CentraleSupélec | université PARIS-SACLAY

FIRST YEAR COURSES CATALOG

Academic year 2023-2024

September 20, 2023 issue

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CORE CURRICULUM COURSES

1CC1000 – Information Systems and Programming

Instructors: **Gianluca Quercini**
Department: **DÉPARTEMENT INFORMATIQUE**
Language of instruction: **ENGLISH, FRENCH**
Type of course: **Common course**
Campus: **CAMPUS DE PARIS - SACLAY, CAMPUS DE RENNES, CAMPUS DE METZ**
Workload (HEE): **60**
On-site hours (HPE): **30,00**

Description

This course consists of two parts: information systems and programming.

The aim is to introduce prospective engineers to the information systems that they will use throughout their careers, and to enable them to properly design and write a computer program.

First year students have varying levels in these fields, depending on their previous experiences (some might already have participated in programming competitions) and education paths.

This course does not require any advanced notion in algorithmic.
At the end of the course all students will achieve a minimum common level of preparation; advanced students with previous knowledge in the subject will be able to improve their skills.

Three successive courses of the engineering program contribute to training students in programming and algorithms. This course is the first, followed by the Coding Weeks (two weeks dedicated to the design and implementation of a software project) and Algorithms and Complexity.

Quarter number SG1

Prerequisites (in terms of CS courses)

None in terms of the CentraleSupélec courses, SIP being the first computer science course of the engineering program.

However, students are expected to have acquired the computer science knowledge required in the classes préparatoires: notions of relational databases, basic knowledge of SQL, basic knowledge of Python programming.

Before the course, students will have to take a test to determine their level in Python: beginner, intermediate or advanced.
Students will be assigned to lab groups based on their initial level in Python.

The result of the test does not have any impact in the final grade of the course.

Syllabus

The course consists of 19 slots of 1.5 hours, with 4 lectures (“amphis”), 15 tutorials (“TD”) and a final exam (1.5 hours).

Information Systems:
- Introduction to computer architecture.
- Network and security basics.

Programming & Python
- Interpreter, command line.
- Variables, objects types.
- Objects and classes.

- Tests, loops, lists, sets, functions, modules, dictionaries, files, databases.
- Finding and using external libraries (numpy, matplotlib)
- Processing unstructured data (text).
- Debugging, test plan, « clean code ».
- GIT.

Class components (lecture, labs, etc.)

The course proposes a series of tutorials ("TD") with classic pencil-and-paper exercises or using a computer.
Students must install on their personal computer a programming environment (Visual Studio Code + Python + Git) before the course.

A technical support is provided by DISI (the CentraleSupélec technical service) to help all students with the installation process.

Classrooms are equipped with a wired or wireless Internet access, which allows students to look up resources on the Internet.
Students are supposed to do their exercises by themselves, although discussions among classmates and the professor is encouraged.

Grading

A written exam is organised at the end of the course. The exam is 1.5 hours long and it covers the entire course (information systems and programming).
Students are not allowed to use their computers and the course material, with the only exception of a Python reference sheet.

A continuous assessment is also planned. It consists of quizzes and homework.
The written exam will count for 80% of the mark; the MCQs and homework reports for 20%.

Course support, bibliography

The course support is:

- A course book on Information Systems (in English).
- A reference manual for Python and “clean code” (in English).

Resources

Teaching staff (instructor(s) names): Guillaume Mainbourg, Dominique Marcadet, Marc-Antoine Weisser (lectures in French), Gianluca Quercini (lectures in English).

- Maximum enrollment (default 35 students): 30-35 students for each tutorial class (“TD”).
- Required hardware: a personal computer with a minimal configuration (communicated to the students before the beginning of the course).
- Software, number of licenses required: open-source software, or free for students.
- Equipment-specific classrooms (specify the department and room capacity): no

Learning outcomes covered on the course

Information Systems:

- Understand how computers and networks work.
- Understand the basics of security of information systems.

Programming:

- Write a program in a high level programming language to solve a problem.

- Apply good programming practices: modularity, code reuse, naming conventions, comments.

- Test a software: debugging, assertions.
- Use software development tools: integrated development environment, command-line interface, Git.

Description of the skills acquired at the end of the course

C2.1 Deepen a field of engineering sciences or a scientific discipline
- C6.1 Solve a problem numerically.
- C6.2 Design software.

- C6.3 Process data.

1CC2000 – Algorithmic and Complexity

Instructors : **Lina Ye**
Department : **DÉPARTEMENT INFORMATIQUE**
Language of instruction: **ENGLISH, FRENCH**
Type of course : **Common course**
Campus : **CAMPUS DE RENNES, CAMPUS DE PARIS - SACLAY, CAMPUS DE METZ**
Workload (HEE) : **60**
On-site hours (HPE) : **31,50**

Description

The goal of this course is to introduce computer science methods for engineering problem solving. It presents different problem families using theoretical models. It shows how to solve these problems using sequential or parallel algorithms. We question the existence of a solution and we take great care to the quality of the computed solution. We study the complexity of the problems as well as the complexity of the resolution algorithms.

Quarter number ST2

Prerequisites (in terms of CS courses) SG1 Informations systems and programming (ISP)

Syllabus

Lecture 1: Introduction – decision and optimization problems, solution, algorithm, algorithm complexity, graph representation, non-weighted graph search
Lecture 2: Directed Acyclic Graph (DAG) traversal and scheduling, weighted graph search
Lecture 3: Minimum spanning tree, Prim and Kruskal algorithms
Lecture 4: Maximum flow, Ford-Fulkerson, applications
Lecture 5: Dynamic programming
Lecture 6: Complexity of problems, polynomial reduction, NP-completeness
Lecture 7: Exact methods for solving NP-hard problems : backtracking; – Traveling Salesman Problem (TSP)

Class components (lecture, labs, etc.)

-7x1h30 lectures
-12x1h30 Tutorials, including 3 labs and 2 practice tutorials
-3h exam

Grading

Written examination: - all hand-written documents allowed

- -Final written examination: 80%.
- -Continuous assessment (practical work reports): 20%.

Course support, bibliography

All slides will be available online.

Students can refer to the following textbooks:

- *Introduction to Algorithms*, Third Edition. By Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest and Clifford Stein. MIT Press, 2009.
- *Algorithm Design*. By Jon Kleinberg et Éva Tardos. Pearson Ed. (Addison-Wesley), 2006.
- *Programmation Efficace : Les 128 Algorithmes Qu'Il Faut Avoir Compris et Codés en Python au Cours de sa Vie.* Par Christophe Dürr et Jill-Jênn Vie. Ellipse, 2016. (in French)

Resources

Teaching staff (instructor(s) names):

- Fabrice POPINEAU
- Arpad RIMMEL
- Nicolas SABOURET
- Joanna TOMASIK
- Benoit VALIRON
- Marc-Antoine WEISSER
- Anaëlle WILCZYNSKI
- Lina YE
-

- Maximum enrolment (default 35 students): 25 students max per tutorial group
- Software, number of licenses required: Python Integrated Development Environment (VSCode, etc)

Learning outcomes covered on the course

After this course, students will be capable of:

- Computational thinking, or reasoning with an algorithmic view to solve real-life problems;
- Knowing the general methods to write an algorithm (brute force, divide and conquer, etc) and applying these methods to solve a problem;
- Using exact methods (dynamic programming, backtracking, etc.) as well as heuristics (greedy, A*, etc.) to obtain approximate solutions to an optimization problem;
- Algorithm analysis to estimate the complexity in time and space;
- Studying the class of complexity of a problem so as to select the most relevant problem-solving methods.

Description of the skills acquired at the end of the course

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

- Reason in algorithmic terms to solve real-life problems (computational thinking). Given a real-life problem, students will propose a model, determine the complexity class of the associated computational problem, propose an algorithmic solution to the problem and evaluate the quality of the solution.
In relation to skill C6.1 (Solve a problem numerically)

- Know generic techniques for designing algorithms (brute force, divide and conquer, etc.) and apply them to solve a problem;

- Use exact methods (dynamic programming, etc.) and heuristic methods (greedy, A*, etc.) to obtain approximate solutions to an optimization problem;

- Analyze algorithms and estimate their temporal and spatial complexity;

- Determine the complexity class of a problem to choose the right solutions.
In relation to skill C6.2 (Designing software)

- 3 labs and 2 practical exercises will allow students to implement the algorithms they studied through a Python program.

1CC3000 – Model representations and analysis

Instructors : **Cristina-Nicoleta Maniu**
Department : **DÉPARTEMENT AUTOMATIQUE**
Language of instruction: **ENGLISH, FRENCH**
Type of course : **Common course**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **60**
On-site hours (HPE) : **31,50**

Description

Current technological and scientific progress would not have arisen without the deep understanding and evolution of complex systems gathering different application fields such as energy, telecommunications, transport, aeronautics and aerospace, economy, finance, healthcare, etc. System modeling plays a crucial role to drive it and to analyse interactions between its components or with other systems.

The students will be expected to be able to represent the behavior of a system with a model that can be exploited either analytically or digitally, well-suited to the model goal in link with some modeling assumptions both in terms of representativeness and complexity, and to evaluate its domain of validity.

To that aim, they will be able to choose the relevant spatial and time scales and to select the most appropriate representation (discrete or continuous). Based on experimental data, they will be expected to be able to define the model structure, to identify its parameters despite inherent measurement noises, and to assess the relevance/validity of the model.

Quarter number ST2

Prerequisites (in terms of CS courses)

Analysis, Probabilities, Basics of Computer Sciences.

Syllabus

1) General introduction: from a system to a formal mathematical expression [Lecture 1h30]
- Model taxonomy (discrete / continuous / hybrid, deterministic / stochastic, mechanistic /data-driven, ...)
- Modeling approach and methodology

2) Modeling of continuous-state systems [Lectures 6h00; Tutorials: 4h30]
• Time representation of dynamical systems:
o Continuous time systems: state-space representation of a differential equation (linear or nonlinear), linearization around an equilibrium point, linear state-space model and its explicit solution, stability analysis by mean of an eigenvalue study.
o Discrete time systems: state-space representation of a difference equation (linear or nonlinear), linearization around an equilibrium point, linear state-space model and its explicit solution, stability analysis by mean of an eigenvalue study.
- Frequency representation:
o Transfer function of a continuous time linear and time invariant system: basic concepts on Laplace transforms, frequency response (Bode diagram), time response (impulse response, step response, focus on 1st and 2nd order systems), link with the state-space representation
o Transfer functions of a discrete time linear and time invariant system: basic concepts on z transform, link with state-space representation

3) Modeling of discrete-state systems [Lectures: 3h00; Tutorials: 3h]
• Automata
o Untimed automata, synchronous and parallel products of automata
o Timed automata, clock structure, guard and invariance conditions
• Petri nets
o Formalization of untimed Petri nets, process modeling (resource sharing, synchronization...), linear algebra analysis, properties of a Petri net

o Extension to the case of timed Petri nets
• Hybrid systems
o Formalization, guard and invariance conditions, continuous state reset function

4) Methods for the sensitivity analysis, the parameter identification and the evaluation of models [Lectures: 4h30; Tutorials: 3h]
• Uncertainty and sensitivity analysis
o Modeling of uncertainties: modeling from available data (histograms, kernel methods, estimation of the mean and variance), principle of maximum entropy
o Propagation of uncertainties: interval computation, combination of variance, Monte Carlo approach
o Sensitivity analysis: case of linear or quasi-linear systems, Sobol indices
• Model assessment
o Identifiability, basics of parameter identification (least square method, based on frequency response, based on time response), digital optimization, AIC (Akaike Information Criterion) / MSPE (Mean Squared Error of Prediction)+
• Applications of the parameter estimation method for a simple model, linear/non-linear regression

5) Illustration and application of the modeling approach [Tutorials: 1h30]
• Tutorial on the modeling approach on real-life problems

6) Written final exam [3h]

7) In parallel, students will have to carry out a project as part of their workload (and not during contact hours). A time slot is provided for Q&A with the teaching team. [Project: 1h30 in person]

Class components (lecture, labs, etc.) See syllabus

Grading

Mandatory assessments:
- Written final exam (3h): 75% of the module mark - individual, all documents and calculator allowed;
- Project: 25% of the module mark, by groups of 3 students; the mark for the project is a compulsory assessment (EO).
- During this course, the C1 skill will be assessed through the final exam and the project.

Course support, bibliography

- T. Chevet, S. Font, M.A. Lefebvre, V. Letort-Le Chevalier, H. Lhachemi, C. Maniu, G. Sandou, C. Vlad (2021) “Modélisation. Représentations et analyse des modèles”, Polycopié CentraleSupélec, 3nd edition in French, Gif-sur-Yvette.
- T. Chevet, S. Font, M.A. Lefebvre, V. Letort-Le Chevalier, H. Lhachemi, D. Madhavan Brochier, C. Maniu, G. Sandou, C. Vlad (2021). “Model Representations and Analysis”, Polycopié CentraleSupélec, 2nd edition in English, Gif-sur-Yvette.
- Walter, É., & Pronzato, L. (1994). Identification de modèles paramétriques à partir de données expérimentales. Masson.
- Lamnabhi-Lagarrigue, F, Annaswamy, A, Engell, S, Isaksson, A, Khargonekar, P, Murray, RM Nijmeijer, H, Samad, T, Tilbury, D & Van den Hof, P 2017, 'Systems & Control for the future of humanity, research agenda: Current and future roles, impact and grand challenges' Annual Reviews in Control, vol 43, pp. 1-64.
- Saltelli, A. et al. (2008). Global sensitivity analysis: the primer. John Wiley & Sons.

Stéphane FONT, Véronique LETORT-LE CHEVALIER, Hugo LHACHEMI, Guillaume SANDOU, Cristina STOICA, Cristina VLAD
- Target size for tutorial groups: 2x12 groups of 40 students
  List to be confirmed:
- Stéphane FONT, Véronique LETORT-LE CHEVALIER, Hugo LHACHEMI, Guillaume SANDOU, Cristina STOICA, Cristina VLAD, Pedro RODRIGUEZ, Chengfang REN, Israel HINOSTROZA, Jacques ANTOINE, Richard COMBE, Joy EL FEGHALI, Jean AURIOL, José PICHERAL
- Software, number of licenses required : Matlab
- Equipment for tutorials classrooms: Tutorials in standard rooms (blackboard, videoprojector, Wifi), with student laptops.

Learning outcomes covered on the course

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

1. Choose the right model typology, that is well-suited to the model objective (simulation, optimization, control…): discrete/continuous, mechanistic (based on physical laws) /data driven (based on measured data), frequency/time based.

2. Model and analyze a continuous process, by using time and / or frequency representations; use basic parameter identification techniques based on a time or frequency response (e.g. least squares methods from frequency or time measurements).

3. Model and analyze a discrete process in a relevant framework including automata, Petri nets, and discrete-events simulation.

4. Take a critical approach and analyze the reliability of the developed models: uncertainty propagation, sensitivity analysis (local and global methods based in particular on variance), selection of a model with regards to certain specifications.

5. Digitally implement the obtained model, simulate and validate, particularly in comparison with experimental data.

Description of the skills acquired at the end of the course

In terms of skills:

- The first three items "**Acquis d'apprentissage"** contribute to core skills C1.1 "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." and C1.2: "Modeling: using and developing the appropriate models, choosing the right modeling scale and the relevant simplifying assumptions".

- Items 4 et 5 correspond to core skill C1.3: "Solve: solve a problem with a practice of approximation, simulation and experimentation".

- Item 5 addresses core skill C1.4: "Design: specify, implement and validate all or part of a complex system".

- Tutorials and projects will give the opportunity to deepen core skill C8.1: "Build the collective to work as a team", as well as core skill C6.1: "Solve a problem numerically".

- The project with a peer-to-peer evaluation scheme will contribute to core skill C7.2: "Know how to convince: On the relationship with others: Understand in an evolutionary way the needs and expectations of his interlocutors. Encourage interactions, be a teacher and create a climate of trust".

1CC4000 – Signal Processing

Instructors : **Charles Soussen**
Department : **DÉPARTEMENT SIGNAL, INFORMATION, COMMUNICATION**
Language of instruction: **FRENCH, ENGLISH**
Type of course : **Common course**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **21,00**

Description

Digital world produces huge amount of data of any kind (audio, image, video, physical measures) related to human activity in different domains such as healthcare, telecommunication, industry or environment. Processing the information of those signal is fundamental :

- For decision making (for instance in medical diagnosis),
- For information coding (for instance in data compression),
- For physical phenomenon analysis (for instance mechanical fault detection),
- For signal reconstruction (for instance to cancel noise in audio signals)

Signal Processing is at the crosspoint between mathematics, physics, and computer science. Mathematic concepts give tools to represent signals and to process them. Physical models allow one to link the measured data to the desired information. Lastly, computer science is necessary to operate the digital processing.

At the end of this course, students will be in grade to understand and use the deterministic and statistical signal processing methods in order to solve different kinds of problems related to information science, like filtering, information transmission, noise canceling, physical parameter estimation and spectral analysis. Those problems appear in many kinds of applications, like automatic recognition of musical tracks, radar localization, climatic data analysis, reconstruction of medical images in IRM, gravitational waves detection in astrophysics, innovative cellular network design (5G, IoT...).

Quarter number ST4

Prerequisites (in terms of CS courses)

- “ Convergence, integration, probabilities” (CIP - 1SL1000)
- “ Partial Differential Equations” (EDP - 1SL1500) - for the theory of distributions
- “Model Representations and analysis” (ST2 -1CC3000)

Syllabus

- **Motivation and applications of signal processing**: signal space, distributions, random signals.
- **Filtering**, convolution, correlation, inner product
- **Spectral representation** of continuous and discrete time signals: Fourier transforms, DFT (Discrete FourierTransform), spectral analysis
- **Digitalization of continuous-time signals** : sampling, Shannon's theorem, reconstruction
- **Signals modeled by random Processes**: definition, properties (stationarity, ergodicity), correlation function, power spectral density (PSD), filtering of stationary processes
- **Characterization of signals modeled by random processes**: estimators of the correlation function and the PSD (periodogram, parametric estimator of AR processes)
- **Examples and applications**: linear prediction, deconvolution, compression, transmission

Class components (lecture, labs, etc.)

7 CM, 6 TD TD labs will include written exercises, study cases, programs coded in Python (Jupyter Notebook)

Grading

- 2 multiple Choice Quizes in self-assessment mode (not graded, online) at mid-session end end of ST4
- 1 final written exam (1h30) on the whole content of the lectures and exercises classes.

