examples of *Reverse Time Migration* (terrestrial and marine geophysical prospecting).

Class components (lecture, labs, etc.)
Part 1 (40HEE):

- Steps 1 and 2: course complements, handling of computing resources, formalization of the problem, choice of an optimisation algorithm.
- Step 3 and 4: Python numerical implementation of the optimisation algorithm used for the Reverse Time Migration method. Result analysis of the geophysical prospecting campaigns, in order to choose the parameters to optimize and to identify the sources of uncertainty and experimental noise.
- Step 5: first implementation of the optimisation algorithm on parallel machine, evaluation of the result quality and computation performances on small and medium size problems, and comparison to a reference analytical solution.

- Midterm report (slides and progress summary) and talk about current results and future work (part 2).

Part 2 - *final sprint* (40HEE):

- Step 6: experiments on real problems with different configurations, identification of the sources of performance locks and losses, and (if required) code improvement to push the limits of supportable problem size.
- Step 7: estimate of the number of sensors/records required for a stable optimisation, function of the available computing resources and of the maximum duration of the project.

- Final report (slides and extended abstract) and global talk about the project approach and results.

Grading

This project will be evaluated by a midterm talk at the end of part 1 (40HEE), and by a final talk at the end of part 2 (*final sprint* 40HEE). Talks will be done by the entire team, but will lead to individual marks in case of strongly heterogeneous teams. Each talk evaluation will consider the overall quality of the talk, of the slides and of the progress summary. Each talk mark will be 50% of the total mark.

- Evaluation criteria of skill **C3.7 (Marker 2)** and of learning outcomes **AA2**, **AA3** and **AA5** : development completion of a high performance simulation software on parallel machines, accuracy and performances reached by this software, quality of the results achieved at the end of an intensive simulation campaign, with respect of the allocated computing resource quota.

- Evaluation criteria of skill **C7.1 (Marker 2)** and of learning outcomes **AA1** and **AA4** : quality of the argumentation about scientific and technical choices all along the project, during meetings with the teaching staff and during the talks at the end of project part 1 and 2, capability to introduce advantages and disadvantages of unselected alternative solutions, balance of the developed solution (at the end of the project) and introduction to the reached results.

- Evaluation criteria of skill **C8.1 (Marker 2)** : constructive attitude of each student during meetings with the teaching staff, regular contribution to the project progress, appropriation of tasks in the project, regular effort to interface his developments with the ones of the rest of the team, and to adapt his developments to make easier the ones of others developers.

Resources

Teaching staff:

- **F. Gatti** (CentraleSupélec & MSSMat)
- **M. Bertin** (CEA-DAM)

Workplace and computing resources:

- Students will work at CentraleSupelec, in a classroom with electrical outlets and reliable wifi Internet access (except lockdown).
- Students will use their laptops to connect to remote **PC clusters** at **Moulon Mesocenter.**
- Final oral exam will take place at CentraleSupelec the last afternoon of the project.

Learning outcomes covered on the course

When finishing the course, the students will be able to:

- **Learning Outcome 1 (AA1):** identify and parametrize an optimisation method adapted when each evaluation/iteration requires many computing resources and computation time,
- **Learning Outcome 2 (AA2):** implement and debug a sequential or parallel Python code on supercomputer (developped from scratch or using libraries), calling distributed C/C++ computing kernels,
- **Learning Outcome 3 (AA3):** deploy intensive computing applications on remote resources,
- **Learning Outcome 4 (AA4):** identify the limitations of the study, function of the available computing resources,
- **Learning Outcome 5 (AA5):** manage a computing resource quota, during an intensive computing campaign.

Description of the skills acquired at the end of the course

- **C3.7:** Make pragmatic and informed choices with the aim of producing tangible results.
    - **Marker 2:** Enforce the designed solution and act in a pragmatic way, in order to get tangible results.
    - Evaluated with learning outcomes AA2, AA3, AA5.

- **C7.1:** Persuade at core value level; to be clear about objectives and expected results. To apply rigour when it comes to assumptions and structured undertakings, and in doing so structure and problematise the ideas themselves. Highlight the added value.
    - **Marker 2:** Convince to adopt a solution among several propositions (according to predetermined criteria).
    - Evaluated with learning outcomes AA1, AA4.

- **C8.1:** Work collaboratively in a team.

- **Marker 2:** Know how to position yourself in a team, identify what can be brought to a collective; Attempt to associate each team member function of his strengths.
- Evaluated considering each student behavior, and his contribution to the learning outcomes validations.

2SC7692 – Shape optimization and drag reduction in aeronautics

Instructors: Stephane VIALLE
Department: DOMINANTE - MATHÉMATIQUES, DATA SCIENCES, DOMINANTE - INFORMATIQUE ET NUMÉRIQUE
Language of instruction: FRENCH, ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 80
On-site hours (HPE): 48
Quota :

Description

Project of ST7 "High Performance Simulation for Footprint Reduction".
Project topic in partnership with ONERA.
Majors: Computer Science (IN) & Math, Data Sciences (MDS).

Air traffic is steadily increasing each year to the point that, without improvements in aircraft performance in terms of energy consumption, the share of air transport in greenhouse gas emissions may become unsustainable in the future.

Aircraft consumption can be decreased by either increasing the engine efficiency or by improving the aerodynamic design of the aircraft, e.g. reducing the aircraft weight. Computational tools have been widely used in aeronautics for a long time to help design and optimize systems. For example the shape of a wing can be improved to reduce its drag, lift, or its inner structure can be lightened.

Technical details of the system and methodology:

Optimization methods require successive calculations for different wing geometries including the calculation of *adjoint models*. The computational costs for each step can become prohibitively expensive for high fidelity numerical models.

The only way to reduce computing times such that results can be obtained fast enough to integrate optimization methods into the industrial design cycle is to use parallel computers. In the case of optimization methods like efficient descent methods (such as the gradient method or the Newton method), the different configurations are not known a priori but determined successively by the algorithm. It is therefore necessary to parallelize each calculation of the *primal problem* and then the *adjoint problem*.

The objective of this project is to achieve the parallelization of the most expensive phase of the optimization loop, namely the resolution of large linear systems resulting from finite element discretization models on large meshes to experiment with different sets of optimization parameters.

For this, the parallelization will be performed, in a message exchange programming environment adapted to the use of very large computers with network computing nodes, by a domain decomposition approach. The global iterative resolution method will be accelerated by solving the local equations in each subdomain. The developed parallel code will be executed and evaluated on parallel machines of CentraleSupélec.

Quarter number

ST7

Prerequisites (in terms of CS courses)

First year courses:

- SG1 common course "Systèmes d'Information et Programmation" (1CC1000)
- ST2 common course "Algorithmique et complexité" (1CC2000)

Courses of the ST:

- ST7 common course "Optimisation" (2CC3000)
- ST7 specific course "Méthodes et algorithmes parallèles pour l'optimisation" (2SC7610)

Others prerequisites:

- Parts of common course "CIP - Convergence, Intégration et Probabilités" (1SL1000)
- Parts of common course "EDP - Equations aux dérivées partielles" (1SL1500)
- Knowledge of linear algebra will also be needed

Syllabus
Main stages of the study:

- Additional information on the subject at the beginning of the first part of the project (presented by ONERA):
    - presentation of fundamental theoretical tools in optimization used in aeronautics
    - presentation of the scientific issues related to the design of aircraft wings, the evaluation of the drag and the estimation of the associated risk when reducing the weight of the materials used.
- Formalization of the problem of representing geometry and structure to characterize the drag of an airplane wing. Use of a fixed optimization method adapted to the problem (method of geometry optimization using the Hadamard representation of the shape derivative). Development of the algorithm on a verification case supported by the analytical solution.
- Identification of the FENICS (OpenSource) code parameters for solving partial differential equations, and their impact on the quality of the flow calculation solution and on the execution time.
- Design and implementation in Python of an optimization code calling FEniCS; optimization code which will then be parallelized by message exchanges based on a domain decomposition approach.
- Test and development of the complete optimization code on a parallel machine of the CentraleSupélec Teaching Data Center, on small and medium problems (short duration of physical simulation, small size of the domain).
- Application to a real case (in terms of the size of the studied area, and geometry):
    - Experiments with larger problems on a larger number of nodes and computing cores (scaling approach),
    - Analysis of the quality of the solution and the performance of the calculations,
    - Optimization of the code to improve the solution quality AND, if needed, the performance of the calculations,
- Estimation of the optimal shape of the wing or flaps to reduce the drag of the flow.
- The study will conclude with the submission of a report and an oral presentation to evaluate: the quality of the proposed solution, the efficiency and extensibility of the algorithm in finding an optimal solution, and the management of the computation resource quota during the project.

Rmk: Different student groups will enforce different optimization methods, evaluated on different examples.

Class components (lecture, labs, etc.)
Part 1 (40HEE):

- Steps 1 and 2: course complements, handling of computing resources, formalization of the problem, introduction to the optimisation method.

- Step 3 and 4: Python numerical implementation of the optimisation algorithm used. Result analysis in order to choose the parameters to optimize and the quality of the solution.

- Step 5: first implementation of the optimisation algorithm on parallel machine, evaluation of the result quality and computation performances on small and medium size problems, and comparison to a reference analytical solution.

- Midterm report (slides and progress summary), and talk about current results and future work (part 2).

Part 2 - *final sprint* (40HEE):

- Step 6: experiments on real problems with different configurations, identification of the sources of performance locks and losses, and (if required) code improvement to push the limits of supportable problem size.
- Step 7: estimate of the optimal shape of the wing or shutters in order to reduce the airplane drag, function of the available computing resources and of the maximum duration of the project.

- Final report (slides and extended abstract) and global talk about the project approach and results.

Grading
This project will be evaluated by a midterm talk at the end of part 1 (40HEE), and by a final talk at the end of part 2 (*final sprint* 40HEE). Talks will be done by the entire team, but will lead to individual marks in case of strongly heterogeneous teams. Each talk evaluation will consider the overall quality of the talk, of the slides and of the progress summary. Each talk mark will be 50% of the total mark.

- Evaluation criteria of skill **C3.7 (Marker 2)** and of learning outcomes **AA2**, **AA3** and **AA5** : development completion of a high performance simulation software on parallel machines, accuracy and performances reached by this software, quality of the results achieved at the end of an intensive simulation campaign, with respect of the allocated computing resource quota.

- Evaluation criteria of skill **C7.1 (Marker 2)** and of learning outcomes **AA1** and **AA4** : quality of the argumentation about scientific and technical choices all along the project, during meetings with the teaching staff and during the talks at the end of project part 1 and 2, capability to introduce advantages and disadvantages of unselected alternative solutions, balance of the developed solution (at the end of the project) and introduction to the reached results.

- Evaluation criteria of skill **C8.1 (Marker 2)** : constructive attitude of each student during meetings with the teaching staff, regular contribution to the project progress, appropriation of tasks in the project, regular effort to interface his developments with the ones of the rest of the team, and to adapt his developments to make easier the ones of others developers.

Resources
Teaching staff:

- **F. Magoules** (CentraleSupélec & MICS), and **S.Vialle** (CentraleSupélec & LRI)
- **S. Claus** and **F.-X. Roux** (ONERA)

Workplace and computing resources:

- Students will work at CentraleSupelec, in a classroom with electrical outlets and reliable wifi Internet access.
- Students will use their laptops to connect to remote PC clusters at the Data Center for Education of CentraleSupelec.
- Final oral exam will take place at CentraleSupelec the last afternoon of the project.

Learning outcomes covered on the course
When finishing the course, the students will be able to:

- Learning Outcome 1 (**AA1**): identify and parametrize an optimisation method adapted when each evaluation/iteration requires many computing resources and computation time,
- Learning Outcome 2 (**AA2**): implement and debug a sequential or parallel Python code on supercomputer (developped from scratch or using libraries), calling distributed C/C++ computing kernels,
- Learning Outcome 3 (**AA3**): deploy intensive computing applications on remote resources,
- Learning Outcome 4 (**AA4**): identify the limitations of the study, function of the available computing resources,
- Learning Outcome 5 (**AA5**): manage a computing resource quota, during an intensive computing campaign.

Description of the skills acquired at the end of the course

- **C3.7:** Make pragmatic and informed choices with the aim of producing tangible results.
    - **Marker 2:** Enforce the designed solution and act in a pragmatic way, in order to get tangible results.
    - Evaluated with learning outcomes **AA2**, **AA3**, **AA5**.

- **C7.1:** Persuade at core value level; to be clear about objectives and expected results. To apply rigor when it comes to assumptions and structured undertakings, and in doing so structure and problematize the ideas themselves. Highlight the added value.
    - **Marker 2:** Convince to adopt a solution among several propositions (according to predetermined criteria).
    - Evaluated with learning outcomes **AA1**, **AA4**.

- **C8.1:** Work collaboratively in a team.
    - **Marker 2:** Know how to position yourself in a team, identify what can be brought to a collective; Attempt to associate each team member function of his strengths.
    - Evaluated considering each student behavior, and his contribution to the learning outcomes validations.

2SC7693 – Optimization of infrasonic wave detection for verification of the Comprehensive Nuclear-Test-Ban Treaty

Instructors: Stephane VIALLE
Department: DOMINANTE - MATHÉMATIQUES, DATA SCIENCES, DOMINANTE - INFORMATIQUE ET NUMÉRIQUE
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 80
On-site hours (HPE): 48
Quota :

Description

Project of the ST7 "High Performance Simulation for Footprint Reduction",
Project topic in partnership with CEA DAM.
Majors: Computer Science (INFONUM) & Math, Data Sciences (MDS).

Rmk : Project proposed to students of **European Union**

CEA-DAM uses high performance computing resources for its various missions, particularly in the environmental monitoring field (e.g. seismic or acoustic wave propagation phenomena). The “Département d'Ile de France” located in Bruyères-le-Châtel is thus the tsunamis and strong earthquakes french warning center. As part of its missions and based on its skills in the nuclear area as well as in detection and identification technologies, CEA-DAM also brings its expertise for fighting against nuclear proliferation and terrorism. In order to inform national authorities in case of a nuclear test, CEA-DAM thus participates in the implementation of verification means to assess the non-violation of the “Comprehensive Nuclear-Test-Ban Treaty” (CTBT).

The study proposed here concerns the characterization and detection of infrasonic waves at long distances, taking into account the topography and atmospheric conditions (e.g. wind here). A compressible 2D axisymmetric / 3D hydrocode which supports adaptive mesh refinement (AMR) and hybrid parallelism (MPI domain decomposition / OpenMP multithreading) on Cartesian grids is developed in our laboratory. It can simulate the propagation of blast and acoustic waves in the presence of relief and buildings, with or without wind. Judiciously located sensors allow overpressure signals recordings.

Two types of problems which will be solved with this AMR hydrocode are addressed here. The first one consists in localizing an explosion and determining its power on the basis of probes' recordings located in the scene. The second one consists in defining judicious sensors locations in order to maximize the chances of detection in case of explosions in a given area. In both cases, a "brute force" investigation consisting in simulating all possible configurations before retaining the best one is unthinkable. It would consume gigantic hours of computations, which would make the design of the solution very long and overpriced.

For these two types of problems, the objective of this study is therefore twofold:

- Propose a solution to characterize the source of acoustic waves.
- Find this solution in a reasonable time on high-performance computers AND with a limited quota of computation hours.

To that end we will develop an optimization loop that uses the hydrocode the most efficiently as possible, by parsimoniously exploring the possible configurations space, to economically find a “good” solution.

Technical details of the studied systems

- **1st topic: characterization of a source at the urban scale, taking into account buildings**

  It consists in locating and determining the power of an explosion, following an accident or a malicious act, knowing only neighboring sensors recordings (whose locations are known). Buildings in the surrounding area will be taken into account. Here, the recordings will come out in practice from a simulation whose fictitious initial conditions (location and power of the source) will not be known by the students.

- **2nd topic: setting up a surveillance network**

  Here, it is question of designing a sensors network allowing the detection of hypothetic explosive experiments around an area that is under surveillance. These sensors - in limited numbers - should be judiciously located in order to maximize chances of detection whatever the weather (we will only consider wind here) and the relief are. Furthermore and for maintenance reasons, the sensors will only be located in so-called "accessible areas”.

Quarter number
ST7

Prerequisites (in terms of CS courses)
First year courses:

9. SG1 common course "Systèmes d'Information et Programmation" (1CC1000)
10. ST2 common course "Algorithmique et complexité" (1CC2000)

Courses of the ST:

- ST7 common course "Optimisation" (2CC3000)
- ST7 specific course "Méthodes et algorithmes parallèles pour l'optimisation" (2SC7610)

Others prerequisites:

- Parts of common course "CIP - Convergence, Intégration et Probabilités" (1SL1000)
- Parts of common course "EDP - Equations aux dérivées partielles" (1SL1500)
- Knowledge of linear algebra will also be needed

Syllabus
Main tasks of the study:

- More information at the beginning of the first part of the project (intervention of the CEA-DAM).
  - Presentation of physical principles and numerical methods used in the provided compressible hydrocode that will be used to simulate the propagation of blast and acoustic waves.
  - Identification of compressible hydrodynamic code parameters and their impact on the parallel execution time.
  - Handling resources in a remote computing center (at the CEA).
- Formalization of the problem and selection of values that are to be optimized. Choice of an optimization method adapted to the problem.
- Design and implementation in Python of an optimization code calling the parallel simulation code. The optimization code will itself

be parallelized if allowed by its algorithm (we would then have a parallel master code calling on demand the parallel hydrocode).

- Tests and debugging of the complete optimization code on CEA's parallel computers, on small and medium problems: simplified reliefs or buildings on reduced maps, without weather for 2D axisymmetric configurations (much faster).
- Scale up in terms of covered land size, and addition of relief and / or buildings and wind maps.
    - Experiments on bigger problems on a more large number of nodes and computing cores.
    - Analysis of the solution quality and the performances.
    - Code optimization to improve the solution found AND the computations performances.
- Estimation of the maximum size of the problem that can be handled regarding available resources and the study duration. Analysis of the feasibility of the extension to 3D cases over the time allocated for the project.
- Submission of a report and a presentation to evaluate: the quality of the solution found, the effectiveness and the extensibility of the code in finding an optimal solution, and the computation resource quota management that will have occurred during the project.

