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2SC8191 – Optimization of aeronautical parts in metal additive manufacturing
2SC8192 – Optimization of parts for biomedical applications in polymer additive manufacturing
2SC8193 – Optimization of civil engineering structures in additive concrete manufacturing
ST7 – 82 – PHYSICAL NEURO-INSPIRATORY SYSTEMS FOR INFORMATION PROCESSING
2SC8210 – Optimization for neuro-inspired computing with physical architectures
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2IN1580 – Artificial intelligence and global health
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2CC1000 – Automatic control

Instructors: Didier Dumur

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

Erasmus ECTS: 2,5

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.

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
- 2. 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.
- 3. 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

- Paris-Saclay campus: lectures are structured based on 8 tracks with about 100 students per track, 7 tracks in French, 1 track in English.

- Rennes Campus: lectures are given in French with specific features to allow students with weak French level to follow them. Support sessions in English are also scheduled.

- Metz campus: lectures are given in French.

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" in French or English

- Control glossary French-English and English-French
- Slides shown during the lectures

Bibliography:

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- 1. J.J. D'Azzo & C.H. Houpis "Linear Control System. Analysis and Design" 3e ed., Mc Graw-Hill, 1988.
- P. Borne, G. Dauphin-Tanguy, J.-P. Richard, F. Rotella et I. Zambettakis - "Analyse et régulation des processus industriels. Tome 1. Régulation continue, Tome 2. Régulation numérique" -Éditions Technip, 1993.
- 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.
- 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 Makarova, Cristina Maniu, Houria Siguerdidjane, Cristina Vlad, Sorin Olaru, Pedro Rodriguez, Guillaume Sandou, Giorgio Valmorbida, Hugo Lhachemi, Clément Chahbazian, 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: 35 students



- Equipment-specific classrooms: capacity of 100 students per half day, Lab work partly in the Control Department (7 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:

- Choose an adequate behavioural model (transfer function, state space representation ...)
- Identify the model parameters based on experimental data and/or a priori knowledge
- 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

- 60
- "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.



2CC1005 – Automatic control - DUAL

Instructors: Didier Dumur Department: DÉPARTEMENT AUTOMATIQUE Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 36,00 Erasmus ECTS: 2,5

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.

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

Work classes 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:



- J.J. D'Azzo & C.H. Houpis "Linear Control System. Analysis and Design" 3e éd., Mc Graw-Hill, 1988.
- P. Borne, G. Dauphin-Tanguy, J.-P. Richard, F. Rotella et I. Zambettakis - "Analyse et régulation des processus industriels. Tome 1. Régulation continue, Tome 2. Régulation numérique" -Éditions Technip, 1993.
- J.B. Deluche "Automatique. De la théorie aux applications industrielles. Tome 2 : Systèmes continus" Edipol, 2000.
- J.M. Flaus "La régulation industrielle" Hermès, 1994.
- G.F. Franklin, J.D. Powell, A. Emami-Naeini "Feedback Control of Dynamic Systems" 7° ed., Ed. Pearson Publishing Company, 2014.
- B. Friedland "Control system design" Mc Graw-Hill, 1986.
- Ph. de Larminat "Automatique. Commande des systèmes linéaires" Hermès, 1996.
- L. Maret "Régulation automatique" Presses Polytechniques Romandes, 1987.
- K. Ogata "Modern Control Engineering" 5e éd., Ed. Pearson Education International, 2009.
- A. Rachid "Systèmes de régulation" Masson 1996.
- M. Zelazny, F. Giri et T. Bennani "Systèmes asservis : commande et régulation" Eyrolles, 1993.

Resources

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

Learning outcomes covered on the course

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

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

- Choose an adequate behavioural model (transfer function, state space representation ...)
- Identify the model parameters based on experimental data and/or a priori knowledge
- 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, DÉPARTEMENT GÉNIE INDUSTRIEL ET OPÉRATIONS Language of instruction: FRENCH, ENGLISH Campus: CAMPUS DE PARIS - SACLAY, CAMPUS DE METZ, CAMPUS DE RENNES Workload (HEE): 10 On-site hours (HPE): 6,00 Erasmus ECTS : 0

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



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 socioethical and environmental responsibilities.



2CC3000 – Optimization

Instructors: Jean-Christophe Pesquet Department: DÉPARTEMENT MATHÉMATIQUES Language of instruction: FRENCH, ENGLISH Campus: CAMPUS DE METZ, CAMPUS DE RENNES, CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 36,00 Erasmus ECTS : 2,5

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

25



2CC3005 – Optimisation - DUAL

Instructors: Charles Soussen Department: DÉPARTEMENT MATHÉMATIQUES Language of instruction: FRENCH, ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 36,00 Erasmus ECTS: 2,5

Description

Optimization arises in many domains including science, mathematics, engineering, economy and finance. For instance, the problems of stock management, resource allocation, control of mechanical structures, and data analysis may all be addressed as optimization problems. Although these problems are of various nature, they can all be formulated as the minimization of a cost function over a given domain and under a set of constraints. Nevertheless, there are many existing optimization methods depending on the structure of the problem at hand.

This course aims at teaching a comprehensive overview of the classical optimization approaches and algorithms. The objective is to provide the background that will allow the participants to practically address the various optimization problems they might encounter, and help them choosing the adequate algorithm. The lecture will cover local and simple global optimization methods. The topics will include gradient-based algorithms, constrained optimization, least-squares methods, and discrete optimization.

Prerequisites (in terms of CS courses)

There are no official prerequisites for this course. However, the students are expected to have basic knowledge of linear algebra and matrix computation.



Syllabus

- 1. Unconstrained optimization : gradient-based algorithms, Newton and quasi-Newton algorithms.
- 2. Least squares problems.
- 3. Constrained optimization.
- 4. Global and discrete optimization.

Class components (lecture, labs, etc.)

Teaching is composed of courses and labs (TD). The labs cover computional aspects (solve KKT systems, in particular) and the practical use of the Matlab optimization solvers.

Grading

Written final exam (2 hours, 100 %)

The evaluation of the course will be based on a written exam (2 hours). The exam may cover all topics seen during the lectures and practical sessions, with a focus on local optimization algorithms: knowledge of algorithms, simple calculations, practical knowledge of how to call optimization solvers (in this case, the help of the matlab solver will be given) using matlab pseudo-code, interpretation of the results of numerical simulations. Only basic knowledge is requested regarding global and discrete optimization. The evaluation will be possibly related to the content of the lab sessions.

The only documents allowed include: photocopies of the lecture slides with possibly handwritten notes Computers and calculators will be forbidden. Mobile phones must be switched off.

Course support, bibliography

- 1. J. Nocedal and J. S. Wright, Numerical optimization, 2nd edition, Springer Verlag, New York, Jul. 2006.
- 2. R. Fletcher, Practical Methods of Optimization, 2nd edition, Wiley, 2000
- 3. A. Björck, Numerical Methods for Least Squares Problems, Society for Industrial and Applied Mathematics, Philadephia, Apr. 1996.
- 4. R. Horst, P. M. Pardalos, and V. T. Nguyen, Introduction to Global Optimization, 2nd edition, Springer, Dec. 2000.



Resources

- Complete slides
- Software tools: see matlab documentation (optimtool)
- Related Courses: see the books in bibliography

Learning outcomes covered on the course

The course aims to introduce students to the main concepts and numerical methods of numerical optimization. The course is mainly focused on local optimization, although some general principles of global optimization algorithms are sketched as well.

Description of the skills acquired at the end of the course

It is expected that by the end of the course, the students will have a good knowledge of the main algorithms and will be able to carry out simple calculations : calculation of gradients, Hessians, resolution of simple optimization problems, e.g. by expressing the KKT conditions and solving the related system. Additionally, the students should have a practical knowledge of how to call Matlab optimization solvers and should be able to give an interpretation of the numerical results.



SEMESTER LONG COURSES



2SL1000 – Economics

Instructors: Pascal Da Costa

Department: DÉPARTEMENT SCIENCES HUMAINES ET SOCIALES

Language of instruction: ENGLISH, FRENCH

Campus: CAMPUS DE PARIS - SACLAY, CAMPUS DE RENNES, CAMPUS DE METZ

Workload (HEE): 40

On-site hours (HPE): 24,00

Erasmus ECTS : 2

Description

You have probably already read the economic press and heard about economic variables and concepts (drivers of growth, inflationunemployment 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 ST5

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.) For the conferences in English only: online videos, textbook reading, online forum 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: 37 students Size of the integrated classes (lectures + tutorials): 55 students. 2 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 an essay in economics

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: Didier Paillard

Department: DÉPARTEMENT MÉCANIQUE, PROCÉDÉS, ÉNERGÉTIQUE

Language of instruction: FRENCH, ENGLISH

Campus: CAMPUS DE PARIS - SACLAY, CAMPUS DE METZ, CAMPUS DE RENNES

Workload (HEE): 10

On-site hours (HPE): 6,00

Erasmus ECTS : 0

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: DÉPARTEMENT SCIENCES HUMAINES ET SOCIALES

Language of instruction: ENGLISH, FRENCH

Campus: CAMPUS DE METZ, CAMPUS DE PARIS - SACLAY, CAMPUS DE RENNES

Workload (HEE): 20

On-site hours (HPE): 12,00

Erasmus ECTS:1

Description

- General introduction to law and its role in society
- Contract law, civil liability
- 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
- Contract law, civil liability
- Patent, trademark and design law
- Software protection

Class components (lecture, labs, etc.)

Lectures (3*1:30) | Tutorials (3*1:30) | Final Exam (1*1:00)

Grading



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

Course support, bibliography

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

Resources

Teaching staff :

• Valérie FERAY : main lecturer - Founder and managing partner - Patent Attorney | IPSILON

• Grégoire DESROUSSEAUX : speaker and teaching assistant - Attorney-atlaw & Partner | August & Debouzy

• Ghislain DEMONDA : speaker and teaching assistant - Patent Attorney | API Conseil

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, DÉPARTEMENT 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): 18,00

Erasmus ECTS : 1,5

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.

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 :

- Truth, scientific evidence
- Knowledge, ignorance
- Technological progress/social progress
- Power, democracy, responsibility
- Ethics

3

Quarter number ST7

Prerequisites (in terms of CS courses)

• none

Syllabus

• Each class session lasts 1h30, the sessions are grouped into 3h sessions

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.

Resources

Specialists give the courses in the form of conferences: Gif: M. Girel et M. Klein Rennes : M. Calori, Mme Gueguen Metz Mme Aubert

• <u>Please note that the course content and examination subjects differ</u> <u>from one campus to another.</u>



Description of the skills acquired at the end of the course

- Understand situations of innovation, uncertainty, controversy, crisis, economic and technological change using a critical analysis of scientific knowledge.
- Identify, in these situations, the normative frameworks, the worldviews, the economic, ethical, and societal stakes of the different actors concerned (collaborators, citizens, scientists, or institutions), and consequently their respective positions.
- Associate in one's analyses, decisions, and actions, technical, scientific and human, and social sciences knowledge.



2SL4000 – Sociology of organizations

Instructors: Cynthia Colmellere

Department: DÉPARTEMENT SCIENCES HUMAINES ET SOCIALES, 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): 12,00

Erasmus ECTS: 1

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

This course in the sociology of organizations deals with the following notions:

- 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



- The 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

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

- Norms and rules in organizations, compliance, adaptations, deviance
- The bureaucratization of organizations
- Notions of power, authority, legitimacy, domination.
- Introduction and practice of strategic and systemic analysis of organizations

- Criticisms of the strategic analysis of organizations and proposals: new approaches to analyze human and social dynamics in organizations.

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 (Gif), Natacha Chetcuti Osorovitz (Rennes et Metz)
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: DÉPARTEMENT DÉVELOPPEMENT PROFESSIONNEL ET MÉTIERS D'INGÉNIEUR

Language of instruction: FRENCH

Campus: CAMPUS DE METZ, CAMPUS DE RENNES, CAMPUS DE PARIS - SACLAY

Workload (HEE): 40

On-site hours (HPE): 21,00

Erasmus ECTS: 1

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: 2-Tons workshop, then project review API 10: Leadership API 11: Multicultural awareness API 12: Project Coaching API 13: Project Coaching API 14: 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

At the end of each semester, validation of some steps of the relevant competencies.



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: DÉPARTEMENT DÉVELOPPEMENT PROFESSIONNEL ET MÉTIERS D'INGÉNIEUR

Language of instruction: FRENCH

Campus: CAMPUS DE PARIS - SACLAY, CAMPUS DE METZ, CAMPUS DE RENNES

Workload (HEE): 20

On-site hours (HPE): 6,66

Erasmus ECTS: 0,5

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)

to have completed a worker anernship (or similar) The workshops are held in French. Summary nor output otes may be written in English.

Syllabus

This course includes:

- half a day to share experience on the blue-collar internship
- a workshop to learn about CV, motivation letter and pitch
- two individual exchanges with one of the professors
- two 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: DÉPARTEMENT DÉVELOPPEMENT PROFESSIONNEL ET MÉTIERS D'INGÉNIEUR

Language of instruction: ENGLISH, FRENCH

Campus: CAMPUS DE RENNES, CAMPUS DE PARIS - SACLAY, CAMPUS DE METZ

Workload (HEE): 90

On-site hours (HPE): 54,00

Erasmus ECTS: 4,5

Description

A project is a collective work modality used to apprehend complex open problems. Its effectiveness depends on the individual skills of each person and on the team's operating practices; the objective being to produce a final product for a client in a given time. The projects proposed in the engineering training program allow students to learn this modality by putting them in increasingly complex situations. The projects must lead to an ambitious achievement, which could not be reached by doing what we already know how to do.

Quarter number

ST5 and SG6

Prerequisites (in terms of CS courses) Project management, API workshops

Syllabus

The projects run from September to January. They follow the usual phases of a project:

- * Define and frame the project
- * Program the actions
- * Define roles and responsibilities
- * Measure progress and proceed to 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: involvement, content and deliverables, communication, and team functioning in project mode.

Milestones will be achieved in competencies C3, C4, C7, C8 and C9 throughout the project.

Resources

Projects are carried out by groups of 5 students. Each project is attached to a cluster where projects of the same nature are grouped together. The clusters provide supervision and software and hardware resources. With some exceptions, students remain assigned to the project cluster in which thay were in semester S6. They can continue to work on the same subject or start a new project in agreement with the people in charge of the cluster. There is no online assignment campaign.

Students who were not attached to a project cluster in semester S6 can ask to join a cluster. They will be able to complete existing teams or initiate a new project for this semester.

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 throughout the project:

* C3 – Act, undertake, innovate in a scientific and technological environment

* C4 – Have a sense of creating value for your company and your customers

- * C7 Knowing how to convince
- * C8 Leading a project, a team

* C9 – Think and act as an ethical, responsible and honest engineer, taking into account environmental, social and societal dimensions



2SL8100 – Project S8

Instructors: Laurent Bourgois

Department: DÉPARTEMENT DÉVELOPPEMENT PROFESSIONNEL ET MÉTIERS D'INGÉNIEUR

Language of instruction: FRENCH, ENGLISH

Campus: CAMPUS DE METZ, CAMPUS DE RENNES, CAMPUS DE PARIS - SACLAY

Workload (HEE): 200

On-site hours (HPE): 96,00

Erasmus ECTS: 8,5

Description

A project is a collective work modality used to apprehend complex open problems. Its effectiveness depends on the individual skills of each person and on the team's operating practices; the objective being to produce a final product for a client in a given time. The projects proposed in the engineering training program allow students to learn this modality by putting them in increasingly complex situations. The projects must lead to an ambitious achievement, which could not be reached by redoing what we already know how to do.

Quarter number

ST7 and SG8

Prerequisites (in terms of CS courses) Project management, API workshops

Syllabus

The projects run from February to June. They follow the usual phases of a project:

- * Define and frame the project
- * Program the actions
- * Define roles and responsibilities
- * Measure progress and proceed to 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: involvement, content and deliverables, communication, and team functioning in project mode.

Milestones will be achieved in competencies C3, C4, C7, C8 and C9 throughout the project.

Resources

Projects are carried out by groups of 5 students. Each project is attached to a cluster where projects of the same nature are grouped together. The clusters provide supervision and software and hardware resources. At the beginning of the year, the clusters are presented at a Project Forum. Students can ask to join a cluster. They can also propose to carry out a personal project with a team that will be hosted in a cluster. All students participate in an online assignment campaign. The cluster leaders help select 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 throughout the project:



* C3 – Act, undertake, innovate in a scientific and technological environment

* C4 – Have a sense of creating value for your company and your customers

* C7 – Knowing how to convince

* C8 – Leading a project, a team

* C9 – Think and act as an ethical, responsible and honest engineer, taking into account environmental, social and societal dimensions



2SL9000 – Sport

Instructors: Stéphane Blondel

Department: SPORTS, DÉPARTEMENT SPORTS

Language of instruction:

Campus: CAMPUS DE PARIS - SACLAY, CAMPUS DE RENNES, CAMPUS DE METZ

Workload (HEE): 30

On-site hours (HPE): 48,00

Erasmus ECTS: 0

Quarter number S7 and S8



SCIENCE COURSES FOR ENGINEERS



2EL0010 – Teaching assistant

Instructors: Mehdi Ayouz, Jocelyn Fiorina Department: DÉPARTEMENT MATHÉMATIQUES Language of instruction: FRENCH, ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

Description

Teaching Assistant Physics: this course consists of tutoring and supporting first year students in their Quantum Physics course. It is a great opportunity to learn about teaching for a potential teaching career or to apply for Teaching Assistant positions in famous North American universities. The objective is that you learn how to (i) pass on your knowledge and understanding to a non-expert audience, and (ii) accompany a student in his or her progress towards a validation of knowledge and understanding of the Quantum Mechanics course.

Teaching assistant Mathematics: this course consists of giving reinforcement and support to pre-selected 1st year students in their CIP-EDP Mathematics course. By taking this course, you will have an enriching personal experience helping your fellow first-year students and you will experience the cultural differences in mathematics teaching. In addition, you will be part of the teaching staff of the mathematics department for a period of time and will be able to have privileged exchanges with the teacher-researchers. Finally, you will be able to develop the acquisition of pedagogical and persuasive skills as a differentiating feature of your training. In particular, if you wish to do a double degree in an American or British university, you will be able to use this experience to obtain one or more teaching assistantships and be partially or totally exempt from tuition fees.

Quarter number SG6 and SG8



Syllabus

Teaching Assistant for Physics: an introductory course will give the necessary elements for the construction of teaching objectives, the construction of qcms and the notions of scripting and pedagogical alignment. However, the majority of this course is do-it-yourself. You will be paired with a group of about 15 first year students with potential difficulties as they come from non-classical backgrounds. There will be ten 1 hour sessions, each session focusing on a chapter of the Quantum Mechanics course. For each session, a pair of students will be in charge of defining the pedagogical learning objectives and of carrying out a qcm testing these pedagogical objectives. The 1 hour session will be dedicated to the correction of the qcm with their assigned group. They will be asked to focus on the points of difficulty encountered to help the progression of the 1st year students.

Teaching Assistant in Mathematics: a kick-off meeting will bring together the Teaching Assistants and the supervising teachers in order to present the year's activities, their objectives and their organisation. Pairs or triples of Teaching Assistants will supervise ten or so first-year students throughout the year and will have a referent teacher to guide them in this activity. Each Enhanced Modality session will be preceded by a briefing with the referring professor, the TAs will propose their plan for the session in a summary sheet, and a debriefing will take place after the session. The aim of the Enhanced Modality sessions is to prepare the 1A students (presentations of fundamental concepts, exercises) so that they can follow the CIP-EDP lecture in good conditions. The Enhanced Modality session precedes the lecture session by a few days.

Class components (lecture, labs, etc.)

Teaching Assistant in Physics: Introductory course and simulation (pair ensuring 10 classes of 1 hour with a total of 15 first year students, design of qcm).

Teaching Assistant in Mathematics: Pairs or trinomials of Teaching Assistants will supervise about ten first year students throughout the year and will have a referent teacher to guide them in this activity. Each Enhanced Modality session will be preceded by a briefing with the teacher, the TAs will propose their plan for the session in a summary sheet, and a debriefing will take place after the session.

Please note: it is not possible to be a Teaching Assistant in Physics AND Maths, but only in one or the other.

Grading

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Teaching assistant in Physics: you will be assessed in pairs on the quality of the qcm constructed and on the animation of a lesson.

Teaching assistant in Mathematics: you will be assessed on the pedagogical and scientific qualities of your lessons, and on the rigour and discipline in the follow-up of the scheme (preparation of briefings, debriefs) and the follow-up of 1A students.

Learning outcomes covered on the course

Teaching Assistant Physics: at the end of this course, students will be able to (1) set up a grid of pedagogical objectives, (2) create a qcm type assessment adapted to the pedagogical learning objectives, and (3) script and lead a session in front of a class of about fifteen students Teaching Assistant in Mathematics: Pedagogical, supervisory and persuasive skills.



2EL1110 – Dynamical systems in neuroscience

Instructors: Antoine Chaillet Department: DÉPARTEMENT AUTOMATIQUE Language of instruction: ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Engineering Sciences Advanced level : Yes Erasmus ECTS : 2,5

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-ST2-SG3 : 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 Makarova Department: DÉPARTEMENT AUTOMATIQUE Language of instruction: ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Engineering Sciences Advanced level : Yes Erasmus ECTS : 2,5

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

Prerequisites (in terms of CS courses)

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

Syllabus



- 1. Introduction, brief historical perspective, industrial and research context
- 2. Basics of modeling in robotics (geometric & kinematic models)
- 3. Dynamic modeling (rigid and elastic body) and control of robots
- 4. Force-feedback tele-operation
- 5. Collaborative robotics
- 6. 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.

- Tutorial #1 and Tutorial #2 : illustration of robot modeling using Matlab/Simulink or python
- **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

- Tutorials #1 & #2 : 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:
 - o 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-Nicoleta Maniu Department: DÉPARTEMENT AUTOMATIQUE Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Engineering Sciences Advanced level : Yes Erasmus ECTS : 2,5

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 autonomous 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 in the flight arena of CentraleSupélec on Crazyflie UAVs and onTurtleBot ground autonomous vehicles (GAVs), and on the Robotarium remote platform are planned as part of this course.

Quarter number SG8



Prerequisites (in terms of CS courses) Automatic Control (ST5), Optimization (ST7)

Syllabus

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This 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 Crazyflie drones and ground vehicles;
- 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 to validate the proposed control techniques both in simulation and on an indoor experiment of a fleet of Crazyflie UAVs and/or Turtlebot mobile robots.

Experiments are planned in the indoor flight arena of CentraleSupélec.

Class components (lecture, labs, etc.)

This course is composed of **interactive lectures, tutorials** and a **case study** (*carried out by team on a subject proposed by the students*) that will serve as a guideline throughout this elective module and will lead to indoor experimentations on UAVs formations and mobile robots 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 (containing a state-of-the-art, the analysis of the results obtained during the case study, etc.) will be delivered and evaluated. The results will be presented using an interactive poster in front of a committee and with a cross-examination of the other groups (peer assessment). The final grade is computed from the report evaluation (50%) and the interactive poster evaluation, both poster design and presentation (50%).

A skill-based assement is also envisaged.



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/asctechummingbird/

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.

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 (flight arena equipement, numerous Crazyflie UAVs and TurtleBot GAVs, etc.) for this course and the construction of an indoor space at CentraleSupélec dedicated to UAVs flight tests (room VI.003, Eiffel building).

Funding via the project DAReTeach – Drone Arenas-based Remote International Teaching with the support of *FACE Fondation – French-American Cultural Exchange in Education and the Arts* allowed to complete the fleet of Crazyflies UAVs and to start an international collaboration with Rutgers University (USA).

Learning outcomes covered on the course

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

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



Description of the skills acquired at the end of the course

- C1.2 Modeling: using and developing the appropriate models, choosing the right modeling scale and the relevant simplifying assumptions
- C1.4 Design: specify, implement and validate all or part of a complex system
- C2.3 Identify and independently acquire new knowledge and skills
- C3.2 Propose alternatives, formulate ideas by integrating the necessary external expertise (technical, commercial, HR, financial, legal, etc.), integrate risks and uncertainty
- C5.3 Analyze global and / or local issues internationally and adapt projects or solutions to them
- C7.1 Know how to convince basically: Structure your ideas and arguments, be synthetic (assumptions, objectives, expected results, approach and value created)
- C7.3 Know how to convince about yourself: Being comfortable and being convinced, showing empathy and managing your emotions
- C8.1 Build the collective to work as a team
- C8.2 Mobilize and train a collective by showing leadership


2EL1210 – Exposure of people to electromagnetism and electromagnetic compatibility

Instructors: Dominique Lecointe

Department: DÉPARTEMENT ÉLECTRONIQUE ET ÉLECTROMAGNÉTISME Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Engineering Sciences Advanced level : NO Erasmus ECTS : 2,5

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

- 1. Presentation of the issues
- 2. TP CEM
- 3. EMC: sources of disturbance
- 4. EXPO: Field Sources
- 5. TD CEM: sources and order quantities
- 6. EMC: coupling and protection
- 7. TD EMC: EMC systems: electromagnetic topology
- 8. EXPO: biological effects
- 9. EXPO: limits, exposure index
- 10. TD EXPO: fixed emitters
- 11. TD EMC: quantification of coupling phenomena
- 12. EMC means of testing, standards
- 13. EXPO: test methods
- 14. TD EXPO: mobile telephony
- 15. CEM EXPO: simulation
- 16. TD EXPO: intermediate frequencies

Class components (lecture, labs, etc.)

- 14 courses
- 6 TD (the MCQ will take place during a TD)
- 1 TP

Grading

1MCQ without document of 15 mn (coefficient 1). 1 final examination without document of 2h00 (coefficient 2).

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.



2EL1310 – Renewable energies

Instructors: Amir Arzande

Department: DÉPARTEMENT SYSTÈMES D'ÉNERGIE ÉLECTRIQUE

Language of instruction: FRENCH

Campus: CAMPUS DE PARIS - SACLAY

Workload (HEE): 60

On-site hours (HPE): 35,00

Elective Category : Engineering Sciences

Advanced level : Yes

Erasmus ECTS: 2,5

Description

This elective includes courses, tutorials and a project. 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 Project:

The title of the project:

Sizing of the electricity production facility using renewable energy sources on an agricultural farm

The pupils are divided into several groups. The project is presented at the start of the sequence. A defense is requested at the end of the sequence. Two 3-hour slots are provided to answer students' questionslements used in this framework will be discussed.

Quarter number SG8

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

Syllabus

5

- 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(1-4) // T--T2(5-6) // CM(7-12) // T3-T4(13-14) // CM(15-18) //project(19-22)//

Grading

The course evaluation method: The evaluation will be done by a written exam and a project defense

For the written exam: There is a written exam of 2 hours with the authorized documents

For the project :

Defense duration: 20 to 25 minutes Questions: 10 to 15min Deliverable: presentation support The evaluation score: 75% for the written exam and 25% for the project.

Note : The report is not requested for this project Presentation in English is accepted

Resources



Teaching staff (names of lecturers): Amir Arzandé, Jean-Claude Vannier, Martin Hennebel and industrial speakers Size of tutorial class (default 35 students): 18 (for a staff of 72 students) Computer rooms for the project

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.



2EL1315 – Electrical Energy Conversion for renewable energy sources and electromobility

Instructors: Marc Petit

Department: DÉPARTEMENT SYSTÈMES D'ÉNERGIE ÉLECTRIQUE Language of instruction: ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Engineering Sciences Advanced level : Yes Erasmus ECTS : 2,5

Description

Considering the decarbonation objectives at worldwide level, the European Commission has planned an ambitious program to reach a net zero emission in 2050. In that way, several scenarios have been built, among them a larger electrification of the energy sector, a better energy efficiency, and development of hydrogen. These scenarios have been also organized in seven strategic priorities. Two of them are the development of renewable energy (with a target of 80% of electricity generated from renewable sources in 2050) and a more electrified mobility. Thus electrical (or electromechanical) converters will be at the heart of this evolution, with the following applications: windmills, PV generation, battery storage, electric powertrain for electric vehicles (EV), more electric aircrafts, all electric ships, new DC lines for electrical grids, power converters for electrolysers and for fuel-cells, energy harvesting for autonomous systems, ...

Whatever the application, an important step will be the design of the optimal solution and its operation in a complex and fully interconnected environment. Thus a deep understanding of the devices and sub-systems is a key point. It means: what is the structure? how does it work? how can the devices be connected together? how to design a more complex system with several devices? How to model them for the optimization and the sizing?



Quarter number

SG8

Prerequisites (in terms of CS courses)

basics about electrical circuits, 3-phase systems, and electrical powers

Syllabus

- Basics about electromechanical converters (AC machines) for generation (wind turbine and hydro power plants) and motor applications (pumping, electric propulsion). Modelling for the sizing, and for simulations

- Basics about power electronic converters for EV (battery BEV and plug-in hybrid PHEV) charging, and electric propulsion (EV, ships, trains). Modelling for the sizing, and for simulations.

- Applications:

a) Connection of an AC generator to an AC power network. Operating point setting in the P,Q diagram.

b) Electronic power converters design for charging an EV battery

Class components (lecture, labs, etc.) slides of the lecture (with their detailed and written comments)

Grading

75% of the mark is from a 2h individual examination (knowledge questions + exercice)25% of the mark is based on the lab session reports.

Resources

lectures (15h) + lab sessions (9h) + exercices (9h)

Learning outcomes covered on the course

Based on selected applications (such as charging system for EV battery, variable speed drive for industrial application or electric propulsion, electrical generator for hydro power plant), we aim at presenting the basics about electromechanical converters and power electronic converters.

Description of the skills acquired at the end of the course

The students will know the basic components to build some widely used electric energy converters. They will be able to make a first sizing of such



system, and they will be able to analyze the integration of such system in a wider environment skills: C1.1 ; C1.2 ; C1.4



2EL1320 – Energy conversion

Instructors: Bruno Lorcet Department: DÉPARTEMENT SYSTÈMES D'ÉNERGIE ÉLECTRIQUE Language of instruction: ENGLISH, FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Engineering Sciences Advanced level : Yes Erasmus ECTS : 2,5

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

Prerequisites (in terms of CS courses)

SPI course 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: DÉPARTEMENT MÉCANIQUE, PROCÉDÉS, ÉNERGÉTIQUE Language of instruction: FRENCH, ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Engineering Sciences Advanced level : Yes Erasmus ECTS : 2,5

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 noncircular 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: DÉPARTEMENT MÉCANIQUE, PROCÉDÉS, ÉNERGÉTIQUE Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Engineering Sciences Advanced level : Yes Erasmus ECTS : 2,5

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, Hypersonics ...



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, Hypersonics, 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



- 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:
 - o 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: DÉPARTEMENT MÉCANIQUE, PROCÉDÉS, ÉNERGÉTIQUE Language of instruction: ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Engineering Sciences Advanced level : NO Erasmus ECTS : 2,5

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

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 and Small Modular Reactors
- 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 microstructure and behavior of 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: DÉPARTEMENT MÉCANIQUE, PROCÉDÉS, ÉNERGÉTIQUE Language of instruction: ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Engineering Sciences Advanced level : NO Erasmus ECTS : 2,5

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 dihydrogen"

- 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)

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: DÉPARTEMENT INFORMATIQUE Language of instruction: FRENCH, ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

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

5

- 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

6

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: DÉPARTEMENT INFORMATIQUE Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes

Erasmus ECTS : 2,5

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: CAMPUS DE METZ Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

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.
- 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 unittee sume (2h00)
 - \circ 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:



- 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:

- [Learning Outcomes 1* (AA1*)] contributing to core skill C1.2:
 - to tune existing numerical methods for high performance computing (HPC)
 - to develop innovative numerical methods for high performance computing (HPC) in order to solve complex problems
- [Learning Outcomes 2* (AA2*)] contributing to core skill C2.1:
 - to design parallel algorithms for intensive simulations, according to high performance computing requirements
 - to implement parallel algorithms for intensive simulations on supercomputers or clusters of multi-core PC
 - to manage a limited set of computing resources when running an intensive simulation
- [Learning Outcomes 3* (AA3*)] contributing to core skill C6.4:
 - $\circ\;$ 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: DÉPARTEMENT INFORMATIQUE Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

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 the data representation models, the data querying and analytics, the performance measures 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

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Conceptual models for data representation SQL (relational) and NoSQL (document, key-value, column, graph).

- Data querying and analytics languages.
- Transaction concepts, ACID properties, CAP theorem.
- Main concepts related to data distribution in a cluster.
- Practical works on data modeling, querying real data (social network data, Wikipedia, ...).
- Softwares : Oracle/postgres, Cassandra, Neo4J, Giraph, ElasticSearch.

Class components (lecture, labs, etc.)

The course is organized as follows:

- 12 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):

50% written exam,30% project ,and 20% continuous assessment (3 best marks).

Resources

Slides, practical exercices/works and solutions, QCMs, bibliography references. Installation and use of free licence softwares. 1 lab instructor by group of 25 students (maximum).

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.
- acquire the fundamental concepts underlying distributed data.

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 problemC6.4 Solve problems through mastery of computational thinking skills.C6.5 Operate all types of data, structured or unstructured, including big data.



2EL1580 – Artificial Intelligence

Instructors: Fabrice Popineau Department: DÉPARTEMENT INFORMATIQUE Language of instruction: ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

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, state space search, 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
 - $\circ~\mbox{Loss}$ function and optimization
 - Neural networks
- State representation and search
 - \circ Planners

5

- Adversarial search
- o 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
 - o Syntax vs. semantics
 - Inference systems
- Conclusion
 - Deeper on deep learning
 - Future of Al

Class components (lecture, labs, etc.)

The course scheduling includes about 21h of lectures and 12h of supervised work.

The supervised work sessions are inserted every second class lecture.

Grading

The overall assessment will be based on:

- a continuous assessment grade on the programming projects (40% of the final grade)

- a 2-hour final exam with documents (60% of the final grade).

Course support, bibliography

Artificial Intelligence : a Modern Approach, 4th ed. (English) Auteurs : Stuart Russel, Peter Norvig ISBN : 9780134610993 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 and its libraries mostly.

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: DÉPARTEMENT INFORMATIQUE Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

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*) and a brief introduction to some optimized Spark-compliant data formats (i.e., Parquet).

Quarter number SG8

Prerequisites (in terms of CS courses)

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

Syllabus

Chapter 1. Introduction.



- 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

- Containerization principles.
- Docker architecture.
- Images, containers, volumes and networks in Docker.
- Deployment of application with Docker.

Chapter 4. Multi-service applications and orchestration.

- Microservices architecture.
- Orchestration principles.
- 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.