- The final mark for session 1 is equal to the written exam grade:final grade = exam.

Course support, bibliography

Handout with bibliography, slides.
The edunao page includes links to external numerical resources.

Resources

- Teaching staff (instructor(s) names): G. Chardon, R. Combes, J. Fiorina, E. Lahalle, J. Picheral, P. Rodriguez, C. Soussen, G. Valmorbida, A. Wautier
- Maximum enrollment (default 40 students): 40
- Software, number of licenses required: Python, jupyter notebok. The recommended Python distribution is anaconda: http://mycs.centralesupelec.fr/ordinateur/installation-logiciels

Learning outcomes covered on the course

After following this course, students will be able to:

1. Model signals in time domain and frequency domain, in discrete time and continuous time
2. Handle the sampling theory and signal reconstruction method
3. Characterize a signal through its time and spectral analysis
4. Model signals through stochastic processes
5. Estimate the characteristics of a random signal from experimental data
6. Analyse a signal to tackle data processing problem like noise canceling, filtering, data compression, prediction, frequency analysis

Description of the skills acquired at the end of the course

The course contributes to validate skills C1 and C6 because it deals with sub-skills C1.2, C1.3, C6.1, C6.3:

C1.2: Modeling: using and developing suitable models, choosing the right modeling scale and relevant simplifying assumptions
C1.3: Solve: solve a problem with a practice of approximation, simulation and experimentation
C6.1: Solve a problem numerically
C6.3: Process data

The final exam validates skills C1 and C6.

1CC5000 – Statistics and Learning

Instructors : **Arthur Tenenhaus**
Department : **DÉPARTEMENT MATHÉMATIQUES, MATHÉMATIQUES**
Language of instruction: **FRENCH, ENGLISH**
Type of course : **Common course**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **60**
On-site hours (HPE) : **31,50**

Description

The objective of this course is to introduce the mathematical, methodological and computational bases of statistical inference from data. First, the principles and formalisms of mathematical statistics will be taught. This includes the definition of statistical models, the bases of estimation theory, the concepts of hypothesis testing. Second, the basic methods and algorithms of statistical learning will be introduced, including supervised learning for regression and classification as well as unsupervised learning. Finally, the students will test several algorithms and libraries of statistical learning in practical classes with Python.

Quarter number ST4

Prerequisites (in terms of CS courses)

Convergence-Integration-Probabilities

Syllabus

1. Random variables and samples, descriptive statistics, empirical measure.

2. Parameter estimation.

    a. Families of distributions and parametric models

    b. A few estimators: method of moments, maximum likelihood

    c. Properties of estimators (bias, consistency, risk, Cramer-Rao bound, asymptotic properties, asymptotic normality, consistency and asymptotic normality of the ML estimator)

    d. Central limit theorem, Delta method, Continuity theorem, Slutsky's theorem

    e. Confidence regions

3. Bayesian Estimation: Bayes theorem, prior and posterior distributions, conjugate distributions, loss function and Bayesian point estimates.

4. Hypothesis Testing

    a. General framework and method for testing statistical hypotheses: alternative hypotheses, risks and power, test statistics, rejection region, p-value

    b. Parametric tests: Neyman-Pearson lemma, asymptotic tests.

    c. Non-parametric tests (adequacy tests: chi2, Kolmogorov-Smirnov, Cramer Von-Mises; population comparison tests: Wilcoxon)

5. Linear regression, generalized additive models, trees.

6. Model selection. L1-penalty (lasso) and L2-penalty (ridge regression), cross-validation.7. Logistic model for classification.8. An introduction to neural networks.9. Principal Component Analysis. Unsupervised learning for clustering (K-means, hierarchical clustering)

Class components (lecture, labs, etc.)

9 x 1H30 lectures + 10 x 1H30 PCs + 3h Exams

Grading

One compulsory written exam covering the entire program

Course support, bibliography

- Lecture notes + exercise book
- Casella, G., & Berger, R. L. (2002). Statistical inference (Vol. 2). Pacific Grove, CA: Duxbury.
- Friedman, J., Hastie, T., & Tibshirani, R. (2001). The elements of statistical learning (Vol. 1, pp. 241-249). New York: Springer series in statistics.

Resources

Teaching staff (instructor(s) names): Arthur Tenenhaus, Laurent Le Brusquet, Julien Bect
    - 9 lectures : Arthur Tenenhaus + Laurent Le Brusquet + Julien Bect (English)
- Maximum enrollment :
    a. Exercise Classes :
        i. 10 PCs with about 50 students (intermediate and advanced) in French or english
- Software: Practical classes in Python (with ScikitLearn, SciPy, StatsModels, Keras)
- Equipment-specific classrooms (specify the department and room capacity): Normal classrooms with practical work on students laptops.

Learning outcomes covered on the course

At the end of the course, students will be able to :
- model a statistical inference problem
- estimate model parameters
- validate statistical hypotheses
- solve regression and classification problems from data
- identify homogeneous groups from data

SEMESTER LONG COURSES

1SL1000 – CIP - Convergence, Integration and Probability

Instructors : **Alexandre Richard**
Department : **DÉPARTEMENT MATHÉMATIQUES**
Language of instruction: **ENGLISH, FRENCH**
Type of course : **Long Semester Course**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **60**
On-site hours (HPE) : **34,50**

Description

The objective is to have students master the mathematical concepts and formalisms of the modelling of complex systems, through

- the analysis of integro-differential models ; the techniques of approximation and their convergence;

- the construction of transforms to solve problems;

- the deep knowledge of measure theory, as the basis of the modern framework of probability, necessary to describe fluctuating phenomena, and of data processing.

This theoretical framework will allow to tackle the techniques of signal processing and the statistical study of data in common core courses. In second year, students will be able to refine these bases by studying stochastic processes and nonlinear phenomena in advanced courses.

Quarter number SG1 and ST2

Prerequisites (in terms of CS courses) None

Syllabus

Topology

Metric spaces

Normed vector spaces

Hilbert spaces

Measured spaces

Construction of the integral with respect to a measure

L^p spaces

Interchanging limits and integrals

Probability, random variables

Product measures, probability on R^N, independence

Convolution, Fourier transform and characteristic functions

Gaussian vectors

Convergence of sequences of random variables

Conditional expectation

Random walks

Class components (lecture, labs, etc.)

Several tracks are proposed within this course, depending on choices and selection of students.
Students will be assigned in one of the following 3 tracks:

Track 1 : classroom setting in French
Lectures and tutorials in classroom in French (several groups of different level, limited enrollment)
• Lectures: 11 slots of 1,5 hrs (16,5 HPE / 25 HEE) in classroom
• Tutorials: 10 slots of 1,5 hrs (15 HPE / 22,5 HEE) in classroom
• Autonomy : In addition to the usual work between each session, students will have 4 homeworks to prepare, which corresponds to the content of 1,5hrs of course material and 3hrs of tutorials, spaced between the classroom sessions (0 HPE / 9,5 HEE).

Some students will be assigned in moderate track with reinforcement (selection from the Direction des Etudes):
• 2 groups of 25 students in French and 2 groups of 25 students in English,
• 10 supplementary slots of 1,5 hrs for reinforcement.

Track 2 : blended in French
Lectures are online, prerecorded videos in French (choice of the language by students). Tutorials happen in classroom in the same language as the lectures. The course content is transmitted via prerecorded video sequences. Interaction with the teachers takes place during the scheduled tutorials and through digital means. This track allows students to adapt their learning pace, especially when the concepts are more difficult to grasp.
• Lectures, 12 slots of 1,5 hrs (1,5 HPE / 28,5 HEE): the first lecture in class, then online videos;
• Tutorials: 11 slots of 1,5 hrs (16,5 HPE / 28,5 HEE): in class with a quiz at the beginning of each session.

Track 3 : classroom setting in English
Lectures and tutorials in English (choice of the language by students, limited enrollment).
• Lectures: 11 slots of 1,5 hrs (16,5 HPE / 25 HEE) in classroom
• Tutorials: 10 slots of 1,5 hrs (15 HPE / 22,5 HEE) in classroom
• Autonomy : In addition to the usual work between each session, students will have 4 homeworks to prepare, which corresponds to the content of 1,5hrs of course material and 3hrs of tutorials, spaced between the classroom sessions (0 HPE / 9,5 HEE).

Some students will be assigned in moderate track with reinforcement (selection from the Direction des Etudes):
• 2 groups of 25 students in French and 2 groups of 25 students in English,
• 10 supplementary slots of 1,5 hrs for reinforcement.

Math Libre 1:
In place of the traditional CIP class, a small group of selected students will follow a special class directed by Erick Herbin. The advanced topics and pedagogical approach of this class will be detailed by Erick Herbin in the beginning of September.

Important: Students assigned to groups where the teaching takes place in a classroom setting will make an honorary commitment to be present at all sessions.

Grading

-For all students *except students of reinforcement groups*, the weighting between the different evaluation will be as follows:

-A single ongoing evaluation [CC] (different within each group), made of several evaluations happening at different dates: 30%.
-A final Exam of 3h common to all students [EF]: 70%,

- For *students of reinforcement groups*, the weighting between the different evaluation will be as follows:

-A single ongoing evaluation [CC] (different within each group), made of several evaluations happening at different dates, including several evaluations during the reinforcement classes [MR] for up to a third of the [CC] grade : 30%.
-A final Exam of 3h common to all students : 70%,

-Note that presence in class is taken into account in the valuation of the reinforcements and that students who are registered in reinforcement cannot leave it without the agreement of the professor in charge of this course.

Documents and electronic devices are not allowed during the evaluations.

The evaluation of students from the Math Libre 1 group will consist only of their grade in the final exam.

Course support, bibliography

Printed Lecture Notes (in English) and an extensive bibliography (books, electronic documents, exercise book)

Resources

-Teaching staff (instructor(s) names):

Julien Bect, Philippe Bouafia, John Cagnol, Ioane Muni Toke, Alexandre Richard - lectures in French
Antonio Silveti-Falls - lectures in English
Erick Herbin - special classes Math Libre 1 in French

-Maximum enrollment: 21 tutorial groups of between 25 and 60 students, depending on level groups
-Software, number of licenses required: None
-Equipment-specific classrooms (specify the department and room capacity): 0

Description of the skills acquired at the end of the course

C1.1 (1st milestone)
Analyze the scientific aspects of the overall behavior of a small-scale system (e.g., isolated part of a complex system), including the identification of factors that influence its behavior.

C1.3 (1st milestone)
Solve: solve a problem with a practice of approximation.

1SL1500 – PDE - Partial Differential Equations

Instructors : **John Cagnol**
Department : **DÉPARTEMENT MATHÉMATIQUES**
Language of instruction: **ENGLISH, FRENCH**
Type of course : **Long Semester Course**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **50**
On-site hours (HPE) : **30,00**

Description

Partial differential equations (or PDEs for short) are equations whose solutions are functions. They appear naturally in modeling in physics, mechanics, biology, economics, finance, and more generally in all engineering fields.

In this course, you will learn the basics of PDEs. We will start with recalling the situation of the ordinary differential equations (ODE) for which we will examine the well-posedness of the questions. Then, you will understand the different classes of PDEs, including elliptic, parabolic and hyperbolic. You will see how one can prove the existence and uniqueness of solutions of some elliptic equations.

You will see how to numerically approximate the solutions of elliptic and parabolic partial differential equations using two standard techniques: the Finite Element Method and the Finite Difference Method. Both of these techniques lead to a huge linear system, so we will see the basics of numerical linear algebra to tackle this problem. You will also learn about FEniCS.

In this course, you will also see the theory of distributions which generalizes the concept of functions. You will learn how to successfully use distributions and apply them. You will also learn about Sobolev spaces which are useful in the context of PDEs.

Quarter number ST2 and SG3

Prerequisites (in terms of CS courses)

Convergence, Integration and Probabability

Modeling (co-requirement)
Information Systems and Programming

Syllabus

Chapter I - Ordinary Differential Equations
Chapter II - Classification of PDEs and Modeling
Chapter III - Distributions
Chapter IV - The Variational Formulation
Chapter V - The Finite Element Method
Chapter VI - The Finite Difference Method
Chapter VII - Numerical Linear Algebra
Chapter VIII - Parabolic PDEs

Chapters I and V are conducted over two sessions each.
Chapter II will be covered by students working on their own.

Class components (lecture, labs, etc.)

The course is available in:

French

Face-to-face (sections 3 to 6) or blended learning (section 1)

English

blended leaning (section 2)

Blended learning means that the lectures take place in the form of video capsules and the TD in person.

Students who need additional help are enrolled in MR (support sessions). They benefit from additional sessions led by students enrolled in the 2nd year "Teaching Assistant" elective class under the responsibility of the teaching staff. The support sessions are compatible with face-to-face French and distance or mixed English.

A special section might be available for a few students with an exceptional mathematical skills who wish to study partial differential equations in greater depth. Admission is subject to approval.

The section and lab group of CIP determines the section and lab group for PDE (not applicable for the special section or in case of compelling reasons).

Grading

The assessment consists of :

-A final exam CF.
-A compulsory assessment EO for :
    -Students in reinforcement: they will have to complete a mini-project which will be a collation of their work in reinforcement.
    -Non-reinforcement students enrolled in a "companion project": they will then be required to complete a "companion" mini-project.
-A single CC continuous assessment test, made up of several parts taking place on different dates, but constituting a single test.

For students without a companion project or reinforcement, the overall grade will be α_f CF + α_1 max(CC,CF)
where $\alpha_f = 0.7$ and $\alpha_1 = 0.3$

For students in reinforcement or with a companion project, the overall grade will be α_f CF + α_o EO + α_1 max(CC, (α_f CF + α_o EO)/(α_f+α_o))
where $\alpha_f = 0.68$, $\alpha_o = 0.12$ and $\alpha_1 = 0.2$

It's important to point out that while enrolment in a "companion project" is optional, this project becomes compulsory for any student enrolled in it. In particular, it is not possible to withdraw and turning in a poor-quality project can lower the overall grade.

Course support, bibliography

Erick Herbin & Pauline Lafitte
CIP and PDE Lecture Notes

Haïm Brézis
Functional Analysis, Sobolev Spaces and Partial Differential Equations.
Springer, 2011.

Grégoire Allaire
Numerical Analysis and Optimization:
An Introduction to Mathematical Modelling and Numerical Simulation
Oxford University Press, USA, 2007

Hans Petter Langtangen & Anders Logg
Solving PDEs in Python. The FEniCS Tutorial I
Springer Open, 2007

Resources

-This course is composed of nine lectures and nine lab sessions.

Courses are given in one of the following sections:
Section 1 - FR - Blended learning - Ph. Bouafia & guests
Section 2 - EN - Blended learning - John Cagnol
Section 3 - FR - Face-to-Face - Guilherme Mazanti
Section 4 - FR - Face-to-Face - Philippe Bouafia
Section 5 - FR - Face-to-Face - Vincent Lescaret
Section 6 - FR - Face-to-Face - Aymeric Vié
It is possible that a special "free maths" section will be created. If this is the case, students will be informed by e-mail and the purpose of this section will be explained.

Each section is subdivisez in lab groups.
A support session is assigned to certain students.

In addition, students who have to work on a modeling problem leading to a PDE in the context of a project, a ST, an associative activity or a personal interest, can ask to benefit from a companion project. This is the completion of additional work. This work is optional and subject to acceptation. It is under the responsibility of Lionel Gabet.

Learning outcomes covered on the course

Description of the skills acquired at the end of the course

For all : C1, C2, C6

For students involved in a companion project: additionally C4, C7

1SL2000 – Business Management and Transformation

Instructors : **Éléonore MOUNOUD**
Department : **DÉPARTEMENT SCIENCES HUMAINES ET SOCIALES**
Language of instruction: **ENGLISH, FRENCH**
Type of course : **Long Semester Course**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **21,00**

Description

This course aims to offer engineering students a structured presentation of the main issues of business management and development. The aim is to ensure that outgoing engineering students have a clear vision of what companies are, their objectives, their organization, their partners, and the social and environmental challenges posed by their current development models as well as the alternatives available to guide their necessary transformation towards more sober models, more resilient and more democratic.

Quarter number ST2

Prerequisites (in terms of CS courses) None

Syllabus

CHALLENGES
A. A globalized and financialized industrial capitalism
B. The external effects of growth: climate, energy, resources
C. Digital transformation and ecological transition, issues
Chapter 1 - BUSINESS AND MANAGEMENT
1. The business model of the company
2. The diversity of companies, the raison d'être
3. Management principles
Chapter 2 - BUSINESS DYNAMICS
1. Knowing the customer, designing an offer, guiding demand
2. Compete, cut costs, improve productivity,
3. What is innovation?
Chapter 3 - COMPANY FRONTIERS
1. The company as a value chain
2. Ways and means of development
3. The value chain, the company as a link in a value chain
Chapter 4 - GLOBAL VALUE CHAINS
1 Impacts: externalities, hidden costs, social costs
2. Corporate responsibility beyond borders
3. Alternative models: fair trade, cooperatives and mission-driven companies
Chapter 5 - BUSINESS MODELS: TOWARDS DECARBONATION?
1. The business model canvas,
2. Circular economy, the 7 pillars, the 5Rs
3. Decarbonization: sobriety, efficiency and renewables
Chapter 6 - BUSINESS MODEL TRANSFORMATION
1. Systemic issues, planetary limits
2. The economic impact of digital technology on WBs
3. Ecological and social impacts of digital technology: extractivism and uberization

Class components (lecture, labs, etc.)

an English class is offered with sessions organized around a lecture and a group case study

a mid-term assessment on December 18 or 20

Grading

Final test: 1.5-hour, WITHOUT DOCUMENT, individual written exam consisting of a multiple-choice test on the course chapters and case studies, plus a written analysis question. This exam accounts for 60% of the final grade.

Continuous assessment :
- a compulsory exam consisting of 1 group case study on the session before Christmas holidays, coefficient 20%.
- 10' MCQs in integrated classes (3) of equal weight, coefficient 20% (only counts if higher than the grade of the final test, in accordance with study regulations).

Competences are assessed
- via the corresponding questions in the CF
- through work done in integrated classes

Course support, bibliography

A book and case studies specifically written for the class (with a list of additional readings) is made available to the students.