Rmk: the different groups of students will work on different topics (topics 1 and 2) and will implement different optimization methods.

Class components (lecture, labs, etc.)
Part 1 (40HEE):

- Steps 1 and 2: course complements, handling of computing resources, formalization of the problem, choice of an optimisation algorithm.
- Step 3: Python numerical implementation of the optimisation algorithm calling the compressible hydrodynamic parallel code, supplied by CEA DAM.
- Step 4: first executions on parallel machines of 2D simulations with basic configurations, debug of the algorithm and of the optimization code, evaluation of the result quality and computation performances on small and medium size problems, and comparison to a reference solution.

- Midterm report (slides and progress summary) and talk about current results and future work (part 2).

Part 2 - *final sprint* (40HEE):

- Step 5: experiments on more complex and/or larger problems, similar to real problems, analyse of the quality of the computed solution, identification of the sources of performance locks and losses, and (if required) code improvement to push the limits of supportable problem size.

- Step 6: estimate of the maximal problem size that can be processed, function of the available computing resources and of the maximum duration of the project, analyse of the feasibility of a 3D simulation.

- Final report (slides and extended abstract) and global talk about the project approach and results.

Grading

This project will be evaluated by a midterm talk at the end of part 1 (40HEE), and by a final talk at the end of part 2 (*final sprint* 40HEE). Talks will be done by the entire team, but will lead to individual marks in case of strongly heterogeneous teams. Each talk evaluation will consider the overall quality of the talk, of the slides and of the progress summary. Each talk mark will be 50% of the total mark.

10. Evaluation criteria of skill **C3.7 (Marker 2)** and of learning outcomes **AA2**, **AA3** and **AA5** : development completion of a high performance simulation software on parallel machines ,accuracy and performances reached by this software, quality of the results achieved at the end of an intensive simulation campaign, with respect of the allocated computing resource quota.

7. Evaluation criteria of skill **C7.1 (Marker 2)** and of learning outcomes **AA1** and **AA4** : quality of the argumentation about scientific and technical choices all along the project, during meetings with the teaching staff and during the talks at the end of project part 1 and 2, capability to introduce advantages and disadvantages of unselected alternative solutions, balance of the developed solution (at the end of the project) and introduction to the reached results.

- Evaluation criteria of skill **C8.1 (Marker 2)** : constructive attitude of each student during meetings with the teaching staff, regular contribution to the project progress, appropriation of tasks in the project, regular effort to interface his developments with the ones of the rest of the team, and to adapt his developments to make easier the ones of others developers.

Resources
Teaching staff:

- **J. Cagnol** (CentraleSupélec & MICS) and **S. Vialle** (CentraleSupélec & LRI)
- **S. Jaouen** (CEA DAM)

Workplace and computing resources:

- During the first part of the project:
  - Students will work at CentraleSupelec, in a classroom with electrical outlets and reliable wifi Internet access.
  - Students will use their laptops to connect to **remote powerful computing resources managed by CEA DAM**.
- During the second part of the project (*final sprint*):
  - Students will work **3 days on TGCC/TERATEC site, at Bruyères-le-Châtel.** CEA DAM will ensure the daily movement of students.
  - Final oral exam will take place at CentraleSupelec the last afternoon of the project.

Learning outcomes covered on the course
When finishing the course, the students will be able to:

- Learning Outcome 1 (**AA1**): identify and parametrize an optimisation method adapted when each evaluation/iteration requires many computing resources and computation time,
- Learning Outcome 2 (**AA2**): implement and debug a sequential or parallel Python code on supercomputer (developed from scratch or using libraries), calling distributed C/C++ computing kernels,
- Learning Outcome 3 (**AA3**): deploy intensive computing applications on remote resources,
- Learning Outcome 4 (**AA4**): identify the limitations of the study, function of the available computing resources,
- Learning Outcome 5 (**AA5**): manage a computing resource quota, during an intensive computing campaign.

Description of the skills acquired at the end of the course

- **C3.7:** Make pragmatic and informed choices with the aim of producing tangible results.
  - **Marker 2:** Enforce the designed solution and act in a pragmatic way, in order to get tangible results.

- Evaluated with learning outcomes AA2, AA3, AA5.

- **C7.1:** Persuade at core value level; to be clear about objectives and expected results. To apply rigor when it comes to assumptions and structured undertakings, and in doing so structure and problematise the ideas themselves. Highlight the added value.
  - **Marker 2:** Convince to adopt a solution among several propositions (according to predetermined criteria).
  - Evaluated with learning outcomes AA1, AA4.

- **C8.1:** Work collaboratively in a team.
  - **Marker 2:** Know how to position yourself in a team, identify what can be brought to a collective; Attempt to associate each team member function of his strengths.
  - Evaluated considering each student behavior, and his contribution to the learning outcomes validations.

2SC7694 – Energy optimization and acceleration of a cloud financial calculation graph

Instructors: Stephane VIALLE
Department: DOMINANTE - MATHÉMATIQUES, DATA SCIENCES, DOMINANTE - INFORMATIQUE ET NUMÉRIQUE
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 80
On-site hours (HPE): 48
Quota :

Description

Project of the ST7 "High Performance Simulation for Footprint Reduction",
Project topic in partnership with ANEO.
Majors: Computer Science (INFONUM) & Math, Data Sciences (MDS).

Application Context

Modern **insurers** have a highly regulated but at the same time relatively broad field of activity: different types of insurance, banking services, etc. One of the difficulties in assessing the accounts of an insurance company (or bank) lies in the valuation of financial assets (e.g. EDF shares, life or car insurance contracts, etc.) and the underlying risks. The approach generally used consists of evaluating for each asset the cost of a devaluation as well as the associated risk. For simple assets such as shares, the calculation is simple. For more complex assets such as insurance products or derivatives, the calculation is more complex since it is usually based on the consideration of many factors. Depending on the valuation of the risks taken, regulations resulting from various economic crises, such as Solvency II or IFRS17, require the insurance or bank to tie up a certain amount of equity capital. Certain risks may cancel each other out between different assets (e.g. the risk of a life insurance asset based on the euro/dollar rate may be covered by other assets based on the euro/yen and yen/dollar rates). In order to maximise this potential for offsetting through the assets owned, these bodies will consolidate the accounts on the widest possible scale, the group as a whole. That is, they will carry out risk analyses as if all assets belonged to a single entity. One of the difficulties of the exercise then consists in distributing the capital requirement among the different legal entities whose accounts have been consolidated, so this process is actually more complex than a simple pooling of assets followed by a global risk analysis.

The ***process of constructing consolidated accounts for an insurance company therefore generates numerous calculations***. These calculations concern, on the one hand, the modelling of the cost of repayment of contracts according to various factors and, on the other hand, the modelling of investments made with the money available. As an example for a life insurance contract, risk modelling is based on mortality tables provided by INSEE and taking into account different factors such as geography, socio-professional category, family situation, etc. To do this, the life of the contract is simulated year after year in order to take into account changes in these factors. Different scenarios are played out in order to reflect all possible changes in situations (moves, changes in family situation, etc.). These scenarios are then aggregated. This process is of course a simplified view and does not take into account various elements such as the aggregation of contracts in order to reduce the volume of calculations, which aggregation is in itself the subject of various optimization works. Other elements of the process include the consolidation of asset/liability risks by contract type, consolidation by legal entity and taking into account the specific regulatory requirements of each country, and the use of these simulations to optimise the risk of the contracts offered as well as their price.

Problem addressed in this project

The process of constructing the consolidated financial statements takes several weeks and includes calculation steps as well as manual steps; we will consider the latter here as instantaneous. The calculation steps correspond to the equivalent of 413177 hours of calculation time, i.e. just over 10 full days on an infrastructure of 1700 cores. However, in reality, the process cannot take place in 10 days on such an infrastructure because of the dependencies between the computing tasks: there are times when there are not enough tasks to occupy the grid. A fine analysis of the dependencies shows that the critical path duration is 11h30. This duration would be that of the whole computation if an infrastructure of infinite size was available.

Project subject: In order to optimize costs without investing in a very large computing grid that would ultimately be little used, we want to use on-demand resources available in the cloud. To make the most of this, **we want to optimize the execution of the task graph** by searching for :

- The best strategy for switching compute nodes on and off.
- The best scheduling of tasks on the available nodes.

The study will have to take into account the following elements:

- The dependencies between tasks
- The duration of the tasks, known in advance

- The duration of the transfer of results between tasks (only the relevant files will be listed).

It should be noted here that the cost mentioned can be energy as well as financial, and that the two are closely linked: in use, more than half of the cost of owning a computing infrastructure corresponds to the cost of electricity, even in France with nuclear energy. We will make the (very simplifying) assumption that the network has no cost.

Project objective: to provide an optimization application working on two files describing on one hand the task graph (durations and dependencies) and on the other hand the characteristics of the computing infrastructure, and which will provide in output a file describing the infrastructure scheduling (switching on and off nodes) as well as the task scheduling (placement of a task on a node at a given time).

Students will be provided with :

- Documentation describing input and output formats and performance evaluation criteria.
- Examples of graphs and infrastructures
- A REST API (calculation function that can be called directly from the Internet) to evaluate the quality of the proposed solution.
- Access to distributed computing resources

Quarter number
ST7

Prerequisites (in terms of CS courses)
First year courses:

- SG1 common course "Systèmes d'Information et Programmation" (1CC1000)
- ST2 common course "Algorithmique et complexité" (1CC2000)

Courses of the ST:

- ST7 common course "Optimisation" (2CC3000)
- ST7 specific course "Méthodes et algorithmes parallèles pour l’optimisation" (2SC7610)

Others prerequisites:

- Parts of common course "CIP - Convergence, Intégration et Probabilités" (1SL1000)

- Parts of common course "EDP - Equations aux dérivées partielles" (1SL1500)
- Knowledge of linear algebra will also be needed

Syllabus
Main steps of the study:

- Complement of courses in hardware architecture of computer systems, including energy aspects.
- Formalization of the problem and the cost function to be optimized.
- Choice of a meta-heuristic optimization method adapted to the problem, examples: genetic algorithms, ant colonies, variable neighborhood method...
- Handling of remote computing resources (in cloud or supercomputer on which ANEO has access).
- Design of an algorithm parallel to the chosen optimization method, capable of scaling in terms of size or complexity of the task graph processed.
- Implementation of a parallel Python code supporting the planned scalability.
- Execution of the parallel resolution code on real data sets provided by ANEO, and within the limits of the computational resources allocated to the study.
- Analysis of the quality of the results of the resolution code, the performance of the resolution calculations performed (calculation speed, scalability), and the associated cost from an industrial exploitation perspective.
- The study will end with a report and an oral presentation aimed at evaluating the overall relevance of the solution found and tested, and the management of the quota of calculation resources that will have taken place during the project.

Rmk: The different groups of students will be confronted with different hypotheses on the targeted computing platforms, leading to equally different choices and implementations of optimization methods.

Class components (lecture, labs, etc.)
Part 1 (40HEE) :

9. Steps 1 to 4: course additions, formalization of the problem, choice of an optimization method, and handling of calculation resources.
10. Steps 5 and 6: first functional parallel implementation of the solving algorithm, small-scale tests.

12. Intermediate report and presentation of progress and the work planned in part 2

Part 2 - *final sprint* (40HEE):

- Steps 7 and 8: execution of the resolution algorithm on intensive computing resources, and evaluation of the results obtained and the performance measured.
- Winding up in part 5 for the improvement of the resolution algorithm and its parallel implementation.

- Final report and full oral presentation

Grading

This project will be evaluated by a midterm talk at the end of part 1 (40HEE), and by a final talk at the end of part 2 (*final sprint* 40HEE). Talks will be done by the entire team, but will lead to individual marks in case of strongly heterogeneous teams.Each talk evaluation will consider the overall quality of the talk, of the slides and of the progress summary. Each talk mark will be 50% of the total mark.

- Evaluation criteria of skill **C3.7 (Marker 2)** and of learning outcomes **AA2**, **AA3** and **AA5**: development completion of a high performance simulation software on parallel machines, accuracy and performances reached by this software, quality of the results achieved at the end of an intensive simulation campaign, with respect of the allocated computing resource quota.

- Evaluation criteria of skill **C7.1 (Marker 2)** and of learning outcomes **AA0**, **AA1** and **AA4**: quality of the argumentation about scientific and technical choices all along the project, during meetings with the teaching staff and during the talks at the end of project part 1 and 2, capability to introduce advantages and disadvantages of unselected alternative solutions, balance of the developed solution (at the end of the project) and introduction to the reached results.

- Evaluation criteria of skill **C8.1 (Marker 2)**: constructive attitude of each student during meetings with the teaching staff, regular contribution to the project progress, appropriation of tasks in the project,regular effort to interface his developments with the ones of the rest of the team, and to adapt his developments to make easier the ones of others developers.

Resources
Teaching staff:

- **A. Rimmel** (CentraleSupélec & LRI)
- **W. Kirschenmann** (ANEO)

Workplace and computing resources:

- Students will work at CentraleSupelec, in a classroom with electrical outlets and reliable wifi Internet access.
- Students will use their laptops to access remote computing resources (cloud or supercomputer on which ANEO has access).
- Final oral exam will take place at CentraleSupelec the last afternoon of the project.

Learning outcomes covered on the course
At the end of this project, students will be able to:

- **Learning Outcome 0 (AA0):** to identify the CPU consuming parts in an optimization chain, and to model the energy cost of a distributed calculation,
- **Learning Outcome 1 (AA1):** to identify optimization methods adapted to the minimization of the execution time of a task graph, and adapted to a large scale parallelization,
- **Learning Outcome 2 (AA2):** to design a parallel algorithm supporting scaling, to implement it and to develop its code on a distributed architecture,
- **Learning Outcome 3 (AA3):** to deploy intensive simulations on remote computing resources
- **Learning Outcome 4 (AA4):** to identify the limits of the study according to the available computational resources
- **Learning Outcome 5 (AA5):** to manage a quota of calculation resources during an intensive calculation campaign

Description of the skills acquired at the end of the course

- **C3.7:** Make pragmatic and informed choices with the aim of producing tangible results.
  - **Marker 2:** Enforce the designed solution and act in a pragmatic way, in order to get tangible results.
  - Evaluated with learning outcomes **AA0**, **AA2**, **AA3**, **AA5**.

- **C7.1:** Persuade at core value level; to be clear about objectives and expected results. To apply rigour when it comes to assumptions and structured undertakings, and in doing so structure and problematise the ideas themselves. Highlight the added value.
    - **Marker 2:** Convince to adopt a solution among several propositions (according to predetermined criteria).
    - Evaluated with learning outcomes **AA1**, **AA4**.

- **C8.1:** Work collaboratively in a team.
    - **Marker 2:** Know how to position yourself in a team, identify what can be brought to a collective; Attempt to associate each team member function of his strengths.
    - Evaluated considering each student behavior, and his contribution to the learning outcomes validations.

2SC7695 – Low cost optimization of acoustic wave propagation code performance

Instructors: Stephane VIALLE
Department: DOMINANTE - MATHÉMATIQUES, DATA SCIENCES, DOMINANTE - INFORMATIQUE ET NUMÉRIQUE
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 80
On-site hours (HPE): 48
Quota :

Description

Project of the ST7 "High Performance Simulation for Footprint Reduction",
Project topic in partnership with INTEL.
Majors: Computer Science (INFONUM) & Math, Data Sciences (MDS).

Regardless of the type of application running on parallel machines in an HPC (high performance computing) environment, and regardless of their level of efficiency (in terms of performance or energy footprint), we can easily see that the impact of input parameters is generally not negligible. In particular, we can act on :

- the parameters of the parallel algorithm used, such as the size and shape of the domains performing a sub-problem partitioning,
- HPC implementation parameters controlling for example *cache blocking* to reduce data access times,
- parallel application deployment parameters, controlling the process-MPI vs. threads-OpenMP distribution and the placement of these computational tasks to efficiently occupy CPU cores,
- parameters controlling the thread scheduling policy (usually controlled through environment variables).

These different input parameters allow to improve the execution of HPC code on a computing platform. But it remains extremely difficult to understand exactly how the application behaves in the processor architecture and even if we could make the application more efficient by modifying the source code, the dependency on test cases and the execution environment would still be preponderant. In this context where the parameter space can be of important dimension, the use of optimization algorithms appears fundamental to converge towards a global (or at least local) minimum of a cost function expressing the execution time and the energy footprint. We will therefore use optimization methods and algorithms to optimize the operation of an HPC calculation code.

However, each execution of a test case of an HPC application can be long, even on a parallel machine. The parameter space is large and an optimization algorithm can require tens of thousands of executions of the application (or even more). What is achievable on the scale of a computing kernel remains unbearable on the scale of a complete application.

It is therefore necessary to choose optimization methods that do not consume too many experiments, and then to optimize their use to reduce the footprint of the targeted HPC code, without this pre-study consuming too many computing resources! This amounts to **"looking for the least expensive optimization method"** to find an optimum between convergence speed (of the optimization algorithm) and the quality of the minimization of execution time and energy footprint (of the targeted HPC application).

Technical details of the system :

We will start this project from :

- a high performance computing code (HPC code) that simulates the 3D acoustic wave equation in a homogeneous isotropic finite-difference medium, and runs on multi-core PC clusters (in MPI + OpenMP),
- a genetic algorithm capable of iterating on many parameters of the HPC code such as: size and shape of domains and *cache blocking*, compilation flags, environment variables, number and placement of threads..., but which remains sequential and limited to a single machine.

The genetic algorithm thus calls successively the acoustic wave simulation code in different configurations, and can only call it in a multithreaded version on one machine (not in a distributed version on a cluster). This allows nevertheless to search for the optimal configuration on each PC, and then to apply it on each PC when running on a cluster of PCs.