- 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:

- 1. Understand the fundamental concepts of cloud computing.
- 2. Master the notion of virtualization and containerisation in the cloud.
- 3. Be acquainted with the different cloud platforms.
- 4. Use the distributed computing paradigms, such as MapReduce and Spark.
- 5. 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: DÉPARTEMENT MATHÉMATIQUES Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

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): Philippe Bouafia

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: DÉPARTEMENT MATHÉMATIQUES Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

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: DÉPARTEMENT MATHÉMATIQUES Language of instruction: ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

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
- 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
- Dimensionality reduction
- 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-F21/

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 (individually):10%; Project (groups of 3-4 students):20%; 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-F21/

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: DÉPARTEMENT MATHÉMATIQUES Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Fundamental Sciences Advanced level : NO Erasmus ECTS : 2,5

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

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

Course support, bibliography

- David Eisenbud, Commutative Algebra (with a View Toward Algebraic Geometry)
- Robin Hartshorne, Algebraic Geometry
- William Fulton, Algebraic curves: An Introduction to Algebraic Geometry
- Henning Stichtenoth, Algebraic Function Fields and Codes
- Michel Demazure, Cours d'algèbre
- Joseph H. Silverman, The Arithmetic of Elliptic Curves
- Joseph H. Silverman, Advanced Topics in the Arithmetic of Elliptic Curves
- Jean-Pierre Serre, Cours d'arithmétique
- Michael Tsfasman, Serge Vlåduţ, Dmitry Nogin, Algebraic Geometric Codes: Basic Notions

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.

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



2EL1750 – Advanced statistics

Instructors: Sarah Lemler Department: DÉPARTEMENT MATHÉMATIQUES Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

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:

- multivariate linear regression
- 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 ((1/3)*DM+(2/3)*EX) 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: DÉPARTEMENT MATHÉMATIQUES Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

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, extensionsPractical 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

S

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 Dynamics & Acoustics

Instructors: Didier Clouteau Department: DÉPARTEMENT MÉCANIQUE, PROCÉDÉS, ÉNERGÉTIQUE Language of instruction: ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Engineering Sciences Advanced level : Yes Erasmus ECTS : 2,5

Description

Vibrations and wave propagation play an key role in many areas: geophysics, behaviour of civil engineering structure subjected to wind, earthquakes or waves, stability and comfort of aeronautical and terrestrial vehicles. Acoustics is also essential in the transportation vehicles for both internal comfort and external noise.

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. It will be based on a set of casestudies to illustrate the fundamental concepts of resonance and radiation.

Quarter number

SG6

Prerequisites (in terms of CS courses)

No prerequisites. However, it is recommended to have followed the course of mechanics of continuous media or a course on waves.

Syllabus

- Dynamic response of a oscillator, principle of vibration reduction (flipped classroom)
- Response to random loads (flipped classroom)
- Mechanical and acoustic waves, resonances (flipped classroom)
- Elastodynamics
- Vibration of beams

- Dynamic response of multi-degree of freedom systems
- Construction of reduced models in dynamics
- Finite element method in structural dynamics
- Acoustic radiation
- Acoustic resonance
- Analysis of a scientific paper in pairs
- Final exam

Class components (lecture, labs, etc.)

S1 to S3: flipped classrooms S4 to S10: Lectures + tutorial classes S11: Paper analysis by groups of 2

Grading

2-hr written exam (coeff 0.5) + analysis of a scientific paper (coeff 0.3) + MCQ (coeff 0.2)

Course support, bibliography

Lecture notes +course slides

Resources

Lectures will be given in French and recorded lectures in English will be made available to students.

Tutorial classes: 35 students with at least one in French and one in English. Software: Comsol Multiphysics or Finite element code

Learning outcomes covered on the course

Completing this course students will be able to:

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

-model the acoustic behaviour of an enclosure and the radiation patern of a acoustic source or an open system.

- model transient and random environmental loads (Wind , seism...)

- build a low frequency surrogate model to solve practical vibration or acoustic problems.

Description of the skills acquired at the end of the course

C1.2 Ability to model the dynamic behaviour of a structure

C1.2 Ability to model random external loads (Wind, earthquakes)

C1.2 Ability to model simple acoustic problems



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





Instructors: Elsa Vennat Department: DÉPARTEMENT MÉCANIQUE, PROCÉDÉS, ÉNERGÉTIQUE Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Engineering Sciences Advanced level : Yes Erasmus ECTS : 2,5

Description

 The link between mechanics and life is much stronger than we might think at first glance. Did you know that our bone tissue evolves and adapts according to the mechanical load it is subjected to? This is important in our daily life (regular moderate physical activity leads to better bone quality) but also in medical care (how to replace or regenerate bone tissue after an accident?).

In this course we will discuss the links between mechanics and life, from biomechanics to mechanobiology.

Tools will first be put in place to describe, model and solve a mechanical problem where living materials are involved: reminders of Continuous Media Mechanics, anisotropy of natural composites, viscoelasticity of soft tissues, introduction and application of the finite element method to solve problems of increasing complexity.

In a second phase, these tools will be used to characterise and model a living material of your choice (bone, tooth, cells, wood...) in a series of numerical and experimental assignments. Living materials are by nature multi-scale. A complete approach will be taken to characterise and model the chosen living material in three stages:

- Bibliographic research (presentation of tools and research by group)
- Observations at the various relevant scales: observation of samples under the microscope, three-dimensional visualisation of the microstructure, image processing and analysis.
- Experimental study of material's behaviour (cells under stress, tissues under loading, etc.), finite element modeling and critical analysis


All practical work can be switched to distance learning in case of a lockdown.

Quarter number SG8

Prerequisites (in terms of CS courses) 1EL5000 - Mécanique des milieux continus

Syllabus

- Modeling the behaviour of materials:
- Continuum Mechanics (recalls)
- Anisotropy of natural composites
- Viscoelasticity of soft tissues
- Experimental and numerical approach:
 - o 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: DÉPARTEMENT MÉCANIQUE, PROCÉDÉS, ÉNERGÉTIQUE Language of instruction: ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Engineering Sciences Advanced level : Yes Erasmus ECTS : 2,5

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,

Resources

Hermès, 2001

• 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: DÉPARTEMENT MÉCANIQUE, PROCÉDÉS, ÉNERGÉTIQUE Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Engineering Sciences Advanced level : Yes

Erasmus ECTS : 2,5

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)

None

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.

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: Guillaume Puel

Department: DÉPARTEMENT MÉCANIQUE, PROCÉDÉS, ÉNERGÉTIQUE

Language of instruction: ENGLISH

Campus: CAMPUS DE PARIS - SACLAY

Workload (HEE): 60

On-site hours (HPE): 35,00

Elective Category : Engineering Sciences

Advanced level : Yes

Erasmus ECTS: 2,5

Description

The aim of this class is to give theoretical and applied insights on multiphysic couplings simulations such as: thermomechanical, piezoelectric, vibroacoustic, magnetomechanic.

Quarter number SG8

Prerequisites (in terms of CS courses)

Partial Differential Equations 1EL1010 - Radiation and propagation or 1EL1500 - Physics of waves or 1EL4000 - Materials or 1EL5000 - Continuum mechanics or 1EL7000 -Transport phenomena

Syllabus

- S1-S2 Variational formulation and 1D FEM / Application: thermoelastic beam (weak thermo-mechanical coupling)
- S3-S4 2D FEM / Application: heated room with an open window (weak coupling thermics and fluid mechanics)
- S5 Multiphysic coupling techniques / Application: thermal microactuator
- S6-S7 Model error estimation / Application: heated room with an open window (error estimation)



- S8-S9 Time- and frequency-dependent problems / Application: Electromagnetic compatibility in a room (Electromagnetic wave dynamics 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 tutorial on Comsol 1h30 S10 to S11: hands-on sessions: MEMS design in groups of 4

Grading

2-hr written exam (1h theory + 1h practical on simulation tool): 65% of the final mark

Project evaluation: 35% of the final mark

Course support, bibliography

Textbook

Resources

Instructor: Guillaume PUEL Tutorial classes: 35 students Software: Comsol Multiphysics (Structural mechanics, MEMS)

Learning outcomes covered on the course

- Solve and model a multiphysic problem including solid mechanics, thermics, fluid mechanics, electricity, and magnetism
- Design sensors and actuators thanks to the use of different coupled physics and technologies
- Model and solve a multiphysic problem using a commercial finite element code with specific attention to solution accuracy.



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

Instructors: François Cointe, Frédérique Delmas-Jaubert

Department: DÉPARTEMENT MÉCANIQUE, PROCÉDÉS, ÉNERGÉTIQUE

Language of instruction: FRENCH

Campus: CAMPUS DE PARIS - SACLAY

Workload (HEE): 60

On-site hours (HPE): 35,00

Elective Category : Engineering Sciences

Advanced level : NO

Erasmus ECTS: 2,5

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/documentshistoriques-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: Christophe Yèche, Bruno Lenzi

Department: DÉPARTEMENT PHYSIQUE

Language of instruction: ENGLISH

Campus: CAMPUS DE PARIS - SACLAY

Workload (HEE): 60

On-site hours (HPE): 35,00

Elective Category : Fundamental Sciences

Advanced level : No

Erasmus ECTS: 2,5

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 partly in reverse class and partly as lectures on particle physics and nine one-and-a-half-hour lectures 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

Part of the course will take place in reverse class teaching with videos, slides, and written documents at home. Then face-to-face, a summary of the course, a question-and-answer session, and finally exercises that count as continuous assessment. The other courses will be lectures that will end with exercises counting as continuous assessment. Slides and written material will be made available.

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: DÉPARTEMENT PHYSIQUE Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

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 Aspects of Quantum Molecular Physics

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 2 components: -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.

Course support, bibliography

The textbook is "Application-Driven Quantum and Statistical Physics" (Vol. 1, 2 & 3, World Scientific). Additional references 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 as well 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: DÉPARTEMENT MÉCANIQUE, PROCÉDÉS, ÉNERGÉTIQUE Language of instruction: ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Engineering Sciences Advanced level : Yes Erasmus ECTS : 2,5

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: DÉPARTEMENT MÉCANIQUE, PROCÉDÉS, ÉNERGÉTIQUE Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Engineering Sciences Advanced level : Yes Erasmus ECTS : 2,5

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))

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
Applications: 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
From coatings, inkjet printing to 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) Techniques to measure surface tension

This case study includes a practical work. It is carried out at the Laboratoire de Génie des Procédés et Matériaux (EIFFEL building, Univers Vivant). Two techniques for measuring surface tension are implemented and analysed in depth:

- The drop weight method (or stalagmometry)
- The pendant drop method.

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: The ascent of sap in trees, Surface phenomena used by carnivorous



plants, Marangoni busrting, The cavitation bubble of the snapping shrimp. Starting from the selected theme, each group has to

- address an issue,

- 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 10 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 (including 3 hours of practical work), 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.

- 60
- 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:

- List and explain the mechanisms and physical phenomena involved in the most common dispersed systems, from industry or daily life;
- Define and calculate the associated characteristic length- and time scale;
- Interpret the dynamic behaviour of any dispersed system;
- Construct a model that captures the essence of the physical phenemona that take place in a dispersed system
- 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: DÉPARTEMENT MÉCANIQUE, PROCÉDÉS, ÉNERGÉTIQUE Language of instruction: ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Engineering Sciences Advanced level : NO Erasmus ECTS : 2,5

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)

No prerequisite knowledge in Biology required, just an interest in living matter and Biology.

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

Final written exam of 2 hours duration (no documents and no computer allowed)

Course support, bibliography

Course slides available online

Resources

• Teaching staff (instructor(s) names): Behnam TAIDI (CS-LGPM), Marie-Anne Debily (Gustave Roussy), 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 $\ensuremath{\mathsf{1}}$



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

Instructors: François Puel, Julien Colin Department: DÉPARTEMENT MÉCANIQUE, PROCÉDÉS, ÉNERGÉTIQUE Language of instruction: ENGLISH Campus: CAMPUS DE PARIS - SACLAY, CAMPUS DE METZ Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Engineering Sciences Advanced level : NO Erasmus ECTS : 2,5

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

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

2. Flow models (perfectly agitated and plug flow)

<u>Case study:</u>

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

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

5. Mass Transfer: Diffusion & Convection

<u>Case study</u>: 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 litterature survey whose topic is an extension of the course (40% of the grade); this presentation may take place either by an oral session of by a poster session take place .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: Flore Vallet Department: DÉPARTEMENT GÉNIE INDUSTRIEL ET OPÉRATIONS Language of instruction: ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Business Sciences Advanced level : NO Erasmus ECTS : 2,5

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-inthe-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-8ab9d017bddb34ca

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/genieindustriel-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 , 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.



2EL2140 – Strategy, Marketing and Organization

Instructors: Éléonore Mounoud Department: DÉPARTEMENT SCIENCES HUMAINES ET SOCIALES Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Business Sciences Advanced level : Yes Erasmus ECTS : 2,5

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. Tetrapak case study / innovation management

5. SKF Case Study / Understanding B to B Marketing and Globalization

6. Testimony of a group leader and start-ups: case studies Vallourec / Metalvalue

7/8/9/10. Digital platforms: models, issues, governance, notion of the digital commons

or 7/8/9/10. Quantification of business models

11 Synthesis session by group: low tech VS hi tech - Digital transition and ecological transition: complementary and rival

Class components (lecture, labs, etc.)

lectures 7 hours case studies 10 hours conferences 10 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 Alain Honnart, ex directeur industriel Vallourec, directeur Métal Value Fedi Soyah consultant de EY Parthenon Bastien Sibille et/ou Maxime Blondeau sur le numérique

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: DÉPARTEMENT SCIENCES HUMAINES ET SOCIALES Language of instruction: ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Business Sciences Advanced level : Yes Erasmus ECTS : 2,5

Description

The course goes into law and finance in depth after the first and secondyear introductory course. It also gives an opening on various Finance/Law professions via speakers working for different business companies (financial consultaing, 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:

- Labor law
- Introduction to corporate law
- Patentability, patent prosecution and related costs
- Software protection

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 (15 * 1:30) | Tutorials (7 * 1:30) | Final Exam (2 hours : Finance 1h + Law 1h)

Grading

Final written exam (100% of final mark)

Resources

• Teaching staff (instructor(s) names)

<u>Law</u>

Valérie FERAY (main lecturer - Founder and managing partner - IPSILON) Pierre-Jacques CASTANET (speaker and teaching assistant - Partner at In Extenso - attorney-at-law specialized in labour law) Mélanie COIRATON (Speaker and teaching assistant - Partner at Racine -Attorney-at-law) Mardson McQUAY (speaker and teaching assistant - Senior IP Attorney -King Abdullah University of Science and Technology) Ghislain DEMONDA (speaker and teaching assistant - Patent Attorney - API Conseil)

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)

- Introduction to corporate law : The benefits of using the coporate form - Definition of the company - Classification of companies - the Key actors - Financial matters - The main stage in a company's life

- Patentability, patent prosecution: 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

- 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: DÉPARTEMENT SCIENCES HUMAINES ET SOCIALES

Language of instruction: FRENCH

Campus: CAMPUS DE PARIS - SACLAY

Workload (HEE): 60

On-site hours (HPE): 35,00

Elective Category : Business Sciences

Advanced level : Yes

Erasmus ECTS: 2,5

Description

The objective of the "Economics of the Environment, Energy and Sustainable Development" course is to address:

i) <u>the major environmental issues</u> of the 21st century and the human factors that structure them (demography, economy, development, etc.);
(ii) <u>the theories</u> 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 <u>in practice</u>, both at the environmental and energy levels (European energy-climate packages, low-carbon electricity mix, etc.).

Quarter number

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%)

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: DÉPARTEMENT SCIENCES HUMAINES ET SOCIALES Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Business Sciences Advanced level : Yes Erasmus ECTS : 2,5

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: 3/8 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
 - o 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: DÉPARTEMENT SCIENCES HUMAINES ET SOCIALES Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Business Sciences Advanced level : NO Erasmus ECTS : 2,5

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.

This course is organised in partnership with the CS Entrepreneurship Department (Anita de Voisins, Rodolphe Rosier) and the entrepreneurship and innovation training association Matrice.io (Emmanuel Ea, Thibaud Dumas).



MASTER CLASS, a series of conferences and testimonials on the challenges of innovation,

you deepen your knowledge of the challenges of transformation (Digital, Carbon, Impact)

you translate them into opportunities/threats to face and strengths to develop (weaknesses to overcome) for the start-up you are studying

BUSINESS CASE: a coaching cycle where you develop your analysis in a team and in an iterative way

you diagnose the business model of a start-up

you formulate development recommendations according to the work areas co-decided with the start-up

Quarter number

SG8

Prerequisites (in terms of CS courses)

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

Syllabus

MASTER CLASSES

1 - Definition of business innovation? Why innovate? What are the issues at stake? Jean François Gallouin

R&D, invention, innovation, Creativity versus innovation, Different nature and intensity of innovation

2 - Climate / Energy issues by Zénon Vasselin, Carbone 4

3- financing and impact investing by Anita de Voisins

4 - digital disruptive innovations by Jean Pierre Remy, Deepreach

5 - new business models for sustainable mobility by Thomas Matagne, founder of ecov_fr, carpooling for daily trips.

6- Talk with a social entrepreneur Nicolas Vonthron for Mama Money, World's First Social Business Money Transfer Operator

BUSINESS CASE

Methodological input with Rodolphe Rosier, Entreprenariat CS (45 minutes) on the theme: how to get started, from the idea to the value proposition, the Business model Canvas and a working session with the coaches on the preparation of the meeting with the start-ups
 Meeting with the START UPs (all teams together), writing a meeting report, the business model with the BMC, the company's challenges



3. Methodological input with Emmanuel Ea on the Lean start up (45 minutes) and working session with the coaches on the preparation of the Lean canvas

4. Methodological input with Thibaud Dumas on the market/competition and working session on the preparation of the deliverable on proposals

- 5. Review of deliverables (by team)
- 6. final deliverable (per team)

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 business case (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

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



2EL2210 – Operations and supply chain management

Instructors: Guillaume Lame Department: DÉPARTEMENT GÉNIE INDUSTRIEL ET OPÉRATIONS Language of instruction: ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Business Sciences Advanced level : NO Erasmus ECTS : 2,5

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.

Examples will be drawn from various industrial sectors.

Quarter number SG8

Prerequisites (in terms of CS courses)

- ŝ
- none

Syllabus

This module will explore:

- The organisational dimension of production and distribution systems
- The performance of production systems through different perpectives
- 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.

Textbooks:

Slack N, Chambers S, Johnston R. Operations management. 5. ed. Harlow: Prentice Hall/Financial Times 2009.

Holweg M, Davies J, Meyer Ad, et al. Process theory : the principles of operations management. First ed. Oxford: Oxford University Press 2018. Chopra S, Meindl P. Supply Chain Management. Strategy, planning and operation. 5th. ed. New York, NY: Pearson Education 2012.

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.

Description of the skills acquired at the end of the course

This course will address the following competencies:

- C1 Analysing, designing and realising complex systems with scientific, technological, human and economic components
 - C1.2 Using and developping relevant models, choosing the righjt modelling scale and simplifying hypotheses to address the problem
 - C1.3 Resolving the problem through approximating, simulating and experimenting
 - C1.5 Leveraging a broad scientific and technical knowledge base in a transdisciplinary effort
- C2 Developing specific knowledge of a scientific or industrial domain et a professional domain
 - C2.1 Exploring a scientific or engineering domain or discipline
- C4 Understanding value creation for organisations and their clients
 - C4.1 Being customer-oriented. Identifying/analysing needs, stakes and constraints for other stakeholders, including on a social and economic level.
 - C4.2 Identifying the value created by a solution for a client and the market. Being able to identify opportunities and seize them.



2EL2220 – Organizational and market theories

Instructors: Yannick Perez Department: DÉPARTEMENT SCIENCES HUMAINES ET SOCIALES Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Business Sciences Advanced level : NO Erasmus ECTS : 2,5

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: DÉPARTEMENT GÉNIE INDUSTRIEL ET OPÉRATIONS Language of instruction: ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Business Sciences Advanced level : Yes Erasmus ECTS : 2,5

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

- Maintenance and Industry 4.0: concepts (3h)
- Modeling and quantification tools: Stochastic processes, Theory of renewal, Monté Carlo simulation, Machine Learning (3h)
- Optimization tools (3h)
- Corrective maintenance and resilience (3h)
- Corrective maintenance optimisation (8h)
- Predictive maintenance optimisation (12h)
- 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

• Examination with use case (3h)

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
 - $\,\circ\,$ 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: DÉPARTEMENT GÉNIE INDUSTRIEL ET OPÉRATIONS Language of instruction: ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Fundamental Sciences Advanced level : NO Erasmus ECTS : 2,5

Description

The course will examine three innovations that are set to profoundly transform the industry associated with personal 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 carsharing, 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

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

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: DÉPARTEMENT SIGNAL, INFORMATION, COMMUNICATION Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

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 Hilbert bases, particularly effective for non stationary signals representation.

Using these mathematical tools, general principles of function and signal approximation applied to compression (principles of 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 (e.g. PNG, FLAC)
- Speech compression (LPC)
- Compression and approximation in orthonormal bases
- Entropy encoding, quantization
- Sparse approximations
- Perceptual models
- JPEG and MP3 type compression

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.

Course support, bibliography

A Wavelet Tour of Signal Processing, Stéphane Mallat, Academic Press

Resources

60

Personal computers, 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: DÉPARTEMENT SIGNAL, INFORMATION, COMMUNICATION Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

Description

In many fields such as health, video surveillance, microscopy or remote sensing, simple or sophisticated image acquisition systems have been designed to produce digital images of all kinds: 2D images, 3D images, color images, videos, hyperspectral images. Image analysis includes the reconstruction of images from indirect measurements (e.g. in MRI and CT scan imaging), the reconstruction of 3D scenes in computer vision, image segmentation, image registration, and hyperspectral image analysis in remote sensing.

The objective of the course is twofold. On the one hand, fundamental concepts of image processing will be taught, ranging from elementary analyses to process grayscale and color images (thresholding, histograming, coding) to linear and non-linear filtering operations, carried out in the spatial domain and in the Fourier domain. On the other hand, advanced processing will be addressed to overcome the limits of conventional filtering approaches. They include image segmentation using geometric models to describe regions and contours, and the so-called variational approach, where image reconstruction is formulated as the optimization of a large-scale criterion. The variational approach is developed extensively and illustrated in the case of image denoising and image deconvolution.

Quarter number SG8



Prerequisites (in terms of CS courses)

- Signal processing : convolution, Fourier transform
- Probability / statistics
- Optimization

Syllabus

Introduction :

Examples of image processing : shape recognition, image registration, image segmentation, image restoration and reconstruction.

Image acquisition systems, process of image formation, image formats.

Basic analysis:

- Histogram, contrast enhancement, thresholding of gray levels.
- Image sampling, image quantization and resizing
- Format of color images (RGB, HSV, etc.) and basic analyses.

Filtering :

Linear filtering :

- Notion of separability in the spatial domain.

- Smoothing and contrast filters : averaging and Gaussian filters, differential filters, Laplacian filter, Prewitt and Sobel filters, etc.

- Filtering in the frequency domain

Nonlinear filtering: median filter, order filter.

Contour detection and image segmentation :

Active contour and region growing approaches.

Variational approach (based on numerical optimization) for inverse problems in imaging :

- Optimization based approach for image restoration
- Tikhonov regularization
- Edge preserving regulariation
- Case of image denoising and deblurring

Class components (lecture, labs, etc.)

The course is organized in two parts to present:

- Basic image processing: 5 lectures , 3 TD
- Advanced image analysis: 4 lectures, long term project (11h)

The main concepts will be illustrated and some image processing algorithms will be implemented using a simulation and data analysis software such as Matlab.

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

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

1. Basic knowledge on systems of acquisition of numerical images (cameras, microscopes, ...) and the process of image formation.

2. Ability to analyze a numerical image.

3. Ability to implement elementary numerical image algorithms : detection of pixels in an image by thresholding the gray levels, histogram computation, linear and nonlinear filtering, smoothing and contour detection.

4. Ability to implement advanced image deconvolution algorithms.

5. Learning advanced notions such as image segmentation based on geometrical models (contours and regions) and 3D image analysis.



Description of the skills acquired at the end of the course

Learning outcomes 3 to 5 achieve milestones: 1of skill C1.2 and 2B of skill C1.3

The long term project allows to participate in the validation of skills: C8.1 and C5.1



2EL2510 – Architecture and design of digital systems

Instructors: Anthony Kolar

Department: DÉPARTEMENT ÉLECTRONIQUE ET ÉLECTROMAGNÉTISME

Language of instruction: FRENCH

Campus: CAMPUS DE PARIS - SACLAY

Workload (HEE): 60

On-site hours (HPE): 35,00

Elective Category : Fundamental Sciences

Advanced level : NO

Erasmus ECTS: 2,5

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 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: DÉPARTEMENT ÉLECTRONIQUE ET ÉLECTROMAGNÉTISME Language of instruction: ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Engineering Sciences Advanced level : Yes Erasmus ECTS : 2,5

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.

The context highlighted in this course is the biomedical context. An ECG (ElectroCardioGram) is designed by the students during the labworks.

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

PC1 : First study of a circuit containing one or two transisto

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 switched 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 labworks schedules of 1h30. During these labwork sessions, the students will build an ECG circuit and observe their own cardiac activity.

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

Quiz + homework + powerpoint presentation

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. Most of the practical cases are illustrated by a LtSpice circuits available to the students, so they can be simulate them simultaneously during the courses and increase the understanding of the phenomena.

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: DÉPARTEMENT ÉLECTRONIQUE ET ÉLECTROMAGNÉTISME Language of instruction: ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Engineering Sciences Advanced level : NO Erasmus ECTS : 2,5

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 = 15 HPE

L1 - Overview of MEMS (applications: sensors, actuators, transducers, main players)

- L2 Accelerometers and gyroscopes
- L3 Mechanics of MEMS
- L4 Transduction and interface 1
- L5 Transduction and interface 2
- L6 Dissipation
- L7 Fabrication
- L8 Integration and packaging
- L9 MEMS industry
- L10 Economics of MEMS

Labs = 9 HPE

Lab 1-2. Pendular accelerometer - Modeling and simulation with Coventor (3h)

Lab 3-6. Resonant gyroscope - Modeling and simulation with Coventor (6h)

Projects = 9 HPE (examples)

Reverse engineering of a commercial 3-axis accelerometer Critical study of a 2-axis resonant accelerometer Electromechanical optimization of a MEMS resonator Reduced-order modeling of a MEMS energy harvester Bibliographical study (quartz vs. silicon)

Class components (lecture, labs, etc.)

Lectures (15h), labs (9h), projects (9h) Lectures and documents in English. Handout available in French.

Grading

Multiple choice test on lectures / labs (50%) Project report (50%).

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) External access to prd-campuslic license server

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: DÉPARTEMENT SIGNAL, INFORMATION, COMMUNICATION Language of instruction: ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Engineering Sciences Advanced level : Yes Erasmus ECTS : 2,5

Description

Communication is a fundamental need in all our societies. The everevolving 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%)

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: DÉPARTEMENT SIGNAL, INFORMATION, COMMUNICATION Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Engineering Sciences Advanced level : No Erasmus ECTS : 2,5

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
 - o 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 (3h)
- TP 2: Capacity and coverage of wireless networks (3h)
- 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: DÉPARTEMENT SIGNAL, INFORMATION, COMMUNICATION Language of instruction: ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

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.

- 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.

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 and quantum simulation of physical systems.

- Applications: quantum communications and cryptography, quantum error correction, quantum tomography and estimation, quantum control, quantum optimization and machine learning.

Class components (lecture, labs, etc.)



33 HPE main and application courses

Grading

2 hour examination personal work: oral presentation with slides of a scientific paper

Course support, bibliography

Nishimori H., "Statistical Physics of Spin Glasses", Clarendon 2001. 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

Learning outcomes covered on the course

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

1) Understand in a multidisciplinary context the importance and impact of classical or quantum concepts of information and entropy

2) Using the mathematical tools of Statistical and Quantum Physics, interpret concrete cases, for example in the field of data sciences, telecommunications, artificial intelligence, computational biology or finance.

3) Propose mathematical models for innovative applications such as machine learning, neural networks, optimization, information networks, quantum computers, etc. using the means of information theory, statistical inference, optimization criteria, logic and quantum information learned during the course.

4) Implement mathematical models in the form of algorithms in different computer environments.

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

Department: DÉPARTEMENT DÉVELOPPEMENT PROFESSIONNEL ET MÉTIERS D'INGÉNIEUR

Language of instruction: FRENCH

Campus: CAMPUS DE PARIS - SACLAY

Workload (HEE): 60

On-site hours (HPE): 35,00

Elective Category : Business Sciences

Advanced level : NO

Erasmus ECTS: 2,5

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) and 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: DÉPARTEMENT DÉVELOPPEMENT PROFESSIONNEL ET MÉTIERS D'INGÉNIEUR

Language of instruction: FRENCH

Campus: CAMPUS DE PARIS - SACLAY

Workload (HEE): 60

On-site hours (HPE): 30,00

Elective Category : Business Sciences

Advanced level : NO

Erasmus ECTS: 2,5

Description

The tutoring of people with disabilities is a pedagogical and solidaritybased 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
- Individual tutoring: in partnership with Sopra-Steria. A tutor accompanies a young person, in the form of learning support. The sessions take place according to the tutors' availability.
- Group tutoring: in partnership with Fédé 100% Handinamique. 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.
- Pre-tutoring training :
 - E-learning: SPOC "disabilities".
 - \circ 1 day (6 hours) of sensibilisation on disability.
 - 1 session (3 hrs) of training and role-playing workshop on conducting mentoring
- Approximately 10-15 tutoring sessions (1h-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.
- Monthly follow-up and discussion (1h)
- 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 Fédé 100% Handinamique
- TD size (default 35 students): 35
- Software tools and number of licenses required: no
- Public works rooms (department and capacity): no

Learning outcomes covered on the course

- Understand what disability means: types of disability, consequences for individuals and societal issues for the school and the professional world.
- Be comfortable interacting with people with disabilities
- 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.
- Think and act as a responsible ethical professional with integrity, taking into account environmental, social and societal dimensions.
 - Acting inclusively when faced with diversity issues: identifying and understanding situations requiring integration actions and participating in an inclusive action in a specific process

Description of the skills acquired at the end of the course

This module contributes to the acquisition of the following competencies:

• C7 : Know how to convince

5

- C7.1 : on the substance : Structure your ideas and your argumentation, be synthetic (hypotheses, objectives, expected results, approach and value created)
- C7.2 : on the relationship with others : Understand the needs and expectations of your interlocutors in an evolving way. Stimulate interactions, be pedagogical and create a climate of trust.
- C7.3 : on oneself : Be at ease and show oneself convinced, show empathy and manage one's emotions
- C7.4 : on communication techniques : master spoken, written and body language, and master basic communication techniques
- C9: Think and act as a responsible and ethical professional, taking into account environmental, social and societal dimensions.
 - C9.4 : Act in an inclusive manner when faced with diversity issues: identify and understand situations requiring integration actions and participate in an inclusive action within a specific process



2EL2730 – Associative Elective

Instructors: Ludovic-Alexandre Vidal, Guillaume Mainbourg, Géraldine Carbonel

Department: DÉPARTEMENT DÉVELOPPEMENT PROFESSIONNEL ET MÉTIERS D'INGÉNIEUR

Language of instruction:

Campus: CAMPUS DE PARIS - SACLAY

Workload (HEE): 60

On-site hours (HPE): 35,00

Elective Category : Business Sciences

Advanced level : No

Erasmus ECTS: 2,5

Description

The associative elective has four distinct paths:

EA1 - Set up a creativity approach in your association

EA2 - Structuring your association: creating values, processes and stakeholder management

EA3 - Set up a risk management approach in your associations

EA4 - IT project management

Other paths could eventually be created depending on the problems encountered by the associations.

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 in the context of the path EAx, which should allow a good evaluation of the acquisition of skills.



Class components (lecture, labs, etc.)

Specific to each path EAx.

Grading

Establishment of precise deliverables regularly submitted.

Resources

3 courses of 1h plus delieverables to submit frequently over the course period.

Learning outcomes covered on the course Specific to each path EAx.

Description of the skills acquired at the end of the course

Specific to each path EAx, but competencies C4, C6, C7, C8 and C9 could be validated with this course.



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): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

Description

Because of their ease of use and their ability to follow us everywhere, mobile devices (phones, tablets) have become first-class terminals and many companies have made the shift from "web-first" to "mobile-first" strategy.

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 reactive web site. 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

Depending on progress: Introduction to Android applications security

- Presentation of common vulnerabilities
- Protection mechanisms

Class components (lecture, labs, etc.)

The structure "6 labs + 16 lectures" is administrative because the course is actually mostly composed 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 with a fellow student 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
- optionally, 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 multi-tier application development and web services

Instructors: Michel Ianotto Department: CAMPUS DE METZ Language of instruction: ENGLISH Campus: CAMPUS DE METZ Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

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

Java programming basics

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 approximate distribution of "student presence hours" will be as follows: 24h of lectures and 9h of tutorial sessions in the computer room. The structure "16 lectures + 6 labs" is administrative because the course is actually mostly composed of "learning by doing" sessions led by teachers.

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 objectoriented 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++

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Instructors: Frederic Pennerath Department: CAMPUS DE METZ Language of instruction: ENGLISH Campus: CAMPUS DE METZ Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Fundamental Sciences Advanced level : NO Erasmus ECTS : 2,5

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

Prerequisites (in terms of CS courses)

No specific requirements are expected, but a basic experience of programming.

Syllabus

• Total course length: 15h of lectures, 18h of labeworks and 2h of exam

Lectures (15h):

- Memory management and variable life cycle (1h30)
- Struct and smart pointers (1h30)
- Types (1h30)
- Functional programming: lambda functions, callable types, exceptions,... (1h30)
- Class and inheritance (1h30)
- Basic mechanisms of templates (1h30)
- Generic programming based on templates (1h30)
- Generic versus object-oriented programming (1h30)
- Standard library: content and concepts (1h30)
- System programming: threads and synchronisation mechanisms (1h30)

Labworks (18h):

- TP on memory manipulation (3h)
- TP on object-oriented programming and inheritance (3h)
- TP on functional programming (3h)
- TP on generic programming (3h + 1h30)
- TP on the standard library (1h30)
- TP on system programming (3h)

Practical exam (2h)

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.

This exam will last two hours and will consist of short programming exercises. Each student will work alone on his or her own computer without access to the Internet, but will be provided with all the necessary documentation to pass the exam (course materials, technical documentation).

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): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

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)
 - o 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, 1 lab
- 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)
- $\circ\;$ 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):
 - $\circ\;$ 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
 - $\circ\;$ 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): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

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, 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

Fundamentals of estimation (6h of course)

 Introduction (goals of estimation, model, bayesian / non-bayesian point of view, examples)
 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 preliminaries6.2 Wiener filtering
- 7. Wiener filtering with linear contraint (3h of tutorials)
- Prediction with infinite past (3h of courses)
 8.1 Case of a signal whose power spectral density is bounded and admits a strong factorization
 2.2 Can analyze Work a decomposition
 - 8.2 General case, Wold's decomposition
- 9. Interpolation of a stationary signal (3h of tutorials)
- 10. Prediction with finite past (1h30 of course)
- 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): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

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)
 - o 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
 - o 2.1. Introduction to some of them
 - o 2.2. Contributions, compared to non-parametric methods
 - o 2.3. Cost of parametric methods
- 3. The sounds
 - 3.1. Models of perception (ear) and production (voice, mainly)
 - o 3.2. Sound localization
 - o 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.