Resources

- Teaching staff (instructor(s) names): Eléonore Mounoud (CentraleSupélec), Eliott Rabin, Colas Cabriel,
- Maximum enrollment : integrated classes of less than 40 students (11 groups for 440 students)
- 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 this course, the student will be able to :
- Express the business, the sector, the issues and the raison d'être of a company
. Describe the main functions of a company and the principles of management
- Identify the economic and non-economic stakeholders of a company as well as the impacts of its activity
- Analyse the business model of a company and the place of digital technology in it,
- Understand what the company is responsible for in its development model
- Identify low carbon, circular, contributory and regenerative alternatives

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 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 and environmental responsibilities.
C9.4 Demonstrate rigour and critical thinking in approaching problems from all angles, be they scientific, social or economic.

1SL3000 – Quantum and Statistical Physics

Instructors : **Jean-Michel Gillet**
Department : **DÉPARTEMENT PHYSIQUE**
Language of instruction: **ENGLISH, FRENCH**
Type of course : **Long Semester Course**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **50**
On-site hours (HPE) : **30,00**

Description

The ambition of this course is to build the foundations of 21st century physics as they were formulated at the beginning of the 20th century (except for relativity). In doing so, we aim to show how models were elaborated, starting from experimental results, firstly, by trying to use the tools of the old theory, then by reconstructing axiomatically a new theory. This is done initially on mechanics and electromagnetism leading then to quantum theory. In a second time, a better understanding of the foundations of thermodynamics lead to the elaboration of statistical physics. The focus is always on applications or the impact of the introduced concepts on the fields where the engineer (or, simply, the citizen) is active.

Ultimately, the goal is to give a better acquaintance of engineering students to the conceptual contributions of physics on which many current innovations are developed. The students will master the vocabulary, will be familiar with some essential steps for an enlightened implementation and will know the limits of applicability.

Quarter number SG3 and ST4

Prerequisites (in terms of CS courses)

Differential equations, linear algebra, vector spaces, thermodynamics, electromagnetism.

Syllabus

I. Period 1
1) Some key experiences (1h30)
2) From phenomenology to axiomatic formulation
a) Schrödinger equation and piecewise potentials (1h30)
(i) TD: Photoelectric effect and infinite quantum wells (2D) (1h30)
(ii) TD: tunnel effect and microscopy (1h30)
3) Postulates and mathematical artillery (1h30)
(i) TD: Flippingl of NH3 and MASER (1h30)
4) The quantum-classical fuzzy border (1h30)
(i) TD: Spreading of the wave packet (1h30)
5) Vibrations and Harmonic Oscillator (1h30)
(i) TD: Molecular vibrations (1h30)
II. Period 2
6) Perturbations (1h30)
7) Angular momentum (1h30)
(i) TD: Morse potential (perturbations) and thermal expansion (1h30)
8) Stability of the atom (1h30)
(i) TD: from H to He (1h30)
9) Statistical physics from thermodynamics to information theory (1h30)
(i) TD: Paramagnetism and Curie Law (1h30)
10) Regulated system of classical particles (1h30)
(i) TD: Sublimation of argon (1h30)
FINAL EXAMINATION (1h30)

Class components (lecture, labs, etc.)

Lectures, tutorials, readings. Being (and remaining) registered in small tutorial groups is conditioned upon an active role in the group.

Grading

The global assessment is a written exam.
The program of the final exam potentially covers all subjects seen in the course. At least one question probes skill C1.

Course support, bibliography

Handout in English and textbook “Application-Driven Quantum and Statistical Physics” (Vol. 1 and 2, World Scientific)

Resources

Teaching staff (instructor(s) names): M. Ayouz, Z. Toffano, M. Caussé, C. Morice, F. Brieuc, F. Brun, J-C Pain, J-B Charraud, P-E Masson, G. Schehr, H. Dammak, I. Kornev, P. Cortona, T. Antoni, R. Santachiara, , R. Landfried, P. Testé, J-M Gillet.

- Maximum enrollment (default 35 students): 90, 50, 25

- Software, number of licenses required:

- Equipment-specific classrooms (specify the department and room capacity): Physique, 1 large amphitheater, 6 rooms of 90, 1 rooms of 50, 10 rooms of 35

Learning outcomes covered on the course

At the end of the course, on the one hand, the student are expected to know how to build and / or use an elementary quantum microscopic model. From the description of an environment and / or a simplified potential, he/she will be able to find the spectrum of energies and eigenstates. He/she will be able to predict a temporal behavior of the quantum states as well as the probabilities of results of a measurement. For this he/she will have to implement the standard methods of resolution, resort to the time-independent approximation method (or the variational theorem). On the other hand, from a proposed quantum law (spectrum of energies and degeneracies), the student must know how to choose the adapted approach of statistical physics which will lead him/her to predict the behavior of a targeted macroscopic property. Emphasis will be placed on the deduction of equations of state and the temperature behavior of macroscopic response functions.

Description of the skills acquired at the end of the course

The competences targeted are C1.2: Use appropriate models, choose the right scale of modelling and relevant simplifying assumptions to deal with the problem and C1.3: Be critical of a solution. In particular by comparing the results of a model with those of experience.
Skill C1 is tested by means of at least one question during the final written exam.

1SL3005 – Physics Q & S - DUAL reinforcement

Instructors : **Mehdi Ayouz**
Department : **DÉPARTEMENT PHYSIQUE**
Language of instruction: **ENGLISH, FRENCH**
Type of course : **Long Semester Course**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **48**
On-site hours (HPE) : **48,00**

Description

The quantum and statistical physics reinforcement course aims to provide support to students (Dual diploma IN UR and OUT EU, Double Diploma IN, Repeating, Admitted on Title, Initial Training, etc.) the tools necessary to better understand the TDs and Quantum and Statistical Physics I (1A). Plethora of pedagogical approaches are proposed during tutorial sessions with the aim of promoting student success in the final test of quantum and statistical physics.

Quarter number SG3 and ST4

Prerequisites (in terms of CS courses) none

Syllabus

The tutorial sessions (TDs) of the reinforcement course come in support of the TDs of quantum and statistical physics I (1A). It aims to provide support to 1st year students. See course sheet for more details on the content of the TDs.

Class components (lecture, labs, etc.)

9 tutorial sessions covering the concepts treated in 1A tutorials. 3 to 4 classes taught in English. Sessions usually take place in the evening (Wednesday and Thursday). For more details, see the "Moyens" section.

Grading

At the beginning of each session (except the first session), a MCQ will be proposed. These multiple choice questions contribute to the test grade (2 tests of the quantum and statistical physics course) according to the following formula*: Max[average[reinforcement multiple choice], average[TD test]].

This formula can be adapted each year to take into account the difficulties of students encountered during the school year.

Course support, bibliography

1A quantum and statistical physics course, reinforcement tutorials developed by the teaching team of the 2A Teaching Assistants course as well as the course manager. The following digital platform: http://prd-mecaqu.centralesupelec.fr/ (beta version), is used to illustrate the concepts discussed during the tutorial.

Resources

The lessons, developed by the teaching team (TA and course manager), are built with the following objective: to give students the tools to better understand the TDs via:

- Mini-projects

- Role play

- Marathon exercises

- Flipped classroom

The second part of this teaching is to give visuals (homeworks or classroom exercises) using the digital platform: http://prd-mecaqu.centralesupelec.fr/

Finally, the third part consists of providing feedback and testing the students' achievements during the sessions via a MCQ (5' max). The MCQs relate to tutorials, homeworks and digital platform, etc. The objective is to improve teaching and better adapt it to the expectations and needs of students.

At the end of each session, homework will be offered to you to deepen certain concepts.

Learning outcomes covered on the course

Better understand the basic concepts of quantum and statistical physics taught in class and 1A tutorials (TDs). Better preparation for the final exam in quantum and statistical physics.

Description of the skills acquired at the end of the course

See above

1SL4000 – Corporate Finance

Instructors : **Maxime Guymard**
Department : **DÉPARTEMENT SCIENCES HUMAINES ET SOCIALES**
Language of instruction: **ENGLISH, FRENCH**
Type of course : **Long Semester Course**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **20**
On-site hours (HPE) : **12,00**

Description
At the end of the course, the students will be able to understand and apply the basics of financial management of a company. This course is intended for every future engineer who is going to work in a company, even those who will not be in front line with the professions of Finance.
Students wishing to deepen these skills in second year will be able to move toward the elective course of Corporate Finance and Law.

Quarter number SG3
Prerequisites (in terms of CS courses) Business Management
Syllabus

- Basics in accounting: Balance Sheet, Income Statement (P&L), Cash flow
- The parameters to monitor for the financial management of a company
- Put into practice: Team simulation game

Class components (lecture, labs, etc.)
3 lectures (1:30 each); Online team simulation game (14:00, including personnal work). Students have the opportunity to interact with the teaching staff during the online game phase via the implementation of a hotline by email and in ad hoc sessions where they can make an appointment for further explanations orally.

Grading
The final mark is composed of the results of the game simulations and the synthesis done at the end by the students.

Course support, bibliography
All documents presented during the lectures are available on line.

Resources
-Teaching staff (instructor(s) names): Maxime GUYMARD, Sylvain DUFOURNY, David LEJEUNE, Nicolas PECH-GOURG
- Maximum enrollment (default 35 students): N/A
- Software, number of licenses required: Internet only
- Equipment-specific classrooms (specify the department and room capacity): No

Learning outcomes covered on the course
- Understand the content of a company's Financial statement (Balance Sheet, Income statement, Cash flow statement)
- Know the basics of Financial management of a company

Description of the skills acquired at the end of the course

C3- Act, undertake, innovate in a scientific and technological environment
C4 - Have a sense of value creation for his company and his customers
C8 - Lead a project, a team

1SL5005 – "Engineering Skills" Workshops - 1A

Instructors: **Christophe Laux**
Department : **DÉPARTEMENT DÉVELOPPEMENT PROFESSIONNEL ET MÉTIERS DE L'INGÉNIEUR**
Language of instruction: **FRENCH or ENGLISH**
Type of course:
Campus: **CAMPUS DE PARIS - SACLAY**
Workload (HEE): **80**
On-site hours (HPE): **30**

Description

This course aims at developing the key softskills expected from a CentraleSupelec engineer: teamwork, communication, complex problems solving, project management, creativity, ethics.
The workshops are held in French or in English. Reports and homework may be written in French or in English.

Quarter number

SG1, ST2, SG3 and ST4

Prerequisites (in terms of CS courses)

Semester 5: no prerequisite
Semester 6: the students must also take the S6 project

Syllabus

Key softskills for engineers:

- teamwork: ability to organize and manage a team, understand the roles of the various team members, understand group dynamics
- oral communication: organize and build impactful presentations, increase one's impact in oral communication, improve public speaking skills,
- complex problem solving: ability to frame a problem, make robust assumptions, develop ability to use relevant order-of-magnitude analysis, manage uncertainty and risk
- develop a working knowledge of basic group creativity methods (brainstorming, inversion, bi-sociation, analogy)

Class components (lecture, labs, etc.)

- Lectures

- Case studies in teams of 5 students
- Application of the acquired experience to an engineering project
- Individual essays to reflect on the acquired experience

API 1: Introduction to engineer's problems.
API 2: Complex systemic problem. Climate change, carbon accounting.
API 3 to 5: Finding creative solutions to a practical problem - Problem framing - Project management - Group dynamics
API 6 and API 7: Communicating effectively

Grading

Attendance at the workshops is mandatory. The marks are based on individual participation, individual quizzes and team production during the workshops, as well as individual or team homework. The individual essays are given full credit if they are handed in time and if their quality is sufficient. The grade does not depend on the opinions expressed in the essays as long as these opinions are rigorously argued. The grade of each semester will be based on: Group productions on the cases - Homework - Quality of participation - Result of the mini-quiz 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 step 1 of the relevant skills: C9 in S5, and C3, C4, C7, C8 in S6.

Resources

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

Group activities on practical engineering cases
Direct application to a real project
Films, videos, case studies
Documents on Edunao

Learning outcomes covered on the course

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

- problem framing
- teamwork and group dynamics
- project management
- communication
- creativity techniques

Description of the skills acquired at the end of the course

At the end of the course, the student will master the first levels of the following skills:

- be proactive, take initiatives, propose new solutions (C3)
- think customer and know how to identify the added value of the project (C4)
- know how to convince (C7)
- lead a project and work in a team (C8)
- work and act as an ethical and responsible engineer (C9)

1SL7005 – Professional Project Workshops - 1A

Instructors: **Christophe Laux**
Department: **DÉPARTEMENT DÉVELOPPEMENT PROFESSIONNEL ET MÉTIERS DE L'INGÉNIEUR**
Language of instruction: **FRENCH or ENGLISH**
Type of course: **Cours hors séquence**
Campus: **CAMPUS DE PARIS - SACLAY**
Workload (HEE): **20**
On-site hours (HPE): **10**

Description

This course aims to help students discover the engineering profession and build their professional project.

Quarter number

SG1, ST2, SG3 and ST4

Prerequisites (in terms of CS courses)

None

Syllabus

This course includes two workshops (6 HPE), half a day of collective meetings with engineers (3HPE), two individual meetings with the professors.

In addition, each student must conduct three engineer interviews and attend two evenings of company presentations (“Soirées Découvertes d’Entreprises”) organized by the School.

Class components (lecture, labs, etc.)

- Work in groups of 5 students
- Collective meetings with engineers
- Individual meetings with the professors
- Individual essays to reflect on the interviews of engineers: what did I learn? What did I like about the job, the career, the company ...? and why? what did I like least? and why ? what surprised me? ... No judgment is given on the opinions expressed as long as they are explained and commented.

Grading

A pass or fail grade is given at the end of each semester.

To obtain a passing grade for the APPs of each semester, the following conditions must be all met:
- attend each collective workshop
- prepare and attend the individual meeting with the professor

- conduct at least three interviews with engineers and submit the summary notes in due time
- attend to the “Soirées Découvertes d’Entreprises”.

Resources

- Workshops in groups of 30 to 40 students, led by two professors
- individual exchanges with one of the professors
- Evenings of presentation of companies, organized by the School
- Collective meetings with engineers organized by the School
- Individual interviews of engineers chosen by each student

Learning outcomes covered on the course

At the end of this course, students will have:

- discovered several engineering professions
- discovered several companies
- reflected on a first version of their professional project

Description of the skills acquired at the end of the course

Knowledge of the engineering profession (C2.5)

1SL8000 – Project S6

Instructors : **Laurent Bourgois**
Department : **DÉPARTEMENT DÉVELOPPEMENT PROFESSIONNEL ET MÉTIERS DE L'INGÉNIEUR**
Language of instruction: **ENGLISH, FRENCH**
Type of course : **Long Semester Course**
Campus : **CAMPUS DE METZ, CAMPUS DE RENNES, CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **100**
On-site hours (HPE) : **54,00**

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 sponsor in a given time. The projects proposed in the engineering training program allow the learning of this modality through increasingly complex situations. The objective of this activity is to collectively implement the different stages of a project, from the definition of the need to the delivery of the product, in order to produce a deliverable for a client. The projects must lead to an ambitious realization, which could not be reached by redoing what we already know how to do.

Quarter number SG3 and ST4

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

Syllabus

The projects are spread over two sequences (SG3 and ST4). They follow the usual phases of a project:

- Define and frame the project.
- Structure the actions.
- Define roles and responsibilities.
- Measuring progress and completing actions.
- Increase technical and organizational skills.
- Communicate your achievements.
- Capitalize on acquired experience.

Class components (lecture, labs, etc.)

The progress of the project is accompanied by numerous and varied interactions with the project environment. It is based on individual and collective actions. We will find :

- collective times at the level of the pole for the transmission of good practices and knowledge ;
- personal work to be defined within the group;
- collective work to align and steer the project group.

The supervisors will monitor the project regularly to ensure that no blockages occur and to validate the steps taken.

Grading

The evaluation will focus on ongoing participation during the year, the quality of the written report and the oral presentations made during the project. These contributions will be looked at from four different angles: involvement, content and deliverables, communication, and team functioning in project mode. A validated project implies that the student has validated at least 2 out of 3 competencies from the set {C4, C7, C8}.

Resources

The 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 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. Pole managers help select the most motivated students.

Learning outcomes covered on the course

By the end of this course, students will be able to:
- interact with a client remotely and face-to-face (telephone discussion, email exchange, oral presentation, conduct a progress meeting, etc.);
- identify the value of their work in solving a complex problem;
- organize a team to produce an original and valuable solution;
- anticipate the human, social and environmental consequences of one's actions, and determine the scope of one's responsibilities;
- present a scientific work in writing and orally (in particular, good management of bibliographic resources and clear and rigorous communication of achievements);
- produce a high value-added deliverable in relation to various stakeholders.

Description of the skills acquired at the end of the course

In general, a successful project is one where students have:

- Properly posed the problem and provided solutions that create value (there is a before and after project for the client) ;
- brought a minimum of innovation or creativity to respond to the problem in an innovative way;
- knew how to work as a team and manage the project with resources;
- were convincing in their oral or written communication;
- were able to take a step back from the ethical aspects.

Throughout the project, we find the following skills:

- C3: Act, undertake, innovate in a scientific and technological environment.
- C4 : To have a sense of creating value for one's company and one's clients.
- C7 : Know how to convince.
- C8 : Lead a project, a team.
- C9 : Think and act as an ethical, responsible and honest engineer, taking into account environmental, social and societal dimensions.

Depending on the nature of the project, skills C1, C2, C5 and/or C6 may also be targeted.

1SL9000 – Sport

Instructors : **Stéphane Blondel**
Department : **DÉPARTEMENT EDUCATION PHYSIQUE ET SPORTIVE**
Language of instruction :
Type of course : **Cours hors séquence**
Campus : **CAMPUS DE RENNES, CAMPUS DE METZ, CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **60**
On-site hours (HPE) : **48,00**

Description

To contribute, through the practice of physical sports activities and self-expression (PSAE), to the training of future citizens.

Quarter number S5 and S6

Prerequisites (in terms of CS courses) none

Syllabus

specific to each APSA.

Class components (lecture, labs, etc.)

problem-solving situation,

Grading

In-course assessment Self-assessment

Learning outcomes covered on the course

Understand the fundamental principles of sports activities
Ability to use scientific and technical knowledge in action.
Ability to mobilise resources (motor, cognitive, affective) in order to perform well.
Take part in a sustainable health and well-being project.