The *finite differences* being quite explicit in terms of the number of floating operations, we can easily count the number of points processed or the number of floating operations performed during an execution, and deduce a processing speed in Giga points/s or GFlops/s. We can then try to minimize the simulation time (or maximize the processing speed). We can also dedicate and collect some hardware counters to obtain the exact power consumption of the processor and memory, to study in detail the energy impact of our optimizations.

But a genetic algorithm is a population-based optimization method that is computationally resource-intensive, and the implementation provided uses only one PC. The search for an optimal configuration of the code can therefore be very long and prohibitive. To overcome this limitation we will adopt two approaches:

- Firstly, we will identify optimization methods that are likely to converge in relatively few tests towards an efficient configuration of the HPC code (i.e. leading to fast and low power consumption executions). We will be able to study optimization methods with trajectories (Hill Climbing, Simulated Annealing, Tabu search..., with or without gluttonous behavior), or other methods with a population less greedy than genetic algorithms (ant colonies...). A very good solution will thus be sought in a rather long time, which would then allow to execute many simulations of very optimized acoustic wave propagations.

- One will then try to experiment an optimization method, or a variant of the one previously experimented, which would converge "very quickly" towards a solution of only "good enough" quality. Such (very fast) optimization could then be integrated into the application in the form of dynamic pre-processing, at the beginning or during execution on parallel machines, and constitute a self-optimization mechanism for the application.

Prerequisites (in terms of CS courses)

First year courses:

- SG1 common course "Systèmes d'Information et Programmation" (1CC1000)
- ST2 common course "Algorithmique et complexité" (1CC2000)

Courses of the ST:

- ST7 common course "Optimisation" (2CC3000)
- ST7 specific course "Méthodes et algorithmes parallèles pour l’optimisation" (2SC7610)

Others prerequisites:

- Parts of common course "CIP - Convergence, Intégration et Probabilités" (1SL1000)
- Parts of common course "EDP - Equations aux dérivées partielles" (1SL1500)
- Knowledge of linear algebra will also be needed

Syllabus

Main steps of the study :

6. Presentation of the provided computing kernel, complementary courses on the methodologies of characterization and acceleration of HPC code (*hardware counters, roofline modeling, NUMA placement, vectorization...*), handling of the remote computing resources of the CentraleSupélec Teaching Data Center with experimentation of the codes provided by INTEL.
7. Identification of promising optimization methods for the problem, and not launching too many HPC simulations of acoustic waves. The development of hybrid methods could be considered.
8. Development of a 1st solution in sequential Python with call of the simulation C code provided for the study.
9. Development of a first optimization-simulation campaign on multi-core machines, with management of a weekly quota of calculation hours. Identification of a solution that best reduces the footprint of the HPC acoustic wave simulation code.
10. Development and experimentation of a 2nd solution, allowing to search "very quickly" for a "good enough" quality configuration, in order to integrate this search into the simulation application at the pre-processing stage.
11. Development of a second optimization-simulation campaign on multi-core machines, with management of a weekly quota of calculation hours.
12. The study will end with a report and an oral presentation to evaluate:
    1. the investigative approach adopted,
    2. the quality of the solution found: in terms of the speed of convergence of each optimization algorithm tested, and the computation time and energy consumption of the optimized parallel simulation,
    3. the management of the quota of calculation resources that will have taken place during the project.

Rmk: The different groups of students will implement different optimization methods.

Class components (lecture, labs, etc.)

Part 1 (40HEE) :

6. Steps 1 and 2: Complementary lectures on HPC code optimizations and on the configuration parameters of the simulation code provided, handling of the remote computing resources of the

Teaching Data Center with experimentation of the initial solution, and identification of two promising optimization methods.

7. Step 3: sequential implementation in Python of a first optimization method calling parallel simulation code and HPC, first optimization-simulation campaign on a multi-core computing server.

- Step 4: execution of an optimization-simulation campaign on parallel machines, with the management of a quota of hours. Analysis of the obtained performances.

- Intermediate report, and presentation of the progress and the work planned in the 2nd part.

Part 2 - *final sprint* (40HEE):

- Step 5: identification of a method to search "very quickly" for a "fairly good" configuration. New implementation in Python.

- Step 6: new optimization-simulation campaign on parallel machines, with the management of a quota of hours. Analysis of the obtained performances.

- Final report and full oral presentation.

Grading

This project will be evaluated by a midterm talk at the end of part 1 (40HEE), and by a final talk at the end of part 2 (*final sprint* 40HEE). Talks will be done by the entire team, but will lead to individual marks in case of strongly heterogeneous teams. Each talk evaluation will consider the overall quality of the talk, of the slides and of the progress summary. Each talk mark will be 50% of the total mark.

- Evaluation criteria of skill **C3.7 (Marker 2)** and of learning outcomes **AA2**, **AA3** and **AA5**: development completion of a high performance simulation software on parallel machines, accuracy and performances reached by this software, quality of the results achieved at the end of an intensive simulation campaign, with respect of the allocated computing resource quota.

- Evaluation criteria of skill **C7.1 (Marker 2)** and of learning outcomes **AA0**, **AA1** and **AA4**: quality of the argumentation about scientific and technical choices all along the project, during meetings with the teaching staff and during the talks at the end of project part 1 and

2, capability to introduce advantages and disadvantages of unselected alternative solutions, balance of the developed solution (at the end of the project) and introduction to the reached results.

- Evaluation criteria of skill **C8.1 (Marker 2)**: constructive attitude of each student during meetings with the teaching staff, regular contribution to the project progress, appropriation of tasks in the project, regular effort to interface his developments with the ones of the rest of the team, and to adapt his developments to make easier the ones of others developers.

Resources

Teaching Staff:

- **L. Cabaret** (CentraleSupélec & MICS) et **S. Vialle** (CentraleSupélec & LRI)
- **Ph. Thierry** et **C. Andreolli** (INTEL)

Workplace and computing resources:

- Students will work at CentraleSupelec, in a classroom with electrical outlets and reliable wifi Internet access.
- Students will use their laptops to connect to remote PC clusters at Data Center for Education of CentraleSupelec
- Final oral exam will take place at CentraleSupelec the last afternoon of the project.

Learning outcomes covered on the course

At the end of this project, students will be able to:

- **Learning Outcome 0 (AA0):** to identify the parameters impacting the execution of a parallel code, and to configure its execution,
- **Learning Outcome 1 (AA1):** to choose and configure optimization methods converging with a limited number of experiments,
- **Learning Outcome 2 (AA2):** to develop a sequential Python code, calling parallel codes on parallel architectures,
- **Learning Outcome 3 (AA3)**: to deploy intensive simulations on remote computing resources,
- **Learning Outcome 4 (AA4)**: to identify the limits of the study according to the available computational resources
- **Learning Outcome 5 (AA5):** to manage a quota of calculation resources during an intensive calculation campaign.

Description of the skills acquired at the end of the course

- **C3.7:** Make pragmatic and informed choices with the aim of producing tangible results.
  - **Marker 2**: Enforce the designed solution and act in a pragmatic way, in order to get tangible results.
  - Evaluated with learning outcomes **AA0, AA2**, **AA3**, **AA5**.

- **C7.1**: Persuade at core value level; to be clear about objectives and expected results. To apply rigor when it comes to assumptions and structured undertakings, and in doing so structure and problematise the ideas themselves. Highlight the added value.
  - **Marker 2**: Convince to adopt a solution among several propositions (according to predetermined criteria).
  - Evaluated with learning outcomes **AA1**, **AA4**.

- **C8.1:** Work collaboratively in a team.
  - **Marker 2**: Know how to position yourself in a team, identify what can be brought to a collective; Attempt to associate each team member function of his strengths.
  - Evaluated considering each student behavior, and his contribution to the learning outcomes validations.

ST7 – 77 – EFFICACITE DES SYSTEMES D’ENERGIE EMBARQUES

Dominante : ENE (Energie)
Langue d’enseignement : Français
Campus où le cours est proposé : Paris-Saclay

2SC7710 – Numerical methods and problem solving for optimizing embedded energy systems

Instructors: Maya HAGE HASSAN, Philippe DESSANTE
Department: ENERGIE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 34,5
Quota :

Description

The optimization of embedded energy systems is a daily problem encountered in the industrial world (aeronautics, space or automotive). The objectives encountered are the gain in volume, cost (optimal design or operating cost), performance or efficiency. The system and multiphysics aspect of the design is now taken into account in order to best meet increasingly demanding specifications.
Numerical methods used: multi-criteria optimization, parameter estimation, dynamic programming, stochastic algorithms.

You will be offered projects under four themes :

- **Energy efficiency**
- **Optimization of electric actuators**
- **Optimal network management**
- **Optimization of a propulsion chain**

You are invited to choose the project you are most interested in under each theme. At the end you will be assigned a single project.

Quarter number

ST7

Prerequisites (in terms of CS courses)

Electrical Energy
Transport Phenomena

Syllabus

Problem formulation
Models related to optimization
Optimization of energy systems
Stochastic optimization (simulated recruit, genetic algorithms, differential evolution)
Parameter estimation
Dynamic programming
Multi-source optimization
Multi-criteria optimization

Class components (lecture, labs, etc.)
Lectures: 24h
TD/TP : 9h

Grading
Written exam : 1h30

Course support, bibliography
Course presentations
Matlab files

Resources
Lecture, TD, TP, Project

Learning outcomes covered on the course
Optimization
Systems
Optimization of embedded systems
Stochastic optimization

Description of the skills acquired at the end of the course
The student will be able to implement an optimization of an embedded system.
- problem formalization
- mathematical optimization
- results analysis
- multi-objectives

2SC7791 – Energy efficiency

Instructors: Tanguy PHULPIN, Bruno LORCET, Mohamed BENSETTI, Maya HAGE HASSAN, Philippe DESSANTE
Department: DOMINANTE - ENERGIE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 80
On-site hours (HPE): 48
Quota :

Description

The energy optimisation of components or a system in a complex energy conversion process is posed on the one hand by a search for lower operating costs, but also by regulations which impose increasingly high efficiency levels in order to control electricity demand.

It is therefore necessary to optimize the efficiency of components such as electric machines, converters, or work at the system level, for example electric bicycles, cars, drones, etc.... Of course, this maximization of efficiency goes against another optimization: that of the manufacturing cost. A multi-criteria optimization between efficiency and cost will therefore be implemented.

Quarter number

ST7

2SC7792 – Optimization of electric actuators

Instructors: Amir ARZANDE, Philippe DESSANTE, Jean-Claude VANNIER, Maya HAGE HASSAN
Department: DOMINANTE - ENERGIE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 80
On-site hours (HPE): 48
Quota :

Description

The rise in the price of fossil fuels as well as environmental constraints are pushing the automotive and mobility sector to turn more and more to electric traction as a replacement or supplement to the combustion engine.

The electric motor in the vehicle is not used on a single point of operation as it is the case for a static application but must respond to the demands of driving. To model these behaviors, many road test cycles are used. The optimization of the traction chain as a system is thus made complicated and expensive by the large number of operating points generated by these cycles. Reduction techniques will therefore be used to optimize the yields or masses of the systems.

Quarter number

ST7

Prerequisites (in terms of CS courses)

Electric energy

Grading

Final project defense

Resources

Classroom (25 pers) reconfigurable with videoprojection and WiFi, Matlab/Simulink

Learning outcomes covered on the course

- Understand the sizing of actuators
- Formulate and reformulate an optimization problem
- Understand the difficulties and constraints related to this type of optimization
- Model and optimize an electric actuator and size it on a road cycle

Description of the skills acquired at the end of the course

C1.1 - Study a problem in its entirety, the situation as a whole. Identify, formulate and analyze a problem in its scientific, economic and human dimensions.

C1.2 - Use and develop adapted models, choose the right modeling scale and simplifying assumptions relevant to the problem.

C1.3 - Solve the problem with a practice of approximation, simulation and experimentation.

C2.5 - Master the skills of one of the core trades of the engineer (junior level).

C3.1 - Be proactive, take initiative, get involved.

2SC7793 – Optimal network management

Instructors: Martin HENNEBEL, Philippe DESSANTE, Marc PETIT, Jing DAI
Department: DOMINANTE - ENERGIE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 80
On-site hours (HPE): 48
Quota :

Prerequisites (in terms of CS courses)
basics in optimization

2SC7794 – Optimization of a propulsion chain

Instructors: Loïc QUEVAL, Maya HAGE HASSAN, Philippe DESSANTE
Department: DOMINANTE - ENERGIE
Language of instruction: FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 80
On-site hours (HPE): 48
Quota :

Description

90% of world trade is transported by ship. As a result, maritime transport is one of the largest contributors to air pollution : 3% of the world's total greenhouse gas emissions. Electric ship propulsion is one of the candidate to replace conventional thermic ship propulsion systems.

In electric ship propulsion, gas turbines or diesel generators generate electricity which is then used to power both the electric motors and the auxiliary loads. The onboard electric grid can be either AC or DC. Such system must be optimized in order to minimize its cost and to optimize its efficiency. Note that if the ship follows a fixed itinerary (such as a ferryboat), the optimization can take the operation cycle into account.

Quarter number

ST7

Prerequisites (in terms of CS courses)

none

Grading

At the end of the project, each group presents their analysis. The optimized grid data for each group is used by the supervising team to evaluate the work of each group.

Course support, bibliography

none

Resources

Classroom (25 pers) reconfigurable with videoprojection and WiFi.

Learning outcomes covered on the course

- Understand the various architectures of the electric grid of an electric ship.
- Master the various steps of the energy conversion in electric ship.
- Understand the difficulties and the constraints related to embed electrical grids.
- Model and optimize an embedded electric grid, taking the operation cycle into account.

Description of the skills acquired at the end of the course

- C1.1 - Study a problem in its entirety, the situation as a whole. Identify, formulate and analyze a problem in its scientific, economic and human dimensions.
- C1.2 - Use and develop adapted models, choose the right modeling scale and simplifying assumptions relevant to the problem.
- C1.3 - Solve the problem with a practice of approximation, simulation and experimentation.
- C2.5 - Master the skills of one of the core trades of the engineer (junior level).
- C3.1 - Be proactive, take initiative, get involved.

ST7 – 78 – SMART GRIDS ET DEFI ENERGETIQUE : GESTION DE L'ENERGIE EN SITE ISOLE

Dominante : GSI (Grands Systèmes en Interaction), ENE (Energie)
Langue d'enseignement : ENGLISH
Campus où le cours est proposé : Rennes

2SC7810 – Renewable energies and micro grids

Instructors: Pierre HAESSIG, Nabil SADOU
Department: DOMINANTE - ENERGIE
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 34,5
Quota :

Description

Faced with the negative environmental impacts of any energy production and the depletion of fossil resources, the transition to renewable sources is a profound trend. While renewable energies provided only 25% of the world's electricity production in 2018, this share is growing rapidly, with a threefold increase over 10 years in wind and solar energy.

These new energies raise specific questions to be addressed in this course:

- What are the wind and solar resources and the main principles of their conversion into electricity?
- What are the storage technologies, in particular batteries, that can manage the variability of these sources?
- What are the technical, environmental and economic challenges of these technologies?

In addition, wind and solar energy are much more *decentralized* than conventional thermal power plants. Thus, electricity production is moving closer to consumption areas, which leads to the emergence of the notion of "microgrid", similar to short food supply chains (SFSCs).

A microgrid is a small electrical system that integrates production and consumption within a delimited area (building, district, island, etc.) and is equipped with a local energy flow management system. A microgrid can be stand-alone or connected to a large network. If connected, it acts as a unique and intelligent actor, able, for example, to buy electricity from the wholesale market at the best moments or to provide grid services. The integration of all these components and functions raises system optimization issues that are covered in this course.

Due to their small size, the issue of reliability is an important one for microgrids. This course aims to study the methods of *dependability* to analyze the risks of failure, plan maintenance and react to outages…

Quarter number
ST7

Prerequisites (in terms of CS courses)
None

Syllabus
Renewable energies (REn) and storage :

10. Solar, wind, hydroelectric, bio-mass,...
11. Modeling and predictability of production
12. flexibility, storage technologies

Micro grids :

- Electrical grid architecture and modeling
- Sizing and operational management: taking into account the impacts of renewable energies, Quality of Service (voltage, frequency, etc.)

Reliability of grids:

- Reliability indicies
- Security bodies
- Reconfigurability
- Failure and reliability of components

Economic models of micro grids:

- Investment plan, profitability
- Uncertainties and risk management
- Energy markets, price signal, trading

Class components (lecture, labs, etc.)
Lecture (~50%): 18h labs (~50%): 6h+9h

Grading
written examination 1h30 - (50%) and labs report (50%)

Resources
Lecture, labs.
This course contains lectures and a large part of labs.

Learning outcomes covered on the course
At the end of this course, students will be able to :

- Understand the economical, ecological and societal context of microgrids
- Identify and characterize the different energy production sources and energy storages.
- Size a microgrid with different energy sources and energy storage, taking into account technical/non-technical constraints and uncertainties.
- Evaluate system performances and system dependability.

Description of the skills acquired at the end of the course

- Understand the economical, ecological and societal context of microgrids. C1.1, C4.1
- Identify and characterize the different energy production sources and energy storages C1.2
- Size a microgrid with different energy sources and energy storage, taking into account technical/non-technical constraints and uncertainties. C1.2, C1.4, C3.6, C4.2
- Evaluate system performances and system dependability. C3.6

2SC7890 – Insular carbon-free micro grid

Instructors: Nabil SADOU
Department: DOMINANTE - ENERGIE, DOMINANTE - GRANDS SYSTÈMES EN INTERACTION
Language of instruction : ENGLISH
Campus : CAMPUS DE RENNES
Workload (HEE): 80
On-site hours (HPE): 48
Quota :

Description

Nearly a billion people are still without access to electricity (IEA 2018). These populations are often found in isolated regions in rural or insular areas. Thus, for 3/4 of them, it is not economically efficient to bring them electricity by expanding the existing large electricity networks. Electrification must therefore be done at the local level, through microgrids.