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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): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

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



- 2.1. Physical modeling
- 2.2. Geometric modeling
- 2.3. Calibration

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- 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

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Instructors: Jean-Louis Gutzwiller Department: CAMPUS DE METZ Language of instruction: FRENCH Campus: CAMPUS DE METZ Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

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): 35,00 Elective Category : Engineering Sciences Advanced level : Yes Erasmus ECTS : 2,5

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.

Class components (lecture, labs, etc.)

Class components (lecture, labs, etc.): 15h of lecture + 12h of tutorials + 6h 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 and digital electronics : component modeling, polarization, linearization, large signal analysis, loopback and feedback, impedance matching, synchronous sequential logic, frequency behavior.
- Master the main tools of CAD and simulation.
- 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): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

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

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- 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

- To be aware of different optical techniques
- To be aware of the operating principles of different spectroscopic components
- Design and realize a device for optical measure
- Be able to interpret obtained spectroscopic results
- 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): 35,00 Elective Category : Fundamental Sciences Advanced level : NO Erasmus ECTS : 2,5

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: micromirrors, 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



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Instructors: Damien Rontani Department: CAMPUS DE METZ Language of instruction: ENGLISH Campus: CAMPUS DE METZ Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

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) Notions of attractors: fixed points, limit cycles, Torus, strange attractors Bifurcations

Route to Chaos and strange attractors. Bifurcation diagrams.

Discrete-time systems (maps). Notions of Lyapunov Exponent. Analysis of complexity: dimension, entropy. Introduction to Cellular Automata.

The 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 (3h)

Introduction to the theory of fractals. Self-similarity and fractal dimension (Hausdorff). Cantor, Mandelbrot, and Julia sets.

Complex phenomena – Introduction to network physics (10.5h)

Definition of complex physical networks. Examples in biology (metabolism, genetic, neurosciences) and in engineering (transportation and power grids)

Collective and emergent phenomena. Notions of synchronization. Examples of synchronization in Biology and Physics Presentation of the Kuramoto Model.

Spreading phenomena on networks (epidemics compartmental modeling and statistical approaches on networks). Contacts networks.

Labs (11.5h):

Numerical simulations of fractals (1.5h)

Analysis of complexity of a nonlinear map (1.5h)

Analyse d'un réseaux social digital (1.5h)

Simulation of epidémic phenomena (1.5h)

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Analysis and simulation of a network of phase oscillators and observation of synchronization (3h)

Numerical simulation and analysis of nonlinear dynamical system (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 experimenting with concepts seen in class and will focus on examples from current research topics.

Hourly volume: Lectures: 24.5h Labs: 11.5h

Grading

Evaluation (Modalities and weight of each quiz/evaluation in the final grade) :

• Lab Reports are 100% of the total grade (they represent individual assignments). Unjustified absences during Lab session and/or missing Lab report: the grade of 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

3. A.-L. Barabasi, "Network Science", Cambridge University Press, 2016, ISBN 978-1107076266

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): 35,00 Elective Category : Engineering Sciences Advanced level : Yes Erasmus ECTS : 2,5

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)

- Systems Modeling (ST5 course)
- ST5 Challenge Week

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

Functional and Structural Modeling

basis for structural decomposition, notions of interfaces

block definition, activities and states diagrams

allocation and traceability

model animation

Decision Making

matrix-based structural complexity management

trade-off analysis

Additional topic

an industrial point of view, topic may vary (example in 2020: the Modelica language, model exchange using the FMI standard)

Class components (lecture, labs, etc.)

The structure "6 labs + 16 lectures" is administrative because the elective is actually composed of sessions that include:



- 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 (<u>https://www.incose.org/docs/default-</u> source/aboutse/se-vision-2025.pdf?sfvrsn=b69eb4c6₄)

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:

60

- will be able to imagine a system modeling approach and will be familiar with a methodology (Magic Grid),
- will know the concepts of systems modeling,
- 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



2EL5150 – Transitions and socio-economic symbiosis

Instructors: Ninel Kokanyan
Department: CAMPUS DE METZ

Language of instruction:

Campus: CAMPUS DE METZ

Workload (HEE): 60

On-site hours (HPE): 35,00

Erasmus ECTS: 2,5



2EL5160 – Social and solidarity economy, transitions and socio-economic models

Instructors: Cynthia Colmellere Department: CAMPUS DE METZ Language of instruction: Campus: CAMPUS DE METZ Workload (HEE): 0 On-site hours (HPE): 35,00

Erasmus ECTS: 2,5



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): 35,00 Elective Category : Fundamental Sciences Advanced level : NO Erasmus ECTS : 2,5

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 :

- 4. to identify the real time aspects of an application, specify it and propose a design solution.
- 5. propose software structures and implementation.
- 6. to conduct performance analysis to demonstrate that the system can successively meet constraints and requiremennts.
- 7. to perform the different phases of the design cycle
- 8. to use a model based design approach.
- 9. 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: ENGLISH Campus: CAMPUS DE RENNES Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

Description

This elective course is open to any interested student while it is also mandatory for the InfoSec track.

Microprocessors are omnipresent in today's society. However, their design, implementation and construction remain a challenge that have a major impact on the performance and 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/software interface and a bottom-up approach to understand how computers work and how they can actually be 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)



This course builds on fundamental concepts from:

- 1CC1000 Information systems and programming
- 1EL8000 Electronic Systems (particularly important is the "digital electronics" part)

Certain notions on algorithms & complexity fundamentals are also interesting

Syllabus

Digital circuit design using a Hardware Description Language (HDL) (4.5h 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 + 12h 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 : 15h Tutorials : 6h Labs : 12h

Grading

Final exam (oral or written): 40%



Lab exam (project technical realization, demonstration and oral defense): 40%

Course assignments (exercises, readings ...): 20%

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.unihamburg.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

- 5
- 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): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

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)

The prerequisites for this lecture are the following ones:

- Knowledge of RISC-V assembly language (e.g. by following the computer architecture course)

- Fluency in C language (e.g. by following the compilation course).

Syllabus

The course is organised as follows:

- I Lesson 1:
- Operating system history
- II Lesson 2 :
- Operating system startup



- Control registers
- Priviledge levels
- Interrupt management
- System calls

III Lesson 3 :

- Process scheduling
- Scheduling algorithms
- Context switching

IV Lesson 4 :

- Synchronization primitives in kernel and user spaces
- Concurrency problems
- Pseudo-concurrency and real concurrency

V Lesson 5 :

- Virtual memory management
- Segmentation vs pagination
- Memory protection
- Binary loading
- Memory allocation algorithms

Class components (lecture, labs, etc.)

Lectures: 15h Labs: 18h

Grading

Final exam: oral exam Mandatory evaluations: short presentations (10 minutes) and two lab reports.

NF =0.25 CF + 0.75 EO

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

Teachers: Frédéric Tronel and Pierre Wilke Hardware: PC equipped with a Linux operating system.



Software: GCC cross-compilation chain for RISC-V, qemu-riscv64 and docker (we provide an installation guide for these tools during the first lecture).

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.

Implementing 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. C8.1 Work collaboratively in a team.



2EL6040 – System programming under linux and windows

Instructors: Pierre-François Gimenez

Department: CAMPUS DE RENNES

Language of instruction: FRENCH

Campus: CAMPUS DE RENNES

Workload (HEE): 60

On-site hours (HPE): 35,00

Elective Category : Fundamental Sciences

Advanced level : Yes

Erasmus ECTS: 2,5

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): 35,00 Elective Category : Engineering Sciences Advanced level : NO Erasmus ECTS : 2,5

Description

This course offers to expand your know-how, as well as your theoretical understanding, of the modeling, analysis and simulation of complex multiphysical systems (e.g.: simulation of drones, building thermal performance, bioreactors...).

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). With bond graph modeling, it becomes possible to perform structural analyses of the modeled system, in particular through the core notion of causality. These analyses reveal the *physical functioning* and the *energy exchanges* of the system.

Modelica is a non-proprietary language* used to address the following needs:

Model systems spanning several physical domains

- Easily build structured models using reusable components
- Collaborate effectively and build up models within a team



*unlike Simulink/Simscape for example

Modelica allows you to easily (e.g. graphically) describe and then simulate the dynamics of complex systems (a few thousand variables). It is thus becoming increasingly popular in industry (building, transportation, electrical networks, etc.).

Thanks to the open source nature of the software being used (OpenModelica), you will be able to freely reuse the know-how of this course in different settings. Beyond Modelica, the acquired skills on model structure and collaboration will be applicable to many other environments.

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.
 - o Analogies between variables: flow and potential
 - Hybrid systems, discontinuity, events (example of a diode rectifier)
- Structuring of models
 - Inheritance and composition

Packages

5

 $\circ\,$ Creation of a customized physical component



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. *New in 2020-2021: modeling de dynamics of the COVID-19 disease!*

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 selfstudy between classes and finally with the final project.

Grading

The evaluation of the elective is based on two activities:

- Final exam on theoretical aspects, without documents, on bond graph and Modelica fundamentals (1/2 of the grade)
- 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.
 - $\,\circ\,$ The project grade can be individualized within a group

Course support, bibliography

Material of the Modelica course: <u>http://éole.net/courses/modelica/</u>



5. including an extended list of references: <u>http://éole.net/courses/modelica/90-references.html</u>

Michael M. Tiller *"Modelica by Example"*, online book, first published in 2014 an continuously updated since. URL: <u>mbe.modelica.university</u>.

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:

- 5. model the system by a bond graph
 - a. including the application of the causality assignment procedure
- 6. analyze the structural properties of the system
- 7. 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): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

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.
- $\,\circ\,$ DragonBox: How do 5-year-olds learn algebra in 50 minutes?

YouTube popularization video (25%)

- a. Subject choice among several proposed themes (game design vs gameplay, role of the score, interaction loop, ...)
- b. Creation of a YouTube video explaining the issues of the chosen theme (1 production per student).
- c. Share and watch videos on the Youtube channel dedicated to the elective.

Realization of a proof of concept of serious game (65%)

- \circ In groups of 3 to 5 people.
- $\,\circ\,$ 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.
- $\,\circ\,$ 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)
- $\,\circ\,$ 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 note Example analysis of a serious game : 1/4 of the note Pitch and Defense 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:

- $\circ~$ Catherine SOLADIE
- Renaud SEGUIER
- \circ 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
- o 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): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

Description Mixed realities: hevend re

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 Student PASS for the World RV Show in Laval

Quarter number SG8

Prerequisites (in terms of CS courses) Computer science :

- o 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 (if available)

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 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)

- \circ Calibration
- o SLAM
- 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 (if available): 5% (3HES)
- Consulting and evaluation: 28% (17 HEE)
- $\,\circ\,$ Project and YouTube video: 50% (30 HEE)

Grading

MCQ of theoretical knowledge on virtual reality, augmented reality, mixed reality: 1/3 of the note Defense of the project of realization of a system of virtual or augmented reality: 1/3 of the note Youtube 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
- o Externals
Size of PW (default 35 students): <= 30 for BEs

3

Software tools and number of licenses needed:

a. 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

- a. Quote and explain several fields of application of virtual, augmented or mixed reality (C6.6)
- b. Describe the impact of these new technologies in the world of tomorrow (C6.6)
- c. Identify issues related to tracking and interaction with users (C6.7)
- d. Compare different algorithms useful for virtual and augmented reality (C3.6)
- e. Design an application using virtual or augmented reality (C6.7)
- f. Choose the appropriate project management methods to achieve such an application (C8.4)
- g. Work autonomously to make a Youtube video (C3.1)

Description of the skills acquired at the end of the course

- C3.1 : Be proactive and involved.
- C6.6 : Understand the digital economy.
- C6.7 : Understand information transmission.
- 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): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

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
 - $\circ\,$ 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
 - \circ Non-negative matrix factorization
- Deep Learning
 - $\circ \ \text{Auto-encoders}$
 - 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* (modalities could be adapted)
 - o 5m of theory-video
 - o 30 min of PW

Class components (lecture, labs, etc.)

- Course: 13% (8 HEE)
- Consulting and evaluation: 37% (22 HEE)
- Online courses: 20% (12 HEE)
- 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 Video on the theoretical part of the BE: 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:

- Catherine SOLADIE
- $\,\circ\,$ 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 Jridi Department: CAMPUS DE RENNES Language of instruction: ENGLISH Campus: CAMPUS DE RENNES Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

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:

- <u>Source Coding</u> trying to remove unnecessary redundancies in the transmitted messages and to gain in information rates.
- <u>Channel coding</u> 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 appropriate 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)
- 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

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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 networking paradigms

Instructors: Guillaume Piolle Department: CAMPUS DE RENNES Language of instruction: FRENCH Campus: CAMPUS DE RENNES Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Engineering Sciences Advanced level : Yes Erasmus ECTS : 2,5

Description

This elective course is part of the InfoSec Track, but is accessible to any 2nd year student validating the prerequisites. 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:

- Dynamic, on-demand adaptation capabilities, including the ability to distribute storage and processing but also to quickly reconfigure infrastructures;
- Resource sharing capabilities (compute, storage and network), generally based on the virtualization of infrastructures;
- The use of decentralized, peer-to-peer models;

• Scalable resource allocation models, etc.

Quarter number

SG6

5

Prerequisites (in terms of CS courses)

1CC1000 – Information Systems and Software Development 1EL6000 – Computer Networks and Security

Syllabus

- Lessons 1 to 5 (7,5h):
 - $\,\circ\,$ Cloud Computing
 - o Data Center Networks
 - Software-Defined Networking (SDN)
- Lessons 6 and 7 (3h):
 - a. IPv6
- Lessons 8 and 9 (3h):
 - LDAP Directories
- Lessons 10 and 11 (3h):
 - Distributed Architectures (Cluster)
 - Distributed File Systems
 - Cluster Management, Orchestration
 - Load Balancing
- Lessons 12 and 13 (3h):
 - Peer-to-peer (P2P) Architecture
 - o Blockchain
- 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.

Course support, bibliography

- 60
- 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: Bernard Jouga, Guillaume Piolle
- Software tools used on the students' PCs (all free and multiplatform): VirtualBox, OpenVPN client, SSH graphical connection;
- Software tools introduced or used (all under free license): OpenLDAP, OpenStack, Open vSwitch, HAProxy, ONOS/OpenDaylight...
- Hardware platform: 5-server OpenStack cluster, accessible via VPN.

Learning outcomes covered on the course

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

- design an architecture based on an Infrastructure as a Service;
- deploy an IPv6 network using dedicated address attribution mechanisms;
- 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): 35,00 Elective Category : Engineering Sciences Advanced level : Yes Erasmus ECTS : 2,5

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"
- $\ensuremath{\circ}$ 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"

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2EL6130 – Embedded systems and internet of things

Instructors: Guillaume Hiet Department: CAMPUS DE RENNES Language of instruction: FRENCH Campus: CAMPUS DE RENNES Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Engineering Sciences Advanced level : Yes Erasmus ECTS : 2,5

Description

This elective course is part of the Infosec track, but can be taken by any second year student that knows how to program in C and Java. The goal of this elective course is to discover the specificities of the development of applications that are executed on embedded 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)

- \circ Know programming with the C and Java language
- $\,\circ\,$ Know the basics of Linux command lines

Syllabus

Chapter : Principles: embedded systems and IoT

- \circ The specificity of embedded OS
- The network protocols for IoT (z-wave, zigbee)
- o The languages for embedded systems
- Real time systems (WCET)

Chapter : RIOT OS

- Discovering RIOT
- Development language
- \circ Lab: manipulating sensors

Chapter : Developing Android mobile applications

- \circ Specificities of Android development
- \circ Graphical User Interfaces
- Client Serveur applications
- \circ Labs: discovering Android, requesting a server

Chapter : Contiki and Yocto

- Discovering of the operating system
- Lab: manipulating sensors

Class components (lecture, labs, etc.)

- 12h of course
- 15h of labs

Grading

 Continuous control: Evaluation of RIOT/Contiki/Yocto/Android labs (0.5) • Continuous control: Presentation of advanced topics (0.5)

Resources

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- Emulators or real devices
- Platform IoT Labs

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 – Electric machinery, power electronics and grids.

Instructors: Alexandros Charalampidis Department: CAMPUS DE RENNES Language of instruction: ENGLISH Campus: CAMPUS DE RENNES Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Engineering Sciences Advanced level : Yes Erasmus ECTS : 2,5

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 firstyear 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 sessions 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 <u>Simscape Electrical</u> 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



Instructors: Romain Bourdais Department: CAMPUS DE RENNES Language of instruction: ENGLISH Campus: CAMPUS DE RENNES Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Engineering Sciences Advanced level : Yes Erasmus ECTS : 2,5

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

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
 - \circ Prediction model
 - Receding horizon principle
 - Specifications and mathematical translation of objectives
 - $\,\circ\,$ Optimization problem solving and closed-loop behavior
 - \circ 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

- Teaching staff (instructor(s) names): Romain Bourdais, Pierre Haessig
- Maximum enrollment (default 35 students): 25 students
- Software, number of licenses required: Matlab/Simulink/Optimization Toolbox
- 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: Thomas Le Texier Department: CAMPUS DE RENNES Language of instruction: ENGLISH Campus: CAMPUS DE RENNES Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Business Sciences Advanced level : NO Erasmus ECTS : 2,5

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
 - $\circ~$ Definitions and highlights
 - o The patent: a corrective tool?
 - $\circ\,$ 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
 - $\circ~$ The "problem" of the manager
 - $\circ~$ 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
 - $\circ~$ 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.





Instructors: Romain Bourdais Department: CAMPUS DE RENNES Language of instruction: FRENCH Campus: CAMPUS DE RENNES Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Business Sciences Advanced level : NO Erasmus ECTS : 2,5

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
 - $\,\circ\,$ 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

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- Inventory management
 - Inventory Management Models for Independent Demand
 - Choosing a model
 - $\circ~\mbox{Flow planning}$
 - Comprehensive planning: development of ICP
 - Detailed planning: developing the PDP
 - Flow programming
 - MRPO Logic
 - MRP1 logic: load-capacity matching
 - Flow scheduling
 - Centralized Scheduling
 - Decentralized Scheduling (Kanban...)
- o 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: Maud Daniel Chever Department: CAMPUS DE RENNES Language of instruction: FRENCH Campus: CAMPUS DE RENNES Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Business Sciences Advanced level : NO Erasmus ECTS : 2,5

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/latransformation-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

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Instructors: Simon Leglaive Department: CAMPUS DE RENNES Language of instruction: ENGLISH Campus: CAMPUS DE RENNES Workload (HEE): 0 On-site hours (HPE): 35,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS : 2,5

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 published in *Journal of Machine Learning Research (JMLR)*, 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/bmlcourse/blob/master/notebooks/00 topic modelling for Bayesian ML pap

ers.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 two sessions on the fundamentals of Bayesian methodology and machine learning, we will study Bayesian networks and exact inference techniques for latent variable models. As exact inference is not always possible, we will move on to approximate techniques based on variational and Markov chain Monte Carlo (MCMC) methods. We will end with deeplearning-based generative models, exploiting recent variational inference methods that scale for large datasets or for high-dimensional data

Theoretical concepts will be applied on concrete data, in particular during lab sessions in Python. Different supervised and unsupervised Bayesian learning models will be implemented (Gaussian mixture model, Bayesian and sparse linear regression, variational autoencoder). These examples 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.

Quarter number

SG6

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

Lectures:

- Fundamentals of Bayesian modeling and inference
- Fundamentals of machine learning
- Bayesian networks and inference in latent variable models
- Factor Analysis
- Variational inference
- Markov Chain Monte Carlo
- Deep generative models

Lab sessions:

- Gaussian mixture model
- Bayesian linear regression
- Sparse Bayesian linear regression

Class components (lecture, labs, etc.)

The course is organized in 7 lectures of 3 hours, 3 lab sessions of 3 hours on Python, and 1 revision or guided reading session. Most of the lectures also include a short practical session (in Python) to apply the theoretical concepts. Students will be asked to do theoretical preparatory work before the lab sessions.

Grading

Students will be evaluated through lab-session reports in the form of Jupyter notebooks, including the answers to the theoretical exercises and the implementation of the algorithms. The evaluation of these reports represents 30% of the final grade, the remaining 70% correspond to a final exam of 2 hours.

Course support, bibliography

Course materials (slides, Jupyter notebooks, Python code and teaching activities) will be made available on Edunao.

References:

• Christopher M. Bishop, « *Pattern Recognition and Machine Learning* », Springer, 2006 (freely available online)



- Marc Peter Deisenroth, A. Aldo Faisal, and Cheng Soon Ong,
 « Mathematics for Machine Learning » Cambridge University Press, 2020 (freely available online)
- Kevin P. Murphy, « *Machine Learning, A Probabilistic Perspective* », MIT Press, 2012 (available at the library)

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.



2EL6200 – Advanced corporate finance

Instructors: Maxime Guymard Department: CAMPUS DE RENNES Language of instruction: FRENCH Campus: CAMPUS DE RENNES Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Business Sciences Advanced level : Yes Erasmus ECTS : 2,5

Description

The course first allows you to deepen the financial management of a company after the initiation course of the first year. Secondly, the course aims to give a broader understanding of the world of finance, by understanding the functioning of the financial system, its role, its history and the main actors intervening in this sector.

Quarter number SG8

Prerequisites (in terms of CS courses) Business Management (1st year)

Introduction to Corporate Finance (1st year)

NB: students who have taken the 2A Corporate Finance and Law elective on the Gif campus (December-January period) are advised not to also take this Advanced Corporate Finance elective. Although the scope of this Advanced Corporate Finance course is broader, there would be significant duplication in the core part of the course.

Syllabus

1. First, the core 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)

2. Once the core lectures mastered:

- Business Valuation
- Start Up financial management
- Bankruptcy and restructuring
- Introduction to Market Finance (stocks, bonds, derivatives)
- Understanding of the role of some key players in the financial world (Banks, Insurance, Rating Agencies)
- History of finance

Class components (lecture, labs, etc.)

Integrated lectures mixing theory and tutorials (11 * 3h); Final Exam (2H)

Grading

The assessment will consist of 3 parts:

o Teamwork: Short oral presentation to the whole group on a subject on the history of finance or key players in the financial world (20% of the grade)

o Teamwork: Financial analysis of a company of your choice, delivery of a written note (20% of the note)

Individual work: assignment on a final evaluation table of 2 hours, consisting of course questions, application exercises and a case study (60% of the mark)

Course support, bibliography

- Corporate Finance. Pierre Vernimmen, Pascal Quiry, Yann Le Fur.
- La gestion financière de l'entreprise. Christian Pierrat
- Manuel de Finance d'Entreprise. Georges Legros
- Dessine-moi la comptabilité. Isabelle de Kerviller

Resources

Teacher: Maxime GUYMARD

Learning outcomes covered on the course

At the end of this module, the student will be able to: - Read and interpret a company's financial statements

- Carry out the financial analysis of a company
- Estimate the valuation of a company



- Determine on quantifiable financial criteria whether a project should be undertaken or not

- Mobilize knowledge of the financial world (professions, actors, history) to understand corporate finance problems

Description of the skills acquired at the end of the course

C3.2 Propose alternatives, formulate ideas by integrating the necessary external expertise (technical, commercial, HR, financial, legal, etc.), integrate risks and uncertainty

C4.1 Identify and (re) formulate the customer's need to create value as well as the associated challenges and constraints. Identify and integrate other stakeholders, internal and external, as well as other dimensions not mentioned initially (technical, economic, human, etc.)

C 7.1: Basically: Structure your ideas and arguments, be synthetic (assumptions, objectives, expected results, approach and value created)



2EL6210 – Geopolitics of resources and objects

Instructors: Raphael Danino-Perraud Department: CAMPUS DE RENNES Language of instruction: FRENCH Campus: CAMPUS DE RENNES Workload (HEE): 60 On-site hours (HPE): 35,00 Elective Category : Business Sciences Advanced level : NO Erasmus ECTS : 2,5

Description

In their future careers as engineers, CentraleSupélec students will be called upon to place their practices in globalized economic and political worlds. These are characterized by the interconnection of different parts of the globe and an intensification of the flow of capital, goods and services on a global scale, made possible in particular by the development of means of transportation and information and communication technologies. Although globalized production and exchange networks appear to be free of all material constraints, they remain highly dependent on natural resources and technical objects.

Since the end of the 20th century, human activities and their impacts (urbanization, climatic and environmental changes) have contributed to increasing the pressure on resources and their availability. The geopolitics of resources and objects influences international power relations and raises power issues at various scales (local, national, regional, global).

To understand the stakes of our globalized political and economic system, we must therefore adopt a critical reading of techniques and resources. To do so, we adopt a perspective centered on a certain number of resources (mining, agricultural and energy, but also waste) and infrastructures (pipeline, electrical network, hydroelectric dam). It is from these geopolitical themes that students will be led to identify the power relationships between actors and the economic stakes associated with them.



Quarter number

SG6

Prerequisites (in terms of CS courses)

None

Syllabus

Detailed course outline (content): 11 sessions of 3h, 1 exam of 1h30 Session 1 - Introduction: a brief epistemology of resources - Raphaël Danino-Perraud and Angélique Palle (TD)

Session 2 - A transnational energy transport infrastructure as a geopolitical object - Noémie Rebière (CM)

Session 3 - Methodology of geopolitical mapping - Léa Gobin and Noémie Rebière (lab)

Session 4 - Geopolitical impacts induced by the energy transition: risks on objects and resources circulation - Angélique Palle (CM)

Session 5 - Project support - Raphael Danino-Perraud and David Juilien (PT) Session 6 - Applied exercise: role-playing - Wahel Rashid and David Juilien (PT)

Session 7 - Producing and feeding ourselves: conflicts over resources - Matthieu Brun (CM)

Session 8 - Hydroelectric dams, a geopolitical object - David Juilien and Wahel Rashid (TD)

Session 9 - Mineral raw materials, globalized resources: the example of lithium - Audrey Sérandour (CM)

Session 10 - Waste, a geopolitical object - Wahel Rashid and Raphaël Danino-Perraud (TD)

Session 11 - The contrasting application of the duty of care for resources and conclusion of the course - Raphaël Danino-Perraud (CM) Session 12 - Homework (1h30)

Class components (lecture, labs, etc.)

Grading

Student learning will be assessed in two ways:

1. A cartographic analysis file, carried out in groups (of 3-4 students) equivalent to 50% of the grade.

Throughout the sequence, students will have to build a geopolitical reflection around a resource or a globalized object. They will have to identify the main actors and issues raised by this resource or object, take a critical look at the materiality of the resources and techniques studied (no

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technology is neutral) and construct a reflection at different scales (global, regional, national, local).

Based on a bibliographic research, students will have to produce two analytical maps presenting a geopolitical reasoning around a globalized resource or object. At least one of the two maps must be produced on a global scale. The supervision of this work will begin during the session on the methodology of geopolitical cartography (session 3), then we will have a session dedicated to the accompaniment of projects (session 5). The restitution will take the form of a written file, including the two maps, a description of the problematized legend (in 1 page) and an analysis of the maps (in 5 pages maximum). This written report will be graded. Follow-up on the project will be organized during the semester through presentations on the state of the art (not graded).

2. A table-top assignment, carried out in session 12 (duration: 1h30) equivalent to 50% of the grade.

This will consist of a commentary on documents (a corpus composed of excerpts from articles, a map and a graph). The corpus will present a case study, which will be analyzed by mobilizing the concepts studied in class.

Course support, bibliography

• ABIS Sébastien, BRUN Matthieu (2020), « Géopolitique de l'agriculture européenne », Études, 2020/2 (Février), pp. 17-28.

 LACOSTE Yves (2008), « La géographie, la géopolitique et le raisonnement géographique », Hérodote, 2008/3, n°130, pp.17-42. [En ligne] URL : https://www.cairn.info/revue-herodote-2008-3-page-17.ht m

• PITRON Guillaume (2018), La guerre des métaux rares : la face cachée de la transition énergétique et numérique, Paris, Éditions Les liens qui libèrent, 296 pages.

• REBIERE Noémie, « Énergie et géopolitique régionale : quel avenir pour le hub turc ? », Orients Stratégiques (n°6), L'Harmattan, Paris, 01/2018, pp.1-15.

• ROTILLON Gilles (2010), Économie des ressources naturelles. Collection Repères, Paris, Édition La Découverte, Collection Repères, 128 pages.

Resources

Teaching team: Raphaël DANINO-PERRAUD (PhD in economics, French Ministry of Defence), David JUILIEN, Wahel RASHID, Audrey SÉRANDOUR, Matthieu BRUN, Léa GOBIN, Angélique PALLE, Noémie REBIERE

Learning outcomes covered on the course

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

- adopt a critical view of resources, discuss the issues of access, distribution and control of these resources, and problematize the issues raised by their exploitation and circulation;

- have factual knowledge on a variety of case studies, located on several continents (Europe, Asia, Latin America) and analyzed at various scales (global, regional, national, local);



- master the basics of the geopolitical analysis method and its key concepts (actors, power relations, representations, territories). He will be able to identify the relevant actors and detect the power relations crystallized around a resource or an object, at various scales;

- read a map and understand it from a geopolitical and critical perspective. They will also have acquired the basics of freehand cartography.

Description of the skills acquired at the end of the course

analyze: study a system as a whole, the situation as a whole. Identify, formulate and analyze a system within the framework of a transdisciplinary approach with its scientific, economic, human dimensions, etc. C2.2: Import knowledge from other fields or disciplines C5.3 : Analyze global and/or local issues at the international level and adapt projects or solutions to them

6	

SCIENCE AND ENGINEERING CHALLENGE N°5 COURSES

ST5 – 51 – PILOTING AND FLIGHT CONTROL IN AERONAUTICS AND SPACE TRANSPORTATION

Dominante : GSI (Large Interacting Systems) and CVT (Construction, City and Transport)

Langue d'enseignement : French

Campus où le cours est proposé : Paris-Saclay

Engineering problem

This sequence addresses the problem of designing flight control laws and dynamic control of vehicle flight (aircraft, satellite and launcher). It aims to give students the basic concepts associated with the design of control systems of a flying object around its 6 degrees of freedom in order to ensure stability of operation and the required performance. The technologies in the fields of aeronautics and space being in constant evolution (propulsion, structure, materials, etc.), the laws of piloting must adapt to guarantee the best performances while taking into account the new constraints, in particular regulatory, environmental and economic.

The integration course allows students to apply the skills and knowledge acquired in the case of an aircraft, a nanosatellite and/or a launcher. These vehicles have become very popular in recent years due to the reduced cost associated with their construction and operation. However, it raises new problems, in particular for the control of attitude and performance due to the miniaturization of the components and thus the reduction of their capacities of action and their effectiveness.

The intervention of industrialists from the aeronautics and space sector in this sequence allows a better understanding of the issues associated with the design and operation of increasingly constrained systems.

Adviced prerequisites

Two main topics are covered in this sequence: modeling of undeformable objects and modeling of linear systems (transfer functions, state representation, differential equations) for control. These recommended prerequisites are part of the common course of Modeling (ST2) and the SPI course of Mechanics and Continuous Media. The rest of the necessary skills are based on the capitalization of CPGE knowledge and self-training.

Context and issue modules: The introduction of the sequence is organized around four half-days of training aiming at presenting the sequence, the integration teaching and introducing the stakes of the various sectors of space and aeronautics, according to the actions:

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1. Presentation of the thematic sequence and introduction to the integration lessons

2. Conference on the civil and military aeronautics sector: from the design of airliners to operations and traffic management (speaker: Air France, Dassault Aviation)

3. Conference on applications and uses in space (speakers: CNES, Thalès Alinea Space)

4. Introductory conference on the law of space activities (speaker: Institut du Droit de l'Espace et des Télécommunications, IDEST). Introduction to the concepts of liability and insurance (speaker: ArianeGroup). Conference on the economy in space (speaker: CNES).

5. Conference on sustainable development in aeronautics and space (speaker: Parrot, ESA).

Specific course (60 HEE) : Performance and flight trajectories

Brief description : The objectives of this specific course are to:

- model the behavior of a vehicle in flight in the framework of rigid body mechanics,

- describe the dynamics of vehicles in the case of flights in and out of the atmosphere (trajectory, eigenmodes, instabilities)

- choose and deploy control and piloting strategies.

It is organized in two steps. First, based on the mechanics course offered in the first year, the mechanics of rigid bodies is introduced to give the necessary tools for the construction of models of aircraft, launchers, satellites, UAVs... For this, two courses will give the basic concepts of flight mechanics and space mechanics. In a second phase, the course will describe the dynamics and control strategies of an aircraft, a satellite and a launcher. These three phases of the course will involve several actors from the aeronautics and space sectors. The sessions will provide an understanding of the models used and the control strategies to be used. The students will take control tools on a specific system and will be able to set up a control strategy in a pre-project phase during the integration teaching.

Challenge Week :

Preamble: The three integration courses are built in the same way and cover the same learning objectives. The aim is to start from a performance specification for an aircraft, a nanosatellite or a launcher and to make architecture and piloting choices to ensure the expected performance. The common objectives are therefore:

- Understand the constraints of flying systems, and the different levels of modeling of dynamic behavior



- Choose the relevant technical solutions for the control of trajectory, stability and orientation (sensors/actuators...)

- Design a complete system by modeling, including actuators and sensors, actuator sizing, power generation and CPU capacity

- Implementation of an optimal control law, taking into account economic aspects

- Validation of the control law on a realistic model

Challenge week n°1 : Control strategy for a nanosatellite

- Associated partner: Thalès Alenia Space via the CentraleSupélec Space Center

- Location: Paris-Saclay campus

- **Brief description:** This integration course will be conducted in collaboration with Thalès Alenia Space. The objective is to design a nanosatellite (Cubesat). For a specific mission defined by a specification, participants will propose an orbit, choose the satellite components, design the operating modes and develop a control law.

Challenge week n°2: Definition and design of a launcher mission

- Associated partner: CNES Direction des Lanceurs

- Location: Paris-Saclay campus

- **Brief description :** The objective of this integration course is to bring the students, through a space launcher design project, to experience a multi-disciplinary dimensioning loop. To this end, the project is articulated in modules reflecting the unfolding of a design loop, with CNES DLA (Launchers Directorate) engineers accompanying the students during each of these modules.

Challenge Week n°3: Aircraft design

- Associated partner: OAD SPRL (aircraft design company)

- Location: Paris-Saclay campus

- **Brief description:** The objective of this integration course is to introduce the different steps of the aircraft design process, both from a theoretical and a practical point of view. Typical methods used in design offices will be presented and then applied to the design of an aircraft chosen by the student. The study will be based on the general steps described in the preamble.



2SC5110 – Performance and flight paths

Instructors: Sihem Tebbani Department: DÉPARTEMENT MÉCANIQUE, PROCÉDÉS, ÉNERGÉTIQUE Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 34,50 Erasmus ECTS : 2,5 (+ introduction: 0,5 ECTS)

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:

2.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.

<u>Elective course</u> (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

3

This course aims to detail the modeling and control of an airplane. It will address the following points:

- Presentation of the specification for the flight performance of an airplane
- Modeling forces acting on the aircraft (including thrust, lift and drag)
- 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

- Orbital Mechanics for Engineering Students, H. D. Curtis, Butterworth-Heinemann. 2013.
- 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.
- Advances In Aircraft Flight Control, M B Tischler, CRC Press, 28 jun. 1996.
- 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
- 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, 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

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): 27,00

Erasmus ECTS : 2

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: 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): 27,00

Erasmus ECTS : 2

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

5

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 multidisciplinary 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

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): 27,00

Erasmus ECTS : 2

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: industrial partner.