Description of the skills acquired at the end of the course

1-
Master techniques to achieve a goal in a sports activity (C2-2, C2-3)
Be able to adapt to the conditions of the game, balance of power, environment and stage space. (C2-2, C2-3)

2-
Respect the rules and procedures of the activity (C3-1, C3-2, C3-4, C3-6, C3-7)
Apply physiological and biomechanical principles. (C3-1, C3-2, C3-4, C3-6, C3-7)

3-
Apply techniques to better manage stress and emotions (C2-2, C7-3, C9-1)
Gather information to make relevant decisions (C3-1, C3-2, C3-4, C3-6, C3-7, C9-1)

Persevere and excel (C3-1, C3-2, C3-4, C3-6, C3-7, C9-1)
Use feedback to regulate your practice (C3-1, C3-2, C3-4, C3-6, C3-7, C9-1)

4-

Know the physiological principles for maintaining good health (preparation for exercise, recovery, diet, regularity and dosage of exercise (C2-2)

Know your motor preferences and identify the reasons for practising (C2-2, C9-1)

Take pleasure so as to make a lasting commitment to practising sports and physical activities (C2-2, C3-1, C3-4, C3-7, C9-1)

SCIENCE COURSES FOR ENGINEERS

1EL1010 – Radiation and propagation

Instructors : **Dominique Lecointe**
Department : **DÉPARTEMENT ÉLECTRONIQUE ET ÉLECTROMAGNÉTISME**
Language of instruction : **FRENCH**
Type of course : **Elective 1A**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **60**
On-site hours (HPE) : **30,50**

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.

For the 21st century engineer, the mastery of electromagnetic theory can not be ignored. But in an environment where the technological challenges are more and more complex, how does the engineer deal with the problems, what are the means at his disposal to solve them? This approach will be the thread of this course of electromagnetism. Starting from varied and concrete applications, this course presents the approach of an engineer to move from a real scene to the equation setting in the form of an electromagnetic problem, then the transition to resolution by use most often of specialized digital tools. The presented problems and their theoretical formulations will cover a broad spectrum of frequencies: from the continuous, via radio frequencies and microwaves to optics. The focus will be on the different types of problems, in particular, free and guided propagation and radiation. The small classes will allow a practical application on a wide variety of problems: free propagation and interference, guided propagation and optical fiber, radiation and antennas ... The rise of digital tools has radically transformed the methodology for solving electromagnetic problems. Several small classes will use industrial electromagnetic software to illustrate the current approach of an engineer for solving electromagnetic problems

Quarter number SG1 and SG3

Prerequisites (in terms of CS courses) None

Syllabus

1. Introduction
- presence of electromagnetism in many industrial sectors
- diversity of applications of electromagnetism
- importance of digital simulation - state of the art for digital tools
- course content and links between parties - course situation throughout the course

2. Equations of an electromagnetic problem: the 3 pillars
- from the real scene to the setting in equation: phase of modeling study in temporal or in harmonic regime
first pillar: Maxwell's equations general case
- second pillar: constitutive equations of media - most classical models - linearity, homogeneity, isotropy, dispersion
- third pillar: equations of passage from one medium to another - writing according to the choice of medium
models link with digital tools (CST example)

Application: Digital TD: CST Presentation and Getting Started

3. Synthesis: the different types of problems: objective, associated hypotheses and simplification, iconic applications
quasi-stationary states
Pread
Influence
Diffraction

4. Free propagation plane wave
polarization of a plane wave
example of another solution - Gaussian bundles
propagation in a conductive medium - skin thickness
transmission of a wave from one medium to another
application: TD: duplexer
application: TD: polarimetry

5. Guided Propagation: Theory of Guides

physical approach of the modes through the parallel blade guide
theoretical development - TE, TM, TEM mode
example of the rectangular guide
example of the coaxial guide
application: TD: optical fiber
Application: Digital TD: Coaxial Line Transition - Rectangular Guide

6. Guided Propagation: Line Theory
from the TEM mode to the line theory
line theory
adaptation
application: TD: realization of an adaptation circuit for micro-ribbon line

7. Radiation and antennas
radiated field - far field
antenna technology
antenna characteristics (experimental approach) - gain and directivity radiation pattern - input impedance
link budget
application: TD: antenna
application: TD digital: realization of a Yagi antenna

Class components (lecture, labs, etc.)

11 lessons of 1h30, 5 TD of 1h30, 3 Digital TD of 1h30, and 1 final exam written of 2h00.
All occurrences are presented in French.

Grading

1 final exam written without documents of 2h00.
The skills acquired will be validated during the final check. Identified questions will validate milestones 1 of competences C1 and C2. At least two questions per skill. The student who obtained the average on the questions associated with the competency assessed will validate milestone 1.

Course support, bibliography

Course and Exercises books.
Slides projected during the course (EDUNAO)
Techniques micro-ondes de Marc Hélier, édition Ellipses

Resources

• Teaching staff (instructor(s) names): Dominique Lecointe, Dominique Picard
• Maximum enrollment (default 25 students): In general, 2 groups in digital TD will alternate with 2 groups in traditional TD.
• Software, number of licenses required: MWS software.
• Workroom (department and capacity): Computer rooms (2 computer rooms with 25 workstations) for digital TD

Learning outcomes covered on the course

At the end of this lesson, the student will be able to:
- put in equations a realistic problem by the choice of more or less complex models.
- to judge the relevance of the models and their limitations.
- choose a resolution methodology that includes modern simulation tools.
- to master, from theory to practice, the structures of electromagnetic waves propagating in a given medium.
- to master, from theory to practice, the systems allowing the propagation of an electromagnetic signal.
- to master, from theory to practice, systems radiating an electromagnetic signal.
These different learning outcomes validate milestone 1 of competency C1.2 (Knowing how to use a model presented in class in a relevant way (model describing a phenomenon, without couplings) Choosing simplifying hypotheses adapted to the studied problem .).

Description of the skills acquired at the end of the course

The different learning outcomes validate milestone 1 of skill C1.2 (Knowing how to use a model presented in class in a relevant way (model describing a phenomenon, without any coupling) Choosing simplifying hypotheses adapted to the studied problem .).
Also, the different learning outcomes make it possible to validate milestone 1 of competency C2.1 (knowing how to define the notion of a scientific field)

1EL1500 – Physics of Waves

Instructors : **Mohammed Serhir**
Department : **DÉPARTEMENT PHYSIQUE**
Language of instruction: **FRENCH, ENGLISH**
Type of course : **Elective 1A**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **60**
On-site hours (HPE) : **30,50**

Description

This course provides students with basic elements necessary to understand the physics of waves through the examples of lectromagnetism and acoustics.
Many disciplines rely on those concepts: seismology, telecommunications, guided waves, imaging techniques, photonics, etc. The notions introduced in this course are basic concepts usefull to several “dominantes”.
Master Fourier analysis, understand concepts of waves and their applications in different domains :

1) spatial filtering methods, such as 4f Fourier optical assembly, for image processing
2) approximations according to the wavelength, the size of the system and the distance at which the phenomenon is observed: diffraction and radiation
3) directivity of an antenna
4) relatioship between dielectric or optical properties and behaviour of a medium (transparent, absorbent or opaque)
5) Calculation of the reflection and transmission coefficients of a wave through an interface.

Quarter number SG1 and SG3

Prerequisites (in terms of CS courses)

- Geometric optics (converging lens)
- Electrostatics, Magnetostatics
- Maxwell's equations in vacuum
- Electromagnetic plane wave.
- Decomposition of a periodic function in Fourier series
- Partial differential equations (Poisson's equation, d'Alembert's equation)

Syllabus

1-Introduction
We present concepts and applications that students will see in the lectures through selected examples (propagation, guidance, emission, different scales ...). The place of the course shall be exposed within the curriculum (present the courses where this course will be useful). Mathematical preliminaries: Fourier transform, Dirac distribution

2-Basic principles of imaging, Plane wave expansion
Propagation: near field, far field, evanescent waves, wave diffraction / self-diffraction, resolution limit
TD1: Propagation, diffraction, Earth-Moon distance measurement, antenna for a geostationary satellite
TD2: Optical image processing

3-Wave sources
Electromagnetic wave sources: retarded potentials, far-field approximation, dipole approximation
TD3: Radiation of a wire antenna / antenna array

4-Radiation
Radiated field: local plane wave structure. Radiated power
TD4: Radiation of a mobile-phone antenna (magnetic dipolar antenna)

5-Diffusion, diffraction by a periodic array
Introduction to diffusion by one or more ordered or disordered diffusers, Bragg diffraction
TD5: Diffusion and diffraction by a 2D photonic crystal

6-Maxwell equations in matter, from microscopic to a macroscopic scale
General Maxwell equations for any medium: transition to spatial averaging for the derivation of macroscopic Maxwell equations
TD6: Dielectric constant, attenuation and energy balance of a wave in an absorbent medium

7-Constitutive equations of matter, generalized Maxwell's equations, free propagation in matter
Effective (generalized) dielectric constant. Notions of homogeneity, linearity, isotropy, dispersion. Links between dispersion and inertia, between phase shift and dissipation. Definition of the optical index. Meaning of the real and imaginary parts of the index and dielectric constant. Energy balance. Definition of transparent, opaque and absorbent media
TD7: Anti-reflective coating, evanescent wave microscope

8-Field continuity relationships, reflection and refraction
Snell Descartes laws. Refraction and reflection phenomena at an interface, total reflection, evanescent wave, Brewster angle
TD8: Dielectric waveguide: application to optical fiber
TD9: Non-linear medium: second harmonic generation
TD10: Brillouin diffusion: coupling between acoustic and electromagnetic waves

9-Negative refractive refraction engineering – Metamaterials:
Propagation in a double negative media. Perfect lens, invisibility

Class components (lecture, labs, etc.)

9 lecture sessions in the Amphitheatre
10 tutorial sessions in groups of 33 students

In the case of the **English version, the lecture is taught in English**, but only **one tutorial class is taught in English** (in the other two tutorial classes, the teaching is in French)
Occurrence 1.2 will be taught in English and occurrence 1.4 will be taught in French

Class components:
1 Lecture 1
2 Lecture 2
3 Tutorial 1
4 Lecture 3
5 Tutorial 2
6 Lecture 4 (Quizz 1)
7 Tutorial 3
8 Lecture 5
9 Tutorial 4
10 Lecture 6
11 Tutorial 5
12 Lecture 7 (Quizz 2)
13 Tutorial 6
14 Lecture 8
15 Tutorial 7
16 Tutorial 8
17 Tutorial 9
18 Lecture 9 (Quizz 3)
19 Tutorial 10
20 Final Exam

Grading

Continuous assessment (MCQ) with no documents : Test 1 of 15 min in session 6 during Lecture 4. Test 2 of 15 min at session 12 during Lecture 7. Test 3 of 15 min at session 18 during Lecture 9. Final exam (written exam) of 2 hours with documents (65%).
Each continuous assessment (MCQ) counts with a weighting of 0.35/3 of the mark, with the final assessment counting with a weighting of 0.65.
Skill C.1 is evaluated through one of the exercises of the final written exam. If the grade for this exercise is higher than 50%, the student will have validated the C.1 skill in this course.
Skill C.2 is validated if the final average mark is higher than 10/20.

Course support, bibliography

Course and Exercises books. Corrections of exercises.

Resources

Teaching staff (instructor(s) names): Hichem Dammak, Pierre-Eymeric Janolin, Bruno Palpant, Thomas Antoni, Charles Paillard, Nicolas Mallick, Mohammed Serhir, Gaëlle Vitali-Derrien, Romain Pierrat (vacataire), Aurélie Bonnefois (vacataire)
Maximum enrollment (default 35 students): 4 TD rooms of 30 for TDs.
Software, number of licenses required: Python already installed on students' laptops
Equipment-specific classrooms (specify the department and room capacity): No

Learning outcomes covered on the course

1) **Apply** spatial filtering methods, such as 4f Fourier optical assembly, for image processing
2) **Apply** the required approximations according to the wavelength, the size of the system and the distance at which the phenomenon is observed: diffraction of a wave or radiation of an antenna
3) **Determine** the radiation area and directivity of an antenna.
4) **Describe** whether a medium is transparent, absorbent or opaque from its dielectric or optical properties.
5) **Apply** the boundary conditions for a system with one or more interfaces.
6) **Calculate** the reflection and transmission coefficients of a wave through an interface.

Description of the skills acquired at the end of the course

C1.1: Analyze the scientific aspects of the overall behavior of a small-scale system (e.g. isolated part of a complex system), including the identification of factors that influence its behavior (**diffraction, diffusion, reflection, transmission, absorption, interference**)
C1.2: Correctly use a model presented in class in its conditions of validity (model describing a phenomenon, without couplings) (**far field approximation, dipolar approximation, planar wave approximation, Fourier optics/image processing, antenna array, scattering by a periodic array, anti-reflection layer, Brillouin scattering**)
C1.3: Compare the results of a simulation with experimental measurements or approximate calculation results, taking into account measurement errors and uncertainties, or model approximations, based on the knowledge of orders of magnitude
C2.1: Deepen your knowledge of an engineering field or scientific discipline

1EL2000 – Electrical Energy

Instructors : **Martin Hennebel**
Department : **DÉPARTEMENT SYSTÈMES D'ÉNERGIE ÉLECTRIQUE**
Language of instruction: **ENGLISH, FRENCH**
Type of course : **Elective 1A**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **60**
On-site hours (HPE) : **30,50**

Description

Electrical energy is indispensable to the functioning and development of society all across the globe. Over 100 years of continuous progress has allowed its integration into new sectors (ground, maritime, and aerial transport, onboard systems, renewable energy, spatial). Presently, environmental and sustainable development objectives have motivated further progress in the technology at different power levels. This course on electrical energy aims to provide students with the fundamentals and methods used for the analysis of systems using electricity as an energy vector. The course associates knowledge of physics and magnetic materials for the characterization of the elements which constitute electrical energy systems. To start with, the course touches on major actors and global issues associated with the use of electrical energy for the functioning of society, with an emphasis on the pertinence of different scientific disciplines. Next, the course presents the principal concepts and tools needed for the analysis of electrical systems along with examples for their application. The course focuses on the importance of understanding magnetic coupling in electrical systems using the laws of electromagnetism. The behavior of the associated magnetic materials and their analysis is then applied to establish models for the systems in order to better understand their performance at different levels of excitation or frequency. The representation of typical magnetic circuits is then used to give students better understanding of how the physics associated with elements of the systems may be used to develop a system model. The natural application of the principals learned by students in the first parts of the course is the study of transformers and inductively coupled systems. Afterward, the conversion of electrical into mechanical energy will be formalized using the principal of virtual work based on magnetic energy associated to magnetic coenergy for the formulation of forces and torques produced by motors and generators. An application of electrical to mechanical energy conversion, the direct current machine, will then be presented in order to provide students with the basis for understanding the principals of motorization or electrical generation at variable speed.

Quarter number SG1 and SG3

Prerequisites (in terms of CS courses) None

Syllabus

Introduction to electrical power engineering Omnipresence of electrical engineering: production, transport, conversion, utilization and control of electrical energy. Multi-physical and economic aspects.

Transport and consumption of electrical energy
Single phase and three phase systems, definition and calculation of electrical power. Equipment sizing and power factor.

Physics associated with electrical power engineering
Electromagnetism applied to electrical power engineering. Magnetic materials, creation and channeling of magnetic fields, permanent magnets. Modeling methods, magnetic circuits, reluctance and electromotive force. Taking into account power losses associated with magnetic circuits.

Principals of magnetic coupling
Notions of magnetic flux and leakage flux. Partial and total leakage inductance. Modeling of magnetic coupling.

Single and three phase transformers
Function and structure; ideal transformer; modelling of a real transformer, transformer operation at 50 Hz and influence of variable frequency; construction of magnetic circuit, insulation and conductors.

Electro-mechanical conversion

Link between electrical, magnetic, and mechanical energy. Systems with moving parts; calculation of forces and torques; resistive torque.

Direct Current machine
Principal and structure/construction. Fundamental equations. Excitation modes. Problems associated with operation. Principles of control with variable speed. DC brushless motor.

Class components (lecture, labs, etc.)

Lectures (CM), tutorials (TD). Pratical works (TP) would be organized depending on the avilability of the laboratory during the works in Building Bréguet.

The objective repartition is :
CM (13h30)
TD (9h)
TP (6h)

Grading

The evaluation will be done by a written examination of 2h. The pratical works will be taken into account in the final grade of the module for 20%. Absence at a pratical work session will give the mark 0/20 to the TP.
Practical work is compulsory assessment (EO)

Course support, bibliography

Text provided by the teaching group.
Electrical Machines, Drives and Power Systems (Theodore Wildi, Prentice-Hall Intl)

Resources

Teaching staff : Martin Hennebel - Michael Kirkpatrick - Romaric Landfried – Mohamed Bensetti
• Maximum enrollment : 25
• Software, number of licenses required:
• Equipment-specific classrooms (specify the department and room capacity): Electrical Energy System departmentq teaching laboratory for practical work.
Occurrence 1.1 is taught in English, occurrences 1.2, 1.3 and 1.4 are taught in French.

Learning outcomes covered on the course

At the end of this course, the student will be able to:
- Modelling electrical devices and equipment based on magnetic coupling
Make the choice of an adapted model of behaviour (integral form of Maxwell's equations, equivalent diagram of type circuit ...)

- Identify the parameters of this model using experimental data and / or geometric and physical properties
- Validate the quality of the model

- Predefining an AC power transmission system (three-phase) with its main elements

- Analyse and evaluate a motorisation based on AC or DC actuators

- Analyse the electrical, magnetic and mechanical behaviour of the actuator
- Compare to nominal behaviour
- Evaluate the performances and criticise the results obtained

Description of the skills acquired at the end of the course

1. This course validates milestone 1 of skills C1 and C2:

The course, and in particular the practical work sessions allow to develop the C1 competence, i.e. the analysis, the modeling and resolution, as well as the design of complex systems. These skills apply to the three-phase power systems, magnetic systems (transformers, magnets) and electromechanical actuation systems (actuators, motors). This course develops an in-depth competence in the field of electrical power systems engineering, which corresponds to milestone 1 of competence C2.