The generation of electricity in a microgrid can be done using fossil fuels (diesel generators) or renewable energies (solar panels...). Thanks to technological advances, the latter are generally cheaper. However, their intermittency pushes to supplement them with more expensive but controllable means (diesel, battery storage...). The size of each of the components of a microgrid (called its "sizing") must therefore be optimized according to different criteria: the economic cost of course, but also the quality of service, energy independence or greenhouse gas emissions. The management of energy flows (e.g.: arbitrage between diesel and battery) also needs to be optimized. This project proposes to address these different optimization challenges in the real case of an isolated island site.

Quarter number

ST7

Prerequisites (in terms of CS courses)

Optimization course.

Syllabus

Problem definition :

Input data:

- collection of production and consumption data
- data analysis and normalization

Modeling and formalization:

- definition of optimization criteria
- formalization of the optimization problem

Resolution:

- choice of resolution method
- sensitivity analysis

Class components (lecture, labs, etc.)

Project 80h

Grading

project report and presentation

Resources

project in groups

Learning outcomes covered on the course

By the end of this course students will be able :

- Understand the economic, ecological and societal context and challenges of microgrids.
- Formalize an optimization problem
- Select the appropriate resolution method.
- Work in groups and results present

Description of the skills acquired at the end of the course

- Understand the economic, ecological and societal context and challenges of microgrids. C1.1
- Formalize an optimization problem. C1.2, C1.3, C2.1
- Select the appropriate resolution method. C2.1, C6.1
- Presentation of the results. C7.1
- Work in groups. C8.1, C8.4

ST7 – 79 – LE NUMERIQUE AU SERVICE DU FACTEUR HUMAIN

Dominante : Info&Num (Informatique & Numérique), MDS (Mathématiques, Data Sciences), VSE (Vivant-Santé, Environnement)
Langue d'enseignement : ENGLISH
Campus où le cours est proposé : Rennes

2SC7910 – 2D-3D image and sound analysis

Instructors: Catherine SOLADIE
Department: CAMPUS DE RENNES
Language of instruction: ENGLISH
Campus: CAMPUS DE RENNES
Workload (HEE): 60
On-site hours (HPE): 34,5
Quota :

Description

Sight, hearing, touch, smell and taste. It is through our 5 senses that we apprehend our environment and interact with it. In recent years, living beings are no longer the only ones who interact and understand the world around them. More and more powerful automatic image and sound analysis tools are created every day. Whether for autonomous driving, space, medical, the fields of application are multiple. And more recently, these techniques have gained new momentum with Deep Learning and generative models. It is now difficult to recognize a true picture of a fake picture And it becomes easy to make artificially but effectively say whatever you want to whoever you want.
In this module, you will discover an overview of analysis and synthesis techniques for 2D and 3D image and sound, through precise use cases. You will be the actors of the understanding and the artificial modification of your environment!

Quarter number

ST7

Prerequisites (in terms of CS courses)

Statistics et machine learning.

Signal processing

Computer science :

- Algorithms
- Programming langages

Syllabus

Background (5%)

- Introduction to the subject
- Historical context.
- Link with the subjects of the program.

Image Analysis (20%)

- Filtering: low-cut filter, high-pass filter, Canny filter
- Segmentation: waterShed, Split & merge, region growing
- Feature extraction: LBP, SIFT, HOG

Pattern recognition (25%)

- Edge Detection and Hough Transform
- 2D and 3D deformable models
- Pattern matching: correlation, rigid ICP, 3D registration

Sound analysis (25%)

- Audio signals and time-frequency representation
- Speech production and modeling
- Spatial audio

Synthesis of image and sound (10%)

- 3D image synthesis: from basics to animation
- Stereoscopy

Personal study (15%)

- Choosing a subject
- Exploration and presentation

Class components (lecture, labs, etc.)

10. Bureau d'étude : mixing theory and practice : 50% (30 HEE)
11. Evaluation : 10% (6 HEE)

- Bureau d'études reports, and personal study : 40% (24 HEE)

Grading

MCQ of theoretical knowledge: 1/3 of the note
Defense of the project of realization of a BE: 1/3 of the note
BE content and justification: 1/3 of the note

Course support, bibliography

For audio, videos available online: https://www.animations.physics.unsw.edu.au/waves-sound/oscillations/index.html
For image synthesis: OpenGL Programming Guide

Resources

Teaching team:

- Catherine SOLADIE
- Renaud SEGUIER
- Simon LEGLAIVE
- PhD Students of FAST research team

Software tools and number of licenses needed:

- Python libraries
- Anaconda and Jupyter Notebooks
- OpenGL

Learning outcomes covered on the course

By the end of the course, you will be able to :

- Cite many techniques for extracting audio and video characteristics (C2.1 and C1.4)
- Choose the relevant treatment for the analysis, understanding and synthesis of audio and video data (C3.7 and C6.4)
- Design, implement and validate a complete audio and / or video processing system (C2.5, C3.8 and C6.3)
- Understand and explain new algorithms in image and sound processing (C2.3)

Description of the skills acquired at the end of the course

- C2.1 Thoroughly master a domain or discipline based on the fundamental sciences or the engineering sciences.
- C2.5 Master the skillset of a core profession within the engineering sciences (at junior level).
- C3.7 Make pragmatic and informed choices with the aim of producing tangible results.
- C3.8 Conceive, design, implement and reach the stage of industrialisation

We also expect :

- C6.3 Conceive of, design, implement and authenticate complex software.
- C6.4 Solve problems through mastery of computational thinking skills.
- C1.4 Design, detail and corroborate a whole or part of a complex system.
- C2.3 Rapidly identify and acquire the new knowledge and skills necessary in applicable domains, be they technical, economic or others.

2SC7990 – What you unwittingly say: decryption and automatic analysis of nonverbal behaviors

Instructors: Catherine SOLADIE
Department: DOMINANTE - MATHÉMATIQUES, DATA SCIENCES, DOMINANTE - INFORMATIQUE ET NUMÉRIQUE, DOMINANTE - VIVANT, SANTÉ, ENVIRONNEMENT
Language of instruction: ENGLISH, FRENCH
Campus: CAMPUS DE RENNES
Workload (HEE): 80
On-site hours (HPE): 48
Quota :

Description

What you unwittingly say: decryption and automatic analysis of nonverbal behaviors.

Letters, words, sentences: the algorithms we have today are more and more effective in decrypting our grammar, and understanding what we can say. And yet this only covers a tiny part of our communication.

Joy, resignation, irony: only our body and the tone of our voice reveal our deep intentions, our real message, and the automated understanding of such human behaviors and emotions is a big challenge.

To take it up, every year, the audio, video and machine learning communities gather around international challenges of research on the automatic analysis of human behaviors: emotions, depression, mood, motion detection, ... (ex: http://sspnet.eu/avec2017/).

Through this project, you will be able to participate in one of these challenges. You will have a large dataset representing people in action and will have to automatically determine their behavior and emotions.

Each project team focuses on a particular study (eg the voice, the face, ...), and all teams will gather their work to collectively deposit a unique participation in the international challenge.

Quarter number

ST7

Prerequisites (in terms of CS courses)

Statistics et machine learning.

Signal processing

Computer science :

- Algorithms
- Programming langages (basics)

Syllabus

Background (5%)

- Introduction by the research team.
- Group organization.
- Provision of the challenge data.

State of the art (20%)

10. Research and understand research papers on the subject.
11. Reproduce a selected subset of state-of-the-art methods (they will serve as a basis for your work).

Pre-processing, understanding and visualization of data (20%)

- Depending on the chosen topic (voice, face, ...), extract the interesting features for your analysis
- Explore the relevant visual representation modes
- Use these representations to guide your analysis strategy

Statistical analysis and learning (40%)

- Choose and build your analysis and learning models
- Quantify your results and compare them to the state of the art

Visibility points and final presentation (15%)

- 3 daily feedback will have to be carried out to present your progress as the project progresses (a different member of the team each time).
- Structure your presentations with the objectives, the state of the art, the architecture diagram, the results tables.
- At the end of the project, present as a team your results to our industrial and academic partners.
- Provide a scientific report

Class components (lecture, labs, etc.)

- Immersion in the FAST research team: supervision by researchers, PhD students and post-docs.
- Organization in teams of 2 to 4 students. Coordination of the different teams for the production of a single overall final result.
- Presentation of the results to our industrial partners (companies and start-ups) and academics.

Grading

Individual daily feedback: 1/4 of the mark
Defense in front of the partners: 1/4 of the mark
Scientific results (system performance): 1/4 of the mark
Scientific report: 1/4 of the mark

Resources

Teaching team:

- Catherine SOLADIE
- Renaud SEGUIER
- PhD students of FAST research team

Software tools and number of licenses needed:

- TensorFlow or equivalent (free)

Learning outcomes covered on the course

At the end of this project, you will be able to:

- Navigate among the research papers of a subject, read them and understand them (C1.5)
- Reproduce a selected subset of state-of-the-art methods in signal processing and / or machine learning (C3.6)
- Mix skills from signal processing, statistical analysis and machine learning to analyze data (C1.5)
- Explore visual representation modes that are relevant to your data (C6.5, C6.7)

- Use these representations to guide your analysis strategy (C3.7)
- Choose and build your analysis and learning models (C1.3, C6.4)
- Quantify your results and compare them to the state of the art (C2.4, C3.6)
- Conduct a large-scale scientific project in a group (C8.3)
- Decrypt a set of non-verbal messages during human interactions (C7.4)

Description of the skills acquired at the end of the course

- C1.5 Bring together broad scientific and technical concepts in a core structure that is nestled in an interdisciplinary approach.
- C2.4 Create knowledge within a scientific paradigm
- C3.6 Evaluate the efficiency, feasibility and strength of the solutions offered.
- C6.5 Operate all types of data, structured or unstructured, including big data.
- C8.3 Engage outside expertise, to go the extra mile. Identify and develop strengths and talents.

We also expect :

- C1.3 Apply problem-solving through approximation, simulation and experimentation.
- C3.7 Make pragmatic and informed choices with the aim of producing tangible results.
- C6.4 Solve problems through mastery of computational thinking skills.
- C6.7 Understand information transmission.
- C7.4 Master spoken, written and body language, as well as basic communication techniques.
- C8.4 Work using project management techniques appropriately tailored to the situation.

ST7 – 80 – SEPARATION DE SOURCES POUR UNE EXPLOITATION OPTIMALE DE SIGNAUX

Dominante : MDS (Mathématiques, Data Science)
Langue d'enseignement : Français
Campus où le cours est proposé : Metz

2SC8010 – Sparse representations of signals

Instructors: Stephane ROSSIGNOL
Department: DOMINANTE - MATHÉMATIQUES, DATA SCIENCES
Language of instruction: FRENCH
Campus: CAMPUS DE METZ
Workload (HEE): 60
On-site hours (HPE): 34,5
Quota :

Description

The parsimonious representation of signals is one of the fundamental concepts in data science. Parsimonious representations make it possible to represent complex signals (such as sounds) by a small number of non-zero coefficients, this in very large spaces. They thus make it possible to find structures or regularities in very large spaces. These representations are at the heart of the mathematical understanding of the effectiveness of recent algorithms and techniques of supervised or unsupervised learning and scattering transformations.

The lecture introduces some mathematical tools used in signal analysis and their properties (complements about the Fourier transform, subsampling, oversampling, harmonic signal, STFT, multi-resolution analysis, Paley-Littlewood wavelet decompositions, and bi-orthogonal analysis, perfect reconstruction filter banks) as well as signal decomposition methods (Matching Pursuit, Basis Pursuit, Independent Component Analysis).

Quarter number

ST7

Prerequisites (in terms of CS courses)

Probability, statistics, signal processing (1CC4000 and 1CC5000) and first year algorithmic lectures (1CC1000); a good knowledge of a programming environment (Matlab/Octave, Python).

Syllabus

Harmonic analysis: reminders and complements on the Fourier transform (under/over-sampling, DFT, filter banks, harmonic signal, Hilbert transform, short term Fourier transform (STFT)).

Multi-resolution analysis: Paley-Littlewood wavelet decomposition, bi-orthogonal, perfect reconstruction filter banks.

Decomposition of a signal: dictionary, parsimonious representation, matching pursuit, orthogonal matching pursuit, basis pursuit.

Independent component analysis: notions of entropy, entropy rate of a random signal, mutual information, independent component analysis (ACI), ACI in an orthonormal basis, blind deconvolution.

Concepts of supervised learning: introduction to basic notions of learning, test basis, over-learning, empirical risk, real risk (or generalization).

Class components (lecture, labs, etc.)
17.5h Lecture
9h Tutorials
8h Labs. A single topic.

Grading
Continuous monitoring (50%, 2/3 MCT at the beginning of the tutorials; individual score) and oral presentation at the very end of the labs (50%). In case of a justified absence to one of the intermediary examinations, the grade of this latter is replaced by the grade of the final examination. Labs : grading by pair; differentiated in the event of an anomaly in a pair.

Course support, bibliography
A wavelet tour of signal processign, Stéphane Mallat

https://www.di.ens.fr/~mallat/papiers/WaveletTourChap1-2-3.pdf

Resources
Teacher : Stéphane Rossignol

Room size for tutorials : 34
Max room size for labs : 34

Software : Matlab (34 licences)/Octave (Python)

Rooms for labs : rooms on Metz campus

Learning outcomes covered on the course

- Being able to design a complete signal processing chain.
- Being able to compare the performances of the various tools at our disposal for the analysis of complicated time series, in order to choose the one which will be best suited for this or that signal to be analyzed.
- Being able use correctly the basic and advanced principles of analog signal processing and digital signal processing.

Description of the skills acquired at the end of the course

C1.1 : Examine a problem in full breadth and depth, within and beyond its immediate parameters, thus understanding it as a whole. This whole weaves the scientific, economic and social dimensions of the problem.

C2.3 : Rapidly identify and acquire the new knowledge and skills necessary in applicable domains, be they technical, economic or others.

C3.6 : Evaluate the efficiency, feasibility and strength of the solutions offered.

C9.4 : Demonstrate rigour and critical thinking in approaching problems from all angles, be they scientific, social or economic.

2SC8092 – Tracking a speaker by a robot

Instructors: Michel BARRET
Department:
Language of instruction: FRENCH
Campus: CAMPUS DE METZ
Workload (HEE): 80
On-site hours (HPE): 48
Quota :

Description

The project, which is part of the ST7-Optimization "Source separation for optimal signal exploitation", will focus on a problem of source separation posed by a client partner: ORANGE, Cognitive Computing in Arcueil. The students will have to deepen in semi-autonomy (that is to say without lectures) a field of knowledge specific to the problem posed by the partner, for example a course of Speech and sound processing. They will benefit from the skills of supervisors who will help them to formalize the problem, to take charge of the data, to choose a model, a method of resolution ... sizing the project and identifying steps to provide deliverables. In the tuning of the model to the data, particular attention should be paid to the risk of overfitting. The problems encountered in the project will highlight the importance of well coding with a programming language to obtain effective solutions, for example to manage large amount of data or to obtain satisfactory execution times.

Quarter number

ST7

Prerequisites (in terms of CS courses)

- Probability 1A (CIP-EDP, 1SL1000),
- Signal processing ST4 (1CC4000)
- Statistics, Machine learning and Data processing ST4 (1CC5000),
- Digital environment, computer and programming SG1 (1CC1000).

Syllabus

"Customer" partner: ORANGE, Cognitive Computing, in Arcueil.

Expected gain for the partner: Increase productivity, improve quality of service

Context: Robots are more and more present in our environment, for example in ORANGE shops. When a robot has started a conversation with a speaker, the problem is to keep the focus on the interlocutor while several people are talking around the robot, or another interlocutor is talking to him. The company ORANGE wants to solve this problem from a monophonic audio signal recorded by the robot only, without adding other modalities.

Problems: Find one or more spaces of representation of the data well adapted to the problem of tracking one speaker; learn from a small number of samples (i.e., a small recording time) the speaker's features to be followed; avoid overfitting that may occur if the learned features depend on the words spoken by the speaker.

Proposed solution: The space of scattering coefficients, obtained by scattering transforms, seems well adapted to the problem of tracking an unknown interlocutor from a speaker recording of short duration. The scattering transformations, based on the wavelet decompositions, depend on meta-parameters that must be adjusted. A heuristic recommends adjusting them to have a more "sparse" representation of transformed coefficients. Different classifiers (linear, SVM, other?)wWill have to be tested in supervised learning to better separate speakers in the space of the scattering coefficients.

Class components (lecture, labs, etc.)

For the duration of the project, students will be asked to keep a "laboratory notebook", specifying in a few lines for each experiment or test carried out, its motivations, the results obtained, the source codes and the data used. During the last week dedicated to the project, students will be asked to:

- provide two project report updates, one at midterm and the other at the end; and
- to carry out two defenses in the presence of the partner, the first at midterm will specify the work to be done during the second period of the project and the second will be the final defense of the project.

A progress report of the project with reading of the "laboratory notebook" will take place regularly.

Grading
Skills will be assessed:

- in continuous control at the advancement points and the "laboratory notebook" reading (individual note CC);
- during the two defenses (individual notes Sout1 and Sout2).

In addition, the quality of the deliverables: final report and commented source codes, will be evaluated (note QL).
Final score = CC / 3 + (Sout1 + 2 * Sout2) / 6 + QL / 6.

In case of a justified absence to one of the intermediary examinations, the grade of this latter is replaced by the grade of the final examination.

Course support, bibliography
Y. Luo & N. Mesgarani, "Conv-TasNet: Surpassing Ideal Time-Frequency Magnitude Masking for Speech Separation", *IEEE Transactions on Audio, Speech and Language Processing*, vol. 27, no. 8, pp. 1256 - 1266, August 2019.

Resources
80 HEE (48 HPE) of project

Learning outcomes covered on the course
At the end of this course, students will be able to:

29. represent and decompose audio signals in an "optimal" way ;
30. fit a model to data ;
31. use a programming language to efficiently write a data processing algorithm.