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 \diamond 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 – CONTROL OF (BIO)PROCESSES FOR SUSTAINABLE PRODUCTION

Dominante : VSE (Living-Health-Environment) and GSI (Large Interacting Systems)

Langue d'enseignement : French

Campus où le cours est proposé : Paris-Saclay

Engineering problem

Sustainable development is playing an increasingly important role in the current and future development of various industrial sectors. Solutions for modernizing and evolving the means of production are being developed in order to limit greenhouse gas emissions, in particular by offering alternatives to fossil fuels. Among the solutions studied, this sequence topic is more specifically interested in biotechnologies and bioprocesses, efficient and sustainable, as alternatives to current technologies.

Their emergence requires the implementation of multidisciplinary knowledge, in particular for the optimization of their functioning (maximization of productivity and/or degradation of pollutants).

This teaching proposes to give elements of response for the design of processes within the framework of sustainable development, by the design of automatic systems for the production of commodity or high added value compounds and/or the treatment of waste. More specifically, it focuses on the development of automated cultures of microorganisms to address issues of energy (e.g. biofuel production), pollution and greenhouse gases (recycling of aquaculture systems, wastewater treatment, CO2 consumption), and reduction of the ecological footprint (production of biopolymers), etc.

In this course, the concept of using bioprocesses for sustainable development is presented, as well as the design of automated systems to maintain the bioprocess in optimal operating conditions (to maximize its productivity). The approach can be extended to other bioprocess applications not covered in this topic in the biotechnology sector (e.g. stem cell culture for medical applications). The concepts presented can also be applied to broader sectors, beyond sustainable development (pharmaceutical, genetic engineering, cosmetics, agri-food, etc.). The intervention of industrialists in the field allows a better understanding of the issues associated with the use and optimization of bioprocesses for sustainable development.

Adviced prerequisites



Self-training (Modeling of microorganism culture in bioreactor). A document detailing these aspects will be provided.

Context and issue modules:: This part is organized around half-days aimed at presenting the subject, the integration teaching and introducing the issues associated with sustainable development and more specifically with the study of bioprocesses, through the following activities

Conference "History and perspectives of biotechnology development" giving an overview of the evolution of biotechnology and the current and future needs of this sector.

Conference on the energy transition providing an overview of energy sources (fossil, nuclear, renewable) and highlighting the interest and role of bioprocesses in the production and storage of energy, as well as the associated challenges.

Conference on the environmental transition, taking stock of the environmental issues that need to be addressed (scarcity of resources, pollution, health risks, etc.) and highlighting the interest and role of bioprocesses in the recovery of waste and the conversion of biomass into sustainable products.

Conference on the contribution of bioprocesses for long duration space missions and the critical importance of their optimal control. These bioprocesses are a relevant solution for nutritional autonomy and for recycling water, air and organic matter in a confined environment. Their control is one of the keys to their reliability, which is absolutely necessary given the needs they meet and the isolation of the space environment.

Conference dedicated to sustainable development.

Conference on bioethics, showing that the use of bioprocesses raises questions on the ethics of the proposed solutions, in particular when these solutions call upon the design of organisms whose genome is modified. This conference is an introduction to the questions related to the use of biotechnologies and, more generally, to the place of Man in the biosphere and to the respect of nature and the environment.

Conference on "Automation and Bioprocesses" focusing more specifically on the role of automation and automatic processes in supporting transitions towards a sustainable economy

Specific course (60 HEE): Chemical Engineering: application to environment and sustainable production ; Ingénierie des procédés : application à l'environnement et aux productions durables

Brief description : Modern Process Engineering consists of designing, operating and optimizing environmentally friendly processes, intended for the elaboration of various products and services in many classical and high-tech sectors (pharmaceuticals, petroleum, fine chemicals, food processing, cosmetics, water and waste treatment, materials, biotechnologies, 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 numerous products and the



purification of liquid and gaseous effluents, thus becoming the tools of choice in the strategy of sustainable development on a global scale. The challenges associated with this environmental dynamic are multiple: reduction of costs, risks and dangers, waste, and consumption of energy and raw materials. The intensification of processes is the major lever to meet them. Bioprocesses are experiencing very strong development, for two reasons: (i) the use of living organisms to transform matter, purify polluted systems (liquid, solid), microorganisms behaving as factories and (ii) the use of biomass to replace fossil resources. This course is an introduction to Process Engineering and its methodologies, allowing students to acquire generalist tools, easily transposable to multiple fields, such as biotechnology and environment. It is fully in line with the environment, energy and health issues.

Challenge Week : The three integration courses cover the same learning objectives and have a similar structure. The aim is to start from a performance specification for a given bioprocess, to proceed to choices of bioprocess design and control law to ensure the expected performances and to maximize the productivity of the system thus designed.

Challenge Week n°1: Optimized biological treatment of urban wastewater

- Associated partner: Véolia
- Location: Paris-Saclay campus

- **Brief description:** In urban wastewater treatment plants, biological processes are designed to eliminate carbon and nitrogen pollution through the action of microorganisms that develop spontaneously in an aerobic or anaerobic environment.

The eliminated pollutants are concentrated in the form of aqueous suspensions or sludge, constituting voluminous waste with fermented target and toxic materials. The treatment of sludge is therefore an important phase of wastewater treatment systems that must ensure the reduction of its volume and odor nuisance. One of the most common processes for this treatment is anaerobic digestion, which produces liquids with a high concentration of nitrogen that must be treated again. The amount of nitrogen contained in these effluents can represent up to a 20% increase in the nitrogen load to be eliminated by the plant. There are two solutions to this problem: (1) a so-called classical one, in which these concentrated effluents are directly returned to the head of the plant or (2) the anaerobic ammonium oxidation process, or Anammox, an innovative alternative to the traditional nitrification/denitrification processes, allowing the direct transformation of nitrite and ammonium into gaseous nitrogen.

The objective of this EI is to propose control strategies for the two mentioned solutions in order to meet the minimum purification requirements of the treated water and to compare their performance in terms of operating costs and biogas production as a vector for energy recovery from sludge.



Challenge Week n°2: Optimization strategies for a biotechnology plant: application to sourdough production.

- Associated partner: Soufflet

- Location: Paris-Saclay campus

- **Brief description**: At the industrial scale, fermentation can be conducted in a continuous or discontinuous manner. When designing or optimizing a plant, this choice is crucial, since it determines the productivity of the process, its management, the logistics organization and the inherent costs. Although more intensive in terms of investment (specific reactors, increased instrumentation and automation), the continuous solution has the advantage of smoothing out production and therefore limiting the storage and handling stages. It is therefore the subject of particular attention.

The Soufflet group has a factory on the outskirts of Caen dedicated to the production of sourdough. This symbiotic mixture of lactic 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 currently involves a succession of batch reactors of increasing size.

The objective of the EI is to support the company in optimizing the existing plant and in designing a new continuous production workshop, according to various strategies: flow management, reactor sizing and implementation of a robust control system.

Challenge Week #3: Advanced supervision of biogas production from waste

- Associated partner: BioEnTech

- Location: Paris-Saclay campus

- **Short description** : Anaerobic digestion is a natural process of degradation of organic matter by micro-organisms (bacteria and archaea) in the absence of oxygen (anaerobic conditions). This process allows to recover a fraction of the energy contained in the waste in the form of biogas, a mixture of methane and CO2. The generalization of these technologies would allow on the one hand to reduce considerably the energy demand necessary to treat the 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 type of accident, a very precise and costly monitoring is necessary. The objective of the IE is to propose and develop supervision and control strategies to reduce the risk of reactor acidification and to optimize the production of energy from the waste.



2SC5210 – Chemical Engineering: application to environment and sustainable production

Instructors: Cristian-Felipe Puentes Mancipe Department: DÉPARTEMENT MÉCANIQUE, PROCÉDÉS, ÉNERGÉTIQUE Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 34,50 Erasmus ECTS : 2,5 (+ introduction: 0,5 ECTS)

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.

The case studies conducted involve biochemical or chemical reactions. However, no prior knowledge of chemistry or biology is required.

Syllabus

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

<u>Case study</u>: Process for the manufacturing of 1st generation bioethanol (conversion of renewable raw materials by white biotechnologies)

2. Flow models (perfectly agitated and plug flow)

<u>Case study</u>: 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

<u>Case study</u>: 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**

- Application exercise: Flash distillation of ethanol-water mixture;
- <u>Case study</u>: Multi-stage distillation of bioethanol (*alternative to fossil fuels*)

5. Mass Transfer: Diffusion and Convection

<u>Case study</u>: Raceway production of Spirulina microalgae (*sustainable production of nutrients for food and feed*)

6. Mass Transfer: Permanent Contact Technologies

<u>Case study</u>: 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.

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- 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: Julien COLIN, Cristian PUENTES, Victor POZZOBON, François PUEL

- Maximum enrolment: 30 to 40
- Software, number of licenses required: Excel, Python, Matlab

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: 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): 27,00

Erasmus ECTS : 2

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.

- Presentation on the Annamox process (principles, technologies and industrial examples).

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 control aspects of the teaching. In order to understand the Anammox process, a second introductory presentation will be made by the pedagogical team. Scientific articles and technical documentation will be available to the students if they wish to deepen the notions treated.

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 control, 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. Anammoxbased 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

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): 27,00

Erasmus ECTS : 2

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: 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): 27,00

Erasmus ECTS : 2

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: researchers from INRIA (Sophia-Antipolis), teacherreseacrhers of CentraleSupélec, with regular contact with the industrial partner.
- 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 – AUTONOMOUS AND CONNECTED VEHICLE

Dominante : SCOC (Communicating Systems and Connected Objects)

Langue d'enseignement : French

Campus où le cours est proposé : Paris-Saclay

Engineering problem

Today's vehicles are equipped with a multitude of sensors and electronic processing that provide driving assistance and even a certain level of autonomy in well-defined contexts. Today's vehicles are also connected to provide information on traffic conditions and navigation. According to roadmaps in the field, by 2030, the vehicle should be subject to complete connectivity via intelligent communication systems and adapted technologies to enable total autonomy, reducing the driver to a simple passenger who will only have to indicate his destination before departure. But before we get there, engineers will have to help answer many questions, of which we can give a taste. First of all, on a technical level, will technology be able to completely replace the driver? Or how can such systems be designed and validated while guaranteeing reliability and safety? From an ethical and regulatory point of view, how can personal data be protected, knowing that the vehicle will be connected to a network at all times and therefore likely to communicate information outside the cabin? From an economic point of view, upheavals are to be expected in the value chain of the automotive sector with the rise of the GAFAMs in this field and the future management of vehicle systems by operators. On the societal level, what new services could emerge? Finally, from an environmental point of view, how can we ensure that the autonomous and connected vehicle minimizes our ecological footprint?

During this thematic sequence, students will be trained in functional modeling methods, a preliminary step in any complex system design, and in control techniques. A specific course on the issue will provide an overview of technologies used in this context such as digital methods of modeling, simulation and validation vehicles, electronic architectures embedded, processing of multi-sensor data fusion, artificial intelligence for the vehicle, and communication protocols V2V and V2X. During the integration course, students will have to put into perspective all the knowledge acquired, starting from a specification and going up to the validation on a physical platform, constituted here by a system of rolling robots.

Adviced prerequisites

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It is advisable to have taken the SPI Electronic Systems course and the SPI Networks and Security course.

Context and issue modules: This part is structured in conferences and round tables allowing to apprehend the problematic, the technologies and the stakes related to the autonomous and connected vehicle, namely the associated societal stakes such as safety, environment, traffic fluidity, the social-economic and industrial stakes.

Specific course (60 HEE) : Architecture and technology of the autonomous vehicle

Brief description:

A first part is interested in defining an autonomous vehicle mobility system and in particular its functional architecture (perception, processing, communication, actuation but also propulsion and energy conversion). At the system level, the aim is also to understand how autonomous driving systems or driver assistance systems (AD/ADAS) are developed and validated in the industry in order to ensure operational safety.

The course then focuses on the hardware architecture of the autonomous vehicle. First, the electrical and electronic architecture of the vehicle is described (power supply network, computers, communication bus). It is also a question of understanding the physical constraints to which these electronics are subjected (physico-chemical environment, EMC, reliability, manufacturing process of the cards, operating safety). The architectures and principles of embedded sensors (LIDAR, RADAR, cameras, intelligent sensors) are also addressed.

For a practical application of the concepts seen in this first part, the analysis of a level 4 autonomous vehicle experiment is conducted during a small group activity.

A second part addresses the treatments and algorithms implemented for the autonomous vehicle. Control laws specific to the autonomous vehicle are discussed (Linear Quadratic Regulator, Kalman filtering, neural networks, fuzzy logic...). The place of data fusion and the different techniques of heterogeneous data fusion are studied. Finally, the positioning of artificial intelligence (AI) in the autonomous vehicle is addressed, namely which architectures are relevant and the problems related to supervised learning and those solved by connectionist AI.

On the processing side, a practical session allows a first approach to image processing.

A third part focuses on vehicular communication technologies with a comparison of existing communication means. The evaluation of the performance of a vehicular communication network will be addressed and this includes a study of the link budget for coverage as well as an analysis of the different channel access mechanisms (Aloha, Slotted-Aloha and CSMA/CA). A practical session allows the practical application of the concepts seen in this part. S

Challenge week : Design of a "last mile" urban delivery system using autonomous and connected vehicles

Associated partner: Mathworks, Renault

- Location: Paris-Saclay campus

- **Short description :** The challenges of autonomous and connected vehicles do not only concern the automotive sector. The integration course proposed here will enable you to understand the design approach of a complex and critical system, and the plurality of issues of the autonomous and connected vehicle, through an industrial scenario in an appropriate context. The scenario chosen is that of a socalled "last mile" delivery, specified below.

The cost and delivery time of a parcel by carrier is strongly impacted by the last mile, especially in urban areas. Because of traffic jams and parking, delivery trucks could advantageously be replaced at the entrance to large cities by lighter means of transport adapted to the urban environment.

The use of bicycles is proving to be too costly; in the short term, transporters are considering a fully automated last-mile delivery. The solution consists of managing a fleet of autonomous and connected robots that carry out delivery routes based on arrivals, delivery addresses and the robots' characteristics.

Delivery trucks drop off the robots at the entrance of city centers. Each robot is in charge of one or more parcels and has a route to follow to deliver all the parcels as quickly and efficiently as possible. In addition to being able to move efficiently in an urban environment while avoiding obstacles, pedestrians and other vehicles, the robots must communicate with each other (V2V) and with the infrastructure (V2I) in order to avoid, for example, congestion points (demonstrations, work zones, etc.) and to have their route re-planned in real time.

You will work in a team in charge of designing such a delivery system. You will follow a model-driven system engineering approach to specify the system's functionalities. You will adopt a modeling methodology to develop the necessary algorithms (control/command, sensor fusion, data fusion, decision making and telecommunications) to meet the specifications. A small-scale test platform will allow you to evaluate the quality of the resulting delivery system and refine the algorithms.

During this work, you will have to take different points of view: system by establishing the control/command and communication strategy between vehicles; functions through the algorithms; components through your choices of implementation of these algorithms in order to take into account the specific constraints of the application (latency, limited resources, etc.)



2SC5310 – Architecture and technologies of smart and communicating vehicles

Instructors: Caroline Lelandais Perrault Department: DÉPARTEMENT ÉLECTRONIQUE ET ÉLECTROMAGNÉTISME Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY

Workload (HEE): 60

On-site hours (HPE): 34,50

Erasmus ECTS: 2,5 (+ introduction: 0,5 ECTS)

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 SPI courses in Electronic Systems (two occurrences in SG1 and two occurrences in SG3) and one of the SPI 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

I Mobility system and embedded electronics

 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

 \cdot The electrical and electronic architecture of the vehicle (power supply network, ECUs, communications bus)

 \cdot Hardware specificities in automotive electronics (physico-chemical environment, EMC, reliability, card manufacturing process, operating safety)

• Intelligent sensors (LIDAR, RADAR, cameras, smart sensors) II On-board algorithms and processing

 \cdot Control laws for the autonomous vehicle (LQR, Kalman filtering, neural networks, fuzzy logic...)

- · Artificial intelligence for autonomous vehicles
- · Heterogeneous data fusion techniques
- III Communication of the vehicle with its environment
- · V2X Technologies

 \cdot 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.

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): 27,00 Erasmus ECTS : 2

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 SPI module "Electronic systems" 1st-year SPI 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 reducedscale 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 – THE ECO-NEIGHBORHOOD, A COMPLEX SYSTEM. SUSTAINABLE DEVELOPMENT & COMPLEX PROJECT MANAGEMENT

Dominante : CVT (Construction, City, Transportation) and GSI (Large Interacting Systems)

Langue d'enseignement : French

Campus où le cours est proposé : Paris-Saclay

Engineering problem

The eco-neighborhood is an interesting case of a complex system. It requires a multidisciplinary approach combining real estate and construction, mobility (flows and infrastructures), urban networks and the problems of consumption of natural resources (water, energy, waste) but also geography, sociology and the history of places and people. It involves implementation at various scales, from the political decisions required for its emergence and implementation, to the geographical location of the catchment area and the various catchment areas for major facilities, to the choice of heating and lighting methods for each home.

The development market is undergoing a major transformation, with public developers ceding ground to private developers who are emerging among the various real estate developers.

The engineering problematic of this thematic sequence is therefore the following: how to approach all the studies necessary to the creation of an eco-neighborhood in order to make a coherent set of decisions?

The different pedagogical activities will allow students to acquire different technical and managerial skills:

- Knowing how to design or transform the complex systems that are econeighborhoods by integrating the many stakeholders with different, even divergent, roles and interests,

- Take into account sustainable development parameters to ensure that the concept of eco-neighborhood is achieved

- Know how to design and plan large complex projects, which can be considered as multiple interdependent projects

Adviced prerequisites

Sufficient level of French to be able to read and understand texts / articles in French

Context and issue modules: This part involves major players in the field who will share their vision and their roadmaps. It includes a presentation of the Plateau de Saclay development project by the EPAPS, a visit to a development project that has

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been or is being carried out in the IIe de France region (and if possible in Paris), and a presentation of international projects by various players.

Specific course (60 HEE) : Sustainable urban planning and development

Brief description: The specific course allows to approach the main disciplines which constitute the urban project, and to prepare the realization during the IE of the main deliverables produced during the design phase.

Disciplines: Initiation to the game of actors and the real estate value chain, smart city and sustainable city, urban and peri-urban agriculture, circular economy, energy issues, the Grand Paris Express and mobility, urban planning and eco-district reference.

Deliverables: Diagnosis, modeling and exploration of alternatives, economic balance sheet, convergence of multiple coordinated decisions, schematization / representation, scenario of use situations, macro-plan.

Challenge Week : Design project for an eco-neighborhood - the case of Corbeville

Associated partner: - finalization in progress

- Location: Paris-Saclay campus - site visit required

- **Brief description:** How to build the city? The city is made up of different structures: streets and public spaces, urban networks and energy in particular, public and individual transport, buildings and equipment... Complex project management tools are applied here to dissect the interplay of actors that allows the transformation of the city and to address all the disciplines and scales of territories to achieve these major projects.

The situation corresponds to one or several major (imaginary) modifying scenario(s): a 20-year delay of the metro line 18 or replacement of the metro by a tramway or any other scenario.... An urban design competition is launched to take into account this fundamental change.

The pedagogical objectives are the following:

- To handle on a concrete case the main concepts, methods and tools related to a complex project in the field of sustainable development and construction. The generic character and reusability to other contexts will also be important.

- Acquire a first set of knowledge related to the sectoral fields of urban planning, real estate development, smart grids and other urban networks, mobility (intermodality, and infrastructure) in particular.

At the end of the IE, students will have experienced the decision-making systems specific to urban development projects by having analyzed the key stages of specification, design and planning of such projects.



2SC5410 – Sustainable urban planning

Instructors: Frédérique Delmas-Jaubert Department: DÉPARTEMENT MÉCANIQUE, PROCÉDÉS, ÉNERGÉTIQUE Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 34,50 Erasmus ECTS : 2,5 (+ introduction: 0,5 ECTS)

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): 27,00

Erasmus ECTS : 2

Description

The purpose of integration project is to design an eco-district. Projects are carried out in groups of about twenty students, organized in smaller teams, according to two criteria : the eco-district objectives (urban form, economic balance, integration of nature, ...) and modules (residential buildings, public equipment, roads and networks). Several deliverables are expected, like: diagnosis of the territory and of the existing project, modeling of decision alternatives, economic results,

convergence towards multiple and coordinated decisions, visualization, usage scenarios, macro-plan.

Quarter number ST5

Prerequisites (in terms of CS courses) Specific module : sustainable urban planning

Syllabus

(if the case is confirmed)

The Corbeville ZAC: what future in the short, medium, and long term for this space near the interchange of the N118? A project was submitted by the EPAPS to a public inquiry in the spring of 2019. One or more significant parameters of the existing studies are modified (political orientation, mobility solutions, the ambition of density, ...). We propose to analyze the

consequences of these changes on the urban project.



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 group deliverables. An individual deliverable is also assessed.

Resources

Supervisors and experts are professors, architects, urbanists, engineers, researchers, ...

Franck Marle, Frédérique Delmas, Ulisse Vizzardi, Romain Iliou, Loup Calosci, François Cointe, François Cluzel, Arnaud Lafont,

Learning outcomes covered on the course

Upon completion of this module, students will progress in:

- using a transdisciplinary approach to complex eco-districts design

- 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 – LIGHT AND MATTER : DEVELOPMENT OF HIGH TECHNOLOGY INSTRUMENTS

Dominante : PNT (Physics & NanoTechnology)

Langue d'enseignement : French

Campus où le cours est proposé : Paris-Saclay

Engineering problem

Modern physics has many outlets through the control of the properties of matter and its functional engineering. In this ST, students will be confronted with the problem of innovation and product development when it is a high-tech instrument using physics, developed in small series for research or R&D. In particular, the students will answer the following questions

- how to qualify and respond to a customer need in this context?

- which approach to design, realization and evolution to implement?

- how to design a solution for an intermediate customer who has customers with various needs?

The integration courses concern devices at the cutting edge of physics requiring a real engineering approach since the theoretical concepts are applied to real devices that must integrate elements of feasibility both technical and economic.

Adviced prerequisites

It is recommended to have taken the SPI course of Wave Physics or Transfer Science

Context and issue modules: This part is structured around half-day training sessions aimed at presenting the sequence, the integration lessons and introducing the theme. The following lectures/presentations will be organized:

- Presentation of the theme and its challenges
- Round-table discussion on professions: What is a physics engineer?
- Visit of a company
- Presentation of the El

Specific course (60 HEE): Physics of Matter

Brief description: The course will provide students with a basic understanding of the physics of solid state matter. Crystallography and wave diffraction (especially X-rays), lattice vibrations (phonons, thermal effects), electronic states (Sommerfeld model, band theory), as well as specific topics: semiconductors, defects,



superconductivity will be covered. The goal is to show students that the understanding and control of material properties requires studies at the microscopic scale.

Challenge Week n°1 : Synchrotron Beamline Design

- Associated partners: European Synchrotron Radiation Facility (ESRF, Grenoble), SOLEIL synchrotron (Gif-sur-Yvette), ALBA synchrotron (Barcelona)

- Location: Paris-Saclay campus

Brief description: the objectives are the following:

- To dimension a device using basic (modern) physics notions and to do functional modeling.

- Identify the relevant heat transfers, model them, and size these systems.

- Know the key points of a pre-project study in a multidisciplinary context

- Have realistic orders of magnitude on the standard mechanical and physical properties of "common" materials.

- Carry out a preliminary design of the scientific instruments studied, justifying the choices made.

- Work in a team, know and be able to identify the different roles of the members of a team, lead and coordinate a work group, collect and share information, format and present the work done (express oneself in front of an audience / defense)

Challenge Week n°2 : Quantum cascade lasers

- Associated partners: Airbus Defence and Space, Thales

- Location: Paris-Saclay campus

- **Brief description:** Quantum cascade lasers are nano devices invented about 20 years ago. Engineering miracles, their operation has been made possible by the latest advances in quantum mechanics, optics and thermics. Due to their very small size, operating wavelength and precision, they are a technological solution of choice for the detection of minute traces of pollutants as well as high-speed communications in free space.

In a team work, the students will be brought to familiarize themselves with these notions and to acquire the mathematical elements necessary to numerically model the behavior of these systems. They will have to implement an engineering approach to transform their theoretical knowledge into an object constrained by the reality of the world.



2SC5510 – Physics of matter

Instructors: Hichem Dammak

Department: DÉPARTEMENT PHYSIQUE

Language of instruction: FRENCH

Campus: CAMPUS DE PARIS - SACLAY

Workload (HEE): 60

On-site hours (HPE): 34,50

Erasmus ECTS: 2,5 (+ introduction: 0,5 ECTS)

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 optoelectronics 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): 27,00 Erasmus ECTS : 2

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
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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 preproject, 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

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

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- 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): 27,00 Erasmus ECTS : 2

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 – MULTI-ENERGY SYSTEMS

Dominante : ENE (Energy) and GSI (Large Interacting Systems) Langue d'enseignement : French Campus où le cours est proposé : Paris-Saclay

Engineering problem

The objectives of reducing energy consumption and polluting emissions make it necessary to use energy systems that call on sources with complementary yields and characteristics. This is the case for electricity production systems, where the growth of intermittent renewable production requires more flexibility from conventional production means, and also for the transport sector, where electric and thermal engines complement each other advantageously.

These multi-energy systems require advanced control modes to take advantage of the complementarity of energy sources, and to satisfy the needs of users and the economic, technical and environmental constraints.

Adviced prerequisites

It is adviced to have taken at least one of the SPI Transfer Sciences or Electrical Energy courses.

Context and issue modules: This part is organized around half-days of training aiming to present the sequence, the integration teaching and to introduce the stakes and associated locks, in particular under the economic aspects and related to the social and geopolitical environment of the topic.

Specific course (60 HEE) : Introduction to energy production

Brief description: the course is structured in two parts:

1. Thermal energy conversion

- Internal combustion engines: introduction to internal combustion engines (architecture, thermodynamic cycle, operation and control, pollutant emissions, basic sizing)

- Turbomachinery (turbojet, turboalternator): introduction to turbomachinery (architecture, thermodynamic cycle, operation, control modes, interest)

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- Introduction to the physics of nuclear reactors: presentation of energy production by nuclear reactors, from the reactor to the steam generator.

2. Electrical energy conversion

- Structure of alternating current machines, motor/generator operation

- Electronic converters.
- Principles for speed variation of machines (machine and converter system)

Challenge week n°1: Regulation and control of energy production and conversion systems

- Associated partners: EDF, GE Converteam
- Location: Paris-Saclay campus

Brief description: the objectives are :

- To be able to model an industrial physical system for a control purpose

- Understand the impact of the regulation of an installation on the overall operation of the electrical system

- To do functional modeling to determine the control strategy of a system
- Be able to develop a control law that meets the specifications

- Take into account the specificities of the conversion elements to associate them and create a system

Challenge week n°2: Hybrid powertrain

- Associated partner: to be confirmed
- Location: Paris-Saclay campus
- Brief description: the objectives are :
- Implement a systemic model of the hybrid powertrain
- Implement numerical processing tools under Matlab/Simulink
- Implement a control approach of the whole hybrid chain from the driver to the wheels

- Introduction to cycle sizing: complexity of the system and contradiction of several objectives to be achieved

Challenge week #3: Hybrid aeronautical propulsion

- Associated partner: Safran Tech



- Location: Paris-Saclay campus

- **Brief description:** The integration course deals with power management in the context of a small single-engine aircraft with a hybrid battery/fuel cell energy architecture. The aircraft is propelled by a propeller powered by an electric motor and electricity is either directly drawn from batteries or generated by the combination of H2 and O2 in a fuel cell. The objectives are as follows:

- Realize a part and then assemble the whole systemic model of the energy architecture of the considered hybrid aircraft

- Implement the numerical resolution tools via Simulink and analyze the data collected

- Develop the regulation strategy of the system according to the given constraints

- Critique the model used in relation to the state of the art



2SC5610 – Introduction to energy production

Instructors: Maya Hage Hassan, Amir Arzande Department: DÉPARTEMENT SYSTÈMES D'ÉNERGIE ÉLECTRIQUE Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 34,50 Erasmus ECTS : 2,5 (+ introduction: 0,5 ECTS)

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

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): 27,00 Erasmus ECTS : 2

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, a cogeneration 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
 - o Definition, if possible, of an innovative control law strategy
 - $\,\circ\,$ 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): 27,00 Erasmus ECTS : 2

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

Prerequisites (in terms of CS courses) Electric energy

Syllabus

 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

 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





Instructors: Antoine Renaud Department: DOMINANTE - ENERGIE Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 40 On-site hours (HPE): 27,00 Erasmus ECTS : 2

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

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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

- 13. Battery core electrochemistry
- 14. Thermal management
- 15. 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 subgroups 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 – CONTROL OF ACOUSTIC AND ELECTROMAGNETIC POLLUTION

Dominante : MDS (Mathematics, Data Science) and Info&Num (Computer Science and Digital)

Langue d'enseignement : French

Campus où le cours est proposé : Paris-Saclay

Engineering problem

Noise pollution is nowadays considered as a major annoyance by the population, while electromagnetic pollution raises many questions and interrogations related to health problems. The practical realizations allowing to control this pollution represent a technical and industrial challenge of the first rank, but do not yet benefit from the new developments that mathematical analysis, numerical simulation and data processing can bring.

This course focuses on the design of innovative products (acoustic or electromagnetic coatings) intended to control acoustic/electromagnetic pollution. Having introduced the physical context, it aims to give students the mathematical and computer science notions associated with the design and manufacture of such products. This teaching proposes two paths of training:

1. Mathematical Methods Track: a track based on mathematical theory (PDEs, functional analysis, Fréchet derivative) associated with numerical algorithms to master the control of waves to define the shape of an acoustic or electromagnetic coating. In particular, in this track are treated the PDEs on irregular edges (fractals) and is developed the method of optimization of shapes and the notion of the derivative with respect to the edge.

2. Scientific Computing, numerical methods and algorithms: the objective of this track is to deepen the numerical methods used in the mathematical track, it is oriented towards scientific computing. By focusing on the same common goal as the mathematical track, this track allows to go further in the numerical implementation of the method of optimization of forms.



Both tracks study methods (theoretical or numerical) that are useful for controlling external acoustic waves (in the vicinity of highways, airports, construction sites) or internal acoustic waves (sound insulation in offices by perforated panels or acoustic liners in aircraft engines for example), as well as for controlling electromagnetic pollution (anechoic chambers).

The integration course allows students to apply the skills and knowledge acquired in the case of a chosen application to guarantee the best performance while taking into account regulatory, environmental and economic constraints.

The intervention of industrialists (ONERA, SIEPEL) and specialists in the design of anti-noise walls allows a better understanding of the economic constraints and issues associated with the design and operation of innovative products.

Adviced prerequisites

For the "Mathematical Methods" track, mastery of the first year PDE course is required. From a general point of view, having followed the SPI course "Physics of Waves" would be a plus.

Context and issue modules: This part is organized around half-days of training aimed at presenting the sequence, the integration teaching and introducing the issues and associated locks. Thus, the following topics will be addressed: fractals for innovation in acoustic and electromagnetic applications, control by acoustic liners in aeronautical engines, current challenges in the control of electromagnetic waves, research and innovation in the control of waves.

Specific course (60 HEE) : Wave control: theory and algorithmic

Brief description: The two proposed tracks have the same objectives. The concepts of the common course of Automatic are deepened in the context of the control of the dissipation of the energy of a wave. The observability in this case depends on the geometry of the absorbing edge. To illustrate the reasons why geometric irregularity is needed, the notions of fractal geometry are introduced with results known in physics and, for the theoretical way, in mathematics. In particular, we present the phenomena of localization and absorption of waves (acoustic or electromagnetic) which are linked by the spectral analysis of the model (theoretical and numerical). In order to better understand the environmental and sociological stakes of the development of acoustic barriers, some psycho-acoustic aspects are presented, which show the importance of the dissipation of certain



frequencies. The course studies in particular, for a fixed frequency, the obtaining of an optimal form for a frequency model via the Helmholtz equations with the aim of allowing its use in AR on two types of control: geometric and topological. For the numerical path, the algorithmic part of this method will be presented in detail. In the mathematical path, these numerical methods will also be presented but much more briefly.

We then consider the main difficulty of having a "near optimal" shape over a large frequency band, important from a psycho-acoustic point of view and from industrial interests. The final goal in AR is to be able to quickly and robustly determine the optimal or "near optimal" shape of the geometry over a frequency band by numerical simulation.

The two proposed tracks include a joint numerical project on eigenmode localization and two different examination topics.

Challenge week n°1: Design of a cladding to control wave pollution Control of external acoustic pollution

- Associated partner: ONERA
- Location: Paris-Saclay campus

Brief description : We position ourselves on the industrial issues that impose economic constraints and technological constraints necessary for the improvement of existing products on the market, to design innovative coatings to absorb noise from aircraft, trains, cars. The aim is to develop these innovative products in an optimal way by controlling the energy of the waves through the geometry of the wall while taking into account the economic constraints. For example, COLAS and École Polytechnique have developed a noise barrier called "Fractal Wall" TM, which was empirically designed with a complex geometry to dissipate the different wavelengths. However, this wall, even if it is four times more efficient than conventional walls for low frequencies, is hardly sold... The explanation lies in the fact that its construction, being done by demolding, risks breaking the wall, which results in a high manufacturing cost. This AR proposes to find, by wave control methods, optimal shapes as absorbent as possible (in decibel) which satisfy the constraints imposed by the industrialist, for example, the lowest manufacturing cost with the highest decibel reduction. First numerical results in this context show the existence of optimal shapes "not too complex" able to improve by a factor of 6 the performances of the "Fractal wall" TM.

Challenge week n°2 : Design of a cladding to control wave pollution. Control of indoor acoustic pollution

- Associated partner: ONERA



- Location: Paris-Saclay campus

- Brief description : We are positioned on the industrial issues that impose economic constraints and technological constraints necessary to improve existing products on the market, in order to design interior coatings to absorb noise inside buildings and also acoustic liners in aircraft engines. In this context we are interested in three main applications: (i) the design of liners in anechoic chambers (so far acoustic anechoic chambers have been designed empirically based on geometries using different scales), (ii) the design of perforated absorbing panels (absorbing materials are made of fibers that have very good absorbing acoustic properties, and are usually covered with wooden panels for aesthetic reasons, which unfortunately impairs their effectiveness) and finally (iii) perforated absorbing insulators in aircraft engines. In the last application it is important to optimize the diameter and positioning of the holes in the material. The objectives are to control the waves as well as possible by an analysis of the optimal shape of the surface of these coatings in order to improve the acoustic absorption in decibel by taking into account the industrial stakes and constraints.