1EL2500 – Information theory

Instructors : **Richard Combes**
Department : **DÉPARTEMENT SIGNAL, INFORMATION, COMMUNICATION**
Language of instruction : **ENGLISH**
Type of course : **Elective 1A**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **60**
On-site hours (HPE) : **30,50**

Description

Information theory provides powerful tools to understand and solve fundamental problems in the moderntechnological world such as designing large communication networks, storage of big data, reliable and efficient transmission of information, data security, biology and machine learning. Information theory, originally introduced in the seminal works of Hartley, Shannon, Wiener and Kolmogorov, is now a rich domain, at the crossroads of probability, statistics, physics and engineering. Information theory has allowed the développement of technology which has transformed the modern world and our economy. The tools of information theory have the potential to impact application domains such as spatial exploration, energy, health, mobility, industry 4.0 and so on and so forth.

The goal of this class is to present the fundamental tools of information theory such as entropy and mutual information and show how those tools apply to practical problems: representation and coding, data compression, communication, error correction, cryptanalysis and inference. For all those problems, the class will propose elegant, provably optimal information theoretic schemes. The links between the course and other relevant courses will be highlighted, in particular probability, statistics and machine learning, signal processing, digital communications, networking and security.

Quarter number SG3

Prerequisites (in terms of CS courses) Probability

Syllabus

Lectures will allow students to discover both fundamental inforamtion theoretic concepts as well as diverse applications.Tutorial sessions offer concrete resolutions of engineering problems for various application fields: cryptography, image compression, communication, learning, finance.

1 - Introduction to information theory
- entropy and thermodynamics
- measures of information, conditional information, entropy
- information measurement units (bits)
- measurement of natural language entropy
- examples

2 - Information Measures
Fundamental mathematical tools of information theory
- entropy, conditional entropy, relative entropy, mutual information
- Properties and interpretations
- entropy positivity, maximum entropy
- relationships between the different information measures: chain rules
- inequalities: log-sum, Fano-Shannon, data processing systems
- fundamental limits of asymptotic equipartition and typicality
- application consequences

3 - Cryptographic security (exercises and practical work – 3h)
- Shannon experiments

- application of entropy to cryptographic security
- design of encryption schemes and cryptanalysis

4 - Data representation: fundamental limits
- binary representation of data
- coding of a data sequence in an M-ary discrete code alphabet
- construction of variable-length codes with unambiguous decoding
- Kraft's inequality for prefixed codes
- consequence of Kraft's inequality: fundamental limit to minimize the average length of a coded message (entropy)

5 – Data compression
Lossless discrete data compression algorithms
- Huffman coding algorithm
- Markov source coding
- universal data compression
Lossy compression algorithms
- vector quantization versus scalar quantization
- rate distortion theory
- rate distortion function for Gaussian vectors

6 – Image compression (exercises and practical work – 3h)
- measurement of the compression rate of an image
- image compression techniques with or without loss
- design of a compression algorithm on test images

7 – Mutual information and communication

Data processing systems
- examples of issues: storage, space exploration, IoT/WiFi/5G etc.
- mutual information output-input of a system

Discrete I/O systems
- erroneous information messages: typing errors, erased data, transmission errors, etc.
- maximum output-input mutual information of a channel (capacity)
- capacity of the bit channel with independent symmetric errors
- diagram of realization of an optimal coding to reach the capacity (achievability)
- examples of practical implementation (error-correcting coding)

Systems with additive Gaussian noise
- calculation of the maximum mutual information of channels with continuous inputs-outputs (capacity)
- discrete-time Gaussian additive noise channels
- parallel Gaussian channels and “waterfilling” algorithm
- fundamental limits of Shannon's theorem for error-free transmission
- compromise: information rate / bandwidth / signal to noise ratio
- examples of practical implementation (modulation and coding)
- performance constraints and metrics (complexity, reliability, secrecy, latency, energy, spectral efficiency, etc.)

8 - Audio communication (exercises and practical work - 4h30)

- mutual information and application consequences
- design and experimentation of a digital audio communication
- evaluation of performances

9 - Economics and finance: portfolio theory
- stock markets and portfolios
- optimality of log-optimal portfolios
- universal portfolios

10 - Machine learning and statistics: inference
- information theory & inference
- f-divergences and statistical distances
- minimax rate for estimation problems

11 - Stock market investment (exercise and practical simulation session – 3h)
- information theory & portfolio strategy
- optimization of an investment strategy with fictitious money

Class components (lecture, labs, etc.)
The course is given once (SG3) The course is scheduled in 19 slots of 1h30 and a 2h exam slot.

- 10 lectures (15h00)

- 9 tutorials (TD/TP) (13h30) organized into 3 3-hour TD/TP sessions with exercises and practical implementation (9h00) and 1 session of 1h30 with MCQ type evaluation (1/2 hour)

Grading

The final mark is a weighted sum of the marks of the MCQ type intermediate evaluation (continuous control CC) man without document and of the final written exam (40%, 60%) with documents allowed.

Course support, bibliography
- Lecture notes

- Thomas M. Cover and Joy A. Thomas, Elements of Information Theory

- David J.C. MacKay, Information Theory, Inference, and Learning Algorithms

- Imre Csiszar, Information Theory and Statistics: A Tutorial

- Alexandre B. Tsybakov, Introduction to Nonparametric Estimation

Resources
- Instructors (lectures): Richard Combes

- Practical Sessions (TD/TP) : 25 students per group.

Learning outcomes covered on the course
At the end of this course, students will be able to:
- model systems carrying information
- manipulate information measures and understand their physical meaning
- understand the fundamental limits for data transmission and storage, security, data processing
- develop algorithms for practical problems and understand application constraints and evaluate their performance
- to design processing architectures

Description of the skills acquired at the end of the course
- The benchmark skills assessed are skills C1 (C1.1 C1.2 C1.4) and C2 (C2.1) . The intermediate exam is used to assess milestone 1 of skill C1. The final exam assesses milestone 1 of skills C1 and C2. Skills C1 and C2 are validated if the final mark is greater or equal to 10.

1EL3000 – Industrial Engineering

Instructors : **Ludovic-Alexandre VIDAL**
Department : **DÉPARTEMENT GÉNIE INDUSTRIEL ET OPÉRATIONS**
Language of instruction: **ENGLISH, FRENCH**
Type of course : **Elective 1A**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **60**
On-site hours (HPE) : **30,50**

Description

• Know the issues and stakes of firms and organisations, their products and services, and their relationships with innovation, economy and human societies.
• Understand the multidisciplinary and complex character of firm-oriented systems along the lifecycle of an organization (design, industrialisation, production, distribution, reliability and return on experience,…).
• Understand how the choices made to determine the strategy for products/services development is a compromise between many constraints : availability of resources and skills, competition, environmental impact, organizational culture and strategy,…
• Understand and use the fondamental concepts, models and tools (and their application through several examples) which are used internationally in the field of industrial enginnering (academic world and industrial practitioners).

Quarter number SG1 and SG3

Prerequisites (in terms of CS courses) None

Syllabus

This course presents to the students the essential concepts and tools of industrial engineering, helping them to understand the stakes of product and organisation lifecycles. Thanks to the tutorials (with a ratio of about 1h theory for 2h tutorial), this course will offer the students a very exhaustive introduction to industrial and organisational systems, as well as their interdependences.

Sessions :
Session 1 (Introduction 1h30) : Life Cycle of an Organization / a Product / a Service Life Cycle Concept, Stakeholders and Values, Systems Thinking, Main Phases and Processes.
Sessions 2&3 : Design Processes - Design Processes and Activities, Functional Analysis, Specifications, Life Cycle Analysis, V-Cycle, Design Flexibility, Product-based FMECA.
Session 4&5 : Production Processes - Make-to-Order Approaches, MRP and Associated Mathematical Models, Make-to-Stock Approaches, Kanban, Associated Mathematical Models.
Session 6&7: Distribution Processes - Stakes of Distribution Activities, Distribution Monitoring and Control, Distribution Performance, Stock, DRP, Warehouses and Cross-Docking Models, Flows & Vehicle Route Optimisation, Supply Chain Sustainability and Performance, Tracking.
Session 8&9 : Quality Processes Product Reliability, Reliability Funcitons, Reliability and Safety Analysis Parameters, Bathtub Curve, Reliability of Parallel or Series Components. Maintenance Processes, Introduction to Statistical Process Control. Introduction to 6 Sigma. Control Charting. Capability Measures.
Session 10 : Industrial Conference (3h) Synthesis of all sessions with an industrial conference.
Session 11 : Final Test (2h) Final Test.

Class components (lecture, labs, etc.)

Some of the sessions will be carried out in reverse pedagogy mode in distance mode for the lectures (to promote proactive and flexible learning of the concepts), followed by on-site tutorials to answer all questions before adressing the exercises of the tutorials.

Occurrences of this course will be taught in the following languages :
Occurrence 1.1. English
Occurrence 1.2. French
Occurrence 1.4. French

Grading
2 continuous controls will take place during the course.
Final exam duration : 2h.
Documents authorized, calculator authorized. No Internet access or computer.
The score of continuous (intermediate) controls will be worth 40% (20% each continuous control) and that of the final exam 60%.

Course support, bibliography
Given Lesson after Lesson (specific references).

Resources
Teaching staff : Ludovic-Alexandre Vidal and Julie Le Cardinal for courses. Loïc Pineau, Ludovic-Alexandre Vidal & Julie Le Cardinal for exercises and case studies. Some industrial conferences.

Learning outcomes covered on the course

At the end of this course, the student will be able to: (Skills)

C1.1 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.

C1.2 Model: use and develop suitable models, choose the right modeling scale and the relevant simplifying assumptions

C1.4 Design: Specify, build and validate all or part of a complex system

C2.1 Deepen a field of engineering sciences or a scientific discipline (adapted to industrial engineering)

Description of the skills acquired at the end of the course

At the end of this course, the student will be able to: (Skills)

C1.1 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.

C1.2 Model: use and develop suitable models, choose the right modeling scale and the relevant simplifying assumptions

C1.4 Design: Specify, build and validate all or part of a complex system

C2.1 Deepen a field of engineering sciences or a scientific discipline (adapted to industrial engineering)

1EL4000 – Materials

Instructors : **Véronique Aubin**
Department : **DÉPARTEMENT MÉCANIQUE ENERGÉTIQUE PROCÉDÉS**
Language of instruction: **FRENCH, ENGLISH**
Type of course : **Elective 1A**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **60**
On-site hours (HPE) : **30,50**

Description

- To make 1st year students aware of materials issues and their importance in society, economy and innovation
- Open them to the multidisciplinary nature of the world of materials and make them aware of the scientific and technological barriers around materials (e.g. aeronautics, fuel cells, ITER, electronics beyond Moore's law, energy recovery and transformation, materials for health, biomaterials, MEMS-NEMS,...)
- To give students the ability to read scientific and technical documents on any material, to extract the characteristics important for a targeted application, and to interpret these elements in relation to the structural, physical and mechanical characteristics of the material
- Show that the choice of a material results from a compromise within a set of constraints: availability of resources, production processes, use properties, life cycle, environmental impact and cost
- To make understand the physical phenomena at the origin of the properties of materials, to propose, through some examples, simple models which capture the essential of the physics of the phenomena and tools which make it possible to apprehend these phenomena, and to give the desire to deepen in more fundamental courses thereafter

Quarter number SG1 and SG3

Prerequisites (in terms of CS courses) None

Syllabus

• Introduction: current importance of materials, challenges associated with materials in major societal issues, taking into account the constraints related to sustainable development
• Introduction to the main families of materials: definition based on the nature of the chemical bond, resulting and use properties, introduction to the choice of materials
• Structures and phase transformations of materials :
- Order-disorder concepts: from crystal to amorphous via polymers and liquid crystals and how to describe and measure order and disorder
- Defects (0D to 3D): crucial role of the defect in the materials, illustration by various couples defect / property
- Thermodynamic balances and phase diagrams, their role in materials development

• Material properties :
- Mechanical properties related to the structure: plastic deformation mechanisms
- Functional properties related to the structure: thermal and electrical conduction, ferroelectricity, magnetism, optics

Class components (lecture, labs, etc.)

(1 session = 3 hours lesson) except session 1 of 1:30 and session 12 that will be 2 hours

- Sessions 1: lecture
- Session 1 to 9: lecture + directed study session
- Session 10: 3 hours working session
- Session 11: exam

Grading

Continuous monitoring during the course (25% of the final grade) by MCQ

Mandatory evaluation:

- summary document produced at the end of the study session on a material and its application (mandatory evaluation): 25% of the final grade.
- Final written exam (2 hours): 50% of the final grade

Skill C1 is validated if the grade is higher than 12 in the final exam or in the case study
Skill C2 is validated if the course is validated (global grade > 10)

Course support, bibliography

Materials of M. Ashby and D. Jones, Introduction to Solid State Physics of C. Kittel

Resources

-Teaching staff (instructor(s) names): Véronique Aubin, Brahim Dkhil, Camille Gandiolle, Jan Neggers, Elsa Vennat
- Maximum enrollment (default 35 students): 35 students
- Software, number of licenses required: CES Edupack, 100 licenses
- Equipment-specific classrooms : computer classrooms
Sessions 1.1 and 1.3 are given in French, session 1.4 in English.

Learning outcomes covered on the course

At the end of this course, the student will be able to:
- Analyze the scientific aspects of the overall behavior of a limited-scale system (e.g., isolated part of a complex system), including identification of factors that influence its behavior
How:
- For a given application, describe the constraints and the loadings imposed by that application. Prioritize these constraints to make a choice of materials. Make a multi-criteria material selection.
- For a given material, explain the macroscopic properties according to its atomic arrangement, its defects and its microstructure at different scales
- Read scientific and technical documents on a material, extract important characteristics for a targeted application, interpret these elements in relation to the structural, physical and mechanical characteristics of the material

- Correctly use a model presented in class, in its conditions of validity (model describing a phenomenon, without couplings)
How to:
- use a phase diagram to predict the microstructure of a material according to its thermomechanical history
- use a diffractogram to identify the structure and the atomic arrangement of the analyzed material
- use the model of interaction of dislocations with the microstructure to explain the mechanical behavior of a crystalline material
- interpret the electronic properties of a material to deduce its functional properties, semiconductivity and ferroelectricity

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 skills in an engineering field and a family of professions

1EL5000 – Continuum Mechanics

Instructors : **Guillaume Puel**
Department : **DÉPARTEMENT MÉCANIQUE ENERGÉTIQUE PROCÉDÉS**
Language of instruction: **ENGLISH, FRENCH**
Type of course : **Elective 1A**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **60**
On-site hours (HPE) : **30,50**

Description

The student should be convinced of the ubiquity of the concepts and tools of mechanics in any industrial project implying either basic or advanced technology. The basic concepts are introduced in a common unified framework for tridimensional deformable solids and slender structures. Problems involving mechanics at different scales illustrate the course, with some applications to civil engineering, transportation, biomechanics and nanotechnology typically.

Quarter number SG1 and SG3

Prerequisites (in terms of CS courses) None

Syllabus

1. Strains: Lagrangian description of movements, Green-Lagrange strain tensor, infinitesimal strain tensor (1h30)
2. Stresses: global equilibrium equations for a material medium, Cauchy stress tensor, local equilibrium equation
3. Strength criteria: mechanical tests, brittle fracture criteria, Tresca and von Mises criteria, stress concentrations
4. Material behaviour: diversity, linear elastic isotropic behaviour, thermoelasticity
5. Elasticity: properties of the mechanical solution, exact and approximate solutions, simplifications of an elastic problem (flipped classroom with a 3h-tutorial)
6. a) Intermediary examination (analysis of numerical solutions: 30 min) / b) Beam approximation: demonstration of the assumptions of the beam model, definition of the internal loadings
7. Beam approximation: approximate kinematics, constitutive relations, connections
8. Beam approximation: solution methods, buckling phenomenon
9. Summary problem on beams (2h)
10. Engineering study: design problem, with graded report (3h)
11. Final examination (2h)

Class components (lecture, labs, etc.)

Typical 1h30 lectures followed by 1h30 tutorial classes, except for session 1 (1h30 lecture) and sessions 5, 9 and 10 (3h-sessions of tutorial classes)
Occurrences 1.1 and 1.4 are in English; occurrences 1.2 and 1.3 are in French.

Grading

Overall grade = 20% intermediary examination (continuous assessment) grade + 20% engineering study report (session 10) (continuous assessment) grade + 60% final examination grade (written exam)
All documents are allowed, as well as non communicating calculators for the final examination

Course support, bibliography

Lecture notes

Resources

-Teaching staff (instructor(s) names): Andrea BARBARULO, Didier CLOUTEAU, Ann-Lenaig HAMON, Guillaume PUEL
- Maximum enrollment: 40 for each tutorial class
- Software, number of licenses required: Comsol Multiphysics (including the Structural mechanics module)
- Equipment-specific classrooms: none (numerical sessions with Comsol are taught in classical tutorial classes)

Learning outcomes covered on the course

Learning outcomes:
- Model the mechanical behaviour of a deformable solid

- Justify the relevant choice of model (2D or 3D, axisymmetry, slender structures, ...)
- Write the correct equations and boundary conditions corresponding to the loads and constraints applied to the domain and its boundaries
- Identify the mechanical properties of constitutive materials that are relevant to model the studied problem (e.g. rigidity, resistance, …)

-Determine the (stationary) mechanical response of a deformable solid
- Find the exact solution or an approximate solution (analytical or numerical) of the studied problem
- Deduce from the obtained solution the quantities allowing to make design choices
- Justify or criticize the validity of the obtained solution

Description of the skills acquired at the end of the course

The intermediate examination on the analysis of numerical solutions allows the evaluation of the milestone 1 of the subskills **C1.2** "Modeling: use and develop appropriate models, choose the right modeling scale and the relevant simplifying hypotheses" and **C1.3** "Solving: solve a problem with the use of approximation, simulation and experimentation".
The report of the engineering study (session 10) allows the evaluation of milestone 1 of sub-skills **C1.1** "Analyzing: study a system as a whole, the situation as a whole. Identify, formulate and analyze a system within the framework of a trans-disciplinary approach with its scientific, economic and human dimensions" and **C1.4** "Designing: specify, realize and validate all or part of a complex system".
These two elements allow the validation of milestone 1 of skill **C1**, while the validation of milestone 1 of skill **C2** is directly related to the final mark for this course.