Description of the skills acquired at the end of the course
C1.2: Select, use and develop modelling scales, allowing for appropriate simplifying hypotheses to be formulated and applied towards tackling a problem.
C6.4: Solve problems through mastery of computational thinking skills.
C7.1: Persuade at the level of core values; to be clear about objectives and expected results. To apply rigour when it comes to assumptions and structured undertakings, and in doing so structure and problematise the ideas themselves. To make the added value known.

2SC8093 – Separation of sound sources from recordings of several microphones

Instructors: Jean-Louis GUTZWILLER
Department: DOMINANTE - MATHÉMATIQUES, DATA SCIENCES
Language of instruction: FRENCH
Campus: CAMPUS DE METZ
Workload (HEE): 80
On-site hours (HPE): 48
Quota :

Description

This project, which is part of the thematic sequence 7 "Source separation for optimal signal exploitation", focuses on the separation of multiple sources in audio signals.

There are many concrete situations in which you want to capture a sound so you can either record it for replay or amplify it live so that all participants have a good perception.
In order to allow good intelligibility in the case of several speakers, a microphone is usually placed in front of each speaker, or, in the theater, a radio transmitter microphone is placed directly on the actors.
A significant improvement could be to use a fixed microphone array and to have a processing algorithm to separate the sources, thus giving the illusion of having an individual microphone per speaker or actor.

Quarter number

ST7

Prerequisites (in terms of CS courses)

Probability 1A (CIP-EDP, 1SL1000),
Signal processing ST4 (1CC4000)
Statistics, Machine learning and Data processing ST4 (1CC5000),
Digital environment, computer and programming SG1 (1CC1000).

Syllabus

Evaluation of sound processing algorithms using matrix programming language (Julia).
Computer development in C / C ++ language of the retained algorithms.

Class components (lecture, labs, etc.)

This teaching is in the form of a project.
For the duration of the project, students will be asked to keep a "laboratory notebook", specifying in a few lines for each experiment or test carried out, its motivations, the results obtained, the source codes and the data used. During the last week dedicated to the project, students will be asked to:
- provide two project report updates, one at midterm and the other at the end; and
- to carry out two defenses in the presence of the partner, the first at midterm will specify the work to be done during the second period of the project and the second will be the final defense of the project.
A progress report of the project with reading of the "laboratory notebook" will take place regularly.

Grading
Skills will be assessed:

- in continuous control at the advancement points and the "laboratory notebook" reading (note CC);
- during the two defenses (notes S1 and S2)

In addition, the quality of the deliverables: final report and commented source codes, will be evaluated (note QL).

Final score = CC / 3 + (S1 + 2 S2) / 6 + QL / 6.

Resources
A network of microphones available in the smartroom of the Metz campus makes it possible to make sound acquisitions. Students will work on computers to develop the computer algorithm to achieve the desired function.

80 HEE (48 HPE) of project.

Learning outcomes covered on the course
At the end of this course, students will be able to:
- Represent and decompose audio signals in an "optimal" way
- Adjusting a model to data
- Use a programming language to effectively write a signal processing algorithm

Description of the skills acquired at the end of the course
C1.2 : Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when addressing a problem (level 2)

C6.4 : Solve problems through mastery of computational thinking skills
C7.1 : Persuade at core value level; be clear about objectives and expected results. Apply rigour when it comes to assumptions and structured undertakings, and in doing so, structure and problematise the ideas themselve

ST7 – 81 – CONCEPTION EN FABRICATION ADDITIVE

Dominante : CVT (Construction, Ville et Transports)
Langue d'enseignement : Anglais
Campus où le cours est proposé : Paris-Saclay

2SC8110 – Multiphysical couplings for additive manufacturing

Instructors: Camille GANDIOLLE, Andrea BARBARULO
Department: DOMINANTE - CONSTRUCTION VILLE TRANSPORTS
Language of instruction: ANGLAIS
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 34,5
Quota :

Description

This course will cover in a broad sense the concepts and challenges of multiphysical coupling.

Quarter number

ST7

Prerequisites (in terms of CS courses)

To have completed the "continuum mechanic" elective course and at least one of the following courses: Materials, Transport phenomena, Thermodynamics.

Syllabus

This course will cover in a broad sense the concepts and challenges of multiphysical coupling.
The following topics will be adressed:

- Strong - weak coupling;
- Coupling of different formulations;
- Coupling of different scales.

Then particular coupling, of interest for additive manufacturing will be studied in more details:

23. Laser on powder: electro-thermal coupling
24. Powder bed melting: discrete-continuous coupling, solid-fluid coupling and thermo-mechanical coupling
25. Cooling phase: aerothermal-mechanical coupling

The course will end with a reflection on the mechanical behavior of the final part (influence of residual stress, porosity, microstructure...)

Class components (lecture, labs, etc.)
8 lessons of 1h30 and 14 tutorial and project sessions of 1h30.

Grading
The knowledge will be tested by a MCQ (multiple-choice questionnaire) (=N1) and the skills acquired will be tested by a group project consisting in implementing a coupled system (N2=60%group result + 40%individual note).
NF= 30%N1 + 70%N2

Resources
The following digital tools will be used to support the course: COMSOL, TopOpt

Learning outcomes covered on the course

- Master the different types of coupling;
- Know how to choose a modeling strategy in a multiphysics system;
- Know how to formulate a model integrating a coupling.

Description of the skills acquired at the end of the course

- C1.2 Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when addressing a problem ;
- C1.3 Apply problem-solving through approximation, simulation and experimentation. / Solve problems using approximation, simulation and experimentation ;
  C1.4 Design, detail and corroborate a whole or part of a complex system ;
- C3.6 Evaluate the efficiency, feasibility and strength of the solutions offered. / proposed solutions ;
- C3.7 Make pragmatic and informed choices with the aim of producing tangible results ;
- C6.1Identify and use the necessary software for one’s work (including collaborative tools) and adapt digital responses according to the context ;
- C7.1 Persuade at core value level; to be clear about objectives and expected results. To apply rigour when it comes to assumptions and

structured undertakings, and in doing so structure and problematise the ideas themselves. Highlight the added value ;

- C8.1 Work collaboratively in a team.

2SC8191 – Optimization of aeronautical parts in metal additive manufacturing

Instructors: Camille GANDIOLLE, Andrea BARBARULO
Department:
Language of instruction: ANGLAIS
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 80
On-site hours (HPE): 48
Quota :

Description

Optimization of metallic aeronautical parts subjected to complex mechanical and/or thermal loading. The optimization will have to take into account the capacities of the process (additive manufacturing or traditional method).

Quarter number

ST7

Prerequisites (in terms of CS courses)

To have completed the “continuum mechanic” elective course and at least one of the following courses: Materials, Transport phenomena, Thermodynamics.

Syllabus

The students will be divided into 4 teams of 5 students, each team will have to optimize the design of a critical metal part of an aircraft under mechanical or even multiphysical stress involving mechanics. The optimized design will have to integrate the choice of manufacturing process (additive manufacturing or traditional method).

Level 1 :
- Taking charge of the subject (specifications, design/simulation tools)
- Optimization of a part in additive polymer manufacturing with respect to a simple mechanical loading with La Fabrique.

Level 2: Simplified representation (simple analytical models) of the studied part to reach a first optimum on a first field of parameters.
Level 3: Optimization of the system in a new parameter space closer to the real system modeled by advanced numerical methods.
Level 4: Analysis of the cost and benefits of the process compared to

conventional machining, e.g., the use of a new parameter space. Manufacturing time, cost of materials, labour used, environmental compatibility, etc...

If the studied piece is suitable, students will be encouraged to confront their model with the reality by making a sample and measuring its properties (tests to be developed during the project).

Grading
Competencies C1.2, C1.3, C1.4, C3.7, C7, C8.1 and C8.4 will be assessed throughout the project and competency C3.7 will be particularly emphasized during the workshop with La Fabrique. C4.2 will be evaluated during the final defense of the project.
La Fabrique Workshop: N1
Continuous monitoring during the project: N2
Teacher's mark for the oral defense: N3
Mark from the industrial partners for the oral presentation: N4
NF = 10%N1 +15%N2 + 15%N3 + 60%N4

Description of the skills acquired at the end of the course

- C1.2 Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when adressing a problem;
- C1.3 Apply problem-solving through approximation, simulation and experimentation / Solve problems using approximation, simulation and experimentation;
- C1.4 Design, detail and corroborate a whole or part of a complex system;
- C3.7 Make pragmatic and informed choices with the aim of producing tangible results;
- C4.2 Know how to identify the value that a given solution affords a client and the market. To be able to detect opportunities and seize them;
- C6.2 Engage in design thinking using classic and agile conception and prototyping tools (CAD, 3D printing etc.);
- C7 Strengthen the art of persuasion;
- C8.1 Work collaboratively in a team;
- C8.4 Work using project management techniques appropriately tailored to the situation.

2SC8192 – Optimization of parts for biomedical applications in polymer additive manufacturing

Instructors: Elsa VENNAT, Camille GANDIOLLE
Department:
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 80
On-site hours (HPE): 48
Quota :

Description

Optimization of a training box for medical application designed entirely in additive manufacturing. Topics may concern the design of the assembly, the measurement chain, the optimization of the material of artificial organs (ultrasound impression) ...

Quarter number

ST7

Prerequisites (in terms of CS courses)

To have completed the “continuum mechanic” elective course and at least one of the following courses: Materials, Transport phenomena, Thermodynamics.

Syllabus

Students will be divided into 4 teams of 5. Each team will have to optimize the design of a polymer part while integrating that the process must be additive manufacturing. Topics may concern the materials of artificial organs or the system in which they are installed.

Level 1:
- Handling of the subject (specifications, design/simulation tools, complementary technical knowledge)
- Optimization of a part in additive polymer manufacturing with respect to a simple mechanical loading with La Fabrique.

Level 2:
Simplified representation (simple analytical models) of the studied part to reach a first optimum on a first field of parameters.
Level 3: Optimization of the system in a new parameter space closer to the real system modeled by advanced numerical methods.

Level 4: Analysis of the cost and benefits of the process compared to conventional machining, e.g., the use of a new parameter space. Manufacturing time, cost of materials, labour used, environmental compatibility, etc...

If the studied piece is suitable, students will be encouraged to confront reality by making a sample and measuring its properties (tests to be developed during the project).

Grading

Competencies C1.2, C1.3, C1.4, C3.7, C7, C8.1 and C8.4 will be assessed throughout the project and competency C3.7 will be particularly emphasized during the workshop with La Fabrique. C4.2 will be evaluated during the final defense of the project.
La Fabrique Workshop: N1
Continuous monitoring during the project: N2
Teacher's mark for the oral defense: N3
Mark from the industrial partners for the oral presentation: N4
NF = 10%N1 +15%N2 + 15%N3 + 60%N4

Description of the skills acquired at the end of the course

- C1.2 Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when adressing a problem;
- C1.3 Apply problem-solving through approximation, simulation and experimentation / Solve problems using approximation, simulation and experimentation;
- C1.4 Design, detail and corroborate a whole or part of a complex system;
- C3.7 Make pragmatic and informed choices with the aim of producing tangible results;
- C4.2 Know how to identify the value that a given solution affords a client and the market. To be able to detect opportunities and seize them;
- C6.2 Engage in design thinking using classic and agile conception and prototyping tools (CAD, 3D printing etc.);
- C7 Strengthen the art of persuasion;
- C8.1 Work collaboratively in a team;
- C8.4 Work using project management techniques appropriately tailored to the situation.

2SC8193 – Optimization of civil engineering structures in additive concrete manufacturing

Instructors: Camille GANDIOLLE
Department:
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 80
On-site hours (HPE): 48
Quota :

Description

Optimization of thermoacoustic properties of structures for civil engineering. The optimized design will have to integrate concrete or plaster additive manufacturing and take into account that fabrication is not done directly on site.

Quarter number

ST7

Prerequisites (in terms of CS courses)

To have completed the “continuum mechanic” elective course and at least one of the following courses: Materials, Transport phenomena, Thermodynamic.

Syllabus

The students will be divided into 4 teams of 5. Each team will have to optimize the design of a wall with regard to specific thermo-acoustic insulation properties. The optimized design will have to integrate concrete or plaster additive manufacturing and take into account that the manufacturing is not done directly on site.

Level 1:
- Getting to grips with the subject (specifications, design/simulation tools, notions of acoustics)
- Handling of existing models and critical analysis of existing solutions
- Optimization of a part in additive polymer manufacturing with respect to a simple mechanical loading with La Fabrique.

Level 2: Implementation of an optimization technique to improve existing solutions using advanced numerical methods.
Level 3: Realization of a sample (elementary cell) and a means of testing

the solution and confrontation with the simulations.
Level 4: Analysis of the cost benefits of the process compared to classical machining ex. Manufacturing time, cost of materials, labour used, environmental compatibility, etc...

Grading
Competencies C1.2, C1.3, C1.4, C3.7, C7, C8.1 and C8.4 will be assessed throughout the project and competency C3.7 will be particularly emphasized during the workshop with La Fabrique. C4.2 will be evaluated during the final defense of the project.
La Fabrique Workshop: N1
Continuous monitoring during the project: N2
Teacher's mark for the oral defense: N3
Mark from the industrial partners for the oral presentation: N4
NF = 10%N1 +15%N2 + 15%N3 + 60%N4

Description of the skills acquired at the end of the course

- C1.2 Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when adressing a problem;
- C1.3 Apply problem-solving through approximation, simulation and experimentation / Solve problems using approximation, simulation and experimentation;
- C1.4 Design, detail and corroborate a whole or part of a complex system;
- C3.7 Make pragmatic and informed choices with the aim of producing tangible results;
- C4.2 Know how to identify the value that a given solution affords a client and the market. To be able to detect opportunities and seize them;
- C6.2 Engage in design thinking using classic and agile conception and prototyping tools (CAD, 3D printing etc.);
- C7 Strengthen the art of persuasion;
- C8.1 Work collaboratively in a team;
- C8.4 Work using project management techniques appropriately tailored to the situation.

ST7 – 82 – SYSTEMES PHYSIQUES NEURO-INSPIRES POUR LE TRAITEMENT D'INFORMATION

Dominante : PNT (Physique et NanoTechnologie)
Langue d'enseignement : Anglais
Campus où le cours est proposé : Metz

2SC8210 – Optimization for neuro-inspired computing with physical architectures

Instructors: Damien RONTANI, Piotr ANTONIK
Department: DOMINANTE - PHYSIQUE ET NANOTECHNOLOGIES
Language of instruction: ENGLISH
Campus: CAMPUS DE METZ
Workload (HEE): 60
On-site hours (HPE): 34,5
Quota :

Description

The ever-increasing amount of data generated requires the development of novel processing/analyzing strategies. Automatic classification techniques originating from the field of Machine Learning are a promising candidate, however, their digital implementations remain relatively low and energy-intensive. An alternate solution consists of designing physical (hardware) neuro-inspired architecture that allows the alleviation of parts if not all of these technological challenges. This theme is the current focus of research laboratories worldwide and has caught the attention of large technological groups such as IBM or Google.

In this particular context and through the framework of *reservoir computing*, which consists of an artificial neural network trained only at its final output layer, This module proposes to the students to discover the principle of conception and design physical (hardware) neuronal networks. Toward this, the students will be familiarized with various optimization techniques such as ridge regression or gradient descent and their accelerated versions, or stochastic heuristics (ex. simulated annealing, genetic algorithms...).

Quarter number

ST7

Prerequisites (in terms of CS courses)

Basics of General Physics (Ordinary differential equations and partial derivative equations) (level L2)
Modeling (1CC3000)
Statistics and Machine Learning (1CC5000).

Digital Signal Processing (1CC4000)
Computing and programming skills in Matlab, Python, or C/C++.

Syllabus

Physical neuro-inspired architecture (10.5h)

- Introduction to artificial neural networks (perceptron, feed-forward and reccurent networks)
- Physical implémentations in electronics, photonics and spintronics
- Review of essential notions in dynamical systems. Introduction to nonlinear systems.
- Notions on echo-state networks (ESN) and liquid state machines (LSM) – Reservoir computer and necessary conditions for information processing
- Memory Capacity (MC) and Computational Ability (CA)

Machine Learning and Optimization for physical neuro-inspired architectures (16.5h)

- Basics in Machine-Learning and connection with optimization
- Supervised and unsupervised learning, loss function, learning curves, cross-validation
- Offline supervised learning (batch): linear (Moore-Penrose) and ridge regression - Online Learning : gradient descent (stochastics, mini-batch, averaged), recursive least square method.
- Acceleration of first order methods.
- Solving classficiation tasks (winner-takes-all, multi-logistic regression)
- Machine Learning and parametric optimisation for physical architecture (reservoir computing architectures).

Small Class #1 : Implementation of online optimization techniques (1.5h)
Small Class #2 : Numerical simulation of a photonic reservoir computer (1.5h)

Emergent approaches (3h)

- Integrated and nanoscopic physical systems for machine learning
- Perspective on deep physical architectures (deep neural networks)

Class components (lecture, labs, etc.)

Lectures with emphasized interactions with numerical and experimental demonstration in the lab. The presentation of mathematical tools is limited to essential notions necessary for the understanding of concepts seen in class.
Two Small classes will be organized for the assimilation of key notions

Hourly volume:
Lectures + interactive demonstrations : 30h
Small class: 3h
Final Exam: 1.5h

Grading

- Final Exam : Duration : 1.5h - 50% of the final grade
    - In case of unjustified absence, the grade is 0 for this part of the grade
- Analysis of a scientific article with a short report (5 pages max) - 50% of the final grade
    - If the report is not sent prior to the deadline, the grade is 0 for this part of the grade.
- Second Session Exam : In case of failure at the final exam, an oral exam of 20 min will be scheduled.

Course support, bibliography

D. Brunner, M. C. Soriano and G. Van der Sande, "Photonic Reservoir Computing: Optical Recurrent Neural Networks" Ed. De Gruyter (2019)

Resources
Teaching Staff / Faculty : Damien Rontani & Piotr Antonik
Computing ressources for numerical simulation and remote access to an experimental setup located in CentraleSupélec Laboratories

Learning outcomes covered on the course
This specific lecture will be divided in three sections with the following learning objectives :

- Simulate and experiment with physical implementation of artificial neural networks
- Apply various optimization techniques as learning strategies and apply them in the specific context of physical architectures

- Synthetize/summarize recent advances and state-of-the-art results on the implemenation of neuro-inspired physical systems on electronic/photonic chips for application in ultrafast information processing

Description of the skills acquired at the end of the course
C.1.3 Apply problem-solving through approximation, simulation and experimentation. / Solve problems using approximation, simulation and experimentation.