Challenge week n°3: Design of a coating to control wave pollution. Control of electromagnetic pollution

- Associated partner: ONERA
- Location: Paris-Saclay campus

- **Brief description :** We position ourselves on the industrial stakes, presented by SIEPEL, which impose the economic and technological constraints necessary to improve the existing products on the market, in order to absorb the electromagnetic waves. As fields of application, we aim at the design and the optimization of an anechoic chamber. We notice that the absorbing materials for electromagnetic waves are different from the dissipative materials for acoustic waves. The different nature of these waves implies an adaptation of the model seen in class.



2SC5710 – Theory and algorithmics for wave control

Instructors: Anna Rozanova-Pierrat Department: DÉPARTEMENT MATHÉMATIQUES Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 34,50 Erasmus ECTS : 2,5 (+ introduction: 0,5 ECTS)

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) 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 boundary.

2) Digital analysis path, numerical and algorithmic methods, directed by M. Magoulès: this path aims to deepen the numerical methods, 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 Els proposed subsequently. More precisely, they study the methods (theoretical or numerical) which are useful for the themes of the three Els: 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)

SPI 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, 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 for the Theoretical Analysis Track.

Numerical project evalueted as 70% in the final note and the project evaluated as 30% in the final note for the Numerical Analysis Track.

Course support, bibliography

- F. Magoulès, P.T.K. Ngyuen, P. Omnes, A. Rozanova-Pierrat, Optimal absorbtion of acoustic waves by a boundary} SIAM J. Control Optim. Vol. 59, No. 1, (2021), pp. 561-583.
- 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 (by the choice of students) 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. To validate the Numerical Analysis track there is a numerical



project and to validate the Mathematical Analysis track there is an written exam of 1.5 hours. 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 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 wellposed 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 Department: DOMINANTE - MATHÉMATIQUES, DATA SCIENCES Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 40 On-site hours (HPE): 27,00 Erasmus ECTS : 2

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: Frédéric Magoules Department: DOMINANTE - MATHÉMATIQUES, DATA SCIENCES Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 40 On-site hours (HPE): 27,00 Erasmus ECTS : 2

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: Anna Rozanova-Pierrat Department: DOMINANTE - MATHÉMATIQUES, DATA SCIENCES Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 40 On-site hours (HPE): 27,00 Erasmus ECTS : 2

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

 $^{\circ}$ 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)

 $\,\circ\,$ Validate the theoretical and numerical techniques of the control of the electromagnetic waves

 $\,\circ\,$ Confront students with the realization of a complex product by numerical simulation techniques



ST5 – 58 – COMPLEX INDUSTRIAL AND CRITICAL SYSTEMS WITH DOMINANT SOFTWARE

Dominante : Info&Num (Computer and Digital)

Langue d'enseignement : Freench

Campus où le cours est proposé : Paris-Saclay

Engineering problem

This thematic sequence approaches an axis of software sciences through the implementation of a development cycle allowing the design of complex industrial and critical systems where software is preponderant. Modern industrial systems are often composed of heterogeneous interacting components that can be defined as complex systems (systems of systems). What characterizes such systems is that they are often software dominated (e.g. cyber-physical systems). Moreover, their behavior is often difficult to apprehend because of the emergence of global behaviors that cannot be anticipated at a more local level. Finally, they are critical in the sense that the slightest design error can have crippling consequences on the global behavior of the system.

More precisely, this thematic sequence aims at addressing both the design and the verification of such complex and critical systems by using techniques from Software Engineering. As the components of such systems are heterogeneous (i.e. both physical and software), the methodologies and tools presented in this topic will be multiple and will be integrated in a development cycle. The idea is to start the analysis phase using semi-formal tools (UML, SysML, ...), often used in systems engineering to describe the structuring of the system and its interactions, and then to scientifically approach the design and validation phases using formal techniques of Software Engineering (timed and hybrid modeling, temporal logic, model-checking) The interaction of the system with its external environment (which can be the human user or not) is one of the main points that will be taken into account.

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 proper functioning. In the latter case, the economic gain is very interesting and appreciable by the engineers who will benefit from correcting the problems detected by the verification of the model before moving on to the implementation stage (programming).

Adviced prerequisites

None



Context and issue modules: This part is structured around half-days of training aimed at presenting the sequence, the integration teaching and introducing the theme. Thus, conferences and round tables will be organized on the current state of model-driven engineering in the industrial world and the challenges for the future; or entitled "The application of Formal Methods to Railway Signalling Software".

Specific course (60 HEE) : Design and verification of critical systems

Brief description: a critical system is a system whose failure can have serious consequences, such as transportation systems (trains, planes, cars ...) or energy production systems (nuclear, wind ...). These systems are complex and in order to guarantee their proper functioning, it is necessary to take into account the continuous and event-driven aspects of their dynamics. A part of the course will therefore be dedicated to the design and modeling of critical and complex systems. In addition, their reliability is a major economic and societal issue. Another part of the course will then be dedicated to the methods and tools (formal or semi-formal) proposed to guarantee the safety properties during the design phase.

Challenge week n°1: Design of a safe signalling system for railways

- Associated partner: Systerel
- Location: Paris-Saclay campus

Brief description: In a railway system, it is essential that the points do not move when a train runs over them, otherwise there is a high risk of derailing. To this end, a signaling system has signals (a bit like traffic lights on the road) that allow to ask trains to stop before the switches. Things get more complicated if the train is too close to the signal to stop (same problem as an orange light for a car). The objective of this case study is to formally model such a system and to show that it is safe: the trains will not derail.

Challenge week n°2: Design of intelligent systems for automated air traffic control

- Associated partner: to be confirmed
- Location: Paris-Saclay campus

- Brief description: Critical information systems in the avionics field are subject to very important time and reliability constraints. Their development therefore requires engineering techniques that take these characteristics into account from the early phases of their life cycle. This AR focuses on the design of models of intelligent systems to control air traffic and the verification of certain safety properties on these models. These systems implement many strongly interacting components, which are parallel and asynchronous. All these subsystems are subject to verification and testing to ensure their own functionality. For example, it is



critical to demonstrate the absence of deadlocks and the ability of each to operate correctly within their own time constraints. It is also important to schedule the actions of these subsystems and ensure a reliable control of the whole system. As an example, some important properties (formulated in STL) to check: 1) Air traffic should never be allowed in both directions simultaneously on the same route 2) The aircraft must respond to messages within a limited time 3) For two aircraft, there must be a separation with a minimum distance.

Challenge week 3: Design and analysis of production systems for smart factories

- Associated partner: to be confirmed
- Location: Paris-Saclay campus

- Brief description: Industry 4.0 or "smart factories" are concepts that define the fourth industrial revolution, which began at the beginning of the 21st century and continues to develop. This revolution is deeply linked to the evolution of information and communication technologies (ITC). When these technologies are integrated into production systems, new characteristics appear. Indeed, production systems are not only able to communicate with other systems and their environment, but they are also able to make decisions at the local level. These characteristics allow for more flexibility and agility in production strategies and entail a need for flexible, low-volume, high-mix manufacturing in a highly uncertain environment in which planning and control of production under disruption becomes a decisive decision-making issue. In this AR, students will tackle, through specific case studies, typical problems in the design of flexible production systems (i.e. task scheduling problem in production, production robustness analysis, etc). Through modeling tools (e.g. probabilistic model checking) that allow to take into account different uncertainty factors, students will learn basic principles for performance analysis and optimization of these systems that are the basis of smart factories.



2SC5810 – Design and verification of critical systems

Instructors: Idir Ait Sadoune Department: DÉPARTEMENT INFORMATIQUE Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 34,50 Erasmus ECTS : 2,5 (+ introduction: 0,5 ECTS)

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, modelchecking). 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)

- \circ Information systems and programming
- Algorithmics and complexity
- $\,\circ\,$ Model representations and analysis

Syllabus

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- 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): 27,00

Erasmus ECTS: 2

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

- - Modeling a critical system using the B formal method.
- - Modeling Safety properties in the railway systems.
- - Verification of Safety properties by using theorem proving.
- - 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

- 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.
- C3.6 Evaluate the efficiency, feasibility and strength of the solutions offered.
- 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): 27,00 Erasmus ECTS : 2

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 important safety properties. 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 of Model 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): 27,00 Erasmus ECTS : 2

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 AND AUTONOMY OF THE PERSON

Dominante : VSE (Living-Health-Environment) and ENE (Energy)

Langue d'enseignement : French

Campus où le cours est proposé : Metz

Engineering problem

This thematic sequence deals with the design of motorized assistance systems for people with reduced mobility, whatever their nature, in its technical, economic and ergonomic aspects. This issue, which has a strong societal impact, is at the heart of two concerns. Firstly, the ageing of the population is increasing the need for this type of system. In addition, due to the evolution of low-cost on-board computer systems, it is now possible to offer increasingly complex functionalities, allowing the spectrum of services provided to be broadened, ranging from motor servoing to more advanced control (trajectory calculation, obstacle avoidance) or even connected and communicating systems.

For example, a very common device nowadays is the wheelchair to help people with reduced mobility (paralysis of the legs). These chairs can be simply mechanical or electrically assisted. Reimbursed by the social security, they are medical devices subject to approval.

Beyond the technical problems, one must also consider the cost (in France the price is fixed by the social security) and the ergonomics. Experiments are taking place on systems that could be different, such as exoskeletons.

Adviced prerequisites

None

Context and issue modules: this part is structured in conferences and round table allowing to apprehend the problematic, the technologies and the stakes of the devices related to the person:

- Environment, type of pathology, manual and electric wheelchairs. Homologation

- How to improve people's lives
- Demonstration of wheelchairs, technological locks, innovation

Specific course (60 HEE): Control of a motorization chain

Short description : This course deals with the notions necessary for the control of a motorization chain in its electronic aspects (converters, power, supply), servo control (modeling, observers, regulators) and digital (analog-digital conversion,



programming, real time). The practical aspects will be tested on microcontroller boards in order to implement a speed control system for a DC motor.

Challenge Week : Design of a motorized wheelchair for people with reduced mobility

Associated partner: Logosilver Company, CERAH (Center for Study and Research on the Fitting of the Handicapped)

- Location: Metz campus

- **Brief description :** A wheelchair for a person with reduced mobility must ensure a minimum level of safety set by standards. Mechanical design and motor control work together to achieve this safety. The confrontation of the students with the normative and security aspects at the same time as with the mechanical and electronic/computer technical aspects opens them to the multidisciplinary dimension. The specificity of this integration course is the consideration of safety in technical designs. In addition, as current trends are for all objects to be increasingly "connected", functions of this type will be considered (steering the chair from a smartphone, steering the house from the chair, etc.).

This integration course is designed to lead to the concrete realization of a wheelchair. The whole is a mini-project sequenced in individual thematic sessions (mechanics, electronics, computer science, automation...). The themes can be variable according to the groups of students (not all groups do all the themes) and will follow a schedule allowing to arrive at the end at an operational chair.

2SC5910 – Control of a motorization chain

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Instructors: Jean-Louis Gutzwiller Department: CAMPUS DE METZ Language of instruction: FRENCH Campus: CAMPUS DE METZ Workload (HEE): 60 On-site hours (HPE): 34,50 Erasmus ECTS : 2,5 (+ introduction: 0,5 ECTS)

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-anda-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 – Design of a motorised wheelchair for people with reduced mobility

Instructors: Jean-Louis Gutzwiller

Department: DOMINANTE - VIVANT, SANTÉ, ENVIRONNEMENT, DOMINANTE - ENERGIE Language of instruction: FRENCH Campus: CAMPUS DE METZ Workload (HEE): 40 On-site hours (HPE): 27,00 Erasmus ECTS : 2

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 otherC6.3 : 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 – SEMI-AUTONOMOUS NAVIGATION OF DRONES

Dominante : MDS (Mathematics and Data Sciences)

Langue d'enseignement : English

Campus où le cours est proposé : Metz

Engineering problem

Data collection by a human is sometimes extremely difficult, e.g. for exploration/monitoring of abandoned mines or disused buildings, crop monitoring, environmental monitoring. What makes it difficult for a human to explore these areas may depend on the congestion of these areas (e.g. riprap in mines), the accessibility of these areas (e.g. monitoring the state of dykes, river banks ...), the size of the territory to be covered (e.g. monitoring agricultural crops, rivers). In this respect, the recent development of drones offers many opportunities but also raises several problems. To date, the piloting of a drone still requires a certain level of expertise since its control is quite low level. We can then consider a piloting assistance where some aspects of the drone control are managed automatically, due to a processing of the sensors' information flows by machine learning techniques. This semi-autonomous control requires in this case to build from the information of the sensors more integrated representations from which the human, as well as the automatic controller which assists him, can ensure in concert a robust navigation of the UAV.

Adviced prerequisites

The specific course and the integration teaching require a mastery of several tools (ROS, Linux,...) to which the students will be trained. However, this training to these new tools requires a real motivation and implication of the students. It is also necessary to have skills in Python programming.

Context and issue modules: This part is structured in conferences and round tables allowing to understand the problems, technologies and stakes related to the use of UAVs in several target areas of the sequence (interventions to be confirmed from Parrot, Safran...)

Specific course n°1 (10 HEE) : Introductory practical work

Brief description : These practical works aim at training students to use Linux (Ubuntu), OpenCV under Python. The knowledge acquired will be used in the other activities of the sequence.



Specific course n°2 (60 HEE) : Autonomous Robotics

Short description : This course will present the field of autonomous robotics (vehicle driving, exploration and inspection robots, ...) by showing how this problematic integrates very diverse technologies (localization (SLAM), point clouds, planning, pattern recognition) and how this integration is achieved at the system level (illustrations with ROS). The laboratory work associated with the course will be carried out on the Turtlebots mobile robots available in the smartroom of the Metz campus. This work will be an opportunity to integrate different machine learning and signal processing techniques on robots moving in their environment by progressively building a system allowing manual control but also autonomous mapping and navigation in an unknown environment.

Challenge Week : Building inspection by a semi-autonomous drone (quadricopter)

Associated partner: Parrot

- Location : Metz campus

- **Short description :** Students will work on issues related to technical inspection by drones (visual and thermal diagnosis) of hard-to-reach areas of industrial sites, on case studies provided by the industrial partners. They will thus provide answers to their needs in terms of improving energy performance and detecting possible degradations, allowing in particular significant savings at the level of the sites considered.

The students will have implemented servo-control techniques with the particularity of including a human operator in the control loop. They will also have integrated machine learning techniques (vector quantization, supervised learning) on an industrial case, for the interpretation of information flows from sensors (mainly video). This is a first contact with the field of machine learning through the application and experimental side. They will have acquired, through this experience, a more general competence on the design of robotic systems with ROS.



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): 34,50 Erasmus ECTS : 2,5 (+ introduction: 0,5 ECTS)

Description

This course will present the field of autonomous robotics (vehicle driving, exploration and inspection robots, etc.) by showing how this problem integrates very diverse technologies (localisation (SLAM), point clouds, planning, pattern 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 Turtlebots mobile robots available in the smartroom of the Metz campus. This work will be an opportunity to integrate different techniques of machine learning and signal processing on robots moving in their environment by progressively building a system allowing a manual control but also a mapping and an autonomous navigation in an unknown environment.

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) : Primer on Bayesian inference
- 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

Total:

Lectures : 13.5 HPE Tutorials : 3 HPE *Introductory Lab : 6 HPE* Lab works: 16.5 HPE

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

<u>Instructor :</u> 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 preinstalled

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): 27,00 Erasmus ECTS : 2

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.

Warning: One of the major achievement of the sequence is the experimental validation on real quadrotors in the corridors and gymnasium of the school. This requires you to master several tools (ROS, Linux, ...) and skills in Python programming. A lot of work and a real motivation are required from the students; The volume of the ST5 and the availability of the teaching staff are reinforced to help you to achieve these goals.

Quarter number



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

ST5

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

<u>Instructor</u> : Hervé Frezza-Buet, Jérémy Fix <u>Student groups</u>: 5 students <u>Softwares</u> : Only open source softwares (Linux, Python, ROS, Gazebo-Sphinx) <u>Hardware</u>: Each group of students will have one bebop2 (lent by Parrot), a joystick, and a laptop <u>Lab works</u> : The computers in the labs will have all the softwares preinstalled



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 (Physics and NanoTechnology), SCOC (Communicating Systems and Connected Objects)

Langue d'enseignement : English

Campus où le cours est proposé : Metz

Engineering problem

Systems using photonics - science and technology exploiting light - allow to measure, regulate and control physical quantities. These properties of photonic systems are widely used in the regulation of a laser for production systems, in the control of the deflection of a beam to visualize an object or observe the dynamics of biological cells, or in the stabilization of ultra-short pulses in telecommunications. In addition, photonic systems are intelligent systems whose measurements are used to facilitate regulation, for example with the development of telemetry and laser velocimetry - techniques widely used in industrial production and in our vehicles, and essential for the industry of the future and the autonomous vehicle.

Very recently, photonic systems have undergone a revolution in their principle and their use with the development of systems that exploit light at the nanometer and attosecond scales. These innovative systems by their new physics pose important challenges for both the measurement of their physical properties - given the very short spatial and temporal scales - and the exploitation of this measurement for the development of sensors and innovative control systems, given the limitations of our signal processing systems. By studying photonic systems, this thematic sequence will also be an opportunity to learn and master the general notions of analysis, identification and control of non-linear physical systems.

Adviced prerequisites

Basic knowledge of electromagnetism, materials, general electricity and electronics

Context and issue modules: This part is structured in conferences, round table and visit of the GDI SIMULATION site - Elancourt, in particular around the theme of "laser remote sensing".

Specific course (60 HEE) : Photonics for the control of physical systems

Brief description:



This course will teach the essential concepts of measurement and exploitation of physical quantities of optical electromagnetic waves, in the context of the exploitation of photonics for the observation and control of physical systems. Thus this course will assemble knowledge of:

- Optical measurement and instrumentation: general metrology and error analysis, photometry, and optical detectors, holographic metrology, velocimetry, interferometry.

- Laser source technologies: solid state physics, materials and semiconductors.

- Modeling and control of sources: analysis and non-linear dynamics of laser sources.

- Optical signal generation: techniques for spatial and temporal modulation of optical signals; engineering and design of optical beams.

The concepts covered in the course are :

- Optical metrology

- Photonic technologies including semiconductor materials and optical fibers, phase and intensity modulation

- Signal analysis using the non-linear dynamics of a physical system
- Properties and control of non-linear systems

Challenge Week : Laser remote sensing (LIDAR) for optronic surveillance and target detection

Associated partner: GDI SIMULATION - Elancourt

- Location: Metz campus

- **Brief 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 a photonic system whose target application is laser ranging (LIDAR). These lidars have a huge potential for defense, environment, security: identification of mobiles, gas detection, active imaging ... The detection and identification of danger or targets is a key element of defense and security devices, and are key elements for example of the devices developed by GDI SIMULATION for civil aviation or the simulation of laser fire for the training of armed forces.

Recent advances in the realization of innovative optical beams will allow the exploration of new beam topologies (e.g. Airy beams: non-diffracting, curvilinear trajectory, self-regenerating in case of obstacles) which open the way to improved performances (spatial resolution, speed, etc.). Through this AR, students will apply: i/ understanding of the essential physical quantities related to an optical electromagnetic wave ii/ design and realization of a servo-driven photonic system iii/ numerical simulation of the optical system iv/ engineering of innovative optical beams by exploiting spatial and temporal signal modulation techniques v/ ability to



make a choice of devices to answer an economic problem of sizing and energy consumption.



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): 34,50 Erasmus ECTS: 2,5 (+ introduction: 0,5 ECTS)

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: Nicolas Marsal, Delphine Wolfersberger, Marc Sciamanna

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: Delphine Wolfersberger Department: DOMINANTE - PHYSIQUE ET NANOTECHNOLOGIES Language of instruction: ENGLISH Campus: CAMPUS DE METZ Workload (HEE): 40 On-site hours (HPE): 27,00 Erasmus ECTS : 2

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 GDI Simulation 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 GDI Simulation

Resources

optical set-ups Pedagogical Team : Delphine Wolfersberger - Nicolas Marsal

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: nondiffracting, 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 ÉNERGÉTIQUE ET SMART BUILDING

Dominante : GSI (Large Interacting Systems) and SCOC (Communicating Systems and Connected Objects)

Langue d'enseignement : French with specific modalities to allow the adaptation of students with a low level in French: all the materials are in English, the tutorials, the practical work as well as the integration teaching are provided in English. Support sessions in English are also scheduled.

Campus où le cours est proposé : Rennes

Engineering problem

Buildings must no longer be considered as simple consumers, but as true energy players, fully integrated into their ecosystems, and must be fully integrated into a renewed vision of society, where comfort and health are in harmony with energy management. To do this, we need to rethink the systems that make up the building, through new control functions and stronger interactions with the occupants. The "building" ecosystem is complex, because it is made up of a heterogeneous set of systems: local production, storage, supply, sale, and the various equipment, which must be coordinated for optimized management.

The engineer's challenges are first to analyze the needs and to specify the 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 lifetime.

Adviced prerequisites

None

Context and issue modules : This part is organized around several conferences that should give students the keys to understanding the major issues associated with this thematic sequence. Starting with the industrial issues: what are the needs of today and tomorrow, in terms of services and technologies: challenges and scientific obstacles. Then presentation of the difficulties encountered for the capture of heterogeneous data from which we can perform analyses and exploit these data.

Knowledge contributions will be given to understand the needs and the heterogeneity to be taken into account for the management of comforts (air quality, thermal comfort, ...). Finally, a last intervention will present the "Research" point of view around intelligent buildings.

3

Specific course (60 HEE) : Students will be required to choose from one of the following two specific courses:

Option 1: Energy-efficient communications

Brief description: With a global electricity consumption of 6 to 10% corresponding to 4% of greenhouse gas emissions, ICST (Information and Communication Sciences and Technologies) must rethink the way they transmit, process and store data. The arrival of 5G (5th Generation mobile) and the explosion of connected objects (Internet of Things) suggest that the sector will continue to grow strongly in the coming years, making it all the more urgent to offer more environmentally friendly communications. The need for spectral efficiency (transmitting a given data rate in a given bandwidth) must then be combined with a strong energy efficiency constraint (transmitting while consuming as little as possible). This course provides training in digital communication concepts and tools for which energy efficiency is explicitly taken into account.

Option 2: System architecture and modeling

Brief description: Today's systems are increasingly complex. This complexity comes from the complexity of their structure and the interactions between the different components, the increase and the complexity of the exchanged data, the heterogeneity of concepts, substances, trades, standards, but also the human complexity (organization, ergonomics, psychology, sociology...). In order to better control this complexity, it is often necessary to rely on a modeling of the different artifacts of the system. This modeling allows, at different phases of the system's life, to better understand the needs it must meet, to structure its architecture, to make analyses in order to predict its behavior and thus to make a justified choice between several solutions. The different models constitute a common reference for the different parties involved in the design of the system. The objective of this course is to train students to model and structure a system architecture. Technological systems will be privileged with domains such as avionics, railways, industry, health, energy etc. Emphasis will also be placed on the ability to identify the characteristic performance attributes essential in the design, implementation, operation and management of complex systems.

Challenge Week : Hierarchical management of thermal comfort

Associated partner: Bouygues Energies & Services

- Location: Rennes campus

- **Brief description :** The objective is to define a modular system, allowing the implementation of hierarchical control strategies between a local regulation of comfort per zone and a supervisor managing the intermittence 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 the



technologies allowing the implementation. The different groups will have to collaborate to address the different aspects of the project and to achieve a proof of concept.



2SC6210 – High energy performance communications

Instructors: Yves Louet Department: CAMPUS DE RENNES Language of instruction: FRENCH Campus: CAMPUS DE RENNES Workload (HEE): 60 On-site hours (HPE): 34,50 Erasmus ECTS : 2,5 (+ introduction: 0,5 ECTS)

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 noconstant envelope signal Continuous Phase Modulation (CPM) modulation format with constant envelope (MSK, GMSK, FSK, OQPSK,) and their associated receivers

- S
- 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

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.

All lectures will be given in french with specificities for students who have a low level in french : all documents will be in english and tutorial classes, laboratory classes and the "enseignement d'intégration" will be given in english. Additional hours as tutoring in english will be scheduled.

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: Herve 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): 27,00

Erasmus ECTS : 2

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

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. The courses are in French with specific modalities to allow the adaptation of students with a low level in French: all the materials are in English, the tutorials, the practical work as well as the integration teaching are provided in English. English support sessions are also scheduled.

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).

3

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 technicaleconomic 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 – SMART AND EMBEDDED SYSTEMS FOR HEALTH

Dominante : GSI (Grands Systèmes en Interaction), VSE (Vivant-Santé-Environnement) et SCOC (Systèmes Communicants et Objets Connectés)

Teaching language: French

Campus where the course is offered: Rennes

Engineering Problem

Technological advances in terms of the measuring elements miniaturization and the control of physiological quantities allow new solutions for patient care: substitution for the control of defective organs, continuous, automated, and patient-adapted delivery of treatments. On the other hand, integrating digital communication capabilities between these control elements and connected everyday objects (smartphones, tablets, etc.) opens new opportunities for better patient involvement and doctor monitoring.

The societal stakes are apparent, both in terms of improved health and daily comfort for the patient and reduced risk of severe pathologies in the longer term. For the engineer, the challenge is to offer a reliable integrated solution that is easy to use and adjust, low in energy consumption, and easily adaptable to a wide variety of patients.

Prerequisites

None

Context and challenges modules: This part is organized around several lectures that should give the students the keys to understand the significant issues associated with this thematic sequence. The following aspects will be addressed: the medical aspects of diabetes treatment, the problem of embedded for health, the ethical, social and human aspects through the influence of connected objects, the security of personal data, the impact of antennas.

Specific course (60 HEE,FR): Energy-efficient communications

- Short description: With a global electricity consumption of 6 to 10%, corresponding to 4% of greenhouse gas emissions, ICST (Information and Communications Sciences and Technologies) must rethink how they transmit, process, and store data. The arrival of 5G (5th Generation mobiles) and the explosion of connected objects (Internet of Things) suggest that the sector will continue to grow very strongly in the next years, making it more urgent to offer



more environment-respectful communications. Spectral efficiency requirements (transmitting a rate within a given bandwidth) must then be combined with an intense energy efficiency constraint (transmitting while consuming as little as possible). This course provides training in digital communication concepts and tools for which energy efficiency is explicitly taken into account.

Specific course (60 HEE,EN): System Architecure and Modeling

Short 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.

Integration teaching: Smart system for personalized blood glucose control

- **Associated partner**: CHU Rennes Diabetology Department.
- Location: Campus of Rennes
- Short description: The objective is to propose a system to help regulate blood sugar levels for diabetic patients. This system must respond to various issues: operational safety and comfort of use for the patient, digital integration of control algorithms, ability to interact with control elements (subcutaneous blood glucose sensor, micro-pump for insulin delivery, ...) via various communication protocols and low energy cost. It must allow local interaction with the patient and remote interaction with a doctor to monitor biomedical data.



2SC6310 – System Architecture and Modeling

Instructors: Herve Gueguen, Nabil Sadou

Department: CAMPUS DE RENNES

Language of instruction:

Campus: CAMPUS DE RENNES

Workload (HEE): 60

On-site hours (HPE): 34,50

Erasmus ECTS: 2,5 (+ introduction: 0,5 ECTS)

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.)

The courses are in French with specific modalities to allow the adaptation of students with a low level in French: all the materials are in English, the tutorials, the project are provided in English. English specific sessions are also scheduled.

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
 - $\,\circ\,$ 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): 27,00

Erasmus ECTS : 2

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 – MODELING AND DEVELOPMENT OF SUPERVISION SOFTWARE

Dominante : Info&Num (Computer Science and Digital) and SCOC (Communicating Systems and Connected Objects)

Langue d'enseignement : French

Campus où le cours est proposé : Rennes

Engineering problem

Today, information technology is omnipresent, and allows in particular the supervision of sensors and connected objects, as well as the processing and analysis of the data coming from them. For example, in the medical field, connected insulin pumps or pacemakers can be used to collect information in order to create histories, statistics on groups of individuals, etc. In the "smart building" context, the information systems can be used to manage or invoice, for example.

The objective of such a supervision system is on the one hand to provide aggregated information to users and supervisors, but also to allow a regulation of the system via the sending of control commands to sensors and connected objects. Thus, the software implementation of such a system relies on several services, with multiple users manipulating data specific to their role. The difficulty of such an implementation lies in the modeling and the volume of data processed in real time, but also in the choice and the definition of the software architecture that will allow to obtain an efficient system while ensuring an easy maintainability.

In this ST, we propose to study the design of such a system. To do so, we will study on the one hand the modeling and the data management, and on the other hand, the design patterns that will allow to accelerate the development while facilitating the maintainability of the system. In addition, the teaching of integration will be an opportunity to illustrate the benefits of an AGILE organization by allowing to design a functional system as soon as possible and to make it evolve according to the customer's needs.

Adviced prerequisites

None

Context and issue modules: The context and issues modules of this thematic sequence are based on those of the two other thematic sequence topics proposed on the Rennes campus, "Health" and "Smart Building". The first two workshops are



therefore "shared" with these other thematic sequences. Then, workshops specific to software development are presented. Depending on the availability of industrialists, the subjects covered are embedded development, Lora networks, and UML modeling. Practical workshops on basic software development tools (git, command line, etc.) complete the lectures given.

Specific course (60 HEE) : Data Models and Design Patterns

Brief description: This course allows students to discover the notions necessary for the design of software manipulating large quantities of data. It approaches objectoriented programming, through two languages, Java and Kotlin. It then approaches software engineering methodologies in close connection with the system modeling course in which the various diagrams (classes, sequence, etc.) are seen. The course allows the student to question the relevance of the structuring of a software code with regard to the existing design patterns. To this end, the tutorials, which are based on the system modeling course that runs in parallel, will be carried out in a reversed pedagogy.

In a second part, the course focuses on the storage and manipulation of data. It will be a question of discovering the foundations of database software and the theoretical problems that this poses (formatting, queries). Finally, this part concludes with the introduction of object-relationship mapping software that allows the data to be linked with the business code of the application and for which a particular modeling skill must be acquired.

Challenge Week : Development of a sensor supervision system

Associated partner: None directly but some in partnership with the other ST5s on campus

- Location: Rennes campus

- Brief description: In collaboration with the students of the thematic sequences of the campus of Rennes "Smart Building" and "Health", the objective is to develop the information system which will make it possible to collect and treat the data coming from sensors, and to provide services for the regulation of these. The pedagogical objective is to discover the specificities of development in the Cloud and to perceive the interest of design choices to facilitate software evolution as well as the benefits of an AGILE organization.

2SC6410 – Data models and design schemas

S

Instructors: Jean-Francois Lalande Department: CAMPUS DE RENNES Language of instruction: FRENCH Campus: CAMPUS DE RENNES Workload (HEE): 60 On-site hours (HPE): 34,50 Erasmus ECTS : 2,5 (+ introduction: 0,5 ECTS)

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 Kotlin. 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. For this, the labs that are based on the course of system modelling that occurs in parallel will be realized in inversed pedagogy.

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, this part is concluded with a presentation of software that helps to implement object-relation mapping.

Quarter number

ST5

Prerequisites (in terms of CS courses)

- Information System and Programming
- Algorithms and complexity



Syllabus Object oriented programming (Java/Kotlin)

- 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

Personal work: finish the lab on oriented programming + databases + software engineering

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): 27,00

Erasmus ECTS : 2

Description

In partnership with other students of the campus following the thematic sequences "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 educational objective is to perceive the specificities of the development of applications in the cloud et to discover 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 – STOCHASTIC FINANCE AND RISK MODELLING

Dominant : MDS (Mathematics, Data Sciences) Language of Instruction : English Campus : Paris-Saclay

Engineer problem

The financialization of the economy is a remarkable phenomenon in the past thirty years, which pushes financial markets to the heart of the globalized economy. Accordingly, risk management by financial institutions is crucial to the economy as a whole.

The subject aims to introduce the fundamental concepts of financial risk management to students, and in particular the corresponding mathematical aspects. This module will allow the students to be familiar with stochastic models of asset pricing, to discover common derivative products and to address real issues of risk management. For engineers working in the financial industry, the understanding and full control of these models are essential.

Prerequisites

Students are required to have followed the courses CIP, PDE and Algorithms and complexity.

Nevertheless, the ST4 Data and Statistics in Finance is NOT necessary.

Modules and challenges : A series of conferences will present different fields of financial risk management methods and their applications. Themes and speakers nay change every year. Conferences may deal with :

- derivatives products ;
- asset management: portfolio allocation and risk management ;
- actuarial science and risk management of insurance ;
- commodities and energy markets ;
- etc.

Specific course (60 HEE) : Modeling of financial risks

Quick description : This course is an introduction to discrete time financial mathematics. It deals in particular with the valuation and hedging of derivative products as well as risk management in a stochastic discrete time framework.



Content : Stochastic calculus in discrete time. Introduction to financial derivatives. Discrete time financial market models. Risk measurs and portfolio optimization. Optimal investment, risk criterion and optimal hedging in discrete time markets. From discrete time to continuous time setting, concerning the Black-Scholes model.

Project : Financial risk management

Associate partners : Industrial partners may change every year. Recent partners include BNP Paribas, Generali, ODDO BHF, etc.

Location : Paris-Saclay

Quick description : Students enrolled in this course are asked to study a quantitative method in a financial risk management setting. Subjects are proposed by an industrial or academic partner.

Goals: to be able to model problems of financial risk management, to be able to implement numerical solutions.

Each project deals with a quantitative method for risk management, e.g., pricing or hedging of a financial product, or asset allocation, portfolio management, client portfolio analysis, etc. Real financial or client data is provided by the project partner. Each project requires the coding of the method investigated.

Students will work in groups (group formation rules will be specified at the start of the ST).

Evaluation : Students will be graded respectively for the course and the project.

Course : The score is given as 0.3*x+0.7*y, where x stands for the TP's score and y is the score of the final exam. More details can be found during the first class or in Edunao.

Project : Final grade is decided after an oral presentation, by a jury including the industrial supervisor.



2SC7110 – Stochastic Finance and risk modelling

Instructors: Gaoyue Guo Department: DÉPARTEMENT MATHÉMATIQUES Language of instruction: ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 34,50 Erasmus ECTS : 2,5

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%).

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.

Learning outcomes covered on the course

The subject aims to introduce the fundamental concepts of financial risk management to students, and in particular the corresponding mathematical aspects. This module will allow the students to be familiar with stochastic models of asset pricing, to discover common derivative products and to address real issues of risk management.



2SC7190 – Risk Management on financial markets

Instructors: Gaoyue Guo, Ioane Muni Toke

Department: DOMINANTE - MATHÉMATIQUES, DATA SCIENCES

Language of instruction: ENGLISH

Campus: CAMPUS DE PARIS - SACLAY

Workload (HEE): 80

On-site hours (HPE): 48,00

Erasmus ECTS: 4,5

Description

Students enrolled in this course are asked to study a quantitative method 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 deals with a quantitative method for risk management, e.g., pricing or hedging of a financial product, or asset allocation, portfolio management, client portfolio analysis, etc. Real financial or client data is provided by the project partner. Each project requires the coding of the method investigated.