1EL6000 – Networks and Security

Instructors : **Pierre Wilke**
Department : **CAMPUS DE RENNES**
Language of instruction: **FRENCH, ENGLISH**
Type of course : **Elective 1A**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **60**
On-site hours (HPE) : **30,50**

Description

This course aims to provide CentraleSupélec students with basic knowledge in computer networking, as well as a reasonable awareness of information security issues.
Regarding networking, the mechanisms allowing users like us to browse and use Internet services will be highlighted. Thus, the various network layers, from the physical to the applicative level, will be introduced, as well as additional network services such as DNS (Domain Name System). Hands-on and tutorial sessions will allow students to face the actual implementation of the various concepts covered, in realistic situations and systems.
Regarding information security, lectures will introduce fundamental concepts and will succintly present a few security mechanisms. They will be complemented by lab sessions illustrating various security risks and the associated countermeasures.

Quarter number SG1 and SG3

Prerequisites (in terms of CS courses)

Information systems and programming
- Basic Python programming

Syllabus

Part 1: Networking – lower layers

- Physical layer / data link layer (Ethernet)
- Address Resolution Protocol (ARP), Media Access Control (MAC) addresses

Part 2: Networking – intermediate layers

1. IP protocol and addresses
2. IP routing and routing protocols
3. Transport protocols (TCP and UDP)
4. Tutorial 1: Network traffic analysis (Wireshark)
5. Tutorial 2: Specification of a communication protocol
6. Lab 1: Networking equipment handling (routers / switches)
7. Personal work: Border Gateway Protocol (BGP), peering, IPv4-IPv6 migration, congestion control, flow control, QoS...

Part 3: Networking – Applicative layers and services

- Domain name resolution (DNS)
- HTTP protocol, web technologies
- Tutorial 3: Implementation of the protocol specified in tutorial 2, in Python (socket programming)
- Personal work: e-mail protocols (IMAP, POP, SMTP), directories (LDAP)...

Part 4: Information security

- Introduction to information security, fundamentals
- Legal and social aspects

- Introduction to cryptography and cryptographic protocols
- Introduction to malware
- Lab 2: Virtual Private Networks (VPN)
- Lab 3: Web application security
- Personal work: IPSec, DNSSec, TLS, secure instant messaging...

Class components (lecture, labs, etc.)

Networking – lower layers: lecture (1h30)
Networking – intermediate layers: lecture (3h), tutorial (6h), lab (3h), personal work (9h)
Networking – Applicative layers and services: lecture (3h), tutorial (3h), personal work (9h)
Information security: lecture (3h), lab (6h), personal work (10h)
Written exam (2h)

Occurrences 1.2 and 1.4 are taught in French
Occurrence 1.3 is taught in English

Grading

The evaluation will be the average of a written examination at the end of the session (CF) lasting 2h and the evaluation of the labs 1 and 2 (mandatory evaluation)
- 50% final exam (written, multiple choice questions, no documents)
- 25% lab 1
- 25% lab 2
Lab grades always participate in the final grade, whether they improve it or not.

Course support, bibliography

Lecture slides provided in electronic format
Books:

- J.F. Kurose and K.W. Ross, *Computer Networking: A Top-Down Approach*, 7th ed. Eyrolles. Pearson. ISBN : 978-0133594140
- Ross J. Anderson, *Security Engineering: A Guide to Building Dependable Distributed Systems*, 2nd Edition. Wiley. ISBN : 978-0470068526 (available online on https://www.cl.cam.ac.uk/~rja14/book.html)

MOOC:

- Stanford Online: *Introduction to Computer Networking* (https://lagunita.stanford.edu/courses/Engineering/Networking-SP/SelfPaced/about)
- Coursera / Université du Maryland : *spécialisation Cybersécurité* (https://www.coursera.org/specializations/cyber-security)
- Cisco Networking Academy: CCNA1 and CCNA2 modules (https://netacad.centralesupelec.fr/)

Resources

- Teaching staff: Rennes/CIDRE team members, as well as Paris-Saclay teachers (computing and telecommunications departments);
- Most tutorials and lab sessions require a personal laptop;
- Software used: Wireshark, Python, VirtualBox, OpenVPN (all free/open source);
- Some tutorials and lab sessions involve specific networking equipment;
- Some lectures may be presented remotely from Rennes.

Learning outcomes covered on the course

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

- Know TCP/IP computer networking concepts, protocols and mechanisms;
- Analyse the network activity generated by web applications;
- Know the main types of cryptographic schemes;
- Know techniques used by malware;
- Set up and manage switched and routed computer networks;
- Design and implement an applicative communication protocol;

- Set up and configure a Virtual Private Network (VPN);
- Detect and analyse some web application vulnerabilities.

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

1EL7000 – Transport Phenomena

Instructors : **Ronan Vicquelin**
Department : **DÉPARTEMENT MÉCANIQUE ENERGÉTIQUE PROCÉDÉS**
Language of instruction: **ENGLISH, FRENCH**
Type of course : **Elective 1A**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **60**
On-site hours (HPE) : **30,50**

Description

The objective of this course is to teach the basic notions of mass, species, momentum and heat transfer necessary to the characterization and scaling of multiple systems. Due to the strong analogy between species transfer and heat transfer on the one hand and the intimate coupling between fluid dynamics and heat transfer inherent to the convection phenomenon on the other hand, this set of engineering sciences is very consistent and is part of the basic academic core in a large variety of industrial sectors covering energy (nuclear, fossil, renewable), transport (automobile, aircraft, aerospace), industrial processes (chemical, biomedical), health, building, … Moreover, a good knowledge of these transfer sciences is absolutely necessary in the booming domain of the optimization of industrial processes. Finally, several current environmental issues and challenges for society such as the reduction, the dispersion or the sequestration of pollutants or the climate change involve physical phenomena partly based on transfer sciences. To solve all the serious problems that humanity is facing in the beginning of this 21st century, many important developments and breakthroughs will have to be achieved in the domains of technology, health and environment. In this context, a good background in mass, species, momentum and heat transfer is a major advantage for engineering students, and this set of sciences is essential for the training of high level engineers. The course is composed of a dense theoretical content (mass and species transfers, fluid dynamics, heat transfer by conduction, convection and radiation in diverse configurations: steady-state or transient, isolated or coupled phenomena, boundary layers), and after each lecture a practical engineering problem illustrating the notions introduced is solved in tutorial classes.

Quarter number SG1 and SG3

Prerequisites (in terms of CS courses)

Basics of mathematics and thermodynamics (studied during the first 2 university years)

Syllabus

-THE BASICS OF RADIATION HEAT TRANSFER:

-Notions of opaque body and of transparent medium. Notions of emitted, absorbed, reflected, leaving, incident and radiative heat fluxes. Writing boundary conditions involving radiative heat exchanges. Notion of spectral directional intensity. General expression of a radiation heat flux. Notion of equilibrium radiation – Properties of the associated spectral intensity.

-RADIATIVE PROPERTIES AND RADIATIVE TRANSFER:

Characterization of the surface of an opaque body: notions of emissivity, absorptivity and reflectivity. Notions of gray body, black body, and diffuse body. Simple models of radiative transfer between 2 opaque bodies separated by a transparent medium: (1) opaque, convex and isothermal body surrounded by an isothermal black body; (2) opaque, convex, isothermal and small body surrounded by an opaque isothermal enclosure.

- INTRODUCTION TO THE STUDY OF FLUID FLOW:

Theorem Pi. Types of flows. Description of motion and material derivative. Velocity and acceleration of a fluid particle. Transport theorems. General local balance of mass. Description of species mixtures.

-SPECIES MASS TRANSFER – DIMENSIONAL ANALYSIS:

Local balance equation of species mass. Species absolute velocity, mixture mass-average velocity, diffusion velocity. Analogy between heat and mass transfers (diffusion and convection). Fick's law (binary mixture, dilute gas or liquid). Physical origins, order of magnitude of the mass diffusivity. Boundary conditions – Discontinuous concentrations at interfaces. Dimensional analysis to carry out a priori approximations. Characteristic time and length scales. Link with Pi theorem. Similitude conditions.

-BALANCE OF MOMENTUM

General motion of a fluid particle. Strain rate tensor. Stresses in fluids. Relation between stress and strain rate tensors in Newtonian fluids. Local balance equation of momentum. Euler equations. Navier-Stokes equations. Dimensional analysis of Navier-Stokes equations. Local balance equation for kinetic energy.

-ENERGY BALANCE EQUATIONS

Local balance equation of energy. General formalism and similarities of transport equations for mass, species concentrations, momentum and energy.Bernoulli theorem and applications. Macroscopic balance of mechanical energy. Study of incompressible flows in pipes. Friction head losses. Moody diagram. Singular head losses. Pump and turbine efficiency.

-MACROSCOPIQUES BALANCES

Macroscopic balance of mass and species. Momentum theorem in steady flows. Moment of momentum theorem. Application to the determination of hydrodynamic forces and moments. Thrust of turboengines and rockets. Macroscopic balance of thermal energy.

-INTRODUCTION TO THE PHYSICS OF BOUNDARY LAYER

Boundary layer theory. A priori estimates of the laminar boundary layer thickness. Separation and transition. Definition of boundary layer thicknesses. The boundary layer equations for a laminar flow over a flat plate. Numerical solutions of equations of a laminar boundary layer on a flat plate without pressure gradient.

-EXTERNAL FORCED CONVECTION – 2D MECHANICAL AND THERMAL BOUNDARY LAYER MODEL

Approximate solutions of the boundary layer equations for a laminar flow over a flat plate with the integral method. Effects of pressure on boundary layers. Thermal boundary layer in external forced convection. General form of correlation formula for external forced convection. Simplifying hypotheses and simplified heat transport equation. Integral method applied to thermal boundary layer.

-NOTIONS OF INTERNAL FORCED CONVECTION:

Elementary notions on the mechanical and thermal entrance zones and on the fully developed mechanical and thermal regimes. Notion of bulk velocity and bulk (or mixture) temperature. Determination of the velocity profile in fully-developed laminar regime. Expressions of the Nusselt number for laminar and turbulent flows and for a duct of circular cross-section. Internal convection in laminar and turbulent regimes. Notion of hydraulic diameter.

Class components (lecture, labs, etc.)

The course is given several times in French or English during the SG1 and SG3 sequences.

Sequence SG1

- Occurrence 1.1 (French) : Hervé Duval
- Occurrence 1.2 (English) : Gabi Stancu
- Occurrence BCPST (French) : Julien Colin

Sequence SG3

- Occurrence 1.3 (French) : Fabien Bellet
- Occurrence 1.4 (French & English) : Ronan Vicquelin, Antoine Renaud
    - Amphitheater + TD (French) : Ronan Vicquelin
        - *Default affectation in occurence 1.4 is in the French course*

- One classroom (English) : Antoine Renaud
  - *Once the students are enrolled in occurence 1.4 (displayed as tough in French in the MyWay poll), they can choose afterwards to follow the English class.*

The course is scheduled over 19 slots of 1h30 each, 3 remote preparation elements (3 x 1h30) and a 2h exam session.

Grading

The Final Examination, held over 2 hours in the last session, can be carried out with documents. Students receive the grade denoted as CF.
Continuous assessment through a minimum of two optional quizzes and tests taken in class, with documents allowed. For each test, the student obtains a CCi mark: CC1 for test n°1, CC2 for test n°2, etc...
Ncc is the number of tests (minimum 2). Continuous assessment thus accounts for a maximum of 33% of the final grade, and final assessment for a minimum of 67%.

Course support, bibliography

-Provided course material
-Polycopié CentraleSupélec « Mécanique des Fluides» ; Tome I ; Sébastien Candel.
-« Transferts thermiques - Introduction aux transferts d'énergie » ; 5ème édition ; auteurs : Jean Taine, Franck Enguehard et Estelle Iacona ; Dunod, Paris, 2014.

Resources

-Teaching staff (instructor(s) names): Fabien Bellet, Julien Colin, Hervé Duval, Antoine Renaud, Gabi Stancu, Ronan Vicquelin
- Maximum enrollment (default 35 students): 100-120 per session, and 35 per tutorial class, which means 3 tutorial classes per session.

Learning outcomes covered on the course

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

1. Identify different modes of heat and mass transfer taking place in a given configuration,
2. Write appropriate balances (mass, species, momentum, energy), jump conditions at interface, to determine the evolution of different fields (species concentrations, velocity, pressure, temperature),
3. Compute stresses, heat fluxes, forces, mechanical and thermal powers, efficiencies, head losses.
4. Model complex systems, a necessary step to their conception and optimization:
   - Make approximations and estimations,
   - Simplify an apparently complex system
   - Use fundamental balances to solve practical problems

Description of the skills acquired at the end of the course

The course is part of the C1 and C2 competencies of the CentraleSupélec engineering curriculum.

C1: Analyse, design and build complex systems with scientific, technological, human and economic components

C1.1: Analyse: study a system as a whole, the situation as a whole. Identify, formulate and analyse a system within the framework of a transdisciplinary approach with its scientific, economic, human dimensions, etc.

C1.2: Model: use and develop appropriate models, choose the right scale of modelling and relevant simplifying assumptions

C2 : Develop an in-depth competence in an engineering field and in a family of professions

C2.1 : Go deeper into an engineering field or scientific discipline

Core skills in CentraSupélec curriculum:

- C1 (C1.1, C1.2) and C2 (C2.1)

C1 is validated if CF >= 10.
C2 is validated if NF >= 10.

1EL8000 – Electronic Systems

Instructors : **Pietro Maris Ferreira**
Department : **DÉPARTEMENT ÉLECTRONIQUE ET ÉLECTROMAGNÉTISME**
Language of instruction: **ENGLISH, FRENCH**
Type of course : **Elective 1A**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **60**
On-site hours (HPE) : **30,50**

Description

Analog and digital electronic systems are today ubiquitous in our lives, whether in the use of connected objects for domotic applications, in the areas of communication, transport and health, in the fields of defense and space, or in the billions of computers connected across the WEB.
Despite a constantly evolving domain (Moore's law), there are a number of constant fundamentals that are common to most systems no matter their complexity:

- interfaces with the physical world (sensors) and persons (display devices, HMI),
- processing of analog signals (filtering, wavelets, ... and soon neuromorphic systems)
- analog-to-digital conversion (with or without data compression) and digital-to-analog (transducers)
- digital processing units onboard or remote (HPC, cloud ...).

This course is conducted in a top-down approach to prepare students to specify and develop electronic systems from existing hardware components (OpAmps, microcontrolers, FPGA).
Also, the principles and physical quantities related to the operation of these components are covered. Nevertheless, the microelectronic design and realization (i.e. Computer Aided Design and microelectronic technologies) will be addressed in more advanced courses to students who want to develop their skills in that field.

Quarter number SG1 and SG3

Prerequisites (in terms of CS courses) None

Syllabus

Analogue electronics :

- lecture 1: Historical and Economic Panorama of Electronic Systems; Linear Circuits
- lecture 2: Non-Linear Circuits - Distortion; Modulation; Saturation; Modeling
- tutorial class 1: Linear Amplifier Assemblies - Instrumentation Amplifier, TIA, 2nd Order Active Filter
- lecture 3: Semiconductor Components - PN Junction; Transistor MOS
- tutorial class 2: Non-Linear Systems Modeling - Analog Voltage Multiplier; Voltage Rectifier; Sample and hold; OTA
- lecture 5: Interface and sensors
- tutorial class 3: Instrumentation Chain LTSPICE Simulation: Radar Ultrason
- LAB : Instrumentation Chain Assembly: Ultrasonic Radar

Analogue to digital conversion :

- lecture : sampling and quantizing, non idealities and characterization, ADC specification
- Homework : ADC families,

Digital electronics :

1. lecture 1: Introduction to logic and digital components, Complex system design: software vs. hardware solutions, design methodology
2. homework : Discovering the Arduino
3. lecture 2: Data representation, logic, gates, flip-flops

4. lecture 3: Advanced functions, operators, state machines
5. lecture 4: Introduction to VHDL language
6. tutorial class 1: Initiation to VHDL language using FPGA
7. lecture 5: Processing unit architecture
8. tutorial class 2: digital processing of FPGA, lab preparation
9. LAB : Implementation of a digital processing of a FPGA

Class components (lecture, labs, etc.)

The course is divided into 3 parts: Analogue, digital, and conversion.
Each analog and digital part is composed of classes, tutorials, homework and one laboratory.

The analog electronics tutorials are essentially modeling and calculations.
One of the digital tutorials is around an electronic board DE10 Altera in initiation to design in VHDL language.

The two labs are a single project comprising a sensor, an analog stage, an ADC and a digital processing. The aim of the first lab is to design, simulate and test the analog stage, while the 2nd lab will focus on the design of the digital part using VHDL language.

The course is given in French for the occurrences 1.1, 1.2 and 1.3. It is given in English at occurrence 1.4

Grading

The course is evaluated on the basis of 2 laboratories and a written exam lasting 2 hours with document.
Final Evaluation = 75% written exam score, 25% analog lab and digital lab.
Labs are compulsory assessment (EO)
The 'analog' labs are prepared by a tutorial which allows to pre-determine the functions that will be tested. The supervisors will check that this preliminary work has been done and will take into account in their notation. The Labs are evaluated on the basis of the report written in real time and the simulation and measurement elements produced, as well as the observation by supervisors of students in situation.
The 2-hour written exam poses an engineering problem for an electronic system for which students must provide a solution by choosing a sensor, an analog processing system, an analog-to-digital converter digital and digital processing.
Assessment of learning outcomes: The skills mentioned above are all assessed at a level 1, that is to say in the case of simple, relatively closed problems, and in a way guided by the professors. The skills will be assessed in 2 ways: - theoretically by means of the written exam and practically by laboratories.

C1 is validated if the average of the 2 labs is greater than 12 and the average of the questions marked C1 during the written exam is greater than 10
C2 is valid if the average of the questions marked C2 during the written exam is greater than 10

Course support, bibliography

"Digital Design and Computer Architecture"
David and Sarah Harris
Morgan Kaufmann Publishers
« Foundations of analog and digital electronic circuits »
Anant Agarwal and Jeffrey H Lang
Morgan Kaufmann Publishers

Resources

- Teaching staff (instructor(s) names):
- Digital : P. Bénabès, C. Lelandais, A Kolar, E. Libessart
- Sensors : J. Juillard & L. Bourgois
- Analogue: E. Avignon, P. Maris, M. Roger.