C.1.5 Bring together broad scientific and technical concepts in a core structure contained within the framework of an interdisciplinary approach

2SC8290 – Classification of image and videos signals with power-efficient photonic systems

Instructors: Piotr ANTONIK, Damien RONTANI
Department: DOMINANTE - PHYSIQUE ET NANOTECHNOLOGIES
Language of instruction:
Campus: CAMPUS DE METZ
Workload (HEE): 0
On-site hours (HPE): 48
Quota :

Description

This project is part of the thematic sequence ST7 "Physical Neuro-inspired Systems" and is about the automatic classification of image / video signals using photonic architectures developed within The CentraleSupelec Research Center. There are many applications to classification of images or video sequences such as assistance of diagnosis in healthcare, autonomous robotics, or scene analysis for defence and security.

Various software-based techniques exist to solve classifcation tasks and they run on central processing units (CPU) or graphical processing units (GPU). The downside is usually reduced processing speed and high power consumption during learning and testing phase. These are strong motivations for the development of alternative hardware (physical)-based architectures using analog electronics or photonics.

The objective of this project will be : (i) the study of the ability of a photonic architecture to classify video or images from publicly available databases, (ii) the optimization of its performance to be competitive with state-of-the-art software solutions and (iii) provide an estimation of the power efficiency of the architecture.

Quarter number

ST7

Prerequisites (in terms of CS courses)

Modeling (1CC3000)
Digital Signal Processing (1CC4000)
Statistics and Machine Learning (1CC5000)

Syllabus

1. Numerical simulation of a large-scale neuro-inspired photonic architecture (>10,000 interconnected dynamical systems)

- Choice of software language : *e.g.* Matlab / Python or C/C++
- Use of different learning strategies : (i) offline (*e.g.* linear and ridge regression, stochastic heuristics) or (ii) online (e.g. gradient descent and their accelerated versions).
- Search of optimal operating points with parametric exploration

2. Handling of a publicaly available database of video or image signals

- Choice and analysis of pre-processing algorithm for "features" extraction suitable for classification tasks.
- Techniques for the dimensionality reduction of the "features"

3. Experiment on prototype architecture

- Implementation of the chosen learning technique on the physical setup. (experimental settings and tuning done by the teaching staff)
- Experimental campaign

4. Performance analysis

- Performance (error / success rate in classification) and comparison with the state of the art (bibliographic search)
- Estimation of the power consumption for the resolution of a task (including the energy consumption during the training and energy use per signal processed)

Class components (lecture, labs, etc.)

This class is a small project with the following requirements :

- team-work (3 à 4 students) for 80 HEE (*i.e.* 48 HPE).
- organization of periodic meeting with teaching staff to monitor overall progress on the project, the code development, and for discussing the numerical and experimental results obtained.
- Writing one mid-term report (approx. 5 pages) on overall progress and including some technical details and a final report (approx. 10 to 15 pages) for the last week of the class.

- Two oral defenses : one mid-term defense (S1) only with the teaching staff and a final defense (S2) at the end of the project with the participation of industrial and academic partners.

Grading

The evaluation process is as follows :

- Continuing evaluation (CC) on project management (including but not limited to regular scheduling of meetings, progress, technical mastery of the topic...). Group and invidual performance will be taken into account and weighted equally.
- Two oral defenses (S1 et S2) Group and invidual performance will be taken into account and weighted equally.
- Technical content and quality of written material (L) (reports, bibliographic archives, commented source codes...).

Final grade = CC / 3 + (S1+S2)/6 + L/3

Resources

- Teaching staff : Damien Rontani, Piotr Antonik
- Desktop computers from the LMOPS laboratory of Metz Campus and the FUSION Super Compyter (Paris-Saclay) available for intensitve numerical simulations and parametric analysis.
- Personal computer of students
- Remote access to an experimental setup for testing on a prototype architecture developed within the LMOPS laboratory on Metz Campus

Learning outcomes covered on the course

By the end of the this project, the students will be able to

- Numerically simulate a large-scale dynamical system with Matlab / Python or C/C++ and apply offline and online learning techniques for the learning of physical architectures
- Analyze operating points and parametric mapping of performance of physical systems
- Use and apply pre-processing to publicly available database of image / video signals
- Experiment on prototype of photonic neuro-inspired architectures

Description of the skills acquired at the end of the course
C1.2: Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when addressing a problem

C6.4: Solve problems through mastery of computational thinking skills

C7.1: Persuade at core value level; to be clear about objectives and expected results. To apply rigour when it comes to assumptions and structured undertakings, and in doing so structure and problematise the ideas themselves. Highlight the added value

INTENSIVE COURSES

2IN1510 – Understanding blockchain

Instructors: Marc-Antoine WEISSER
Department: INFORMATIQUE
Language of instruction: French
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 45
On-site hours (HPE): 27
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

The objective of this course is to understand the blockchain technology, to be able to explain it, to know in which context to use it and why it is not adapted in all contexts.

Quarter number

Intensive week SG6

Prerequisites (in terms of CS courses)

Good knowledge of the basics of Python 3.

Syllabus

The course is divided into 5 major parts.

I. Introduction to the blockchain and cryptographic elements :

- The shared ledger,
- Block chaining,
- One-way function.

II. Implementation of the blockchain :

- Proof of work
- Nodes and miners
- Composition of a transaction
- Initialization of a chain
- Composition of a block
- Validation process

III. Advanced concepts :

- Mining
- Crypto risk
- Other proofs

- Smart Contract
- Consensus
- Fork of the chain and resolution

IV. Issues :
- Pool and governance
- Vulnerabilities
- Ethics and legal

V. TP
- Implementation of a simple blockchain in Python
- Proposal of an application integrating it

Class components (lecture, labs, etc.)
- Lectures: 6x3h
- TP: 3x3h

Grading
Validation on the TP and a report.

Resources
Lectures
Practical Work
Reading of support and synthesis

The courses and supervision of TP are provided by Marc-Antoine Weisser.

Learning outcomes covered on the course
At the end of this course, the student will be able to understand how works a shared ledger using blockchain technology, to know its possibilities, its issues and its limitations. The student will have acquired:
- basic elements of asymmetric cryptography (one-way function, hashing, public key and private key, etc.);
- the fundamental elements of blockchain technology (block chaining, proof of work, nodes, mining, composition of a block, etc.);
- some extensions and alternatives (proof of stake, smart contract, consensus, ...);
- the stakes (security, governance, vulnerability, ...).

Learning outcomes:

- Know the principles of asymmetric cryptography
- Understand how blockchains work
- Implement a blockchain
- Distinguish the relevant use cases of a blockchain
- Design an application implementing a blockchain

Description of the skills acquired at the end of the course

C1.1: Examine problems in their entirety and beyond their immediate parameters. Identify, formulate and analyse the scientific, economic and human dimensions of a problem

C1.4: Design, detail and corroborate a whole or part of a complex system.

2IN1520 – Risk analysis - INFOSEC

Instructors : Valerie VIET TRIEM TONG
Department : CAMPUS DE RENNES
Language of instruction : French
Campus : CAMPUS DE RENNES
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description

This week of courses alternates between lectures and practical case studies to present cyber risk analysis. A cyber security risk analysis is about understanding, managing, controlling and mitigating cyber risk across a digital organization. Risk analysis a crucial part of data protection efforts.

Syllabus

Threat Analysis

Who the attackers are, what are their motivation and organisation, their characteristics.
Cyber Threat Intelligence.
Study of some APTs.

Risk analysis

- purpose of risk analysis
- presentation of different approaches
- focus on Ebios-RM

Technical security

Legal framework

Physical Security

Study of the modus operandi of attacks exploiting vulnerabilities in the implementation of physical security

Security in the Industrial sector

Crisis management
Practical study of three cases of cyber-attacks and the coordination of the response of internal and external actors in the management of the related crisis.

- Crisis management process (Attack against TV5 Monde)
- Crisis communication (Attack on Norsk Hydro)
- Remediation (NotPetya attack against Maersk)

Social Engineering
Analysis of pressure tactics based on social engineering techniques

Class components (lecture, labs, etc.)
A week with some traditional classes and lots of interaction with lecturers through

Concrete situation on many small examples.
Practical case studies in small groups and feedback to the whole group.
Discussion with Philippe Thomazo, CEO of the ECOCERT group who will testify on his experience of cyber risks.

Grading
Evaluation of written knowledge with the help of a quiz and via oral restitution of the case studies made during the week.

Resources
Course materials, videos, testimonials, case studies

Learning outcomes covered on the course
Taking into account the Cyber risk
Assessing the real impact of a cyber-attack on the company's business
Understanding the threat organization
Consider the different aspects of cyber crisis management

Description of the skills acquired at the end of the course
At the end of this course, the student will master the stakes, the steps and the means of a risk analysis in a digital organization. He/she will be able to restitute it to different instances of the organization (technical, organizational and decisional).

2IN1570 – Web and mobile application development

Instructors : Benoit VALIRON
Department : INFORMATIQUE
Language of instruction : French
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27
Quota :
Elective Category : Fundamental Sciences
Advanced level : Yes

Description

Current web technologies go beyond than simple static webpages. Dedicated to interactions, they are versatile enough to be able to design application for all kind of terminals, from desktop to smartphones. Connected to the internet, these apps exchange data based on a common set of formats to structure and manipulate it, such as XML for example.

The objective of this course is to discover the technologies on which are based web-apps and mobile-apps, focusing on the use and manipulation of concepts and the realization of a small, yet complete application.

Quarter number

Intensive week at the end of the SG8

Prerequisites (in terms of CS courses)

The course "Information Systems and Programming" (ISP)

Syllabus

The course shall consists of the following 5 modules. 1 - Core concepts and technologies for the web ; 2 - Dynamic interaction with the user in the browser ; 3 - Structured data ; 4 - Architecture of a web-app and of a mobile-app ; 5 - Advanced topics.

Class components (lecture, labs, etc.)

The course focuses on practicing the concepts: The presentation of a notion is followed with a lab-session to immediately apply and practice it.

Grading

The grading of the course is based on two things : 1 - continuous assessment, each lab session being submitted for evaluation, and 2 - each student will build and hand over a project implementing the concepts seen along the course.

Course support, bibliography

The course consists in a series of tutorials, available online as the course will progress.
One can nonetheless cite the following bibliography:

- W. S. Means, E. Rusty Harold, XML in a Nutshell: A Desktop Quick Reference. O'Reilly, 2001.
- A. T. Holdener III, Ajax: The Definitive Guide. O'Reilly, 2008.
- B. Bibeault, Y. Katz, jQuery in Action. Manning, 2008.
- D. Flanagan, JavaScript: The Definitive Guide. O'Reilly, 2011.

Resources

The course is made of 5 modules incrementally presenting the core concepts of web and mobile programming. Each module consists in a theoretical part (with a corresponding lecture) and a practical part (lab sessions) for the students to manipulate the concepts.

Learning outcomes covered on the course

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

32. Know and use standards techniques of web-app design
    - Describe the various parts composing a web-app.
    - Implement each technology seen along the course to a simple case-study.

26. Design and build a complete web-app, with client and server.
    - Propose a consistent orchestration of the components of the web-app
    - Allow different access mode to the service depending on the web-client

- Evaluate and choose the pertinent technologies for a given goal

Description of the skills acquired at the end of the course

Skill C6.4 : Solve problems through mastery of computational thinking skills.

2IN2180 – Procurement management

Instructors: Thierry REBOUD, Philippe ROUGEVIN-BAVILLE
Department: SCIENCES ENTREPRISE
Language of instruction: English
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27
Quota :

Description

This program intends to provide students with basic knowledge and skills to master the main purchasing processes in which they will be involved whatever function they will perform in a company.

As future top managers, students will be able to evaluate the full benefit they can expect from the purchasing Function, and to identify the main drivers to monitor and leverage the relations with suppliers (organization, purchasing policy, performance assessment, targets...)

Quarter number

Intensive week at the end of the SG8

Prerequisites (in terms of CS courses)

No prerequisite

Syllabus

The program is split into several modules
1 – What is Purchasing? Target is to introduce the basic concepts (Vocabulary clarification, purpose of purchasing, Scope of activity...)
2 – Purchasing policy - Marketing approach. Target is to explain the concept of “purchasing strategy” (why? What? How?)
3 – Pricing. Target is to fully understand the fundamental gap between "cost" and "selling price"
4 – RFQ – Supplier selection. Target is to understand the 4 steps of the selection process, how to choose the relevant criteria to evaluate quotations, and how to organize the selection
5 – Make or Buy. Target is to understand the various aspects to be considered for a Make or Buy decision, and how to process it
6 – Legal. Target is to provide the legal background requested in the purchasing activity, and identify the main legal risks related to purchasing
7 - IP. Target is to highlight the importance of IP protection, and explain

how to secure IP in the relations with suppliers
8 – Negotiation. Targets are :
- to understand why and how to prepare negotiations, identify the successful negotiation behaviours for a buyer,
- to provide background about some specific negotiation situations (conflicting, multicultural, negotiation team..)
- to give an overview on "auction" tools.

9 – Supplier assessment – Sustainability. Target is to identify the list of useful criteria, to understand how to perform such assessment, and to give some financial background to detect the sustainability risks.
10 – Value creation – Performance. Target is to explain the purpose of the purchasing performance assessment, and how to implement it, what is “value” for a company, what are the KPI, how to choose them
11 – Ethic & Management : Targets are to identify the main successful skills and qualities for a purchasing function, and to give an overview about the main ethical issues that may result from relations with suppliers.

Learning outcomes covered on the course
On completion of the course, students should be able to:
- Identify and monitor the key purchasing processes
- Elaborate a purchasing policy consistent with the company strategy
- identify the main risks outcoming from relations with suppliers
- Assess suppliers and compare quotations, according to the most relevant criteria for the considered business.
- Prepare and perform negotiations
- Identify the created value that can be leveraged through the bargaining power

2IN2310 – Individuals, Work, Organizations

Instructors: Cynthia COLMELLERE
Department: SCIENCES HUMAINES ET SOCIALES
Language of instruction: FRENCH, ENGLISH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 45
On-site hours (HPE): 27
Quota :

Description

Starting with the basics of sociology, psychology, philosophy, politics, ethics, students will :

- Better know companies and the various working environments of engineers, specifically in relation to company organization and management,
- Understand the social and political and economic contexts of these various working environments,
- Understand the technical, scientific, social, human, economic and managerial dimensions of work and their relations,
- Understand individual and collective behaviour at work,
- Understand the relations and the mechanisms of power in situations of cooperation, negotiation, conflicts,
- Understand the phenomena of abnormality and fraud,
- Understand failures and success of organizational change.

Quarter number

Intensive week of SG6 and SG8

Prerequisites (in terms of CS courses)

none

Syllabus

Examples of courses provided :

- Negotiation and management
- Conflicts and mediation
- Assuming responsibility in duty

Grading

Written essay to be delivered within ten days after the end of the course (at least 50% of the final mark). Oral participation and presentations. Individual and team works. In case of a justified absence to one of the intermediary examinations, the grade of this latter is replaced by the grade of the final examination.

2IN2320 – Perspective on Key Social Issues

Instructors: Cynthia COLMELLERE
Department: SCIENCES HUMAINES ET SOCIALES
Language of instruction: English, French
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 45
On-site hours (HPE): 27
Quota :

Description

These courses aim to help the students to:

- Understand and analyze the major issues related to contemporary environmental, human and social problems: for example: global warming, challenges arising in the energy field, social justice, participation in civil society…
- Fully grasp the impact and effects of human practices on the natural, economic, social environment.
- Comprehend these issues from ethical, social, politic and economic perspective
- In order to direct their actions in front of " big contemporary challenges " by means of an approach based on the human sciences (psychology, sociology, economy, demography, anthropology, etc.).

Quarter number

Intensive week of SG6 and SG8

Prerequisites (in terms of CS courses)

none

Syllabus

Examples of courses (in french) :

- Justice sociale, quelles contributions de l'ingénieur ?
- Exclure/Inclure dans les sociétés contemporaines : le regard des sciences sociales
- Représentations, usages et pratiques de l'espace urbain

Grading

Written essay to be delivered within ten days after the end of the course (at least 50% of the final mark). Oral participation and presentations. Individual and team works.

2IN2330 – Science, Technology, Society

Instructors: Cynthia COLMELLERE
Department: SCIENCES HUMAINES ET SOCIALES
Language of instruction: French, English
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 45
On-site hours (HPE): 27
Quota :

Description

These courses aim at helping future engineers understand the representations of science and technical progress to better their action and its effects. These courses are based on scientific studies, sociology of innovation, history of science and techniques, philosophy, ethics and politics.
Students will be able to understand and analyze in various contexts and situations:

- The elaboration of the scientific and technical knowledges ·
- Distribution,
- Appropriation,
- Practices
- Effects on individuals and society, specifically in terms of controversies

Quarter number

SG6 and SG8

Prerequisites (in terms of CS courses)

none

Syllabus

Examples of courses (in French and in English) :

- Historical, Philosophical and Ethical Perspectives on AI and Data Science
- An introduction to philosophy of science from the perspective of measurement
- Neurosciences, Management et Leadership

Grading

• Written essay to be delivered within ten days after the end of the course (at least 50% of the final mark). Oral participation and presentations. Individual and team works.

2IN2340 – Innovation, Arts and Creativity

Instructors: Cynthia COLMELLERE
Department: SCIENCES HUMAINES ET SOCIALES
Language of instruction: ENGLISH, FRENCH
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 45
On-site hours (HPE): 27
Quota :

Description

The main objective of these courses is to address the issue of innovation through artistic creation. Students will be able to:

- Understand the production of artistic works in various domains: architecture, painting, literature, design …
- Understand the relations between the various domains of the artistic creation ant science and techniques
- Understand the individual and collective dimensions of this work
- Understand the influence of the cultural, social, economic and political contexts in which they take place.