List of 2021 subjects (may differ in 2022):

- Optimal portfolio allocation (in partnership with BNP Paribas)
- Optimization for insurance products (in partnership with Generali)
- Hybrid portfolio optimization (in partnership with Volga Technologies)
- Heuristic portfolio construction (in partnership ODDO BHF)

Class components (lecture, labs, etc.)

Project with regular supervision. Short lectures if needed.

Grading

Source code, technical report and oral presentation



ST7 – 72 – OPTIMIZATION OF NETWORK INFRASTRUCTURE FOR SMART CITIES

Dominante : SCOC (Systèmes Communicants et Objets Connectés)

Teaching Language : English

Campus: Paris-Saclay

Introduction

The advent of the Internet of Things and the proliferation of applications based on cheap sensor networks are now paving the way for the development of smart, connected and sustainable cities. Many cities in Europe (Antony, Dijon, Malaga, Santander, Barcelona, etc.) are in the process of creating intelligent environments with experiments deployed for better adaptive management of traffic and transport, for better management of energy and water consumption, for reduction of CO2 and pollution level, and for a better quality of life, etc. The creation and management of smart cities require high-speed communications infrastructures and edge networks for the collection, delivery and processing of a large amount of information (traffic sensors, cameras, localizable vehicles, profiles and movements of users / people, etc.), which will overload current telecommunications networks and / or require the development of new communication systems. It is estimated that the density of connected objects in smart cities will reach one million objects per km2 in the next years. Obviously, the optimization of communications networks is essential in this case. In this context, one of the main objectives of the fifth generation of communications systems is to be able to meet the needs of smart cities, in particular by allowing the communication of a large number of machines, the virtualization of network functions, and the intelligent data processing. The routing of packets in the network, allocation of servers for data processing and transmission of packets are of utmost importance in optimizing and dimensioning network infrastructures. This ST focuses on these issues that need to be understood and applied in the context of smart cities. Due to the high density of objects, the use of distributed decision techniques, especially game theory, is of great importance in this context. This ST will hence introduce the fundamentals of game theory and discuss its use for optimizing network performance and functions.

Prerequisites

Basics in Modelling, Statistics, and signal processing.



Context and Challenges Modules: These modules include seminars on smart cities (challenges and experiments) and a Panel dedicated to markets and economic models confronting the visions of telecommunication and service operators as well as public services, and presentations by industrial partners focusing on technological and scientific challenges.

Specific Course (60 HEE): Optimization of network infrastructure

Brief 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.

Project : Smart cities : the connected cities

Partners : Orange, Nokia, Thales

Place: Paris-Saclay

Brief 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.

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, fairness, and operational risk



2SC7210 – Optimization of network infrastructures

Instructors: Mohamad Assaad Department: DÉPARTEMENT SIGNAL, INFORMATION, COMMUNICATION Language of instruction: ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 34,50 Erasmus ECTS : 2,5

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)

Communication networks (basic notions), optimization

Syllabus

- General introduction
 - a. smart cities and game theory
 - b. Game theory: normal and extensive form
 - c. Decision and solution concepts (rationality, Nash equilibrium, etc)
 - d. Correlated Equilibria
- Different Game types and application to the problems of smart cities
 - a. Zero sum and non zero sum games
 - b. Finite games and mixed strategies

- 60
- c. Routing games
- d. Revolutionary games
- e. Repeated games
- f. Stable Matching: stable mariage 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

- 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 game 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: DOMINANTE - SYSTÈMES COMMUNICANTS ET OBJETS CONNECTÉS

Language of instruction: ENGLISH

Campus: CAMPUS DE PARIS - SACLAY

Workload (HEE): 80

On-site hours (HPE): 48,00

Erasmus ECTS: 4,5

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)

Communication networks (basics), 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 rigour and critical thinking in approaching problems from all angles, be they scientific, social or economic.



ST7 – 73 – CIRCULAR ECONOMY AND INDUSTRIAL SYSTEMS

Dominante : GSI (Large Interacting Systems), VSE (Living-Health-Environment), CVT (Construction, City and Transport)

Langue d'enseignement : French

Campus où le cours est proposé : Paris-Saclay

Engineering problem

Companies are becoming actors in the transition to a more environmentally friendly economy. For example, several of them called for a strong agreement at COP21 and more and more of them are deciding to act and transform their practices towards more "circular" models. This new way of doing business translates into action several mutually reinforcing factors: the growing awareness of the challenges of the ecological and energy transition, the multiplication of initiatives on a territorial scale, the strengthening of laws and standards towards a more sustainable economy, and market balances that are changing and making sustainable practices more profitable.

The circular economy aims to move away from a culture of extraction and waste and to optimize the use of resources to minimize the impact of human activities on the environment. Industrial ecology is a scientific approach to integrated metabolism that makes it possible to implement this circular economy, via - among other things - industrial synergies (pooling of material, water or energy flows between companies), the eco-design of products and services, or the economy of functionality.

It is a formidable field of innovation, commercial differentiation and a sustainable and profitable growth relay that is emerging. This circular economy needs leaders capable of understanding the issues at stake, trained to initiate and manage ambitious projects at the level of companies and territories.

Adviced prerequisites

None



Context and issue modules: The introduction of the sequence is organized around three half-days aiming at presenting the sequence, the projects and introducing the issues of the Circular Economy, with the following activities:

Introductory conferences and round table: introduction to Circular Economy by field actors (National Institute of Circular Economy, Law firm specialized in Circular Economy)

Discovery workshops: workshop "Impacts of the Smartphone" (example of the Fairphone), workshop "Circular business models" (example of the SEB company), workshop "Reuse and repair strategies" (example of recycling centers)

If possible, site visits (e.g. Paris-Saclay heating and cooling network), or industrial conferences.

Specific course (60 HEE) : Circular Economy and Industrial Ecology Methods

Brief description: The course aims to go through the different dimensions of the Circular Economy to give students an overview of the field. Then the focus will be on the operational tools of Industrial Ecology that students will learn to manipulate (MFA and LCA software) to carry out an "academic" Industrial Ecology project by modeling material and energy flows and by measuring environmental impacts. These tools can be used in the industrial project of the thematic sequence.

Projects:

The sequence is built around an industrial project; 2 to 4 topics in connection with industrial partners will be proposed to students, including at least one project carried by the VSE major and one by the CVT major. The topics described below are those of past years and are provided for information purposes only. Those of 2022 will be on similar topics.

Project n°1 (example 2020): Biorefinery: optimization of flows and/or associated processes

- Associated partner: Chair of Biotechnology, ARD

- Location: Paris-Saclay then Pomacle (CEBB and partner industrial site)

- **Brief description:** The biorefinery can be defined as an industrial ecosystem that enables the valorization of biomass (plant and animal resources, waste) in the form of various products, both food and non-food (energy, chemical intermediates, materials, cosmetics, health, etc.). France is, on a global scale, very advanced in this field, in particular thanks to the biorefinery of Pomacle Bazancourt which processes more than 4 Mt of biomass per year. The biorefinery is therefore one of the credible industrial tools to support the ecological transition, both to meet the climate and humanitarian issues but also to relocate the industry, especially within the agricultural or forestry production areas. It thus meets the triple objective of sustainable development (environmental, social and economic).



The objective of this project is, at the scale of the industrial site, to understand the organization of processes and flows in order to identify optimization opportunities. Through a multidisciplinary approach (data sciences, modeling-simulation-optimization, process engineering, etc.), students will have to work in groups to identify, develop and present an operational solution contributing to the reduction of the environmental impact of the biorefinery.

Project n°2 (example 2020): Building sites of Greater Paris

- Associated partner: Valerian

- Location: Paris-Saclay campus + half-day visit to a Grand Paris Express station construction site

- Brief description: "200 km of automatic lines, as much as the current metro, and 68 stations: the Grand Paris Express is the largest urban project in Europe!" Much more than a transportation network, it opens up new horizons and offers numerous opportunities. It will make the city bigger and more united. 90% of the future Grand Paris Express network will be underground, requiring the excavation of huge volumes of earth during gigantic worksites involving a total of some 20 tunnel boring machines. Construction and public works waste in the Île de France region represents approximately 30 million tons per year. The construction sites of the Grand Paris Express will represent an increase in waste of 10 to 20% per year. The aim of this project is to have students work on technical and economic scenarios for the recovery of excavated material from the Grand Paris Express, from a circular economy perspective. In the first phase of the project, in partnership with the company Spie batignolles valérian, the students will develop their skills and characterize the available soil deposits from the Grand Paris Express construction sites. In a second phase, the students will work on one of the following two subjects of land reclamation - Recovery of excavated soil for the backfill of the future CDG Express line that will serve Roissy-Charles de Gaulle airport by 2025, a topic proposed by Spie batignolles valérian;

- Valuation of excavated earth as innovative raw earth construction materials, subject proposed by the Cycle Terre and CRAterre project.

Project n°3 (example 2021): ESA_Lab@CentraleSupélec

- Associated partner: European Space Agency (ESA)

- Location: Paris-Saclay campus

- **Brief description:** The objective of the ESA MELiSSA (Micro-Ecological Life Support Alternative) project is to develop a regenerative life support system that can reproduce the main functions of the terrestrial ecosystem (water production, oxygen), in a reduced mass and volume and with extreme safety. MELiSSA is one of the world's most successful examples of circular economy, in the sense of extreme looping of material and energy flows. The ESA_Lab@CentraleSupélec, created in 2020, is a privileged collaboration framework between ESA and CentraleSupélec. Its objective is to develop interest and knowledge of peaceful space exploration activities and the resulting cross-cutting applications, such as climate monitoring, Earth observation, navigation, (cyber)security, artificial intelligence, sustainability,



space economy, etc., for the mutual benefit of both organizations and society. The aim of this ST7 project is to specify and propose first preliminary design scenarios of a future "demonstrator laboratory", which would be a place of experimentation and scientific projects around the concept of Circular Economy, and thus in close connection with the MELiSSA project. The project is structured in two main phases:

- Specification of the laboratory demonstrator: collection of needs and first ideas through a state of the art, and interviews with various CentraleSupélec actors and ESA experts

- Preliminary design of the demonstrator laboratory

Project n°4 (example 2021): New innovative and circular business models

- Associate partner: BNP Paribas

- Location: Paris-Saclay campus

- Brief description: BNP Paribas Personal Finance wants to become a key player in the ecological transition by embracing the concept of the circular economy. As a financing institution, BNP Paribas is investigating new partnerships and new financing products that integrate the principles of the circular economy. In this context and prior to any proposal for new business models, BNP Paribas wishes to map and diagnose three major sectors of activity: furniture, home renovation and beautification, and the communication technologies sector. Based on the sectoral levers and obstacles to the deployment of the circular economy identified, the challenge is to propose new circular business models that are more respectful of the environment and that integrate changes in user behavior towards eco-designed products and services. The project is structured around the following deliverables:

- Characterization of products in terms of material and energy balance

- Characterization of the state of maturity of end-of-life management of products

- Technical and economic characterization of products and associated services

- Characterization of the value chain and in particular of the actors of maintenance, reuse and valorization of products at the end of life

- Identification of the technical and economic obstacles and levers to the deployment of circular initiatives

- Proposal of new circular business models with regard to the identified opportunities and the evolution of consumption habits



2SC7310 – Circular economy and industrial ecology methods

Instructors: Yann Leroy, François Cluzel

Department: DÉPARTEMENT GÉNIE INDUSTRIEL ET OPÉRATIONS

Language of instruction: FRENCH

Campus: CAMPUS DE PARIS - SACLAY

Workload (HEE): 60

On-site hours (HPE): 34,50

Erasmus ECTS: 2,5

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 (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

12. Adoue, C., 2007. Mettre en œuvre l'écologie industrielle. PPUR, Lausanne.



13. Buclet, N., Barles, S., 2011. Écologie industrielle et territoriale : Stratégies locales pour un développement durable. Presses Universitaires du Septentrion, Villeneuve d'Ascq, France.

- 14. Erkman, S., 2004. Vers une écologie industrielle, 2e éd. ed. Charles Léopold Mayer, Paris.
- 15. 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 (all members of the Industrial Engineering Research Department) and some other PhD students or 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

- 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
 - 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
 - C1.5 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
 - C2.5 Master the skillset of a core profession within the engineering sciences (at junior level)
- 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.
- 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 rigour and critical thinking in approaching problems from all angles, be they scientific, social or economic.



2SC7391 – Circular Economy industrial project

Instructors: Julien Lemaire, Yann Leroy, François Cluzel

Department: DOMINANTE - GRANDS SYSTÈMES EN INTERACTION, DOMINANTE - VIVANT, SANTÉ, ENVIRONNEMENT, DOMINANTE - CONSTRUCTION VILLE TRANSPORTS

Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 80 On-site hours (HPE): 48,00

Erasmus ECTS: 4,5

Description

The Circular Economy industrial project is a core element of ST7 Circular Economy & Industrial Systems. Every year, 2 to 4 subjects in close relation to industrial partners are proposed to students, including at least one project leaded by the Major VSE (Vivant, Santé, Environnement), and one by the Major CVT (Construction, Ville, Transports). During the first project session, at the beginning of ST7, subjects are presented to students that provide then their preferences (MyWay campaign). Student are assigned to one project by maximizing their satisfaction and respecting the quotas (all subjects have to be filled). Each projet is coached by one or two teachers, and by one or several industrial partners. This project is not a school project; a mission is given to the students, answering to real needs, and they work with real data provided by the industrial partners (and most often students sign a Non-Disclosure Agreement). Thus, subjects and partners evolve each year to fit with the "current needs", even if some continuity exist with some partners/subjects (for example the subjects Biorefinery or Grand Paris). The proposed subjects are all dealing with Circular Economy, but with different points of view and objectives (optimization of flow or processes, territorial approach implying a fine consultation of stakeholders, technico-economic study, prospective study, business models definition, ...) that allow each student to deepend a particular dimension of Circular Economy in accordance with his/her preferences.

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 in the agenda (8 sessions during the first part, interspersed with the slots for specific and common courses, then 4 full days to close the ST). Students will have to divide the tasks and roles within their groups, and they will use agile project management. The 8th session will be dedicated to an intermediary oral presentation. Finally, the final oral defense will happen during the very last session. Students will deliver after this defense a finalized version of their group report.

Subjects described below are from the two past years, and provided for information only. Subjects for the 2022 edition will deal with similar areas.

Projet #1 (example 2020) : Biorefinery : optimization of flows and/or associated processes

- Industrial Partner : Chair of Biotechnology, ARD

Location : Paris-Saclay then Pomacle (CEBB and partner industrial site)
Short description : The biorefinery can be defined as an industrial ecosystem that transforms biomass (agro resources and animal waste) into several products from alimentary to energy, chemicals, raw materials, cosmetics, health...). France is a leading country in this field at the international level, thanks to the biorefinery located in Pomacle Bazancourt, which treats more than 4 Mt of biomass per year. The biorefinery is, therefore, a relevant industrial tool to accompany the ecological transition, first to answer the issue of climate change and second to help the industrial relocation, especially in territories of agricultural and forestry production. The biorefinery also contributes actively to Sustainable Development (environment, economy, and social pillars).

The project aims to map the different production units and characterize and quantify the inputs and outputs streams. Second, from this exploration phase, the goal is to propose new stream exchange architecture to optimize the environmental footprint of the biorefinery. The proposed approach is multidisciplinary and mixes data science, modeling-simulationoptimization, process engineering, and industrial engineering. The students are expected to work in a group to identify, develop and present operational solutions that reduce the environmental impact of the biorefinery.

Projet #2 (example 2020) : Construction sites of Grand Paris



 Industrial Partner : Spie batignolles valérian, Cycle Terre & CRAterre
 Location : Campus Paris-Saclay + visit (1/2 day) of a construction site of a Grand Paris Express station

- Short description : "200 km of automatic lines, equalling the actuel Parisien subway, and 68 stations: Grand Paris Express is the biggest urban project in Europe!" More than a transportation network, it open new horizons and offer numerous opportunities. With it, the metropolis becomes bigger and more unified. 90% of the futur Grand Paris Express network will be underground, which requires to excavate huge volumes of clay, through huge construction sites using in total about twenty tunnel boring machines. Waste in the Construction sector in Île-de-France represent about 30 million tons per year. The Grand Paris Express construction sites will represented a increasing of waste by 10 to 20% per year. During this project, students will work on technico-economic scenarios for valorizing the clays of Grand Paris Express in a Circular Economy perspective. During a first phase of the projet, in partnership with the company Spie batignolles valérian, students will gain knowledge and they will characterize the available clay deposits from the Grand Paris Express construction sites. In a second phase, students will work on one of the two valorization subjects:

Valorization of the excavated clays for the embankment slopes of the future CDG Express line (from Paris to Roissy-Charles de Gaulle airport, expected for 2025); subject proposed by Spie batignolles valérian;
Valorisation of the excavated clays as innovative construction material in raw clay; subject proposed by Cycle Terre and CRAterre.

Projet #3 (example 2021) : ESA_Lab@CentraleSupélec

- Industrial Partner : Agence Spatiale Européenne (ESA)
- Location : Campus Paris-Saclay

- Short description : Le projet MELiSSA (Micro-Ecological Life Support Alternative) de l'ESA a pour objectif de développer un système de support de vie régénératif permettant de reproduire les fonctions principales de l'écosystème terrestre (production en eau, oxygène), dans une masse et un volume réduits et avec une sécurité extrême. MELiSSA est un des exemples les plus aboutis au monde d'économie circulaire, au sens du bouclage extrême des flux de matière et d'énergie. L'ESA Lab@CentraleSupélec, crée en 2020, est un cadre de collaboration privilégié entre l'ESA et CentraleSupélec. Il a pour objectif de développer l'intérêt et la connaissance des activités d'exploration pacifique de l'espace et les applications transverses qui en découlent, telles que la surveillance du climat, l'observation de la Terre, la navigation, la (cyber)sécurité, l'intelligence artificielle, la durabilité, l'économie spatiale, etc., au bénéfice mutuel des deux organisations et de la société. Le but de ce projet de ST7 est de spécifier et proposer des premiers scénarios de conception préliminaire d'un futur « laboratoire démonstrateur », qui serait un lieu d'expérimentation et de projets scientifiques autour du concept d'Economie Circulaire, et donc en lien étroit avec le projet MELiSSA. Le

projet est structurée en deux grande phases :

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- Spécification du laboratoire démonstrateur : recueil des besoins et des premières idées par un état de l'art, et des entretiens auprès des différents acteurs de CentraleSupélec et d'experts de l'ESA

- Conception préliminaire du laboratoire démonstrateur

Projet #4 (example 2021) : New innovative and circular business models

- Industrial Partner : BNP Paribas
- Location : Campus Paris-Saclay

- Short description : BNP Paribas Personal Finance (BNP PF) aims to become a key player in ecologic transition, tackling the circular economy concept. As a funding institution, BNP PF explores new partnerships and new financial products integrating circular economy principles. In this context and before proposing new circular business models, BNP PF needs to map and diagnose three main economic sectors: the furnishing sector, the energy renovation and beautification of the dwelling sector and, the communication technologies sector. From barriers and levers identified to deploy circular economy in these sectors, the challenge is to propose new circular business models more respectful of the environment. Furthermore, these new business models must also integrate users' behaviors concerning eco-designed products and services.

The project is structured around the following deliverables :

- Characterisation of products in terms of materials and energy balance

- Characterisation of value chain maturity with regards to end-of-life management

Technico-economic charactérization of products and services

- Characterization of the value chain and especially the maintenance, the reuse, and the end-of-life

- Identification of barriers and levers to the deployment of circular initiatives

- Proposal of new circular business models taking into account identified opportunities and changes of users' behaviors.

Class components (lecture, labs, etc.)

Project-based learning Agile project management Group work with support from supervisors Several scheduled exchanges with the industrial partners 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 Previous years' reports and deliverables Documents and data provided by the industrial partners.

Resources

Teaching staff : François CLUZEL (LGI), Yann LEROY (LGI), Franck MARLE (LGI), Julien LEMAIRE (LGPM – Chair of biotechnology), Romain ILIOU (dominante CVT) Software tools : to be defined according to the needs (for exemple LCA software (OpenLCA) and MFA software (Stan))

According to the subjects, travels will be organized (industrial visit, interviews of stakeholders...).

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.



ST7 – 74 – OPTIMIZATION OF PASSENGER TRANSPORT SYSTEMS

Dominante : Info&Num (Computer Science & Digital), GSI (Large Interacting Systems)

Langue d'enseignement : French

Campus où le cours est proposé : Paris-Saclay

Engineering problem

Transportation systems are essential to today's society because they provide crucial mobility services for both personal and business travel. The massification of travel and the diversity of mobility services, as well as new autonomous vehicles, make these systems complex to size, design and operate.

The optimization of such systems is therefore essential. For an airline, it is particularly important to be able to :

- take advantage of available information to forecast demand on "origindestination" routes and define flight schedules that best cover the demand,

- Pricing flights to ensure the best possible fill rate and revenue management for the company,

- to size the services (check-in, baggage, ...) at the hubs allowing to operate the flight plans,

- planning flight crew schedules in accordance with legislation and crew preferences,

- assigning aircraft to flights in order to minimize costs, and being robust to possible delays.

Beyond the ability to operate efficiently, the engineer's role is also to inform strategic decisions through quantitative models evaluating different scenarios in which a company might choose to engage.

Adviced prerequisites

SIP and Algorithms and Complexity Course

Context and issue modules: These modules include an introductory lecture on the topic, presentations on the technological and scientific challenges of passenger transport optimization, and a presentation of related projects.

Specific course (60 HEE) : Decision support / Operational research (AD/OR)



Brief description : Optimization and decision making is an intrinsic activity of the engineer/manager profession. In order to understand the complex decision problems they will be confronted with, tomorrow's engineers and managers must have the concepts and methods of optimization to formalize a decision problem. The course aims at introducing a certain number of classical models allowing to represent and solve decision problems in different contexts. The aim is to present models of different concrete decision problems.

Project: The project aims at putting the students in a real situation of solving a decision problem involving the formulation of a model, the choice of a resolution method(s), the implementation of a solution allowing a resolution on real data sets, the validation of the solution by numerical tests. The objective of the project through this activity is to make the students progress in the comprehension of the scientific, technical, but also human and economic stakes which underlie the implementation of a project of operational research and decision support in an organization.

Project n°1: Optimization of on-demand transportation systems

- Associate partner: Karhoo
- Location: Paris-Saclay
- Brief description :

- Brief description: The problem considered consists of designing vehicle routes and schedules for n users who specify pick-up and drop-off requests between origins and destinations. The objective is to plan a set of minimum-cost vehicle routes capable of accommodating as many users as possible, under a set of constraints. The data concerns a shuttle system that transports suburban customers to RER stations.

Project n°2: Optimization of an airline's operations

- Associate partner: Air France - Operational Research / Artificial Intelligence Group

- Location: Paris-Saclay campus

- **Brief description:** This project deals with one of the multiple problems of managing the operations of an airline company: for example, assigning flights to boarding gates, placing passengers in a plane, assigning planned flights to a fleet of planes, etc.

Project n°3 : Planning of a mobile team

- Associated partner: Decision Brain
- Location: Paris-Saclay campus



- **Brief description :** The aim of this project is to design and implement a planning tool for a mobile team of technicians, initially planned to create the daily routes of 500 technicians who have to carry out some 10 000 tasks.



2SC7410 – Decision Support : Models, algorithms and implementation

Instructors: Vincent Mousseau

Department: DÉPARTEMENT GÉNIE INDUSTRIEL ET OPÉRATIONS Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 34,50 Erasmus ECTS : 2,5

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 decisionmaker/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 Python + GUROBI,

- Decision in the presence of risk, decision in the uncertain, utility theory, decision trees,

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- 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 exercices: 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: Python + optimisation solvers + metaheuristics 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: Anaëlle Wilczynski, Vincent Mousseau

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): 48,00

Erasmus ECTS: 4,5

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.

Class components (lecture, labs, etc.)

Project pedagogy with support from professors and professionals from the professions concerned by the problem and the operational research profession.



Grading

The project will be evaluated in a defence.

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



Instructors: Vincent Mousseau, Mathieu Lerouge

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): 48,00

Erasmus ECTS: 4,5

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 schedule for a team of workers, given their skills, in order to satisfy a list of tasks to be performed on different worksites and involving certain skills. Project data and collaboration :

- This project is in collaboration with Decision Brain (DB)

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.

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

- Modeling skills : translating real-life problems into mathematical models
 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, Vincent Mousseau

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): 48,00

Erasmus ECTS: 4,5

Description

Karhoo is a startup that develops a SaaS solution for real-time dispatching and optimisation, which is aimed at on-demand transport fleets: taxis/VTCs, last mile logistics and the on-demand bus sector. We currently have around 50 customers worldwide, with a total volume of more than 2 million trips, and we have been supported since August 2017 by the Renault-Nissan Group via RCI Bank. Our integration with the world's largest car manufacturer is intended to eventually enable us to work on the management of autonomous car fleets, a major industrial revolution of the next decade. Experiments are already underway, such as on the Saclay plateau (see article). Introduction

The project presented here is inspired by real problems that we have in the on-demand bus sector. Together with Ratp Dev, we operate a public transport on demand service in the Vexin area around Mantes-la-Jolie (https://www.karhoo.com/fr/pool-transport-a-la-demande/). This solution makes it possible to meet the needs of the inhabitants of certain rural communities by providing a link to the most common destinations in daily life. For the price of a bus ticket, they can book a journey on board the vehicle between two stations close to their places of departure and arrival. Some journeys are shared in the same vehicle in order to offer more availability and reduce transport costs for the operator.



The Dial-a-Ride Problem (DARP) is an extension of the vehicle touring problem, which consists of determining the routes of a fleet of vehicles to deliver a list of customers. It extends this problem by considering transport requests (pick-ups and drop-offs), by adding time windows on these pickups and drop-offs, and by adding a maximum transport time between pickups and drop-offs. This last constraint is explained by the fact that, unlike the Pickup and Delivery Problem (PDP) for example, the requests concern the transport of people and not objects. This constraint therefore aims to maintain a quality of service for the customers.

Quarter number

ST7

Course support, bibliography

- J.-F. Cordeau and G. Laporte. The dial-a-ride problem: models and algorithms. Annals of operations research 153:29-46, 2007. <u>cordeau2007.pdf</u>
- S.C. Ho, W.Y. Szeto, Y.-H. Kuo, J.M.Y. Leung, M. Petering, T.W.H. Tou. A survey of dial-a-ride problems: Literature review and recent developments. Transportation Research Part B, 111:395-421, 2018 <u>ho2018.pdf</u>

Learning outcomes covered on the course

Give a PLNE model of the problem.

Find with the help of a solver (CPLEX or Gurobi for example), an optimal solution for the small dataset day_data.

Build a metaheuristic or heuristic that computes a good solution that is feasible in a very short time (a few seconds) for the 2 datasets. The quality of the solutions given by your heuristic will be evaluated on a 3rd dataset comparable to the large week_data dataset, which will be provided to you at the time of the final evaluation. So make sure you are able to run your heuristics on other data!



ST7 – 75 – OPTIMIZATION AND MANAGEMENT OF FLOWS

OF COMPLEX SYSTEMS

Dominante : GSI (Large Interacting Systems) and VSE (Living-Health, Environment)

Langue d'enseignement : French

Campus où le cours est proposé : Paris-Saclay

Engineering problem

The growing complexity of products and services, the globalization of operations and the increasing demands of customers place the issue of flow management at the heart of the concerns of industrial and service companies.

The competitiveness of these companies is strongly linked to their ability to organize themselves to produce and distribute products and services that meet customer expectations while ensuring the sustainability of the company in its economic, social and environmental dimensions.

This leads these companies to develop innovative solutions

- in the definition of the services offered to customers (time, personalization, place of delivery,...)

- in the best way to size and use their resources (material resources, infrastructure, human resources, information systems, etc.)

One of the major challenges to meet these objectives is to optimize the management of flows, from suppliers to end customers.

This topic addresses these issues by presenting approaches, qualitative and quantitative models from Industrial Engineering and Operations Research.

Adviced prerequisites

None

Context and issue modules: These modules will include presentations by industrial partners to illustrate the problems of flow management in different sectors.

Specific course (60 HEE) : Optimization and management of flows



Brief description : Product flow in a factory, parcel flow in a post office, patient flow in a hospital, customer flow in a supermarket, student flow in an educational institution: the problems related to the understanding and management of flows are present in all sectors of activity. More than a specific problem, flow management is an approach to industrial problems that can be adapted to many sectors. Knowing how to understand and control flows is a major challenge for industrial performance. This course introduces the problems related to industrial flow management and presents a tool to tackle these problems, the discrete event simulation.

Project: Flow management in industrial gas delivery

- Associated partner: Air Liquide
- Location: Paris-Saclay

- **Short description :** This project will allow, on an industrial case proposed by a partner, the application of the tools seen in the specific course, and in particular of the discrete event simulation of industrial flow systems. It will consist in defining a conceptual model, transposing it into a computer model, validating this model, experimenting with it, and building a recommendation for managers based on the simulation results.



2SC7510 – Managing and optimising industrial flows

Instructors: Guillaume Lame Department: DÉPARTEMENT GÉNIE INDUSTRIEL ET OPÉRATIONS Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 34,50 Erasmus ECTS : 2,5

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. The use of discrete event simulation to tackle these issues is presented.

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 simulaiton-optimisation.Perspectives on the industriel 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, videos.

Textbook for this course: Robinson S. Simulation the practice of model development and use. 2nd ed. London: Palgrave Macmillan 2014.

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 softare 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.

This course will address the following competencies:

- C1 Analysing, designing and realising complex systems with scientific, technological, human and economic components
 - C1.2 Using and developping relevant models, choosing the righjt modelling scale and simplifying hypotheses to address the problem
 - C1.3 Resolving the problem through approximating, simulating and experimenting
- C2 Developing specific knowledge of a scientific or industrial domain et a professional domain
 - C2.1 Exploring a scientific or engineering domain or discipline
- C3 Acting, innovating in a scientific and technological environment

 C3.6 Evaluating the effectiveness, feasibility and robustness of proposed solutions

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Description of the skills acquired at the end of the course

Use of discrete-event simulation fo rmodelling industrial systems, and implementation on Simul8.



2SC7591 – Flow management in industrial gas delivery

Instructors: Guillaume Lame, 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): 48,00

Erasmus ECTS: 4,5

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. Conceptual modelling, implementation into a computer simulation model, model validation, experimentation.

This course will address the following competencies:

- C1 Analysing, designing and realising complex systems with scientific, technological, human and economic components
 - C1.2 Using and developping relevant models, choosing the righjt modelling scale and simplifying hypotheses to address the problem
 - C1.3 Resolving the problem through approximating, simulating and experimenting
- C2 Developing specific knowledge of a scientific or industrial domain et a professional domain
 - d. C2.1 Exploring a scientific or engineering domain or discipline
- C3 Acting, innovating in a scientific and technological environment
 - C3.6 Evaluating the effectiveness, feasibility and robustness of proposed solutions
- C7 Being convincing.
 - C7.1 Being clear on objectives and expected results. Being rigorous on the hypotheses and the method. Structuring ideas and arguments. Highlighting value creation.
- C8 Leading a project, a team.
 - $\,\circ\,$ C8.1 Working as a team/collaboratively.
 - C8.4 Working in project mode, using project management techniques as required by the situation.

Description of the skills acquired at the end of the course

Implementation of discrete event simulation on a real case-study.


ST7 – 76 – HIGH PERFORMANCE SIMULATION FOR FOOTPRINT REDUCTION

Dominante : MDS & INFONUM

Langue d'enseignement : English

Campus où le cours est proposé : Paris-Saclay

1. General description of the thematic sequence

Simulation is nowadays at the heart of many design and optimization approaches to reduce the footprint or the impact of the products created: reduction of the risk of destruction in case of natural disasters, reduction of an airplane's drag to minimize the fuel consumed and the CO2 emitted, reduction of the time of a large-scale calculation and of the resources used (the simulations themselves end up consuming a lot of energy on a lot of processors),...

But these are often complex system simulations, which require both skills in high performance and large scale simulations, and in optimization methods to limit the scope of investigations and the hours of computation required. Moreover, each study must still be done by seeking a compromise between the quality of the solution found and the number of hours of computation used, because hours of computation are expensive (especially on high-performance computation clusters or on a large scale in clouds). It is therefore essential to learn how to manage a quota of computing hours.

This ST thus includes numerical mathematics, parallel computing, optimization methods, and development and experimentation on PC clusters or in clouds. Students will learn:

- to develop parallel modeling and simulations to reduce the duration of the most expensive phase of the optimization loop,

- to associate these simulations with adapted optimization methods and algorithms, which will minimize the number of configurations to be simulated and evaluated (brute force approaches will be avoided)

- to experiment the programming of high performance computing platforms (PC clusters or clouds),



- to exploit these platforms under the constraint of a quota of hours of calculations not to be exceeded.

2. Organization of the thematic sequence

2.1 Context and issues modules

The modules presenting the context and the issues will begin with a presentation of the objectives and organization of the ST. Then, a succession of presentations by industrial partners will illustrate different cases of use of high performance simulation for footprint reduction (reduction of energy consumption, reduction of financial cost, reduction of simulation time, reduction of data volumes...). On this occasion, the associated scientific and technical challenges will be identified, as well as the induced needs in optimization.

The topics of the ST projects will also be presented during the context and stakes modules: in aeronautics, in seismic exploration, in infrasound wave detection, in risk calculation on the cloud, and in temporal and energy optimization of parallel calculations. These presentations will also present the economic and societal issues related to the investments required to carry out high-performance simulations, and the impact of simulation on the evolution of the technologies that surround us.

A visit of the Very Large Computing Center (TGCC) in Bruyères-le-Châtel, under the leadership of the CEA, will allow to see modern infrastructures of high performance computing, and their support infrastructures (power supply, cooling, protections). Finally, a round table with all the industrial partners will allow to discuss the trends for the future.

2.2 Specific course "Parallel computing and optimization

This course includes mathematical, numerical, algorithmic and programming aspects on parallel and distributed machines, associated with optimization issues.

Among the notions covered, this course describes, in a first part, the basics of parallel and distributed computing, by detailing in particular the computer architectures and parallel programming models as well as the parallel and distributed algorithms used on these architectures. In a second part, this course presents parallel optimization methods and algorithms, commonly used in parallel computing codes. Two classes of methods used for optimization problems are successively discussed, namely parallel partitioning and domain decomposition methods, and genetic algorithms and parallel meta-heuristics. These methods and algorithms will be used in the different integration courses of this ST, in order to deal with problems from the engineering sciences. In a third part, this course focuses on the performance analysis of the developed solutions. The notions of performance metrics and scaling, as well as the analysis of experimental performances are also studied.



2.3 Industrial partners and proposed project topics

1. The CEA DAM (Direction des Applications Militaires) proposes a study of "Optimization of a seismic exploration campaign for the protection of structures

(Optimization of a seismic exploration)

CEA-DAM is the French warning center for tsunamis and strong earthquakes, and uses its high-performance computing resources for various missions.

After the Fukushima accident (Japan), the use of high performance computing resources has become more and more common for the estimation of the seismic risk associated with nuclear power plants: within the framework of the design of new plants, but also in order to study the performance of existing plants in the face of extreme events, not foreseen at the time of their design.