- Maximum enrollment (default 35 students): 100 students for classes, 35 for tutorials, ans 16-18 for laboratories

- Software, number of licenses required: Quartus Student edition (Free softwares)

- Equipment-specific classrooms (specify the department and room capacity)

2 laboratories in the department of electronic systems and telecommunications, 32 students by laboratory (4 assistants).

Learning outcomes covered on the course

The "Electronic Systems" course will provide students with a basic understanding of:

A) Specify an analog processing chain
- Understand the different electronic technologies (integrated circuits vs printed circuits) and their evolutions (traditional technologies towards 'more than Moore' or 'beyond CMOS'), Systems on Chip, packaging, interconnections
- Design analog architectures from simple models (Laplace block for example) up to AOP-based circuits, capacitors, resistors, inductors.
- Analyze in matrix form the simple Kirchoff networks (RLC + AOP circuits).
- Determine if the limitations of the AOPs are respected (bandwidth, Gain-band product, input and output impedances, sweep rate) with respect to a given application
- Choose a sensor interface between the physical world and electronic signals

B) Simulate and test a simple circuit
- Take control of Spice simulation software (schematic input, AC, DC, and transient simulation)
- Set up a simulation efficiently: simulation time and not adapted, solving possible convergence problems in simple cases (RLC + AOP circuits).
- Make clean montages on test plates (simulation versus measurement)
- Measure currents, voltages, impedances with the appropriate equipment (oscilloscopes, impedance meters, ...).
- Choose the appropriate component from its documentation (AOP limitations)

C) Specify and select the correct analog-to-digital converter adapted to a given problem in terms of sampling frequency, resolution, family, and analyze the effect of sampling and quantification on the signal to be processed (effects of aliasing, saturation or non-linearity).

D) Specify and choose a digital processing architecture adapted to a given problem
- Type of processing unit adapted to the problem (processor, microcontroller, DSP, programmable circuit, dedicated ASIC)
- Choice of the development tools necessary for the implementation of these components

E) Implement a simple application with a microcontroller or a FPGA.
- Available peripherals in a microcontroller according to their potential use, and their simple implementation in C language
- Program, download and test a simple application on a microcontroller or FPGA in VHDL language

Description of the skills acquired at the end of the course

This course allows you to validate certain skills of type C1 - Analyze, design and build complex systems.
This validation is done by means of practicals (C13 Solve, C14 design) and the written exam (C11-Analyze, C12 Model).
The written exam also makes it possible to validate C2-type skills (C21-Deepen an engineering field, C22-Import knowledge from other fields)

So we will learn during this course who to:
A) Specify a simple analogue processing chain
B) Simulate and test a simple circuit
C) Specify and choose the right analogue-to-digital converter
D) Specify and choose a digital processing architecture adapted to a given simple problem
E) Implement a simple application with a micro-controller or a programmable logic device

Some basic concepts will need to be learned or reviewed independently (the basics of logic, Arduino microcontrolers, ADC converters families), and we will use
mathematical concepts studied elsewhere (sampling theory, filtering, signal processing)

1EL9000 – Thermodynamics

Instructors : **Marie-Laurence Giorgi**
Department : **DÉPARTEMENT MÉCANIQUE ENERGÉTIQUE PROCÉDÉS**
Language of instruction: **ENGLISH, FRENCH**
Type of course : **Elective 1A**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **60**
On-site hours (HPE) : **30,50**

Description

The objective of this course is to provide the theoretical bases, tools and good practices necessary for engineers to understand and design systems that transform raw energy into useful energy, and /or that modify the physicochemical properties of matter through controlled transformations. The knowledge acquired in this course will allow for the design of these systems by determining their optimal operating points (for example by using phase transitions) in order to optimize their energy efficiency.

In particular, the course will show how thermodynamic concepts can be used to meet the challenges of the 21st century (conventional and renewable energy production, energy efficiency of engineering processes, smart materials, recycling, water and waste treatment, etc.) and how recent scientific advances can help predict multiphysical couplings in complex systems.

Quarter number SG1 and SG3

Prerequisites (in terms of CS courses) None

Syllabus

1) Energy efficiency

General description of the fundamental concepts (open systems, state functions)
Open systems of energy transformation (energy, entropy and exergy balance)
Efficiency of energy recovery cycles (design of thermodynamic cycles)

2) Phase transitions
Thermodynamic properties of pure substances and solutions
Phase equilibria, phase diagrams
Phase transitions (equilibrium and departure from equilibrium, chemical reactions, germination / growth)

Class components (lecture, labs, etc.)

The course will be divided into 3 hour periods (1.5 hours of lecture and 1.5 hours of tutorials).
At the end of each part of the course, students will carry out a project by 2 or 3 students (2 x 3 hours to realize the projects and write the reports).
A final evaluation (2-hour written test) will complete the course.
The second session will be an individual assessment of 2 hours.
The language of instruction is French for occurrences 1-1 and 1-2 and English for occurrence 1-3.

Grading

Two projects with two reports (40%) and an individual final assessment (60%)

Course support, bibliography

D. Kondepudi, I. Prigogine, Modern Thermodynamics – From Heat Engines to Dissipative Structures, John Wiley and sons, England, 1998.
C.H.P. Lupis, Chemical Thermodynamics of Materials, Elsevier Science Publishing, New York, 1983.

Resources

-Teaching staff (instructor(s) names): Marie-Laurence Giorgi, Sean Mc Guire
- Maximum enrollment: 35
- Software, number of licenses required: open source software

Learning outcomes covered on the course

At the end of the course, students will be able to:
1. Write energy, entropy and exergy balances
2. Designing and optimizing energy recovery cycles
3. Propose and evaluate solutions to optimize the energy efficiency of systems
4. Understand and use phase diagrams for material design
5. Construct thermodynamic models describing phase equilibria
6. Work as a team independently and interdependently towards a common team objective

Description of the skills acquired at the end of the course

C1.1, C1.2, C1.3, C2.1

SCIENCE AND ENGINEERING CHALLENGE N°2 COURSES

ST2 - 21 - MEDICAL ROBOTICS

Dominante **: GSI (Large Interacting Systems)**

Langue d'enseignement **: French**

Campus où le cours est proposé **: Paris-Saclay**

Engineering problem

The development of robotics was originally motivated by industrial problems (manufacturing, evolution in a hostile environment, etc.). However, current developments are increasingly directed towards new markets: healthcare, services to the person, assistance, urban services, logistics, transportation, agriculture, etc. In healthcare, the assistance systems both to medical staff and to patients are inseparable from the notion of human-robot interaction.

These new use cases often require shorter hardware and software development times, an increased customization, and a strict performance validation under constraints of security, costs, size, weight, etc. Design methods regularly include optimization phases based on models of robotic systems and their environments. These phases appear during mechanical design, control design, development of artificial intelligence modules (as for example in medical imaging) etc.

In the context of robotics, the development of models requires a generalized and well-structured approach. In particular, dynamic modeling often uses the Lagrangian formalism which offers a very general scope. The methods discussed in the present thematic sequence are contextualized in the disciplinary field of robotics but their application scope largely exceeds this context.

The present thematic sequence addresses more precisely the problems of robotics within the medical environment through several components: interventional radiology (more precisely vascular radiology) which constitutes an important help in terms of guidance to the medical staff during the phases of intervention; the mini-invasive surgery, often associated with systems of computer vision, which limits the surgical traumas; and the gesture assistance which can be provided by an upper-limb exoskeleton, with interesting prospects for the functional rehabilitation among others.

Advised prerequisites

Prerequisites for the specific module (rigid body dynamics): elementary knowledge of point mechanics (notions of velocity, acceleration, force, moment).

Context and issue modules:

These modules aim to give a vision of the theme from several angles:

- General introduction with an opening lecture on the theme "Robotics in the French healthcare system, current status and perspectives"

- Highlighting of the main clinical issues of interventional robotics

- Highlighting of legal aspects, risks, safety and standards, constraint aspect and cost produced by GE Healthcare

- Presentation of existing technologies and barriers via presentations on the theme of "Computer-assisted or robotic medical and surgical procedures

Specific course (40 HEE): Rigid body dynamics

Short description: Many mechanical systems are intended to ensure specific movements or to transmit forces in a controlled way; they are then mechanisms generally made up of several solids in connection with each other, where one can consider that the displacements are mainly notable at the level of these connections, and that it is thus reasonable to suppose that the solids are indeformable. The study of these mechanisms then allows to quantify the performances they can offer, as well as to dimension them pertinently. In addition, the modeling tools used can be adapted to describe systems from other fields: thus, the course will give many examples from various fields of application, such as, typically:

- the dynamics of land, aeronautical and space vehicles, which involves in particular the problems of control and piloting;

- robotics, with the dimensioning of motion transformation mechanisms and the design of control laws;

- biomechanics and the study of sports gestures.

Challenge week n°1: Modeling and dimensioning of an upper limb exoskeleton

- Associated partner: CEA-LIST

- Location: Paris-Saclay campus

- Short description: An upper limb exoskeleton is a robotic system that can be worn by a human being to assist him/her in performing gestures, carrying heavy loads, etc. Such a system should ideally offer the same possibilities of movement to the human arm as when it is completely free, while bringing the desired assistance. In this project, we are particularly interested in the way in which the design and the control of the exoskeleton allow to conform to the human morphology and movements. Indeed, the choices of mechanical design and mechatronic dimensioning directly influence the comfort and the anthropomorphism of the possible movements, or the transmitted efforts. In this project, the aim is to develop models of the exoskeleton allowing the analysis of its movements and the efforts transmitted in order to offer the level of performance required for the assistance to the human being.

Challenge week n°2: Modeling and sizing of a medical robot - Modeling of a polyarticulated vascular radiology robot

- Associated partner: GE Healthcare

- Location: Paris-Saclay campus

- Short description: Interventional radiology has become an essential aid to surgeons during vascular operations (heart, lungs, brain, kidneys). Indeed, this type of system reduces recovery time and patient trauma during operations compared to conventional "open" surgery. A vascular radiology system can be made up of one or two polyarticulated robots, placed on the ground or suspended. The system studied has five motorized axes allowing the movement of the image-taking system consisting of an X-ray tube and a receiver. The level of precision required during the movement is closely linked to the imaging objective and depends in part on the design of the actuation system. Moreover, to guarantee safety, this type of system must be able to remain motionless in case of power failure, which leads to a specific choice and dimensioning of the motorization chain. Moreover, the robot sharing its working space with the medical staff and the patient, the problem of detection of unexpected collisions arises to ensure the safety of people. In this project, the aim is to model this type of robot by considering its multi-axis structure.

Challenge week n°3: Modeling and dimensioning of a medical robot - Modeling of a minimally invasive surgery robot

- Associated partner: SAAS Laboratory of the ULB (Free University of Belgium)

- Location: Paris-Saclay campus

- Short description: Surgical robots allow, among other things, to improve the precision of the surgeon's movements and to reduce the effect of tremors. They also provide more freedom of movement and more visibility thanks to the onboard vision system. Minimally invasive surgery aims to reduce the impact of an operation on the patient in terms of trauma and recovery time. The surgeon operates directly inside the patient's body using a camera and tools inserted through holes called trocars. The assistance of the surgeon by means of a robotic system makes it possible to overcome a certain number of constraints encountered by the surgeon in this type of operation (restricted working space, partial visibility, constraining posture...). The design of such robotic systems requires to consider new constraints of geometry (fixed point at the trocar level), instrumentation (sensors, end effectors...) and safety (collisions in the patient's body or in the working space of the medical staff). In this project, we are interested in the modeling of a robot with four degrees of freedom in order to evaluate its working space and to estimate the external forces in case of collision.

1SC2110 – Rigid body dynamics

Instructors : **Guillaume Puel**
Department : **DÉPARTEMENT MÉCANIQUE ENERGÉTIQUE PROCÉDÉS**
Language of instruction : **FRENCH**
Type of course : **Specific course**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **19,50**

Description

Many mechanical systems are designed to allow specific movements or to transmit forces in a controlled way; these mechanical linkages are generally composed of several solids in connection with each other, which can considered as perfectly rigid, since relative displacements are particularly significant in the joints. The study of these linkages then allows to quantify their performance as well as to design them in a relevant way. Besides, the modeling tools that are used can be adapted to describe systems from other fields: the course thus gives numerous examples coming from various fields of application, such as:

-vehicle dynamics (for terrestrial, aeronautical and space vehicles), which implies control and steering challenges;
-robotics, dealing with the design of mechanical linkages and of command laws;
-biomechanics, with the movement analysis of sports techniques.

Quarter number ST2

Prerequisites (in terms of CS courses)

Elementary knowledge of point mechanics (notions of velocity, acceleration, force, moment).
1EL5000 - Continuum mechanics could be useful, but is not mandatory to follow the course.

Syllabus

Kinematics of a perfectly rigid body (1h): placement vector, velocity field, acceleration field. Forces and moments. Fundamental principles of dynamics for a rigid body
- Change of frame. Application to joints. Perfect joints: kinematics and forces
- Static determinacy/indeterminacy. Solution methods
- Intermediary examination (45 min)
- Energetic methods: work-energy principle, principle of virtual work (application to a single rigid body)
- Real/virtual work for linkage forces. Application in the energetic methods. Lagrange's equations.
- Additional joint models (friction, backlash, elasticity, ...) out-of-classroom
- Sum-up session on problem solving
- Final examination (1.5h)

Class components (lecture, labs, etc.)

1h30 lectures followed by 1h30 tutorial classes, except for session 1 (1h lecture) and sessions 6 and 8 (3h tutorials)
Total in-class: 7h lectures, 10h30 tutorial classes, 1h30 final examination

Grading

Final examination: 1h30 with documents and non communicating calculators allowed
The final exam counts for 70% of the grade
The intermediate assessment (continuous assessment) counts for 30% of the grade

Course support, bibliography

Lecture notes
Online resources

Resources

Instructor name: Guillaume Puel
Maximum enrollment: 35 for each tutorial class

Learning outcomes covered on the course

Learning outcomes:

- model in a relevant way a mechanical linkage made of several rigid bodies:
- justify the relevant choices of model and the associated parameterization (2D or 3D, perfect joints or not, ...)
- determine the characteristics of each body, which are relevant for its dynamic study (location of the mass center, calculation of the inertia tensor)
- determine the motion of the different rigid bodies with respect to time and the actions in play:
- choose and apply a relevant solution strategy (isolations, projections, energetic approach or not) in order to obtain the motion equations of the different solids
- solve these equations analytically or numerically in order to determine the relevant quantities allowing for making design choices

1SC2191 – Modelling and sizing of an upper limb exoskeleton

Instructors : **Maria Makarova, Guillaume Puel, Emmanuel Godoy**
Department : **DOMINANTE - GRANDS SYSTÈMES EN INTERACTION**
Language of instruction : **FRENCH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

Many fields, from industrial to medical, are currently looking for solutions to reduce costs and drudgery, or ensure better control of the performed operations. One of the solutions that has emerged over the last decade or so is the use of exoskeletons, which are devices placed as close to the body as possible to relieve it during physically difficult operations. The majority of exoskeletons currently available for sale are passive exoskeletons (i.e. non-motorized). The limitations of these exoskeletons have led to the development of active, motorized exoskeletons, offering much more freedom in the movements performed and on the level of assistance provided.
The upper limb exoskeleton studied here belongs to this second category. This exoskeleton possesses mechanical characteristics linked to its actuating system, allowing very high levels of transparency. Transparency corresponds to the robot's capacity to be operated by the user without exerting any or as little resistance as possible. This characteristic is particularly important for the application areas of this type of robot, an example of which is functional rehabilitation.
Functional rehabilitation is an important step towards improving the quality of life of patients with motor disabilities, whether innate or after trauma or stroke, for example. The main advantages recognised in the use of exoskeletons in the field of functional rehabilitation (especially for the upper limbs) are an extended, three-dimensional workspace, limb tracking throughout the workspace allowing work to be carried out on movements that are natural for the patient and therefore the possibility of working on movements using the synergies and dependencies between the different joints of the arm. All the possible developments and applications mentioned above can only be made possible by a fine knowledge of the characteristics of the exoskeleton under consideration, which is crucial in order to achieve a high level of transparency.

Quarter number ST2

Prerequisites (in terms of CS courses) None

Syllabus

Possible projects (typical topics, to be specified):

- Modeling and dynamic simulation of the exoskeleton
- Load-dependent friction modeling
- Study of human-exoskeletal coupling
- Effort transmission study

Grading

involvement in the team work during the challenge week + deliverables at the end of the week + final defense

Resources

- room for 30 students, with projector, organized in blocks by group
- 3 teachers per room
- Matlab/Simulink (network access for license) on individual students' PCs

Learning outcomes covered on the course

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

1. Describe the current context of medical robotics through the main technical, application and economic challenges associated with it.
2. Identify current topics in medical robotics, and describe their technical specificities.
3. Describe the main hardware and software components of an industrial and medical robotic system.
4. Develop and simulate models of polyarticulated or mobile robots.
5. Designing, modeling and simulating a motorization chain.
6. Analyze a system in interaction with the external environment.

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
C4 - Have a sense of value creation for one's company and one' customers
C7 - Know how to convince
C8 - Lead a project, a team

1SC2192 – Modeling of a polyarticulated vascular radiology robot

Instructors : **Maria Makarova, Emmanuel Godoy, Guillaume Puel**
Department : **DOMINANTE - GRANDS SYSTÈMES EN INTERACTION**
Language of instruction : **FRENCH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

During vascular operations (heart, lungs, brain), interventional radiology is an essential aid for surgeons. A vascular radiology system can consist of one or two polyarticulated robots, placed on the ground or suspended. The system studied here has five motorized axes allowing the movement of the imaging system consisting of an X-ray tube and a receiver. The level of accuracy required during movement is closely related to the imaging objective and depends in part on the design of the actuating system. In addition, to guarantee safety, this type of system must be able to remain stationary in the event of a power failure, which leads to a specific choice and dimensioning of the motorization chain. In addition, since the robot shares its workspace with the medical staff, the problem of detecting unexpected collisions arises in order to ensure staff safety. This challenge week deals with the modelling of this type of robot taking into account its multi-axis structure.