These courses are based on history, sociology, architecture, politics, philosophy

Quarter number

Intensive week of the SG6 and SG8

Prerequisites (in terms of CS courses)

None

Syllabus

Examples of courses (in French and in English) :

- Art, territoires, écologie
- Addressing Fiction : storytelling, literality and fake news
- From cradle-to-grave : Tech won't save us

Grading

Written essay to be delivered within ten days after the end of the course (at least 50% of the final mark). Oral participation and presentations. Individual and team works.

2IN4000 – Business Games

Instructors: Xavier LEON
Department: SCIENCES HUMAINES ET SOCIALES
Language of instruction: ENGLISH, FRENCH
Campus: CAMPUS DE PARIS - SACLAY, CAMPUS DE RENNES, CAMPUS DE METZ
Workload (HEE): 30
On-site hours (HPE): 30
Quota :

Description

The business games offer a practical, playful and synthetic approach to economics, management and psychosociology. They are an experience in collective decision-making, team interdependence and organization, conflict management, role taking and personal positioning in a group. The main objectives are:

- Discover the company and its main functions
- Introduction to management and accounting
- Experiment and become aware of the processes that develop in a teamwork (decision, organization, etc.)
- Analyse its contribution to the working group

Quarter number

Intensive week before the ST5

Prerequisites (in terms of CS courses)

Basic management knowledge and group work experience are useful

Syllabus

Business games are simulations of the lives of several companies competing in the same market. A game unit consists of 5 or 6 teams of 5 or 6 players each.

Each player has a particular responsibility: production, finance, human resources, marketing, general management. At the beginning, the situation of companies is identical. The task of each team is to analyse this initial situation and make decisions: sales, production, price, etc. objectives. The decisions of each team, aggregated and compared with each other, then shape a new market state where the situations of companies differ. The analysis of this new situation gives rise to new decisions and several cycles follow one another.

Class components (lecture, labs, etc.)
The games take place over 4 consecutive days, alternating simulation and debriefing sequences.

Grading
Three dimensions are taken into account in the evaluation of the games: - Acquired knowledge in economics and management and in the human and social sciences - Participation (leadership, involvement in the role) - The quality of the analyses during debriefings, both in terms of strategy/management and team life beyond a day of unjustified absence, students do not validate the business game.

Resources
Teaching team (names of the teachers of the lectures): There are two types of teachers: the facilitators in charge of the game sessions and the specialists (SHS) in charge of the discussion and debriefing sessions.

Learning outcomes covered on the course
- Understand the vocabulary of business management
- Understand the conditions of growth and difficulties of a company
- Understand the usefulness of summary accounting documents
- Understand the interdependence between strategy and operational decisions
- Understand the articulations of functions in a group
- Understanding human phenomena occurring in a group
- Identify your personal contribution in a team

2IN5010 – Bridge Building challenge

Instructors: Guillaume PUEL
Department: MÉCANIQUE GÉNIE CIVIL
Language of instruction: French
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 45
On-site hours (HPE): 27
Quota :
Elective Category : Engineering Sciences
Advanced level : Yes

Description

The principle of this experimental teaching is to build, according to a given set of specifications, a cardboard bridge model capable of supporting the greatest possible load. The main objective is to highlight the interactions between modelling, experimentation and numerical simulation.

Quarter number

Intensive week of the SG6 and at the end of the SG8

Prerequisites (in terms of CS courses)

1EL5000 (Continuum mechanics) or 1EL4000 (Materials) or ST2 CVT (Performance modelling and hybridization in the preliminary design phase) or ST4 CVT (Digital transformation and integrated engineering: digital model and life cycle of structures and vehicles)

Syllabus

- Monday, all day (in parallel):
  - Characterization of the mechanical properties of the cardboard
    - tensile tests on cardboard specimens cut in different directions to determine the moduli of elasticity, Poisson's ratio (using marker tracking) and tensile strengths (each group offers two different specimens and thus contributes to the realization of a collective experimental basis)
  - Brainstorming on the possible architectures for the bridge
    - use of topological optimization software (TopOpt)
    - study of first simple models with Comsol
- Tuesday, all day (in parallel):
  - Structural tests

        - compression tests on "profiled" beams
        - tensile tests on beams assembled by gluing
        - (possibly) tests of various assemblies
    - Design of bridge models
        - precise design of bridges using finer numerical models on Comsol and structural tests
- Wednesday, all day (in parallel):
    - Construction of bridge models (laser cutting of the designed parts at la Fabrique)
    - Complementary numerical models (or additional experimental tests)
    - Preparation of the next morning's presentations
- Thursday :
    - Morning: presentation of the different models
        - every group of students must announce the load that their model will be able to support
        - the groups also vote for the model they think will win
    - Afternoon (for those who can): test of bridge models in a "challenge" configuration, open to the public
- Friday:
    - Morning: analysis of test results and interpretation of discrepancies with predictions
    - Afternoon: writing of a summary note on the learning of the activity

Grading

work within the project + intermediate defence + final summary note.

Resources

- Software: Comsol (Structural Mechanics module)
- Equipment-specific classrooms: MSSMat laboratory (Matter block of Eiffel building)

Learning outcomes covered on the course

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

- conduct tests for the mechanical characterization of a material or structure
    - experimentally determine the mechanical properties of a material for use in a real structure

    - conduct tests on real structures to evaluate their mechanical performance

- dimension a structure from a mechanical point of view

    - propose models, analytical or numerical, and of increasing complexity, of real structures
    - obtain, using these models, relevant quantities to make design choices

- present in a convincing and reasoned way a mechanical design approach

    - present the modeling choices and the results resulting from a mechanical dimensioning
    - explain the differences in performance of the actual structure with respect to the developed model(s)

Description of the skills acquired at the end of the course

The validation of this teaching allows to reach milestone 2 of competence C1.2, i.e. "Knowing how to choose the right model for a given problem, choosing the modeling scale". It also makes it possible to achieve milestones 1A and 3B of competency C1.3, i.e. "Know how to measure a quantity by quantifying measurement uncertainty. Know how to interpret observations and errors. Know orders of magnitude" and "Make a choice of simulation relevant to a given problem". Finally, it enables the student to achieve milestones 2 of competencies C7.1, C7.2 and C7.4, namely "Convincing to retain/decide on a solution/recommendation chosen among others or an opinion", as well as competency 8.1.

The first two learning outcomes are assessed throughout the week, as well as in the Intermediate Defence and the Final Briefing Note. The last learning outcome is assessed more specifically in the intermediate defence and the final briefing note, respectively.

2IN5020 – Semiconductor innovation

Instructors: Tanguy PHULPIN
Department: ENERGIE
Language of instruction: French
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27
Quota :
Elective Category : Engineering Sciences
Advanced level : No

Description

Welcome in the semiconductors area. This domain has a really strong impact on our lives and future innovation requires new topology, new improvements, new researchers. To understand what are the challenges and possible responses, it is fundamental to possess the basics and to handle them.

After 10 hours of lesson, let's start in a laboratory with several projects for 2 or 3 days. Most are in Paris but 2 are in Grenoble. the last day, an oral presentation behind the class on your project will be held and a form will complete the global evaluation.

Quarter number

Intensive week SG6

Prerequisites (in terms of CS courses)

None

Syllabus

Energy band model will be described in this lesson. You will study the different semiconductors interfaces with a focus on a PN junction and the FET effect. You will be able to understand how a bipolar transistor or a MOSFET or a solar cell is working. You will estimate the main characteristics of semi-conductors to be able to understand what are the requirement of this domain.

Class components (lecture, labs, etc.)

A conference and 4 hours of lesson before the week. Then the lesson takes place the full Monday before going into industry for 2,5 days to work on a project. The Friday afternoon, the oral presentation is followed by an exam.

Grading
Oral defence then written exam

Resources

- Teaching staff (instructor(s) names): JP.Kleider, T. Phulpin, J-R. Lequereys (guest)
- Maximum enrolment: 7 trinomes, 21 students

Learning outcomes covered on the course
Basics in semi-conductor physic: Energy Band, Electric field, Current density, Field-Effect transistors, PN junction, photovoltaic cell.

Description of the skills acquired at the end of the course
After the short lesson, students will understand the basic knowledge of semiconductors technology.
They will meet professionals, and work in laboratories. They will work on new topics with high technology measurement tools.

2IN5030 – Experimental physics work

Instructors: Brahim DKHIL
Department: PHYSIQUE
Language of instruction: French
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27
Quota :
Elective Category : Fundamental Sciences
Advanced level : No

Description

It is an experimental learning in physics that aims to (i) illustrate and experimentally apply the content of CentraleSupélec's physics teaching, (ii) demonstrate creativity and initiative, (iii) work in groups and in a concerted manner, (iv) transmit knowledge. In order to achieve these objectives, the pupils will have at their disposal a set of equipment and apparatus from which, with the help of their teachers/teachers, they will have to imagine and implement their own experiments in order to illustrate the following 5 physical themes: structure of matter, radiation-matter interaction, phase transition, transport phenomena, energy conversion.

Quarter number

Intensive week of the SG6 and SG8

Prerequisites (in terms of CS courses)

Basics in Physics

Syllabus

Each group will be made up of 10 students divided into 5 pairs (one pair = one physical theme) and must have a common thread (guideline). The capacity of reception and supervision (4 teachers) allows a total of 30 students.
At the beginning of the sequence, during two half-day sessions, which will be called "preparatory" sessions, and with all the supervisors, the students will have to divide themselves up and will have the free will to define their common thread and the experiences they will have to implement and present in April over 4 days.
During the preparatory sessions, the students will have access to a list of equipment and materials (visit to the InnoPhysLab room + SPMS laboratory equipment) which will be made fully available to them to carry out their experiments. Within a certain limit and according to the needs expressed,

small additional equipment may be purchased to complete the equipment already made available.
Each group will have 4 days to set up their experiments in accordance with the physical themes, to take measurements, to criticize the results, and to make a "YouTube" type video which will be submitted to an external committee of physics teachers from CentraleSupélec.

Class components (lecture, labs, etc.)

2 sessions of 3 hours to prepare the experimental work.
4 days of 7.5 hours of experimental work implementation and presentation.

Grading

The evaluation is based on the behaviour and work done during the experimental sessions as well as on the video realized by the students which aims at describing their work.

Resources

4 teachers for 30 students distributed into 3 groups of 10 students.
Acces to InnoPhys room and SPMS lab equipment.

Learning outcomes covered on the course

- consolidate their knowledge in Physics
- knowhow for mounting an experiment
- work in a group, exchange and organize the work
- develop creativity and initiative
- learn how to transmit their knowledge

2IN5040 – Experimental work about information transmission

Instructors: Alain DESTREZ
Department: TÉLÉCOMMUNICATIONS
Language of instruction: French
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27
Quota :
Elective Category : Engineering Sciences
Advanced level : Yes

Description

Objectives are the conception, realization and test of a full radio or optical transmission system.

Quarter number

Intensive week SG6 and SG8.

Prerequisites (in terms of CS courses)

1EL8000 (*systèmes électroniques*), or equivalent electronics basics (calculation of typical electronic circuits) and modelling (CAD)

Syllabus

Four subjects for 4 x 2 students are constituting the four parts of two common projects to realize a full link with a radio or optical transmitter and an associated receiver. Students must connect their realizations and test the transmission quality for audio or data signals (link budget, bit rate, bandwidth, linearity, reliability).

Class components (lecture, labs, etc.)

One day talking about the projects (explanations), with some lecture summaries and/or complements about the required functions (oscillators, amplifiers, filters), then 3 days of experiments in laboratory, half a day for a final oral presentation of the projects. Students will work in laboratories in the domain of radio and optical transmissions and will use specific material (spectrum analyzers, photometers, optical test bench, transmission analyzers, integrated circuits, amplifiers).

Grading
Final oral presentation + final report.

Course support, bibliography
Presentation of the projects, required lecture complements.

Resources

- Teaching Team : Alain Destrez
- Software and number of required licences : no required software (students may use TSpice if needed, freeware)
- Will take place in the different laboratories of the Telecommunication Department, ideally 4x2 students)

Learning outcomes covered on the course
Realizing a radio or optical telecommunications system. Using in practice the theoretical knowledge (from various lectures) compare to the practical results. Increasing the transmission system if needed. Understanding the data transmission (C6.7). Finding a solution to a given problem using approximation, simulation and experimentation (C1.3). Specifying, designing, realizing and validating all or part of a complex system (C1.4). Evaluating the efficiency, feasibility and robustness of the possible solutions (C3.6).

Description of the skills acquired at the end of the course
Realizing a radio or optical telecommunications system. Use experimentally the theoretical knowledge (from various lectures), compare to the practical results. Increase the transmission characteristics, if needed.

2IN5106 – Introduction to Marketing

Instructors: Emmanuel Helbert
Department: CAMPUS DE METZ
Language of instruction: French
Campus: CAMPUS DE METZ
Workload (HEE): 40
On-site hours (HPE): 27
Quota :
Elective Category : Business Sciences
Advanced level : No

Description

Understand the place of Marketing in organizations and the links with other professions.
Understand the main principles of Marketing, its vocabulary and know a panel of tools and their implementation.

Quarter number

Intensive week SG6

Prerequisites (in terms of CS courses)

None

Syllabus

1. Introduction: Definitions, corporate/marketing strategies, strategic/operational marketing
2. The market :

- a. Markets
- b. The consumer
- c. Studies
- d. Tools: SWOT, PESTEL

3. Marketing strategy

- a. Segmentation
- b. Targeting
- c. Positioning

4. Operational marketing

- a. Marketing mix
- b. Brand management
- c. Product Management

- d. Distribution
- e. Awards
- f. Communication
- g. Focus: Digital marketing, content marketing, B2B marketing

5. Marketing today

- a. Lean Start-Up
- b. Design Thinking

Class components (lecture, labs, etc.)
Alternating between presentation of concepts and group work (3-4 students). Each group will explore a project that will be the common thread of the week allowing the concepts to be put into practice.

Grading
Alternance entre la présentation des concepts et le travail en groupe (3-4 élèves). Chaque groupe explorera un projet qui sera le fil rouge de la semaine permettant de mettre les concepts en pratique.

2IN5110 – Ethics and Responsibility

Instructors : Jean-Marc CAMELIN
Department : LEADERSHIP ET MÉTIERS DE L'INGÉNIEUR
Language of instruction : FRENCH
Campus : CAMPUS DE PARIS - SACLAY
Workload (HEE) : 40
On-site hours (HPE) : 27
Quota :
Elective Category : Business Sciences
Advanced level : Yes

Description

This elective course addresses the issue of ethics and responsibility for an engineer, using concrete situations described during the 1 week seminar (witnesses, videos, theoretical contributions) as engineers are facing them, and leads to an awareness and a capacity of questioning individually the adequacy between their actions and decisions and their own values.

High-level engineers have a key role in the evolution of our society. This course is designed for students intending to pursue a career either in management, potentially as very high-level decision makers (decision making in conscience), or in research, including fundamental research (representation of future uses of their research). Objectives are to:

- Expose each student to the ethical, social, societal, economical and political consequences of their actions as an engineer, in an increasingly multicultural environment
- Help students develop an awareness of ethical and societal issues in their future professional career
- Educate students on what influences their decision-making, beginning with their choice of curriculum and job

Quarter number

Intensive week at the end of the SG8

Prerequisites (in terms of CS courses)

Advanced level elective requesting to have done the 2nd year API on ethics

Syllabus

- Introduction to ethics: responsibility, concept, history, reference texts, tangible actions involved, meaning.

- Illustration of the problem: labor and work (concept, role, suffering at work, empowerment), environment (sustainable development, decisions, impact), world global issues
- Understanding the System: the current system (capitalism, economic regulation, impact on the actions of decision makers, measures, GDP), alternatives (how to think the world differently, microcredit, virtual economy), science and the engineer of the 21st century (role of the engineer within the system, his/her influence on ethical issues, research and its impact)
- Ethic as an action: individual issues (I decide and act in conscience), political decision (provide guidance to the whole society), broadening the issue (global-international-national-local levels, time representations in the short-medium-long terms, the CEO decision-making process: strategy, innovation), you as a student (how I understand my environment and how I project myself into the future as an engineer, my gap year, my professional dreams)

Class components (lecture, labs, etc.)
Alternate plenary sessions and half-promo workshops, conferences, Alumnis witnesses.

Grading
Oral presentation of group project conducted throughout the seminar
Active participation during conferences.
Competencies auto-evaluation and peer-evaluation.

Course support, bibliography
Course material, bibliography: provided to students in the introduction of the course.

Resources
Course material, bibliography: provided to students in the introduction of the course.
Teaching team:

- Fabienne Bergé - enseignante coordinatrice de pôle projet et de l'électif DYW – psychologue du travail
- Bruno Lefèbvre - Associé Fondateur Alteralliance - spécialiste psycho-dynamique du travail
- Patricia Midy - enseignante APP/API - coach indépendante
- Témoignages d'Anciens
- Conférenciers extérieurs

Learning outcomes covered on the course

- To take the necessary step back from the professional context to consider the ethical aspect of the action
- Understand the constraints of the socio-economic system to be able to question them
- Critical thinking and discernment of the system
- Transforming difficulties and constraints into opportunities to pursue one's career while respecting one's personal ethics

Description of the skills acquired at the end of the course

C3.2 Question assumptions and givens. Overcome failure

C9.2 Identify, within a given structure, the scope of liability as well as socio-ethical and environmental responsibilities.

C9.4 Demonstrate rigor and critical thinking in approaching problems from all angles, whether scientific, social or economic.

2IN5120 – Public Finances

Instructors: Pierre BERTINOTTI
Department: CAMPUS DE METZ
Language of instruction: FRENCH
Campus: CAMPUS DE METZ
Workload (HEE): 40
On-site hours (HPE): 27
Quota :
Elective Category : Business Sciences
Advanced level : No

Description

from factual data: concepts, procedures, figures.., allow each student to develop his or her own thinking on the major issues of public finances.