This study concerns the optimization of a geophysical exploration campaign on an experimental site, using its digital twin. The project consists in optimizing (minimizing) the number of sensors needed to discover the geological configuration of the site of interest. Many realistic simulations using the SEM3D code (Reverse Time Migration method) will have to be called in an optimization loop. We will therefore look for an optimization method that allows us to achieve a good quality of optimization while respecting the time quota.

The calculations will be done on machines of the Moulon mesocenter, under the constraint of a quota of calculation hours.

2. ONERA (Office National d'Etudes et Recherche Aérospatial) proposes a study of "Optimization of shapes and reduction of drag in aeronautics".

(Drag reduction in aeronautics)

Recent studies show that air traffic is constantly increasing. Without improvements in aircraft performance in terms of energy consumption, the share of air transport in greenhouse gas emissions may become unbearable in the future. Reducing aircraft fuel consumption requires both an increase in engine efficiency and an improvement in aircraft aerodynamics and weight reduction.

Numerical tools have been widely used for a long time in the aeronautical field to help in the design and optimization of systems. For example, the shape of a wing can be improved in order to reduce its drag, at constant lift, or its internal structure can be lightened. The optimization methods require successive calculations for different wing geometries. The higher the accuracy of the numerical models, the higher the computational costs for each step. The only way to reduce the computation time to be able to integrate the optimization methods in the industrial design cycle is to use parallel computers. The objective of this project is to realize the parallelization of the most expensive part of the optimization phase, i.e. the ŝ

resolution of large linear systems from finite element models on large meshes, and to experiment with different sets of optimization parameters.

The tests will be carried out on the parallel machines of the CentraleSupélec Teaching Data Center, under the constraint of a quota of computing hours.

3. The CEA DAM (Direction des Applications Militaires) proposes a study of "Optimization of infrasound detection for the verification of the Comprehensive Nuclear Test Ban Treaty".

(Detection of infrasound waves)

CEA-DAM is the French warning center for tsunamis and strong earthquakes, and also participates in the implementation of the verification means of the Comprehensive Nuclear Test Ban Treaty (CTBT) by using its high performance computing resources.

A parallel compressible hydrodynamics code has been developed at CEA DAM, which allows the simulation of blast wave and acoustic wave propagation in the presence of terrain and buildings, with or without wind. On the other hand, it is considered that judiciously placed sensors allow the recording of overpressure signals in case of an explosion. Two types of problems can then be studied: (1) find the location of an explosion and determine its power from the recordings of sensors located in the field, (2) define where to judiciously position sensors to maximize the chances of detecting an explosion within a given area.

A "brute force" investigation simulating all possible configurations of the parameters would consume too many hours of computation. We will therefore develop an optimization loop exploring the space of possible configurations sparingly and using the hydrodynamics code efficiently.

The computations will be done on CEA clusters under constraints of a quota of computation hours, and three of the last days of the study will take place on the Bruyères-le-Châtel site. This study is reserved for students from the European Union.

4. ANEO is an IT company expert in high performance computing and cloud operation, which proposes a study of "Energy optimization and acceleration of a financial computation graph on cloud".

(Graph of financial calculations)

One of the difficulties in assessing the accounts of an insurance company (or a bank) lies in the valuation of financial assets (shares, life or car insurance contracts, etc.) and the underlying risks. Depending on the valuation of the risks taken, the regulations resulting from the various economic crises oblige the insurance company or the bank to immobilize a certain amount of equity capital.

The steps of such a calculation, managed by ANEO, form a task graph with numerous dependencies, and the sum of the execution times corresponds to the equivalent of 413177 hours of calculation. On an infrastructure of 1700 cores the computation time would be a little more than 10 full days if all cores could work at any time. But because of the dependencies between the computational tasks, it

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happens that there are not enough tasks to occupy all the allocated resources, and the process finally takes more than 10 days.

In order to optimize the cost of this computation, we want to: (1) use on-demand resources available in the cloud, and (2) optimize the execution of the task graph by looking for the best turn-on/off strategy for the compute nodes, and the best scheduling of tasks on the available nodes. To do this, we will develop a cost function that calculates the execution time of the task graph as a function of a node management and task scheduling strategy, and we will implement an optimization algorithm that seeks the best parameterization of this strategy.

5. INTEL proposes a study of "Low Cost Optimization of Acoustic Wave Propagation Code Performance".

(Reducing the footprint of a code)

Any high performance application running on a parallel machine has many configuration parameters in its source code and compilation, which have a significant impact on its performance and energy footprint. But the behavior of the application depends on the architecture of the processors used, the test case data and the software configuration of the machine. In the end, this behavior is extremely difficult to model, and the configuration parameter space can be very large. The use of optimization algorithms therefore appears fundamental to converge towards a configuration of the application minimizing its execution time and its energy footprint on the machine used.

However, each execution of a test case of an HPC application can be long, even on a parallel machine. We will therefore target optimization methods that are not too greedy in terms of the number of experiments, so that the pre-stage of optimizing the HPC code does not itself consume too many computing resources! This amounts to looking for a compromise between the energy spent to optimize an HPC code, and the energy saved by this application once optimized.

The tests will be carried out on the parallel machines of CentraleSupélec's Teaching Data Center, under the constraint of a quota of computing hours.



2SC7610 – Parallel Computing Methods and Algorithms, and Optimization Methods

Instructors: Frédéric Magoules Department: DÉPARTEMENT INFORMATIQUE Language of instruction: ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 34,50 Erasmus ECTS : 2,5

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 ressources 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): 48,00

Erasmus ECTS: 4,5

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:

- S
- 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,
- $\circ\;$ 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 propecting 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):

- 6. 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.
- 7. 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.

- 60
- 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.

- 17. 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 developpers.

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.
 - $\,\circ\,$ 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: ENGLISH

Campus: CAMPUS DE PARIS - SACLAY

Workload (HEE): 80

On-site hours (HPE): 48,00

Erasmus ECTS: 4,5

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.

- 60
- 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 developpers.

Resources Teaching staff:

- F. Magoules (CentraleSupélec & MICS), and S. Vialle (CentraleSupélec & LISN)
- 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 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.



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): 48,00

Erasmus ECTS: 4,5

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.

6. 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:

- 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)
- \circ 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.

- S
- 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.

- 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 developpers.

Resources Teaching staff:

- J. Cagnol (CentraleSupélec & MICS) and S. Vialle (CentraleSupélec & LISN)
- 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 (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

- S
- 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).
 - $\,\circ\,$ Evaluated with learning outcomes AA1, AA4.
- \circ **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): 48,00

Erasmus ECTS: 4,5

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 :

 \circ 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) :



- Steps 1 to 4: course additions, formalization of the problem, choice of an optimization method, and handling of calculation resources.
- Steps 5 and 6: first functional parallel implementation of the solving algorithm, small-scale tests.
- 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 developpers.

Resources Teaching staff:

- A. Rimmel (CentraleSupélec & LISN)
- 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).
 - $\,\circ\,$ 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): 48,00

Erasmus ECTS: 4,5

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 finitedifference 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 behaviour), 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 selfoptimization mechanism for the application.

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 :

- 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.
- 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.
- Development of a 1st solution in sequential Python with call of the simulation C code provided for the study.
- Development of a first optimization-simulation campaign on multicore 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.
- 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.
- Development of a second optimization-simulation campaign on multi-core machines, with management of a weekly quota of calculation hours.
- The study will end with a report and an oral presentation to evaluate:
 - $\circ\;$ the investigative approach adopted,
 - 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,

• 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) :

- 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.
- 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.

- 60
- 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 **AAO**, **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 developpers.

Resources

Teaching Staff:

- H. Talbot (CentraleSupélec & CVN) et S. Vialle (CentraleSupélec & LISN)
- Ph. Thierry (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 (AAO): 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.
 - o Evaluated with learning outcomes AAO, 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.



ST7 – 77 – EFFICIENCY OF ON-BOARD ENERGY SYSTEMS

Dominante : ENE (Energy)

Langue d'enseignement : French

Campus où le cours est proposé : Paris-Saclay

Engineering problem

The optimization of embedded energy systems is a problem encountered daily in the industrial world.

Whether the objective is to reduce production or usage costs, or to participate in the energy transition by minimizing the carbon footprint, optimization is essential in the energy world.

Volume, cost (optimal design or operating cost), performance or efficiency gains are objectives that can be found in aeronautical, space or automotive systems. The system and multiphysics aspect of the design is now taken into account in order to best meet increasingly demanding specifications.

During this sequence, industrial examples will be discussed: optimization of the efficiency and cost of an electric drive train on a few operating points or on road cycles, optimal management of energy sources in a hybrid system.

Adviced prerequisites

It is adviceed to have taken the course "Electrical Energy".

Context and issue modules : These modules include an introductory conference on the theme, a round table involving the partners in the sequence, presentations on the technological and scientific obstacles, and an innovation workshop.

Specific course (60 HEE) : Optimization of embedded energy systems

Brief description: After a description and formulation of the problem and a presentation of the models related to optimization, the techniques of optimization of energy systems, stochastic optimization, parameter estimation, multi-source optimization and multi-criteria optimization will be examined.

Project n°1 : Energy efficiency of electrical machines

- Associated partner: Leroy-Sommer

- Location: Paris-Saclay



- **Brief description :** The problem of energy optimization of electrical machines is posed on the one hand by a search for lower costs of use but also by the regulation which imposes increasingly high yields to control the electrical demand.

It is therefore necessary to optimize the efficiency of electrical machines. Of course, this maximization of the efficiency goes against another optimization: that of the manufacturing cost. A multi-criteria optimization between efficiency and cost will therefore be implemented.

Project n°2 : Optimization of the traction chain on road cycle

- Associated partner :
- Location: Paris-Saclay campus

- **Brief description :** The increase 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 complement to the combustion engine.

The electric motor in the vehicle is not used on a single operating point as it is the case for a static application, but must respond to the solicitations of driving. To model these behaviors, numerous road test cycles are used. The optimization of the powertrain as a system is 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 the masses of the systems.

Project n°3 : Optimal management of a hybrid generator

- Associated partner :
- Location: Paris-Saclay campus

- **Brief description:** An energy production generator converts a source into energy. A generator is said to be hybrid when there are several sources available (in the electric case, it can be a battery and a thermal engine and alternator). The choice of the primary energy source is therefore made at the time of use.

On an operating cycle (power demand curve for example), it is necessary to find the optimal set point leading to the best management of the hybrid generator: to know if the electricity is produced from the battery or from the thermal generator.

An optimization is therefore necessary to reduce the operating costs or to increase the efficiency. Subsequently, an optimization of the system according to this optimal management is possible.

Project n°4: Optimization of a naval propulsion chain on cycle

- Associate partner: DCNS

- Location: Paris-Saclay campus



- **Brief description:** 90% of world trade is carried out by sea. As a result, maritime transport is one of the main contributors to air pollution: 3% of total greenhouse gas emissions in the world. Naval electric propulsion is one of the candidates to replace conventional thermal propulsion systems.

In an electric ship, gas turbines or diesel generators produce electricity that is then used to power both the electric propulsion motors and auxiliary loads. The electrical system on board can be AC or DC. Such a system must be optimized to minimize its cost and maximize its efficiency. In particular, if the vessel follows a fixed route (such as a ferry), the optimization can take into account the operating cycle.



2SC7710 – Numerical methods and problem solving for optimizing embedded energy systems

Instructors: Maya Hage Hassan, Philippe Dessante Department: DÉPARTEMENT SYSTÈMES D'ÉNERGIE ÉLECTRIQUE Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 60 On-site hours (HPE): 34,50 Erasmus ECTS: 2,5

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





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: 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): 48,00 Erasmus ECTS: 4,5

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 – Optimisation of the drive train on the road cycle

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): 48,00

Erasmus ECTS: 4,5

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

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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 management of a hybrid generator

Instructors: Martin Hennebel, Philippe Dessante, Marc Petit Department: DOMINANTE - ENERGIE Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 80 On-site hours (HPE): 48,00 Erasmus ECTS: 4,5

Description

Projects will be proposed on the theme of the optimisation of electrical networks. This may concern the management of the recharging of fleets of electric vehicles, in relation to the constraints of an electrical network. It also concerns the management of consumption sites with local production, for example in the context of an individual or collective self-consumption strategy.

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): 48,00 Erasmus ECTS: 4,5

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 embedded 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 – ENERGY TRANSITION IN ISOLATED SITES

Dominante : GSI (Large Interacting Systems), ENE (Energy)

Langue d'enseignement : English

Campus où le cours est proposé : Rennes

Engineering problem

This topic focuses on the problems associated with a transition to a more just and sustainable world in terms of access to energy. Indeed, some sites, houses or others, are not and cannot be connected to the distribution network because of the technical complexity of connection and extension of the network or because the cost of such an operation is either not justified or is not feasible for areas located in poor regions of the world. It is therefore necessary to propose solutions based on the development of microgrids. Microgrids allow the local deployment of small-scale collective installations thanks to hybrid systems with decentralized production and storage as well as intelligent management of production, storage and demand for each user.

The deployment of microgrids requires a system approach where the following questions arise:

- how to manage a multi-component system subject to different constraints,

- how to manage and take into account the multiplicity of stakeholders: users, communities, financiers, standards, etc.

- how to manage the trade-off between economic cost, environmental impact on life cycle, and quality of service.

Throughout the thematic sequence (context and issues modules, specific course, project) students will address these issues. They will be interested in defining the need for a given situation, in modeling and formalizing the optimization problem. They will be led to propose technically and economically reliable solutions in an uncertain environment.

Adviced prerequisites

Modeling, Probability/Statistics course



Context and issue modules: These modules include an introductory lecture on the theme, presentations on the technological and scientific challenges, and a presentation of the associated projects.

Specific course (60 HEE) : Renewable energies and microgrids

Brief description : Faced with the negative environmental impacts of all energy production and the depletion of fossil resources, the transition to renewable sources is a fundamental trend. While renewables provided only 25% of global electricity production in 2018, this share is growing rapidly, with wind and solar tripling over 10 years.

These new energies raise specific questions that this course proposes to address:

- what are the wind and solar energy sources and the main principles of their conversion into electricity?

- What are the storage technologies, in particular batteries, capable of handling the variability of these sources?

- What are the technical, environmental and economic challenges of these technologies?

Moreover, wind and solar power are much more decentralized sources than traditional thermal power plants. Thus, the production of electricity is closer to the places of consumption, which gives rise to the notion of "microgrid", analogous to the short circuits in agriculture.

A microgrid is a small electrical system that integrates production and consumption in a defined area (building, district, island, etc.) and is equipped with local management of energy flows. A microgrid can be autonomous or connected to a large network. If it is connected, it behaves as a single, intelligent player, capable, for example, of buying electricity from the wholesale market at the best times or providing network services. The integration of all these components and functions poses system optimization questions addressed in this course.

Due to their small size, reliability is an important issue for microgrids. This course proposes to study the methods of dependability to analyze the risks of failure, plan maintenance and react to failures...

Project: Decarbonized island microgrid

- Associated partner:

- Location: Rennes campus



- **Brief description :** Nearly one billion people still do not have access to electricity (IEA 2018). These populations are often in remote areas in rural or island regions. Thus, for 3/4 of them, it is not economically efficient to bring electricity to them by expanding existing large-scale power grids. Electrification must therefore be done on a local scale, through what are known as microgrids.

The generation of electricity in a microgrid can be done by fossil fuels (diesel generators) or by renewable energies (solar panels...). Thanks to technological progress, the latter are generally less expensive. However, their intermittency pushes to complete them by more expensive but controllable means (Diesel, battery storage, hydrogen...). The size of each of the components of a microgrid (called its "dimensioning") must therefore be optimized according to various criteria: economic cost, of course, but also quality of service, energy independence or greenhouse gas emissions. The management of energy flows (e.g.: arbitration between diesel and battery/hydrogen) is also to be optimized. This project proposes to address these different optimization issues on the concrete case of isolated sites.

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2SC7810 - Renewable energies and micro grids

Instructors: Pierre Haessig, Nabil Sadou Department: CAMPUS DE RENNES Language of instruction: ENGLISH Campus: CAMPUS DE RENNES Workload (HEE): 60 On-site hours (HPE): 34,50 Erasmus ECTS: 2,5

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 :

- Solar, wind, hydroelectric, bio-mass,...
- Modeling and predictability of production
- 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 bdies
- 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): 48,00 Erasmus ECTS: 4,5

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 – DIGITAL TECHNOLOGY AT THE SERVICE OF THE HUMAN FACTOR

Dominante : Info&Num (Computer Science & Digital), MDS (Mathematics, Data Sciences), VSE (Living-Health, Environment)

Langue d'enseignement : English

Campus où le cours est proposé : Rennes

Engineering problem

The massive recourse to computer automation of numerous processes, to Al-type decision-making agents, and to the analysis of ever larger data sets, question the relationship between humans and information technologies.

In fact, the current speed of development of these technologies, and the wealth of tools that are emerging, allow us to get even closer to the human being. Analysis of expressions and emotions by extraction of multi-sensor data (webcam, kinect, micro, EEG, sweating), modeling of human behavior in critical contexts (crisis, health problems, depression) and advanced analysis of interactions between different agents, are all possibilities offered by digital tools.

For research in the humanities and medicine, these new methods represent an opportunity to refine our understanding of subjects, patients and their relationship to the world or to others (autistic behavior, collaborative contexts).

The CentraleSupélec engineer will be able to understand how to put digital technology at the service of the human factor, what its possibilities and limits are, and which technologies are appropriate for building the computer science of tomorrow.

Adviced prerequisites

Courses in Algorithms and Complexity, Statistics and Learning, Signal Processing

Context and issue modules: These modules include an introductory lecture on the theme, presentations on the technological and scientific challenges,



and a presentation of the associated projects. The whole will allow to highlight a common problem (the analysis of non-verbal behavior) with very varied application fields, and will give an introduction to social psychology, on the aspects of verbal and non-verbal language.

Specific course (60 HEE): 2D-3D Image and Sound Analysis

Brief description: the course will cover three important parts necessary for project completion:

Image analysis:

filtering: high pass, low pass, Canny filter

segmentation: by region (WaterShed, Split&Merge, Region Growing)

feature detection: LBP, SIFT, HOG, ...

Pattern recognition :

edge detection and Hough transform

deformable models

pattern matching: correlation, 3D registration by rigid ICP

Sound analysis :

fundamentals of audio analysis: wavelets, cepstres, ...

speech analysis

3D sound: transfer function, spatialization

Project: What you say without meaning to: deciphering and automatic analysis of non-verbal behavior

- Associated partner :

- Location: Rennes

- **Brief description:** Every year, the audio, video and machine learning communities gather around international research challenges on the automatic analysis of human behaviors: emotions, depression, mood, motion detection, etc. (e.g. http://sspnet.eu/avec2017/). The project consists in the participation to one of these challenges. It is about, from a large corpus of data representing subjects in action, to automatically determine information about their behavior and emotions.

Each project team will focus on a particular study (e.g. voice, face, etc.), knowing that all the teams will participate in the same international challenge.



It will therefore be necessary to choose and apply certain methods seen in the course of image and 3D sound analysis. The classification and regression tools will lead to the implementation of optimization algorithms (neural network regression, fuzzy logic, SVM,...).

2SC7910 – 2D-3D image and sound analysis

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Instructors: Catherine Soladie Department: CAMPUS DE RENNES Language of instruction: ENGLISH Campus: CAMPUS DE RENNES Workload (HEE): 60 On-site hours (HPE): 34,50 Erasmus ECTS: 2,5

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 :

- \circ Algorithms
- Programming langages



Syllabus

Background (5%)

- Introduction to the subject
- Historical context.
- Link with the subjects of the program.

Image Analysis (25%)

- Filtering: low-cut filter, high-pass filter, Canny filter
- Segmentation: waterShed, Split & merge, region growing
- Feature extraction: LBP, SIFT, HOG

Sound analysis (25%)

- Audio signals and time-frequency representation
- Speech production and modeling
- Spatial audio

Text analysis (20%)

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.)

- Bureau d'étude : mixing theory and practice : 50% (30 HEE)
- Evaluation : 10% (6 HEE)
- $\,\circ\,$ 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: <u>https://www.animations.physics.unsw.edu.au/waves-</u> <u>sound/oscillations/index.html</u> For image synthesis: OpenGL Programming Guide

Resources

Teaching team:

- \circ Catherine SOLADIE
- \circ Renaud SEGUIER
- \circ Simon LEGLAIVE
- \circ 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

Campus: CAMPUS DE RENNES

Workload (HEE): 80

On-site hours (HPE): 48,00

Erasmus ECTS: 4,5

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: <u>http://sspnet.eu/avec2017/</u>).

Through this project, you will be able to face 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 compare your results to those of the competitors of 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%)

- \circ Research and understand research papers on the subject.
- 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
- \circ Explore the relevant visual representation modes
- \circ 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. If possible, coordination of the different teams for the production of a single overall final result.
- Presentation of the results to our partners.

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
- Simon LEGLAIVE
- 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 – SOURCE SEPARATION FOR OPTIMAL SIGNAL PROCESSING

Department : MDS (Mathematics, Data Science)

Language of instruction: Français

Campus : Campus de Metz

Engineering problematic

In order to increase productivity, to reduce ecological impact or to improve the quality of services, manufacturers and research centers must respond to the issues of data analysis made up of overlapping signals. Indeed, in many applications, sensor signals are mixtures of several sources that emit at the same time, and the information carried by these signals can only be exploited if we manage to separate what comes from each source. For example, in oil exploration, companies are now carrying out acquisition campaigns in simultaneous source mode (several sources emit at the same time). It is then necessary to distinguish in the signals of the geophones the echoes due to the various sources to obtain an image of the subsoil. Or in a "hi-tech" store, a robot that has started a conversation with a person may be disturbed by other customers or by ambient noise, while it must continue its conversation with the same person. Or in electrocardiograms, to separate the signal of the fetus' heart from that of its mother. Or for sound recording in a conference or round table with several speakers, rather than giving a microphone to each speaker, it would be practical to separate what each speaker says from recordings of microphones placed in fixed positions. The solutions to these problems are based on the same mathematical concepts:

• The knowledge of a data representation space adapted to the problem, where data have a sparse representation (in other words the data can be represented by a vector which has a few non-zero coordinates, in a space of great dimension);

- the minimization of a criterion that depends on the data; and
- a learning and testing stage to verify that the obtained solution generalizes and thus avoid overfitting.

Necessary prerequisites



First year courses in probability, statistics, signal processing and algorithms; good skills in a programming environment (Matlab, Python, ...).

Context and issues modules: These modules include an introductory lecture on the theme, presentations on environmental and societal issues and on technological and scientific challenges, as well as a presentation of related projects.

Specific course (60 HEE): Sparse representations of signals

Brief description: This course presents the mathematical tools of signal analysis and their properties (complements on the Fourier transform, subsampling/oversampling, harmonic signal, STFT, multiresolution analysis, Paley-Littlewood and bi-orthogonal wavelet decompositions, perfect reconstruction filter banks) as well as signal decomposition methods (Matching Pursuit, Basis Pursuit, Independent Component Analysis).

Projet n°1 : Tracking a speaker by a robot

Associated partner: ORANGE, Cognitive Computing

Campus: Campus de Metz

Brief description: Robots are increasingly present in our environment. 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 it. ORANGE wants to solve this problem by using a monophonic audio signal recorded by the robot, without adding other modalities.

The issue is therefore to find one or more data representation spaces well adapted to the problem of speaker tracking; to learn from a small number of samples (i.e. over a small recording duration) the features of the speaker to be tracked; to avoid overfitting which may occur if the learned features depend on the words spoken by the speaker.

Projet n°2: Separation of sound sources from recordings of several
microphones

Associated partner: CentraleSupélec, audio plateform of the « smartroom

Campus: Campus de Metz

Brief description: 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. Dans certaines de ces situations, plusieurs sources peuvent intervenir (par exemple, une conférence ou table ronde dans laquelle plusieurs locuteurs sont présents).



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.

The problem is therefore, starting from a fixed microphone array and assuming a finite number of sources (e.g. speakers), to ensure the separation of the sources and to provide an output channel per source (speaker), which channel would also contain the position information of this source. For simplicity, we will start by assuming that the speakers are at fixed positions known in advance. This is the case, for example, for speakers at a round table. In this case, the system could be calibrated beforehand using white noise generators, and then could operate using the fixed parameters determined in this way.

Projet n°3 : Non-invasive foetal electrocardiogram extraction

- Associated partner: INSERM
- Campus: Campus de Metz
- Brief description: Non-Invasive foetal electrocardiography (NI-FECG) represents an alternative foetal monitoring technique to traditional Doppler ultrasound approaches, that is non-invasive and has the potential to provide additional clinical information. However, despite the significant advances in the field of adult ECG signal processing over the past decades, the analysis of NI-FECG remains challenging and largely unexplored. This is mainly due to the relatively low signal-to-noise ratio of the FECG compared to the maternal ECG, which overlaps in both time and frequency.

The issue is to find one or several data representation spaces well adapted to the problem of foetal ECG extraction. It will be a question of applying and testing one or several methods starting from an article that reviews recent advances in NI-FECG research including: publicly available databases, NI-FECG extraction techniques for foetal heart rate evaluation and morphological analysis, NI-FECG simulators and the methodology and statistics for assessing the performance of the extraction algorithms..

2SC8010 – Sparse representations of signals

S

Instructors: Stephane Rossignol Department: CAMPUS DE METZ Language of instruction: FRENCH Campus: CAMPUS DE METZ Workload (HEE): 60 On-site hours (HPE): 34,50 Erasmus ECTS: 2,5

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%). 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: DOMINANTE - MATHÉMATIQUES, DATA SCIENCES Language of instruction: FRENCH Campus: CAMPUS DE METZ Workload (HEE): 80 On-site hours (HPE): 48,00 Erasmus ECTS: 4,5

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.

Robots are increasingly present in our environment. 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 it. ORANGE wants to solve this problem by using a monophonic audio signal recorded by the robot, without adding other modalities.

The issue is therefore to find one or more data representation spaces well adapted to the problem of speaker tracking; to learn from a small number of samples (i.e. over a small recording duration) the features of the speaker to be tracked; to avoid overfitting which may occur if the learned features depend on the words spoken by the speaker.

Quarter number ST7

Prerequisites (in terms of CS courses)

- Probability 1A (CIP-EDP, 1SL1000),
- Signal processing ST4 (1CC4000)
- o Statistics, Machine learning and Data processing ST4 (1CC5000),

o Digital environment, computer and programming SG1 (1CC1000).



Syllabus

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.

Other approaches are possible (convolutional neural networks on raw data or separation in the MFCC --- Mel-Frequency Cepstral Coefficients) --- representation).

We will try to split the problem into sub-systems and try to treat a part of it well and/or to evaluate speaker separation algorithms for which implementations are available on the net.

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:

- o provide the project report; and
- \circ to carry out the defense in the presence of the partner.

A progress report of the project with reading of the "laboratory notebook" and the draft report will take place regularly.

Grading

Skills will be assessed:

- in continuous control at the advancement points, the "laboratory notebook" reading and the draft report reading (individual note CC);
- during the final defense (individual note S).

S

In addition, the quality of the deliverables: final report, "laboratory notebook" and commented source codes, will be evaluated (note QL).

Final score = CC/3 + S/2 + 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 defense.

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:

- 5. represent and decompose audio signals in an "optimal" way ;
- 6. fit a model to data ;
- 7. 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): 48,00

Erasmus ECTS: 4,5

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 the project report; and

- to carry out the defense in the presence of the partner.

A progress report of the project with reading of the "laboratory notebook" and the draft report will take place regularly.

Grading

Skills will be assessed:

- in continuous control at the advancement points and the "laboratory notebook" reading and draft report reading (note CC);
- during the defense (note S)

In addition, the quality of the deliverables: final report, "laboratory notebook" and commented source codes, will be evaluated (note QL).

Final score = CC / 3 + S / 2 + 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 themselves. Highlight the added value (level 2)



2SC8094 – Non-invasive extraction of the fetal electrocardiogram

Instructors: Jean-Luc Collette

Department: DOMINANTE - MATHÉMATIQUES, DATA SCIENCES

Language of instruction: FRENCH

Campus: CAMPUS DE METZ

Workload (HEE): 80

On-site hours (HPE): 48,00

Erasmus ECTS: 4,5

Description

The project, which is part of the ST7-Optimization "Source separation for optimal use of signals", will focus on a source separation issue raised by a client partner: INSERM in Nancy.

Non-invasive fetal electrocardiography (NI-FECG) represents an alternative fetal monitoring technique to traditional Doppler ultrasound, which is non-invasive. However, despite significant advances in adult ECG signal processing over the past decades, analysis of NI-FECG remains difficult and largely unexplored. This is mainly due to the relatively low signal-to-noise ratio of the FECG compared to the maternal ECG, which overlaps in both time and frequency.

The problem therefore consists in finding one or more data representation spaces well suited to the problem of fetal ECG extraction. It will be a question of applying and testing one or more methods starting from an article which reviews recent advances in research on NI-FECG, in particular: databases accessible to the public, techniques of NI-FECG extraction for fetal heart rate assessment and morphology analysis, NI-FECG simulators, and methodology and statistics to assess the performance of extraction algorithms.

Quarter number

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 and implementation of non-invasive fetal ECG extraction algorithms, based on the article by Joachim Behar et al. "A practical guide to non-invasive fetal electrocardiogram extraction and analysis", Physiol. Meas. 37, 2016.

Class components (lecture, labs, etc.)

This teaching is done in the form of a project.

Throughout the duration of the project, students will be asked to keep an up-to-date "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 a project report; and

- to carry out a defense in the presence of the partner.

A progress update on the project with reading of the "laboratory notebook" and the provisional version of the report will take place regularly.

Grading

Skills will be assessed:

- in continuous control at the advancement points, the "laboratory notebook" reading and the draft report reading (individual note CC);
- during the final defense (individual note S).

In addition, the quality of the deliverables: final report, "laboratory notebook" and commented source codes, will be evaluated (note QL). Final score = CC/3 + S/2 + 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 defense.

Course support, bibliography

Joachim Behar, Fernando Andreotti, Sebastian Zaunseder, Julien Oster and Gari D Clifford, "A practical guide to non-invasive fœtal electrocardiogram extraction and analysis", Physiological Measurement, 37, R1 – R35, 2016.

Resources

80 HEE (48 HEE) of project carried out in groups of students.



Learning outcomes covered on the course

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

- represent and decompose electrocardiograms in an "optimal" way;
- fit a model to data;

- use a programming language to effectively implement 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.



ST7 – 81 – ADDITIVE MANUFACTURING DESIGN

Dominante : CVT (Construction, City and Transportation)

Langue d'enseignement : English

Campus où le cours est proposé : Paris-Saclay

Engineering problem

Since its inception, additive manufacturing has proven to be a fundamental change in manufacturing processes, allowing for total customization and artisanal quality at the cost and precision of a modern industrialized process. All additive manufacturing technologies consist of layering through the machine-controlled movement of either a high energy source capable of causing a phase change or a material injector. Multiple types of AF processes exist depending on the material and technology used: 1) Additive manufacturing on metal (mechanical parts, prostheses) 2) Additive manufacturing on ceramics (biomedical applications, parts under high thermal constraints) 3) AF on plastic (rapid modeling, design, products of everyday use) 4) AF on concrete (construction of GC structures in adverse conditions). Due to their nature, these processes allow unprecedented freedom in the design of parts and structures. However, it is a young process, and therefore, not yet fully mastered. The mechanical properties of the parts produced are often unpredictable, severely limiting their use in high-end applications. This is why the development of methods (analytical and numerical) capable of predicting the final characteristics of the part by optimizing the design process seems a necessity.

The topic is focused on the optimization of the design by additive manufacturing:

- Optimal choice of material and microstructure (Young's modulus, material phase, porosity...);

- Optimization of the shape with respect to multiphysical constraints (thickness, shape of the section, length...);

- Optimization of process parameters (printing path, laser power, powder characteristics...)



- Evaluation of the economic and social stakes of FA compared to standard processes (manufacturing time, cost of materials, labor employed, environmental compatibility...)

This design presents a major challenge due to the multiphysical nature of the additive manufacturing process (thermal, mechanical, electromagnetic, metallurgical, phase change) and poses a multiscale problem both in space and in time (evolutionary nature of the process).

Adviced prerequisites

It is advisable to have taken the SPI course "Mechanics of Continuous Media" and at least one of the following courses: Materials, Transfer Science, Thermodynamics.

Context and issue modules : These modules include lectures, a round table and a mini-project, aimed at presenting the problem, the social and economic stakes and making a simple object using 3D printing.

Specific course (60 HEE) : Multiphysics coupling for additive manufacturing

Brief Description: This course will address the concepts and issues of multiphysics coupling in a broad sense. The following topics, among others, will be covered during the course:

- Strong weak coupling
- Coupling of different formulations
- Coupling of different scales

Then we will focus on particular couplings, of interest for additive manufacturing:

- Laser on powder: electro-thermal coupling

- Powder bed melting: discrete-continuous, solid-fluid and thermomechanical coupling

- Cooling phase: aerothermal-mechanical coupling

The course will end with a reflection on the mechanics of the final part (residual stress, porosity, microstructure...)

Projects:



The sequence is built around two projects carried by the VSE and CVT majors respectively.

Project n°1: Optimization of aeronautical parts in metallic additive manufacturing

- Associated partner: SafranTech
- Location: Paris-Saclay

- **Brief description:** The students will be divided into 4 teams of 5. Each team will have to propose a design model of a metallic part in additive manufacturing. 2 different parts, each made by 2 additive manufacturing processes (SLM, EBM) will constitute the 4 subjects.

Level 1: Simplified representation (simple analytical models) to reach a first optimum on a first field of parameters e.g. Modeling of a beam subjected to a dynamic load and a temperature field - optimization of the geometrical parameters of the beam (section, aspect ratio...) and of its material properties

Level 2: Confrontation with reality by realization of a sample and measurement of its properties e.g. tensile test to characterize the properties of different materials and differences in properties for a fixed material but with specimens made with different parameters of the process

Level 3: Optimization of the system in a new parameter space closer to the real system modeled by advanced numerical methods e.g. FEM model of a turbine blade - optimization under thermomechanical constraints

Level 4: Analysis of the cost benefits of the process compared to conventional machining eg. e.g. Manufacturing time, cost of materials, labor employed, environmental compatibility...

Project n°2: Optimization of parts for the biomedical industry using polymer additive manufacturing

- Associate partner: Biomodex
- Location: Paris-Saclay campus

- **Brief description:** The students will be divided into 4 teams of 5. Each team will have to propose a design model for a polymer part in additive manufacturing. 2 different organs studied according to 2 different manufacturing strategies will constitute the 4 subjects.



Level 1: Simplified representation (simple analytical models) to arrive at a first optimum on a first field of parameters e.g. Modeling of a microstructured beam crossed by an ultrasonic wave - optimization of the microstructural parameters of the beam (section, aspect ratio...) and of its material properties

Level 2: Confrontation with reality by realization of a sample and measurement of its properties e.g. wave propagation test to characterize its echographic footprint.

Level 3: Optimization of the system in a new parameter space closer to the real system modeled by advanced numerical methods e.g. FEM model - optimization of the ultrasound footprint.

Level 4: Analysis of the cost benefits of the process compared to a conventional casting e.g. manufacturing time, material cost, etc. Manufacturing time, cost of materials, labor employed, environmental compatibility...

Project n°3: Optimization of civil engineering structures using concrete additive manufacturing

- Associate partner: XTreee
- Location: Paris-Saclay campus

- **Brief description:** The students will be divided into 4 teams of 5 with the aim of designing walls with thermo-acoustic insulation properties. 2 teams will focus on noise reduction properties, and the other 2 on insulation properties. Then they will merge on a wall model with a multi-scale structure reconciling the 2 properties.

Level 1: Simplified representation (simple analytical models) to reach a first optimum on a first field of parameters e.g. Modeling of an elementary cell of a stratified plane wall subjected either to a temperature field or to an acoustic wave - optimization of microstructural parameters (section, aspect ratio...) and of its material properties

Level 2: Confrontation with reality by realization of a sample and measurement of the properties of this one ex. test to characterize the attenuation of the wave or the temperature.

Level 3: Optimization of the global thermo-acoustic system by advanced numerical methods e.g. FEM model.



Level 4: Cost benefit analysis of the process compared to standard solutions e.g. manufacturing time, material cost, etc. Manufacturing time, cost of materials, labor employed, environmental compatibility...



2SC8110 – Multiphysical couplings for additive manufacturing

Instructors: Camille Gandiolle, Andrea Barbarulo

Department: DÉPARTEMENT MÉCANIQUE, PROCÉDÉS, ÉNERGÉTIQUE

Language of instruction: ENGLISH

Campus: CAMPUS DE PARIS - SACLAY

Workload (HEE): 60

On-site hours (HPE): 34,50

Erasmus ECTS: 2,5

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" SSI 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:

- Laser on powder: electro-thermal coupling
- Powder bed melting: discrete-continuous coupling, solid-fluid coupling and thermo-mechanical coupling
- Cooling phase: aerothermal-mechanical coupling

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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: DOMINANTE - CONSTRUCTION VILLE TRANSPORTS

Language of instruction: ENGLISH

Campus: CAMPUS DE PARIS - SACLAY

Workload (HEE): 80

On-site hours (HPE): 48,00

Erasmus ECTS: 4,5

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" SPI 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: DOMINANTE - CONSTRUCTION VILLE TRANSPORTS

Language of instruction: ENGLISH

Campus: CAMPUS DE PARIS - SACLAY

Workload (HEE): 80

On-site hours (HPE): 48,00

Erasmus ECTS: 4,5

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" SPI 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: DOMINANTE - CONSTRUCTION VILLE TRANSPORTS

Language of instruction: ENGLISH

Campus: CAMPUS DE PARIS - SACLAY

Workload (HEE): 80

On-site hours (HPE): 48,00

Erasmus ECTS: 4,5

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" SPI 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 – PHYSICAL NEURO-INSPIRATORY SYSTEMS FOR INFORMATION PROCESSING

Dominante : PNT (Physics and NanoTechnology)

Langue d'enseignement : English

Campus où le cours est proposé : Metz

Engineering problem

In a context of constant increase of the volume of information to be processed, it is necessary to define new analysis strategies. Automatic classification methods based on machine learning are promising, but their numerical implementations remain slow and very energy-consuming. An alternative solution consists in designing hardware architectures called neuro-inspired, which allow to lift a large part of these barriers. This theme is attracting growing interest both in fundamental research and among startups and large high-tech groups such as IBM and Google.

In this context, and through a specific architecture known as the reservoir computer (an artificial neural network for which only a final reading layer is trained), we propose to students to discover the design principles of physical neural networks. For this, students will use many optimization techniques such as ridge regression and gradient descent, as well as their accelerated versions, or stochastic heuristics (e.g. simulated annealing, genetic algorithms).

The objective will be to simulate and test a prototype of a physical neuroinspired processing architecture comprising several tens, even hundreds of thousands of neurons and to demonstrate its low energy consumption, to determine the equivalent number of floating operations per second achievable compared to a computer on classification tasks.

Adviced prerequisites

Knowledge of equations and dynamical systems. Courses in statistics, signal processing and automation, good command of a programming language (e.g. Matlab, Python, or C/C++).



Context and issue modules: These modules include an introductory conference on the theme by personalities from the academic and industrial worlds, presentations on the technological and scientific obstacles, and a presentation of the associated projects.

Specific course (60 HEE) : Optimization for learning physical systems

Short description: This course presents the physical and mathematical tools for the realization and training of artificial neural networks: echo state network (ESN), electronic and photonic implementations, memory and computational capacity of physical architectures, supervised and unsupervised learning, ridge regression and regularization, accelerated gradient descent techniques, heuristic methods, hardware approaches for deep networks, emerging technologies (e.g. integrated photonics, nanophotonics and spintronics)

Project: High performance and low energy cost classification of video signals and images by photonic systems

- Associated partners: Start-up Light On, CentraleSupélec / Photonics Chair and FEMTO-ST Institute

- Location: Metz campus

- **Short description**: The project will focus on the learning/optimization of an experimental photonic architecture of a neuro-inspired analog computer (developed in CentraleSupélec laboratories in collaboration with the FEMTO-ST Institute). Students will have to choose learning/optimization strategies from the course and implement them so that the photonic architecture can perform image/video signal classification or solve industrially oriented problems proposed by our industrial partner Light-On. The organization of the project is as follows:

1) Rapid bibliographical study of the image or video signal classification task (or task proposed by the Light-On partner)

2) Numerical simulation on a realistic model of the architecture (provided) under Matlab. Implementation of learning methods based on linear/ridge regression, multi-logistic regression, or stochastic heuristics (unknown cost function model).

3) Identification of important physical hyper-parameters (experimentally adjustable) for the photonic architecture

4) Experimental tests, performance analysis, evaluation of the computational capacity (flops) and comparative study of the energy



performance (energy cost per processed image/video sequence) compared to software methods.



2SC8210 – Optimization for neuro-inspired computing with physical architectures

Instructors: Damien Rontani, Piotr Antonik Department: CAMPUS DE METZ Language of instruction: ENGLISH

Campus: CAMPUS DE METZ

Workload (HEE): 60

On-site hours (HPE): 34,50

Erasmus ECTS: 2,5

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 (9h L + 4.5h SC)

- 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)

Small Class #1 : Numerical simulation of an ESN for solving a regression task (1.5h)

Small Class #2 : Numerical simulation of a reservoir computer for solving a classification task (3h)

Machine Learning and Optimization for physical neuro-inspired architectures (16.5h L + 1.5h SC)

- 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 classificiation tasks (winner-takes-all, multi-logistic regression)
- Machine Learning and parametric optimisation for physical architecture (reservoir computing architectures).

Small Class #3 : Implementation of online optimization techniques (1.5h)

Emergent approaches (1.5h L)

- 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 : 27h Small class: 6h Final Exam: 1.5h

Grading

Final Exam : Duration : 1.5h - 50% of the final grade

- $\circ\,$ In case of unjustified absence, the grade is 0 for this part of the grade
- Homework (similar to.a mini project)with numerical simulation to solve a particular task or 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): 48,00

Erasmus ECTS: 4,5

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 problemC6.4: Solve problems through mastery of computational thinking skillsC7.1: 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



2PC3000 – Compilation - Infosec

Instructors: Pierre Wilke
Department: CAMPUS DE RENNES

Language of instruction: FRENCH

Campus: CAMPUS DE RENNES

Workload (HEE): 0

On-site hours (HPE): 34,50



2PC3090 – Project Compilation - Infosec

Instructors: Pierre Wilke Department: CAMPUS DE RENNES Language of instruction: FRENCH Campus: CAMPUS DE RENNES

Workload (HEE): 0

On-site hours (HPE): 48,00



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): 27,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS: 2,5

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): 27,00 Erasmus ECTS: 2,5

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.

Quarter number semaine bloquée en fin de SG8

Prerequisites (in terms of CS courses) none

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

5

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: DÉPARTEMENT INFORMATIQUE Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 40 On-site hours (HPE): 27,00 Elective Category : Fundamental Sciences Advanced level : Yes Erasmus ECTS: 2,5

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

- 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.
- 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.



2IN1580 – Artificial intelligence and global health

Instructors: Bich-Lien Doan, Marie-Anne Lefebvre Department: DÉPARTEMENT INFORMATIQUE Language of instruction: ENGLISH Campus: CAMPUS DE RENNES, CAMPUS DE METZ, CAMPUS DE PARIS - SACLAY Workload (HEE): 40 On-site hours (HPE): 27,00 Elective Category : Fundamental Sciences Advanced level : No Erasmus ECTS: 2,5

Description

The European University ALLIANCE FOR GLOBALHEALTH (Eugloh) is composed of five universities (Saclay, Porto, Lund, Munich, Szeged). They share the ambition of combining their expertise and resources in Global Health to offer the best education and training to their students. A pilot university, not only innovative, but also fully conscious of its responsibilities and ready to face societal challenges, in particular those related to Global Health. Training students as future leaders, both as experts in their fields and responsible citizens: curious, creative, and adaptable to diverse ecosystems and cultural environments. A collaboration framework open to contributions from all players and all fields concerned by Global Health.....

(see the brochure at https://www.eugloh.eu/about/vision-andobjectives/plaquette-EUGLOH-EN-page-par-page%20(1)%20(1).pdf)

This course is part of this alliance and offers students from five European universities an introduction to AI issues applied to health and well-being.

During the week, students will receive a course on artificial intelligence to understand more specialized interventions in the use of AI models in health and wellness applications.



The following courses will be given in the form of lectures or interactive workshops, face-to-face and distance, mixing students from 5 European universities. This course will therefore both acquire skills and knowledge in AI and health, but also an intercultural and international openness through exchanges between research professors and students of the Eugloh alliance

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Quarter number

Intensive week at the beginning of SG6

Prerequisites (in terms of CS courses)

No prerequisites except the level of English to follow the lectures in English.

Syllabus

o Introduction (Prof : Fabrice Popineau) Artificial Intelligence (AI) is the most powerful technology humans have ever had access to. AI will



revolutionize all aspects of our lives, of which healthcare is not the least. But what exactly is AI ? We will see that this question is more complex than one might think at first glance. From image classification to knowledge processing to medical robotics, we will see on selected examples that AI is diverse and cannot (yet) be reduced to a one-fit-all technology. We will review the main AI techniques, what they rely on and their field of application. As the field is constantly growing, many questions are still open.

o Wellness workshop at home (Prof : Catherine Soladié) No more TV couch where you receive formatted information. Replace it with a zone of action and interaction, to take care of yourself, your body and your mind, at home ! After discovering some examples of industrial or research concerts, we will invite you to imagine, in groups, tomorrow's solutions that will allow you to take care of your physical and mental health at home. What tools are needed ? What role can AI play ? How can information taken at home be returned to specialized services (sports coach, doctor, etc.) ? How acceptable can these solutions be for their users? Because well-being is not reserved for gyms or yoga studios and health is not only a matter for physiotherapists or hospitals, we will propose to imagine how this can be integrated in your homes, in an ethical and responsible scientific approach.

Course on parsimonious decomposition to aid diagnosis (Prof. Clément Elvira) Chronic liver diseases are a major health problem in our modern societies. However, nowadays the reference procedure for diagnosis is based on biopsy, a potentially dangerous method that cannot be repeated regularly. In this course, we will see how "parsimonious decomposition" methods can be used to exploit "vibrational spectroscopy" data in order to develop new non-invasive and inexpensive automatic diagnostic methods.
 Lectures given by experts in the field of AI and global health. (Eugloh Speakers)

o Course on Ethical Issues. (Prof. Dr. Effy Vayena, Deputy head of Institute of Translational Medicine). The Coronavirus pandemic has shaken our lives, reminding us of the fragility of existence, and bringing to the surface pressing ethical issues at individual, collective and international levels. Such issues include clinical ethics decisions regarding scarce healthcare resources allocation, the dilemma of protecting public health vs. suspending individual rights, and the research ethics question of testing vaccines without the usual precautions.

Class components (lecture, labs, etc.) Interactive workshops, courses and conferences

Grading



Evaluation by a final test in the form of a quiz associated with the various interventions

Resources

Face-to-face/off-site at the Gif, Rennes or Metz campuses, off-site for teachers from other Eugloh universities

Description of the skills acquired at the end of the course

• 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

• C6.7 Exploit the possible connections between objects and people

• C9.1 Analyze and anticipate the possible consequences of one's choices and actions with respect to oneself, others and the environment

• C9.4 Demonstrate rigour and critical thinking in the approach to problems from all angles, scientific, human and economic



2IN2100 – Communicating sustainable research projects

Instructors: Bich-Lien Doan Department: DÉPARTEMENT GÉNIE INDUSTRIEL ET OPÉRATIONS Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 45 On-site hours (HPE): 27,00 Elective Category : Fundamental Sciences Advanced level : No Erasmus ECTS: 2,5

Description

At the heart of the environmental crisis we are experiencing, transmitting and disseminating scientific and technical knowledge is a major expertise for engineers and researchers. This course is a life-size initiation to scientific mediation: in the space of one week, the objective is to appropriate, popularize, and format, via different media, a scientific and research discourse. By working on a real research project carried out by a researcher, the aim is to enhance its value by designing a tailor-made scientific mediation tool.

This course, which follows the Vive la Recherche! 2021 event, aims to introduce students to scientific mediation through an active pedagogy involving sustainable research projects, researchers, experts in the field and an audience in a real environment. It will be punctuated by lectures by accomplished popularizers.

Scientific mediation is a discipline that consists in establishing a link between the scientific world and society. It is as much about popularization and dissemination of scientific culture as it is about ethical or political dialogues. This discipline is therefore aimed as much at the general public who wish to satisfy their curiosity or make decisions as citizens, as at policy makers who must understand the scientific world and appropriate its knowledge. Engineers trained at CentraleSupélec, through the variety of their scientific skills and their familiarity with technical, economic and societal issues, are in a favorable position to participate in this mediation.



In this course, the topics addressed by the speakers and students will all be related to the Sustainable Development Goals, which represent a particularly important issue for scientific mediation in our time, and to which it is essential to raise the awareness of the general public and the political class.

Quarter number

semaine bloquée de SG6

Prerequisites (in terms of CS courses)

A strong motivation! This week requires a significant commitment to produce a mediation medium that is equal to the quality of the speakers and experts solicited.

Syllabus

Detailed course outline :

o Introduction to the course, its objectives and organization o Presentation of the Sustainable Development Goals (SDGs) set out by the UN in its Agenda 2030, contextualization, need for mediation and the main tools of scientific popularization

o Lectures and discussions led by two great witnesses, mediators or accomplished popularizers: discover the environment of scientific mediation, its habits and methods, learn the basics of mediation and the advice of experts, discover the behind-the-scenes of major projects o Scientific popularization project on a target medium: students meet with CentraleSupélec researchers and take ownership of their research project, then choose a type of media to present this work to a non-specialist audience or to the general public. In addition to the researchers, the students are accompanied by the course supervisors and by experts in popularization or mediation, specialists in the media they have chosen.

Organization of the course

The elective is coordinated by a team of supervisors in order to ensure coherence from the introductory course to the project defense. - Monday :

o Morning: Introduction and presentation of the week's issues, mediation tools

o Afternoon: Project exchange, meeting between researchers and students, led by the supervisors of the elective. Choice of topics and media

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- Tuesday:

o Morning: Conference and discussion with a major witness o Afternoon: Beginning of the work in project mode, with coaching by the supervisors and intervention of a media expert

o CHALLENGE: My Project in 180 seconds

- Wednesday :

o Morning: Conference and discussion with a major witness o Afternoon: Project mode work coached by the supervisors and intervention of an expert

- Thursday :

Morning: Work in project mode coached by the supervisors and intervention of an expert.

- Friday :
- Morning: Finalization of the project
- Afternoon: Project presentation and defense

Class components (lecture, labs, etc.)

- Conference and discussion with a major witness

- Work in project mode, with coaching by the supervisors and the intervention of a media expert

- CHALLENGE: My Project in 180 seconds

Grading

Evaluation on the quality of the project, as well as the quality of the end-ofweek presentation. Evaluation by peers and by the supervisory team.

Resources

Slides of the supervisors and experts

Learning outcomes covered on the course

- Create a simple outreach material for a specific audience
- Carry out a popularization project, from the research of ideas to the presentation of the material
- Know the stakes of scientific communication, in the context of sustainable development

- Evaluate the quality of a popularized information, and know how to correct or improve it if necessary

- Describe the different environments favourable to scientific communication, their advantages and their habits
- Use research to transmit their knowledge to a non-initiated public



Description of the skills acquired at the end of the course

- C1.1 Study a problem and the situation as a whole. Identify, formulate and analyze a problem in its scientific, economic and human dimensions
- C3.5 Propose new solutions/tools either in rupture or in continuous progress

- C6.7 Exploit the possible connections between objects and people
- C7.1 Convince on the substance. Be clear about the objectives and expected results. Be rigorous about the hypotheses and the approach.
Structure his/her ideas and arguments. Highlight the value created
- C7.4 Master spoken, written and body language. Master basic communication techniques

- C9.2 Perceive the field of responsibility of the structures to which one contributes, by integrating the environmental, social and ethical dimensions

- C9.4 Demonstrate rigor and critical thinking in the approach of problems from all angles, scientific, human and economic



2IN2180 – Procurement management

Instructors: Thierry Reboud Department: DÉPARTEMENT SCIENCES HUMAINES ET SOCIALES Language of instruction: ENGLISH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 40 On-site hours (HPE): 27,00 Elective Category : Business Sciences Advanced level : No Erasmus ECTS: 2,5

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 fundamnetal 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





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 – Nonotiation, Targets are :

8 – Negotiation. Targets are :

to understand why and how to prepare negotiations, identify the successful negotiation behaviours for a buyer,

to provde 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 a 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.

Grading

The students grade is the result of 2 grades of identical 'weight': The first one measure active participation to the course (presence in class and active interventions during the course or case reviews) The second one results from a case analysis done outside class, individually of in teams.

Resources

The sessions combine formal review of the subject matter, plus reviews of one or several case studies which have been distributed in advance for preparation by the students. The purpose of these studies is to understand how theory has to be sometime adapted to match 'real life situations'.

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: DÉPARTEMENT SCIENCES HUMAINES ET SOCIALES

Language of instruction: FRENCH, ENGLISH

Campus: CAMPUS DE METZ, CAMPUS DE RENNES, CAMPUS DE PARIS - SACLAY

Workload (HEE): 45

On-site hours (HPE): 27,00

Erasmus ECTS: 1,5

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 behavior 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

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• 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: DÉPARTEMENT SCIENCES HUMAINES ET SOCIALES

Language of instruction: ENGLISH, FRENCH

Campus: CAMPUS DE RENNES, CAMPUS DE PARIS - SACLAY, CAMPUS DE METZ

Workload (HEE): 45

On-site hours (HPE): 27,00

Erasmus ECTS: 1,5

Description

• The main objective of this seminar is to help students orient their actions in the face of "major contemporary challenges".

To this end, the courses propose knowledge and methodologies of psychology, sociology, political science, economics, history, and anthropology to help students :

- Understand and analyze issues related to contemporary environmental, human, and social problems. For example: global warming, energy challenges, social justice, participation of civil society.
- Understand the effects of human practices on the natural, economic and social environment
- Understand the ethical, political, social, and economic dimensions of the engineer's actions concerning these issues.

Quarter number

Intensive week of SG6 and SG8

Prerequisites (in terms of CS courses) none

Syllabus

- Courses include:
- Business, Fraud, and Deviance: Managerial and Sociological Perspectives

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- Exclusion/Inclusion in Contemporary Societies: The Social Science Perspective
- The media: socio-technical devices of social control?

Class components (lecture, labs, etc.)

The courses alternate theoretical contributions, case studies, and situational exercises.

The materials used are varied: texts (scientific articles), videos, podcasts.

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.

Resources

The courses are given in classes of a maximum of thirty students by a teacher specialized in the proposed subject.

Description of the skills acquired at the end of the course

- Analytical skills: knowing how to identify the different components and actors of the situation, examining them in order to understand the relationships between them, bringing out non-obvious links.
- Ability to synthesize: synthesize the elements of a situation, identify the points of support and the difficulties.



2IN2330 – Science, Technology, Society

Instructors: Cynthia Colmellere

Department: DÉPARTEMENT SCIENCES HUMAINES ET SOCIALES

Language of instruction: FRENCH, ENGLISH

Campus: CAMPUS DE PARIS - SACLAY, CAMPUS DE RENNES, CAMPUS DE METZ

Workload (HEE): 45

On-site hours (HPE): 27,00

Erasmus ECTS: 1,5

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 knowledge ·
- 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 English) :

- Historical, Philosophical and Ethical Perspectives on AI and Data Science
- An introduction to the philosophy of science from the perspective of measurement
- Introduction to scientific and technical controversies



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.

Resources

The courses are given in classes of a maximum of thirty students by a teacher specialized in the proposed subject.

Description of the skills acquired at the end of the course

Contextualize the problems engineers will address as professionals to understand the different dimensions (technical, managerial, human, organizational, économical) and their direct connection with the dynamics of society

- Identify the normative frameworks, world views, economic, ethical, and societal issues of the different actors concerned (employees, citizens, scientists, or institutions), and consequently their respective positions
- Understand situations of innovation, uncertainty, controversy, crisis, economic and technological change, etc., to build the most appropriate solutions.
- Knowing how to reconcile, articulate and integrate technical and scientific ("hard") knowledge and knowledge dealing with the human, social and cultural dimensions into their analyses, decisions, and actions.



2IN2340 – Innovation, Arts and Creativity

Instructors: Cynthia Colmellere

Department: DÉPARTEMENT SCIENCES HUMAINES ET SOCIALES

Language of instruction: ENGLISH, FRENCH

Campus: CAMPUS DE RENNES, CAMPUS DE PARIS - SACLAY, CAMPUS DE METZ

Workload (HEE): 45

On-site hours (HPE): 27,00

Erasmus ECTS: 1,5

Description

The main objective of theses courses is to adress 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
- Adressing Fiction : storytelling, literarity and fake news
- From cradle-to-grave : Tech won't save us

Class components (lecture, labs, etc.)

- 69
- The courses are given in classes of a maximum of thirty students by a teacher specialized in the proposed subject.

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.

Description of the skills acquired at the end of the course

Analytical skills: knowing how to identify the different components and actors of a situation, a place, a creation/innovation environment, examining them to understand the relationships between them, revealing non-obvious links



2IN4000 – Business Games

Instructors: Xavier Leon

Department: DÉPARTEMENT SCIENCES HUMAINES ET SOCIALES

Language of instruction: ENGLISH, FRENCH

Campus: CAMPUS DE PARIS - SACLAY, CAMPUS DE RENNES, CAMPUS DE METZ

Workload (HEE): 40

On-site hours (HPE): 30,00

Erasmus ECTS: 2,5

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 lifebeyond 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: DÉPARTEMENT MÉCANIQUE, PROCÉDÉS, ÉNERGÉTIQUE Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 45 On-site hours (HPE): 27,00 Elective Category : Engineering Sciences Advanced level : Yes Erasmus ECTS: 2,5

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)

- $\,\circ\,$ 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):
 - a. Structural tests
 - i. compression tests on "profiled" beams
 - ii. tensile tests on beams assembled by gluing
 - iii. (possibly) tests of various assemblies
 - b. Design of bridge models
 - i. 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
- \circ 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 defense + final summary note.

Resources

- o Software: Comsol (Structural Mechanics module)
- \circ 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:


- $\ensuremath{\circ}$ 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 Defense and the Final Briefing Note. The last

as in the Intermediate Defense and the Final Briefing Note. The last learning outcome is assessed more specifically in the intermediate defense and the final briefing note, respectively.



2IN5020 – Semiconductor innovation

Instructors: Tanguy Phulpin Department: DÉPARTEMENT SYSTÈMES D'ÉNERGIE ÉLECTRIQUE Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 40 On-site hours (HPE): 27,00 Elective Category : Engineering Sciences Advanced level : NO Erasmus ECTS: 2,5

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 possibles responses, it is fundamental to possess the basics and to handle them.

After several industrial conferences the 18th November afternoon, and after 6 hours of lesson and 1h30 of TD the 22th November, let's start in a laboratory with several projects for 2,5 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 the thursday afternoon before the week. Then the lesson in addition of a TD 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 examen

Grading

Oral defense then written exam

Resources

- Teaching staff (instructor(s) names): JP.Kleider, T. Phulpin, J-R. Lequereys (guest)
- Maximum enrollment: 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: DÉPARTEMENT PHYSIQUE Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 40 On-site hours (HPE): 27,00 Elective Category : Fundamental Sciences Advanced level : NO Erasmus ECTS: 2,5

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 work4 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 equipments

Learning outcomes covered on the course

consolidate their knowledge in Physics knowhow for mounting an experiment work in a groupe, exchange and orgnaize the work develop creativity and initiative learn how to transmit their knowledge



2IN5040 – Experimental work about information transmission

Instructors: Alain Destrez

Department: DÉPARTEMENT SIGNAL, INFORMATION, COMMUNICATION Language of instruction: FRENCH Campus: CAMPUS DE PARIS - SACLAY Workload (HEE): 40 On-site hours (HPE): 27,00 Elective Category : Engineering Sciences Advanced level : Yes Erasmus ECTS: 2,5

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 électronic 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
- Softwares and number of required licences : no required softwares (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 pratice 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 expérimentation (C1.3). Specifying, designing, realizing and validating all or part of a complex system (C1.4). Evaluating the efficiency, feasability 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 – Marketing and its tools: towards responsible marketing?

Instructors: Emmanuel Helbert Department: CAMPUS DE METZ Language of instruction: FRENCH Campus: CAMPUS DE METZ Workload (HEE): 40 On-site hours (HPE): 27,00 Elective Category : Business Sciences Advanced level : NO Erasmus ECTS: 2,5

Description

What is the use of marketing for an engineer? The objective of this course is to show that marketing is not intended to sell useless products, but can be a lever for detecting, initiating and accompanying major societal changes and a driver of technological innovation by positioning it as a means and not an end in itself. The different concepts and tools will be approached from the engineer's point of view by illustrating how they support his job.

Quarter number

Intensive week SG6

Prerequisites (in terms of CS courses) None

Syllabus

1. Introduction:

- Definitions
- corporate/marketing strategies
- strategic/operational marketing
- Impact of sustainable development on Marketing Opportunity or constraints
- 2. The market :

- a. Markets
 - b. The consumer
 - c. Studies

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- d. Tools: SWOT, PESTEL
- 3. Marketing strategy
 - \circ a. Segmentation
 - \circ b. Targeting
 - \circ c. Positioning
- 4. Operational marketing
 - \circ a. Marketing mix and sustainable development
 - o b. Brand management
 - c. Product Management
 - \circ d. Distribution
 - \circ e. Awards
 - \circ f. Communication and corporate social responsability
 - \circ g. Focus: Digital marketing, content marketing, B2B marketing
- 5. Marketing today
 - 8.a. Lean Start-Up
 - 9.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: DÉPARTEMENT DÉVELOPPEMENT PROFESSIONNEL ET MÉTIERS D'INGÉNIEUR

Language of instruction: FRENCH

Campus: CAMPUS DE PARIS - SACLAY

Workload (HEE): 40

On-site hours (HPE): 27,00

Elective Category : Business Sciences

Advanced level : Yes

Erasmus ECTS: 2,5

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

C3.1 Observe and allow oneself to criticize the world as it is, to doubt, to go beyond injunctions, to question one's initial assumptions, to allow oneself to learn from one's failures, to diagnose

C5.2 Listening, making oneself understood and working with actors of diversity, cultures, codes, training, disciplines, etc. varied

C9 (C9.1-2-3-4) Think and act as an ethical, responsible and honest engineer, taking into account the environmental, social and societal dimension



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): 27,00

Elective Category : Business Sciences

Advanced level : NO

Erasmus ECTS: 2,5

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

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.

The presentation can be made orally using the usual computer and digital tools.

Course support, bibliography Bibliography

- Waserman F., Les finances publiques, La Documentation Française, 9th edition, 2018.
- Bouvier M., Les finances locales, L.G.D.J, 18th edition, 2020
- Bouvier M., Esclassan M.-C., Lasalle J.-P., Finances publiques, L.G.D.J, 19th edition, 2020

Useful links

- INSEE https://www.insee.fr/fr/accueil
- The platform for public finance, the State budget and public performance https://www.budget.gouv.fr
- Public life https://www.vie-publique.fr
- Local authorities https://www.collectivites-locales.gouv.fr
- Légifrance The public service for the dissemination of law https://www.legifrance.gouv.fr
- Court of Auditors https://www.ccomptes.fr/fr
- National Assembly https://www.assemblee-nationale.fr
- Senate http://www.senat.fr

- Social Security https://www.securite-sociale.fr/accueil#
- Direction de la recherche, des études, de l'évaluation et des statistiques: L'expertise statistique publique en santé et social https://drees.solidarites-sante.gouv.fr/systeme-de-protectionsociale
- Agence France Trésor https://www.aft.gouv.fr
- European Commission https://ec.europa.eu/info/index_fr

Resources

A PowerPoint presentation will be used to support the course. It will be accompanied by podcasts, video sequences and consultations of online sites.

Learning outcomes covered on the course

At the end of the course, the student will be able to understand the daily information on public finances, whether it is about the State, local authorities, social protection or Europe. He or she will be able to place this information in its political and economic context. This data relating to public finance is an essential element of the company's environment. They influence companies' investment and research decisions. They structure the economic and social behavior of all economic agents

Description of the skills acquired at the end of the course

Legal skills: notions of public law, parliamentary law, constitutional law, budget law

Political science skills: functioning of the State, local authorities and European institutions

Economic skills: the interactions between public finance and the economy at the local, national and European levels

General skills to allow each student to deepen his or her political reflections





LC0100 – English

Instructors: Mark Pitt

Department: DÉPARTEMENT LANGUES ET CULTURES

Language of instruction: ENGLISH

Campus: CAMPUS DE PARIS - SACLAY, CAMPUS DE RENNES, CAMPUS DE METZ

Workload (HEE): 30

On-site hours (HPE): 21,00

Erasmus ECTS: 1,5 (for exchange students only)

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.

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.

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Learning outcomes covered on the course

- Consolidate and develop the four basic language skills (reading, writing, listening and speaking).
- C5: Consolidate and develop intercultural skills and comprehension essential to an international career.
- C7: Improve one's persuasive skills
- 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 (or even beyond) the C1 level required for the CentraleSupélec diploma.
- Other skills (C5, C7) will have been reinforced.



LC0200 – French as a Foreign Language

Instructors: Geraldine Ofterdinger

Department: DÉPARTEMENT LANGUES ET CULTURES

Language of instruction: FRENCH

Campus: CAMPUS DE METZ, CAMPUS DE RENNES, CAMPUS DE PARIS - SACLAY

Workload (HEE): 30

On-site hours (HPE): 21,00

Erasmus ECTS: 1,5 (for exchange students only)

Description This document is for 1st, 2nd and 3rd year students.

Quarter number S5 from September to January S6 from February to June

Prerequisites (in terms of CS courses) None.

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: Daniela Moncys Moncevicius

Department: LANGUES ET CULTURES, DÉPARTEMENT 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): 21,00

Erasmus ECTS: 1,5 (for exchange students only)

Description

General German courses from level A0 to C1, with specialization (thematic courses) possible from level B1+.

Quarter number

S5 from September to January S6 from February to June

Prerequisites (in terms of CS courses)

Beginner courses (A0) are only possible in the first semester of the first year.

If you have previously studied German, the minimum level required at the end of the first year is A2+ and at the end of the second year B1-.

Syllabus

GENERAL GERMAN

Beginner level: Practice of oral and written skills. Introduction to the culture and current affairs of German-speaking countries. Level A1-B1: Acquisition of basic skills, with particular emphasis on oral and written language. Intercultural approach to German-speaking countries and cultures.

THEMATIC COURSES: From level B1+ Practice of the German language at an intermediate and advanced level by means of thematic sequences: economy, science, history, current events, culture, arts and others - also depending on the motivation of the learners - and by means of weekly debates. All courses include written and oral grammar and structure exercises. Preparation for the Goethe Institute certificates (B1 to C2) possible.



Class components (lecture, labs, etc.)

After a test, each student is placed in a course corresponding to his/her level: A1-A2, B1-B2, C1 (according to the Common European Framework of Reference).

Throughout his or her schooling, the student will follow weekly classes of 1.5 hours each, between which he or she will do individual or group work of about 1 hour.

The principles of the flipped classroom can be applied, leaving full space during the class session for interaction, exchange and role-playing.

Grading

Continuous assessment and involvement in classes at least 80%, up to 100%; possibility of an end-of-semester exam (written exam/audit/oral test) which counts for a maximum of 20% of the grade

Course support, bibliography

A variety of materials: textbooks, audio, video, written documents, interactive exercises that emphasize language practice and teamwork.

Resources

Diverse, varied, communicative and interactive courses focused on current events and interculturality, adapted to the interests and needs of learners

Learning outcomes covered on the course

To consolidate and develop the four language skills (written and oral comprehension, written and oral expression) which will provide the tools to communicate in an internationalized and varied school, professional and/or personal environment. To consolidate and develop the tools of intercultural understanding that will allow students to initiate cultural openness and to approach the International. To allow each student to develop the means to continue learning by encouraging autonomy, responsibility, teamwork and project work as well as critical thinking in the learning process. To propose, throughout the three years of study, varied and innovative approaches allowing each student to find himself in a suitable teaching program.

Description of the skills acquired at the end of the course

Understand and express oneself in written and spoken German, in everyday life as well as in a professional and academic context (internships, academic exchanges, e-tandem ...). Acquire intercultural skills allowing better communication with interlocutors in German-speaking countries. Consolidate the skills of the engineer C5.1, C5.4, C7, C8.1, C8.4



LCO400 – Spanish

Instructors: Antonio Barrejon Lopez

Department: LANGUES ET CULTURES, DÉPARTEMENT 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): 21,00

Erasmus ECTS: 1,5 (for exchange students only)

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: DÉPARTEMENT LANGUES ET CULTURES, 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): 21,00

Erasmus ECTS: 1,5 (for exchange students only)

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 (80-100%) Written exam / listening-speaking test at the end of each semester (0-20%)

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.

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LC0600 – Portuguese

Instructors: Claude Mezin-Wilkinson

Department: DÉPARTEMENT LANGUES ET CULTURES, 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): 21,00

Erasmus ECTS: 1,5 (for exchange students only)

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 2A

Instructors: Claude Mezin-Wilkinson

Department: LANGUES ET CULTURES, DÉPARTEMENT 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): 21,00

Erasmus ECTS: 1,5 (for exchange students only)

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: DÉPARTEMENT LANGUES ET CULTURES, 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): 21,00

Erasmus ECTS: 1,5 (for exchange students only)

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, DÉPARTEMENT 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): 21,00

Erasmus ECTS: 1,5 (for exchange students only)

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: DÉPARTEMENT LANGUES ET CULTURES, 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): 21,00

Erasmus ECTS: 1,5 (for exchange students only)

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: DÉPARTEMENT LANGUES ET CULTURES, 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): 21,00

Erasmus ECTS: 1,5 (for exchange students only)

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.