Quarter number

semaine bloquée SG8

Prerequisites (in terms of CS courses)

none

Syllabus

Introduction
Public finances: what are we talking about?

1. The major issues related to public spending and taxation :
Relationships with politics, the economy and society
2. Government finances :
Drawing up the budget:
Content: missions, programs, actions
The procedure: the European semester and the national semester
The State's financial resources: taxation and debt
Budget implementation: the main business rules
Control of expenditure and evaluation of actions
3. Local authority finances :
Who finances what? Powers and expenditure
The financial autonomy of local authorities: local taxation
Preparation, execution and control of local government budgets
4. Social protection accounts :
The scope of social protection: the various social benefits
The financing of social protection: contributions, taxes and public contributions
Social protection: a political issue

Translated with www.DeepL.com/Translator (free version)

Class components (lecture, labs, etc.)
the active participation of students will be favoured: briefs Introductory lectures, case studies, role-playing... Collective reflection will be encouraged.

Grading
Grouped in groups of 3 or 4, the students will write a thesis. of about fifteen pages on a theme related to the course, decided in agreement with the teacher.

LANGUAGE AND CULTURE COURSES

Modern Languages, Cultures and Civilisation

Instructors: Claude MEZIN-WILKINSON

Department:

Language of instruction:

Campus: CAMPUS DE PARIS - SACLAY

ECTS:

Workload (HEE):

On-site hours (HPE):

Quota :

Syllabus

The study of English and one other modern language is compulsory. The second language may be chosen from : French as a foreign language (for non-native speakers of French), Arabic, Chinese, German, Hebrew, Italian, Japanese, Russian or Spanish. Language courses are also open to international students in semester- or year-exchange programs. We highly recommend they take French as a Foreign Language (FLE) at the appropriate level. Students from non English-speaking countries are advised to take English courses. Students who are already at the C2 level in FLE or English, and who have a TDC (Test de Dispense de Cours) may study another language.

LC0100 – English

Instructors: Mark PITT
Department: LANGUES ET CULTURES
Language of instruction: ENGLISH
Campus: CAMPUS DE PARIS - SACLAY, CAMPUS DE RENNES, CAMPUS DE METZ
Workload (HEE): 28
On-site hours (HPE): 21
Quota :

Description
In 1st and 2nd years two courses per year are offered, each extending over two consecutive sequences.
3rd year classes are of varying duration, depending on student profile.
The following information concerns classes of all three years.

Quarter number
Two courses per year, each lasting two sequence, 1 and 2 and / or 3 and 4

Prerequisites (in terms of CS courses)
none

Syllabus
General and thematic courses are on offer, depending on the level and the availability of the student

Class components (lecture, labs, etc.)
Student-centred active learning, flipped classroom, whole class or group activities. One hour minimum per week of homework to prepare or prolong in-class activities.

Grading
Continuous assessment (various spoken and written exercises) counting for at least 80% of the final grade.

Course support, bibliography
Varied: audio and video, written documents, news articles, documentaries, works of Literature, English language textbooks, depending on the course taken.

Learning outcomes covered on the course

- Consolidate and develop the four basic language skills (reading, writing, listening and speaking).
- Consolidate and develop intercultural skills and comprehension essential to an international career.
- Give students an awareness of language that will allow them to develop their self learning skills propose a varied and innovative approach to language learning.

Description of the skills acquired at the end of the course

- The student will have progressed towards the C1 + level required for the CentraleSupélec diploma. (Skill C5.1)
- Other skills (e.g. C7) may be reinforced, depending on the class selected.

LC0200 – French as a Foreign Language

Instructors: Geraldine OFTERDINGER
Department: LANGUES ET CULTURES
Language of instruction: FRENCH
Campus: CAMPUS DE METZ, CAMPUS DE RENNES, CAMPUS DE PARIS - SACLAY
Workload (HEE): 28
On-site hours (HPE): 21
Quota :

Description
This document is for 1st, 2nd and 3rd year students.

Quarter number
S5 from September to January S6 from February to June

Syllabus
Those weekly courses are offered at several levels, depending on the results of the placement test. Classes are organized as practical workshops focusing on oral understanding and communication, written understanding and communication, structural proficiency (grammar, vocabulary). Students will work individually or in groups on themes related to contemporary French culture in relation to its historical past.

Class components (lecture, labs, etc.)
A placement test will determine the level of the course: A1, A1, B1, B2, or C1 (European reference framework)

Grading
The evaluation is organized in two ways: continuous assessment and control of the end of half-year.

Course support, bibliography
Specific to each course and group level: printed documents (press, literature), audio/video (films, recordings), textbooks

Learning outcomes covered on the course
Develop and solidify the four language competences (written and oral

comprehension, written and oral expression) to communicate in the academic, professional and/or personal environments. Develop and solidify the tools of intercultural understanding to allow students to engage in the discovery of the culture. Allow students to develop their learning process in an autonomous and responsible wayOffer various innovative approaches suited to individual needs

Description of the skills acquired at the end of the course
Master French for academic courses, as the common language of international communication on campus, and as a professional communication language. Master French as an effective communication tool to understand contemporary French culture.

LC0300 – German

Instructors: Sabine GEISERT
Department: LANGUES ET CULTURES
Language of instruction: ALLEMAND
Campus: CAMPUS DE RENNES, CAMPUS DE METZ, CAMPUS DE PARIS - SACLAY
Workload (HEE): 28
On-site hours (HPE): 21
Quota :

Quarter number
S5 from September to January S6 from February to June

Syllabus
A variety of courses are on offer, depending on the level of the student. From a level B1+ and up, students may choose a thematic course (economics, scientific, history, cultural, etc.). All courses include grammar, structure exercises, and work on oral and written skills

Class components (lecture, labs, etc.)
Following a test, students are place in a level group. Lessons are 1.5 hours long per week in the CS curriculum.

Grading
CS: Continuous assessment (various spoken and written exercises) counting for at least 80% of the final grade.

Learning outcomes covered on the course
Consolidate and develop the four basic language skills (reading, writing, listening and speaking)Consolidate and develop intercultural skills and comprehension essential to an international career Give students an awareness of language that will allow them to develop their self learning skills propose a varied and innovative approach to language learning

Description of the skills acquired at the end of the course
Understand and express oneself in written and spoken German, both in everyday life and in a professional and academic context (internships, academic exchanges, e-tandem ...). Acquire intercultural skills to enable better communication with interlocutors from German-speaking countries.

LC0400 – Spanish

Instructors: Antonio BARREJON LOPEZ
Department: LANGUES ET CULTURES
Language of instruction: ESPAGNOL
Campus: CAMPUS DE RENNES, CAMPUS DE METZ, CAMPUS DE PARIS - SACLAY
Workload (HEE): 28
On-site hours (HPE): 21
Quota :

Quarter number
S5 from September to January S6 from February to June

Syllabus
SPANISH GENERAL Beginner level : Practice of oral and written skills. Awareness of the culture and current affairs of Spain and Latin America. Level A1-B1: Reinforcement of basic notions, with special emphasis on oral and written language. Openness to the civilization of Spain and Latin America. THEMATIC COURSES - From level B2 onwards Although the linguistic aspect remains an essential component of this course, the materials used allow an approximation to the historical and cultural realities of Spanish-speaking countries. -Spanish civilization and culture. -Latin American civilization and culture. -Economic Spanish. -Cinema. -Preparation for the official level exam, DELE ("Diploma de Español Lengua Extranjera") of the Cervantes Institute.

Class components (lecture, labs, etc.)
Following a test, students are placed in level groups. Lessons are 1.5 hours long.

Grading
CS: Continuous assessment (various spoken and written exercises) counting for at least 80% of the final grade.

Learning outcomes covered on the course
Consolidate and develop the four main language skills (reading, writing, listening and speaking) Consolidate and develop intercultural skills and comprehension essential to an international careerGive students an awareness of language that will allow them to develop their self learning

skills propose a varied and innovative approach to language learning

Description of the skills acquired at the end of the course
Understand and express yourself in Spanish, both in everyday life and in a professional and academic context (internships, academic exchanges ...). Acquire intercultural skills that will enable you to communicate better with people in Spanish-speaking countries.

LC0500 – Italian

Instructors: Claude MEZIN-WILKINSON
Department: LANGUES ET CULTURES
Language of instruction: ITALIEN
Campus: CAMPUS DE METZ, CAMPUS DE RENNES, CAMPUS DE PARIS - SACLAY
Workload (HEE): 28
On-site hours (HPE): 21
Quota :

Syllabus
General language course at all levels (beginner to advanced) focussing on: Oral understanding and expression (pronunciation, intonation, rhythm, lexicon, structures), interaction; Written understanding and expression (lexicon, structures); Acquisition of the tools enabling successful communication; Increased cultural and cross cultural awareness.

Class components (lecture, labs, etc.)
Following a test, students are placed in level groups.
Student's levels are evaluated each semester, and the groups made accordingly.
Lessons are 1.5 hours long.

Grading
Continuous assessment (80%) Written exam / listening-speaking test at the end of each semester (20%)

Learning outcomes covered on the course
Consolidate and develop the main language skills (reading, writing, listening and speaking)
Consolidate and develop intercultural skills and comprehension essential to an international career
Give students an awareness of language that will allow them to develop their self learning skills
Propose a varied and innovative approach to language learning.

Description of the skills acquired at the end of the course
C5: Be comfortable in a multicultural and international environment, C5.1 more specifically.
At the end of this course, the student will be able to communicate according to the skills of the CEFR, with increased fluency and accuracy.

LC0600 – Portuguese

Instructors: Claude MEZIN-WILKINSON
Department: LANGUES ET CULTURES
Language of instruction: PORTUGAIS
Campus: CAMPUS DE PARIS - SACLAY, CAMPUS DE RENNES, CAMPUS DE METZ
Workload (HEE): 28
On-site hours (HPE): 21
Quota :

Quarter number
S7 and S8

Syllabus
General language course at all levels (beginner to advanced) focussing on: Oral understanding and expression (pronunciation, intonation, rhythm, lexicon, structures), interaction; Written understanding and expression (lexicon, structures); Acquisition of the tools enabling successful communication; Increased cultural and cross cultural awareness.

Class components (lecture, labs, etc.)
Following a test, students are placed in level groups.
Student's levels are evaluated each semester, and the groups made accordingly.
Lessons are 1.5 hours long.

Grading
Continuous assessment (80%) Written exam / listening-speaking test at the end of each semester (20%)

Learning outcomes covered on the course
Consolidate and develop the main language skills (reading, writing, listening and speaking)
Cconsolidate and develop intercultural skills and comprehension essential to an international career
Give students an awareness of language that will allow them to develop their self learning skills
Propose a varied and innovative approach to language learning.

Description of the skills acquired at the end of the course

C5: Be comfortable in a multicultural and international environment, C5.1 more specifically.

At the end of this course, the student will be able to communicate according to the skills of the CEFR, with increased fluency and accuracy.

LC0700 – Chinese

Instructors: Claude MEZIN-WILKINSON
Department: LANGUES ET CULTURES
Language of instruction: CHINOIS
Campus: CAMPUS DE RENNES, CAMPUS DE METZ, CAMPUS DE PARIS - SACLAY
Workload (HEE): 28
On-site hours (HPE): 21
Quota :

Syllabus
General language course at all levels (beginner to advanced) focussing on: Oral understanding and expression (pronunciation, intonation, rhythm, lexicon, structures), interaction; Written understanding and expression (lexicon, structures); Acquisition of the tools enabling successful communication; Increased cultural and cross cultural awareness.

Class components (lecture, labs, etc.)
Following a test, students are placed in level groups.
Student's levels are evaluated each semester, and the groups made accordingly.
Lessons are 1.5 hours long.

Grading
Continuous assessment (80%) Written exam / listening-speaking test at the end of each semester (20%)

Learning outcomes covered on the course
Consolidate and develop the main language skills (reading, writing, listening and speaking)
Consolidate and develop intercultural skills and comprehension essential to an international career
Give students an awareness of language that will allow them to develop their self learning skills
Propose a varied and innovative approach to language learning.

Description of the skills acquired at the end of the course
C5: Be comfortable in a multicultural and international environment, C5.1 more specifically.
At the end of this course, the student will be able to communicate according to the skills of the CEFR, with increased fluency and accuracy.

LC0800 – Japanese

Instructors: Claude MEZIN-WILKINSON
Department: LANGUES ET CULTURES
Language of instruction: JAPONAIS
Campus: CAMPUS DE PARIS - SACLAY, CAMPUS DE METZ, CAMPUS DE RENNES
Workload (HEE): 28
On-site hours (HPE): 21
Quota :

Syllabus

General language course at all levels (beginner to advanced) focussing on: Oral understanding and expression (pronunciation, intonation, rhythm, lexicon, structures), interaction; Written understanding and expression (lexicon, structures); Acquisition of the tools enabling successful communication; Increased cultural and cross cultural awareness.

Class components (lecture, labs, etc.)

Following a test, students are placed in level groups.
Student's levels are evaluated each semester, and the groups made accordingly.
Lessons are 1.5 hours long.

Grading

Continuous assessment (80%) Written exam / listening-speaking test at the end of each semester (20%) In case of a justified absence to one of the intermediary examinations, the grade of this latter is replaced by the grade of the final examination

Learning outcomes covered on the course

Consolidate and develop the main language skills (reading, writing, listening and speaking)
Consolidate and develop intercultural skills and comprehension essential to an international career
Give students an awareness of language that will allow them to develop their self learning skills
Propose a varied and innovative approach to language learning.

Description of the skills acquired at the end of the course
C5: Be comfortable in a multicultural and international environment, C5.1 more specifically.
At the end of this course, the student will be able to communicate according to the skills of the CEFR, with increased fluency and accuracy.

LC0900 – Russian

Instructors: Claude MEZIN-WILKINSON
Department: LANGUES ET CULTURES
Language of instruction: RUSSE
Campus: CAMPUS DE RENNES, CAMPUS DE METZ, CAMPUS DE PARIS - SACLAY
Workload (HEE): 28
On-site hours (HPE): 21
Quota :

Syllabus

General language course at all levels (beginner to advanced) focussing on: Oral understanding and expression (pronunciation, intonation, rhythm, lexicon, structures), interaction; Written understanding and expression (lexicon, structures); Acquisition of the tools enabling successful communication; Increased cultural and cross cultural awareness.

Class components (lecture, labs, etc.)

Following a test, students are placed in level groups.
Student's levels are evaluated each semester, and the groups made accordingly.
Lessons are 1.5 hours long.

Grading

Continuous assessment (80%) Written exam / listening-speaking test at the end of each semester (20%) In case of a justified absence to one of the intermediary examinations, the grade of this latter is replaced by the grade of the final examination.

Learning outcomes covered on the course

Consolidate and develop the main language skills (reading, writing, listening and speaking)
Consolidate and develop intercultural skills and comprehension essential to an international career
Give students an awareness of language that will allow them to develop their self learning skills
Propose a varied and innovative approach to language learning.

Description of the skills acquired at the end of the course
C5: Be comfortable in a multicultural and international environment, C5.1 more specifically.
At the end of this course, the student will be able to communicate according to the skills of the CEFR, with increased fluency and accuracy.

LC1000 – Arabic

Instructors: Claude MEZIN-WILKINSON
Department: LANGUES ET CULTURES
Language of instruction: ARABE
Campus: CAMPUS DE PARIS - SACLAY, CAMPUS DE METZ, CAMPUS DE RENNES
Workload (HEE): 28
On-site hours (HPE): 21
Quota :

Syllabus

General language course at all levels (beginner to advanced) focussing on: Oral understanding and expression (pronunciation, intonation, rhythm, lexicon, structures), interaction; Written understanding and expression (lexicon, structures); Acquisition of the tools enabling successful communication; Increased cultural and cross cultural awareness.

Class components (lecture, labs, etc.)

Following a test, students are placed in level groups.
Student's levels are evaluated each semester, and the groups made accordingly.
Lessons are 1.5 hours long.

Grading

Continuous assessment (80%) Written exam / listening-speaking test at the end of each semester (20%) In case of a justified absence to one of the intermediary examinations, the grade of this latter is replaced by the grade of the final examination.

Learning outcomes covered on the course

Consolidate and develop the main language skills (reading, writing, listening and speaking)
Consolidate and develop intercultural skills and comprehension essential to an international career
Give students an awareness of language that will allow them to develop their self learning skills
Propose a varied and innovative approach to language learning.

Description of the skills acquired at the end of the course

C5: Be comfortable in a multicultural and international environment, C5.1 more specifically.

At the end of this course, the student will be able to communicate according to the skills of the CEFR, with increased fluency and accuracy.

LC1200 – Hebrew

Instructors: Claude MEZIN-WILKINSON
Department: LANGUES ET CULTURES
Language of instruction: HEBREU
Campus: CAMPUS DE RENNES, CAMPUS DE PARIS - SACLAY, CAMPUS DE METZ
Workload (HEE): 28
On-site hours (HPE): 21
Quota :

Syllabus

General language course at all levels (beginner to advanced) focussing on: Oral understanding and expression (pronunciation, intonation, rhythm, lexicon, structures), interaction; Written understanding and expression (lexicon, structures); Acquisition of the tools enabling successful communication; Increased cultural and cross cultural awareness.

Class components (lecture, labs, etc.)

Following a test, students are placed in level groups.
Student's levels are evaluated each semester, and the groups made accordingly.
Lessons are 1.5 hours long.

Grading

Continuous assessment (80%) Written exam / listening-speaking test at the end of each semester (20%)

Learning outcomes covered on the course

Consolidate and develop the main language skills (reading, writing, listening and speaking)
Consolidate and develop intercultural skills and comprehension essential to an international career
Give students an awareness of language that will allow them to develop their self learning skills
Propose a varied and innovative approach to language learning.

Description of the skills acquired at the end of the course

C5: Be comfortable in a multicultural and international environment, C5.1 more specifically.

At the end of this course, the student will be able to communicate according to the skills of the CEFR, with increased fluency and accuracy.