Quarter number ST2

Prerequisites (in terms of CS courses) None

Syllabus

Possible projects:

- Development of a simulator for a dynamic model of the Innova robot
- Identification of the parameters of a dynamic model of an interventional surgery robot
- Modeling of an irreversible transmission chain
- 3D robot trajectory planning for a "cardiac spin" analysis
- Development of a model of a two-wheel drive carrier robot

Grading

involvement in the team work during the challenge week + deliverables at the end of the week + final defense

Resources

Room for 30 students, with projector, organized in blocks by group

- 3 teachers per room
- Matlab/Simulink (network access for license) on individual students' PCs

Learning outcomes covered on the course

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

- Describe the current context of medical robotics through the main technical, application and economic challenges associated with it.
- Identify current topics in medical robotics, and describe their technical specificities.
- Describe the main hardware and software components of an industrial and medical robotic system.
- Develop and simulate models of polyarticulated or mobile robots.

- Designing, modeling and simulating a motorization chain.
- Analyze a system in interaction with the external environment.

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
- C4 - Have a sense of value creation for one's company and one' customers
- C7 - Know how to convince
- C8 - Lead a project, a team

1SC2193 – Modeling of a minimally-invasive surgical robot

Instructors : **Pedro Rodriguez-Ayerbe, Guillaume Puel, Emmanuel Godoy, Maria Makarova**
Department : **DOMINANTE - GRANDS SYSTÈMES EN INTERACTION**
Language of instruction : **FRENCH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

Surgical robots can improve the surgeon's precision of movement and reduce the effect of tremors, among other things. They also provide more freedom of movement and visibility thanks to the on-board vision system.
Minimally-invasive surgery aims to reduce the impact of an operation on the patient in terms of trauma and recovery time. The surgeon operates directly inside the patient's body using a camera and tools inserted through holes called trocars. The assistance of the surgeon by means of a robotic system makes it possible to overcome a certain number of constraints encountered by the surgeon in this type of operation (restricted work space, partial visibility, constraining posture...).
The design of such robotic systems therefore requires new constraints to be taken into account in terms of geometry (fixed point at the trocar), instrumentation (sensors, effectors, etc.) and safety (collisions in the patient's body or in the workspace of medical staff).
In this project, we are interested in modelling a robot with four degrees of freedom in order to evaluate its working space and estimate external forces in the event of a collision.

Quarter number ST2

Prerequisites (in terms of CS courses) None

Syllabus

Possible projects:

- Study of interaction forces with the patient or surgeon
- Study of virtual sensors for the reconstruction of interaction forces
- Development of a simulator for a dynamic robot model
- Study of joint friction based on experimental data
- Study of the design of the actuators and sensors of the robot
- Study of robot movements for control

Grading

involvement in the team work during the challenge week + deliverables at the end of the week + final defense

Resources

- large room for 30 students, with projector, organized in blocks by group
- 3 teachers per room
- Matlab/Simulink (network access for license) on individual students' PCs

Learning outcomes covered on the course

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

- Describe the current context of medical robotics through the main technical, application and economic challenges associated with it.
- Identify current topics in medical robotics, and describe their technical specificities.
- Describe the main hardware and software components of an industrial and medical robotic system.
- Develop and simulate models of polyarticulated or mobile robots.
- Designing, modeling and simulating a motorization chain.
- Analyze a system in interaction with the external environment.

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
- C4 - Have a sense of value creation for one's company and one' customers
- C7 - Know how to convince
- C8 - Lead a project, a team

ST2 - 22 - BIOINGENEERING: PRODUCE, PROTECT, REPAIR

Dominante **: VSE (Vivant-Santé Environnement)**

Langue d'enseignement **: French**

Campus où le cours est proposé **: Paris-Saclay**

Engineering issues

Bioengineering transfers and applies the engineering concepts, methods, and tools to living systems to produce more sustainably, protect a threatened natural environment or repair an organ.

Living systems are complex. Many scales are involved: cell, organ, organism, population, or ecosystem. The phenomena at play are multiple, requiring a multidisciplinary approach.

Modeling is currently one of the major challenges in bioengineering, to understand, describe and predict the behavior of living systems and participate in their control.

In the present Engineering Challenge Term, the students will learn about life sciences and carry out a modeling approach to address one issue in the field of health, sustainable production, or environment: (i) how the use of living systems may improve the healthcare, (ii) how to mitigate microbial communities (biofilms) which grow in cooling systems and may affect the production of power plants, (iii) how to use living organisms to produce high added value molecules in a sustainable way (iv) how to deliver a drug at a targeted body site at the right time and in the right amount .

4 Challenge weeks are proposed, offering the opportunity to:

- address the basics of (living) tissue engineering and regenerative medicine (bone reconstruction),
- analyze the industrial and economic problems raised by the microbial development in cooling systems,
- produce high-value molecules, in a sustainable way, using an innovative biofilm process,
- design new controlled-release drug delivery systems to increase efficacy, facilitate patient use and reduce dosage-related side effects.

Prerequisites: None

Engineering Challenge Introduction: The context and the challenges of bioengineering will be presented at conferences and round tables. Specifically, the students will discover the contribution of modeling to meet the challenges of the living world and the environment. The lectures will address the following topics: (i) Modeling in neuroscience, (ii) Development and modeling of innovative devices for cardiology, and (iii) Mathematical models for studying and controlling viral propagation in the human population. Experts will also discuss the economic perspectives of biomedical and industrial biotechnology. Finally, the ST partners, i.e., INSERM, EDF, INALVE, and GALIEN INSTITUTE, will present the Challenge weeks.

Specific Course (40 HEE): Life sciences

Short description: The general principles that define life will be presented. The numerous scales that can be considered and the level of complexity that increases with the change of scale will be progressively covered from one course to another (macromolecule / cell / population of cells in suspension and in the form of a biofilm / organ). The first part of the course is a cell biology course that presents the macromolecular and cellular scale, and that finally proposes a review of the aspects of living organisms that it is now possible to model for an engineer. It will be followed by a course on bioprocesses, the aspects of bioproduction and bioremediation will be addressed, and finally a course on a living material (bone tissue). The course will be completed by practical exercises illustrating these fields. At the end of this course, it is possible to understand how to use living organisms to treat wastes (environmental challenge), produce sustainably from renewable resources (industrial challenge) and repair living systems (health challenge).

Challenge week n°1: Biomaterials for bone tissue engineering

Partner: INSERM

Location: Paris-Saclay campus

Short description: The excellent natural healing capacity of bones is sufficient to repair most fractures. However, in some clinical cases (such as severe traumatic injuries with bone loss or extensive resections of bone tumor), a bone graft is mandatory. For extensive or multiple bone reconstructions, the available volume of bone material for autologous graft may be insufficient. In this context, INSERM is developing an alternative therapy for which a synthetic microporous biomaterial replaces bone flaps.
The Challenge week focuses on the modeling of cell proliferation within the biomaterial. Different aspects of the multiphysics modeling will be addressed: (i) the characterization and the geometric representation of the microporous biomaterial, (ii) the hydrodynamics within the pores, (iii) the transport of the chemical species (oxygen and glucose), (iv) the cell proliferation and (v) the coupling between the biomaterial morphology, the hydrodynamics, the solute transport, and the cell proliferation.

Challenge week n°2: Biofilm: a hindrance to electricity production coupled with environmental and health risks

Partner: EDF

Location: Paris-Saclay campus

Short description: In this challenge week, the objective is to evaluate the negative impact of the growth of a biofilm in a heat exchanger cooled by sea water in an energy production plant. After establishing a model on a reference case, an industrial case will be considered. The students will develop scenarios that allow a level and safety of energy production in accordance with the customer's demand, based on computational results. They will take into account the environmental and sanitary constraints of water discharge into the natural environment. They will establish the amount of the investment in equipment and the associated operating costs according to the characteristics of the production site (Europe and Asia). Key Performance Indicators (KPIs) will be used to rank these scenarios and quantify the value created for the client.

Challenge week n°3: Microalgae production using a biofilm-based photobioreactor

Partners: INALVE and INRIA

Location: Paris-Saclay campus

Short description: Microalgae are sun-light driven cell factories that convert carbon dioxide into food, feed and high-valuable molecules with a broad of industrial applications (chemical, pharmaceutical, cosmetics, …). They are cultivated in reactors, generally located outdoors and therefore subject to significant daily and seasonally variations in light and temperature. The objective of this Challenge week is to improve an innovative bio-system for microalgae/ associated compounds production through a modelling approach. The students will develop a model of the bioprocess integrating thermal and mass transfers that will allow to predict the productivity of the production system subject to variations in light and temperature. Finally, they will propose recommendations for the design and operation of the bioprocess by analyzing the results of the model.

Challenge week n°4: Controlled release systems for pharmaceutical agents

Partner: GALIEN INSTITUTE Paris Saclay (School of Pharmacy)

Location: Paris-Saclay campus

Short description: The design of a pharmaceutical solution requires to consider the kinetics of release of its active agent into the bloodstream or tissue, and to maintain the adequate drug concentration over a specific period. To achieve this, the active agent is usually formulated in specific forms to control their release. However, in order to predict the kinetics in the body, the physiological parameters of the patients must also be taken into account.

The objective of the Challenge week is to model the drug release kinetics of specific pharmaceutical systems in order to reduce the number of tests in a clinical trial. The models will be developed in an incremental manner: first a PBPK (Physology Based Pharmaco Kinetics) model will be implemented and validated against experimental data. This model will then be extended in order to account for the specificities of the client problematic, that is to say the nanoparticule based drug delivery system, the inoculation mode, and the population characteristics.

1SC2210 – Life sciences

Instructors : **Filipa Lopes**
Department : **DÉPARTEMENT MÉCANIQUE ENERGÉTIQUE PROCÉDÉS**
Language of instruction : **FRENCH**
Type of course : **Specific course**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **19,50**

Description

The general principles that define life, presented as a complex system, will be addressed via a multi-scale approach from the cell to the population: macromolecule, intracellular organelle, cell, population of cells (e.g., cell tissue, microorganisms in suspension and immobilized).

The general objective of this course is to introduce the basic concepts of life necessary to better understand it and finally to be able to exploit it for a given objective: 1) to repair it (health challenge), 2) to purify an ecosystem (environmental challenge) and 3) to produce molecules of interest (industrial challenge).
The principles will be presented through a multidisciplinary approach at the interfaces of biology, biochemistry, bioprocesses, mechanics and mathematics in order to obtain a global and integrated vision of life systems.

Quarter number ST2

Prerequisites (in terms of CS courses) none

Syllabus

- Part 1: The Cell:

The bricks of life
Prokaryotic/eukaryotic cell
Cellular organellesThe general functioning of the cell: from gene to protein
Cellular metabolism (anabolism and catabolism)
Computational approach to life.

- Part 2: Cell Population :

Suspended and immobilized microorganisms (biofilm). Bioprocess applications (production of molecules of interest and environmental applications).
Bone tissue.

- Part 1: The Cell

Understanding life is essential for the engineer of tomorrow. Whether it is handling it to produce drugs or fuels industrially, or to cure pathologies. Modern biology uses all the techniques of engineering (mathematics, physics, chemistry, thermodynamics, computer science, etc.). It is inherently multidisciplinary. This course is an introduction to living organisms. Life as we define it is only a set of chemical reactions assisted by enzymes and energy. The molecules used in the cells come from the primitive ocean. We will see how they have been used to generate the cells we now know, including amino acids, sugars, lipids, up to DNA. We will see that there are different types of cells, some of which are already used on an industrial scale.
The focus of the course will be on how cells make the molecules they need, using genetic coding. In addition, the genetic code can be manipulated to use living organisms for specific purposes.
To make everything work, energy is required. Particular attention will be paid to the mitochondria, a real factory supplying energy to many cells.

Finally, we will discover how computational approaches are used to better understand and control living organisms.

-Part 2: Cell Population

Microorganisms, such as bacteria, yeasts and microalgae, are widely used in industry, particularly inthe food, pharmaceutical, cosmetics, waste treatment and energy production sectors.
They can be suspended or immobilized, aggregated in the form of flocs or on a support (biofilm).
Biofilms are the microbial way of life par excellence and are ubiquitous. They develop in natural, industrial and hospital environments and are responsible for the fouling of heat exchangers, cooling towers and catheters.
They are also used for the production of molecules of interest and wastewater treatment.
In this course, we will cover these two microbial lifestyles and their associated applications in ndustry and the environment.

This course is also an introduction to bioprocesses. The basic principles (the different stages of bioreactor production up to the recovery of products of interest, the different ways of operating bioreactors) will be illustrated with real industrial examples and applications. Bioprocess modeling will also be discussed.

Bone: an evolving biological tissue - The human skeleton is made up of different types of bones. These are made up of two major tissues: trabecular bone and cortical bone, which are in constant evolution. Indeed, under the effect of the mechanical environment, bone adapts its density and architecture. In this course, we will discuss the microstructure of bone, its relationship to the mechanical environment and the bone remodeling process initiated at the cell level. Then we will see how studying the mechanical-biological link can help to consider innovative regeneration therapies.

Class components (lecture, labs, etc.)

Lectures (70%) and training classes (30%)

9 lectures of 1h30 each and 3 training classes of 1h30 each

Grading

Continuous control (30% of the final grade) and final written examen (70% of the final grade).

Course support, bibliography

- The presentations of the various speakers.
- Books :

- Madigan, M. (2007). Brock Biology of microorganisms;

- Meyer, A., Deiana, J., & Bernard, A. (2004). Microbiology course with problems and corrected exercises - 2nd edition;

- Doran, P. M. (1995). Bioprocess engineering principles. Academic press;

- Marsily, G., Quantitative Hydrogeology Ed. Masson Paris (1981)

- Marsily, G., Quantitative Hydrogeology. Groundwater Hydrology for Engineers Ed. Academic Press, New York (1986)

- Bear J., Dynamics of Fluids in Porous Media, Elsevier Publishing Company, Inc.

Resources

- Teaching team : C. BERNARD, C. PUENTES, E. VENNAT, T. BOUCHEZ and F. LOPES.
- Size of the training classes: 30.

Learning outcomes covered on the course

- Define the different bricks of life: amino acids, sugars, bases and their assembly method.
- Describe the method of protein coding: genetic code, DNA, RNA and protein transcription and translation.
- Explain the basics of enzymatic reactions and energy processes in the cell.
- List and explain the different steps of the bioprocess.
- Estimate the growth rate of a microbial population and discuss the factors impacting it.
- Define biofilms and list associated impacts.
- Write the material balances within the bioreactor.

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

1SC2291 – Biomaterials for bone tissue engineering

Instructors : **Hervé Duval**
Department : **DOMINANTE - VIVANT, SANTÉ, ENVIRONNEMENT**
Language of instruction : **FRENCH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

Biomaterials for bone tissue engineering is one of the 4 courses (EI) that ends the Engineering Challenge Term (ST2) **Bioengineering: Produce, Protect, Repair**. This course illustrates how bioengineering may contribute to **Repair** human body.

A public health issue
The excellent healing capacity of the bones, combined with immobilization of the limb, is sufficient to repair most fractures. However, in some clinical cases, such as serious traumatic injuries with bone loss or extensive resections of bone tumor, the spontaneous healing process can be very slow or even completely ineffective. For these difficult cases, a bone graft is mandatory. However, for extensive or multiple bone reconstructions, the available volume of bone material for autologous graft may be insufficient. In this context, INSERM is developing an alternative therapy for which bone flaps are replaced by a synthetic microporous biomaterial.

A quicker way to get biomaterials with optimized properties
The development of a biomaterial to its clinical application is long and costly. In order to accelerate this process, INSERM's LVTS laboratory and CentraleSupélec's LMPS and LGPM laboratories are implementing a new strategy that breaks with the traditional empirical approach. This innovative strategy relies on bioreactor engineering, multiphysics modelling and numerical simulation. Bioreactors make it possible to study in vitro the repair of a bone defect. Numerical simulation makes it possible to examine more systematically the influence of the microgeometry of the biomaterial on this repair. Both tools should help to pre-optimize the properties and the microarchitecture of the biomaterial before moving on to in vivo testing.

Multiphysics modelling of the bioreactor
The course focuses on the modelling of cell proliferation within the biomaterial. In the bioreactor, the biomaterial is perfused by a liquid that (i) provides the nutrients and oxygen needed by the cells, (ii) eliminates the waste they produce and (iii) exerts a shear stress on the cells that stimulates their proliferation and/or differentiation. The course will address different aspects of the multiphysics modelling: (i) the characterization and the geometric representation of the microporous biomaterial, (ii) the hydrodynamics within the pores, (iii) the transport of the chemical species (oxygen and glucose), (iv) the cell proliferation and (v) the coupling between the biomaterial morphology, the hydrodynamics, the solute transport and the cell proliferation.

Quarter number ST2

Prerequisites (in terms of CS courses) No prerequisite

Syllabus

- Presentation of the project
  - What is tissue engineering?
  - Bioreactors: an overview
  - Focus on the bioreactor of the project

-Comprehensive analysis of the problem

- Different time and space scales
- The relevant scale to describe cell proliferation within a bioreactor
- Break down of the problem into smaller parts
- Bibliographical review
- Data research

-Description of the biomaterial
- Analysis of 3D images of the biomaterial
- Characterization of its porous structure

-Experimentation
- Initiation to cell culture
- Determination of proliferation kinetics under static conditions

-Pore-scale modelling
- Hydrodynamics
- Solute transfer
- Cell proliferation

-Modelling at the bioreactor scale
- PNM approach, Pore Network Model
- Permeability calculation

-Numerical implementation
- Algorithms
- Validation of the model on test configuration

-Parametric study
- Adjustment of microgeometry and operating conditions
- Optimization of the cellularization

Class components (lecture, labs, etc.)

Biomaterials for bone tissue engineering is a course dedicated to **Problem solving**. Students will confront the multiphysics and multi-scale aspects of bioengineering problems. They will apply the concepts introduced in the basic courses of the **ST2 Bioengineering** and in the mathematics and computer science courses of the common core.
The course is scheduled over 5 consecutive days. It begins with a half-day project launch (Monday morning). During the week, the students work in groups of 4 and are supervised by a team of researchers from LGPM and LMPS laboratories. Each group addresses the different aspects of the modelling approach and confront reality through a cell culture training (in pairs).
Updates will be held daily: sharing of information, methodological input, additional courses. The week ends with a debriefing session on Friday afternoon in the presence of D. Letourneur (CNRS senior scientist) director of the LVTS laboratory (INSERM).

Grading

The EI final mark depends on: individual assiduity, group involvement, relevance of the model, numerical implementation, code quality, oral presentation, report.
The skills C1 and C7 are validated if the EI final mark is greater than or equal to 14/20.
The skill C4 is assessed by the jury (including the client) using a rating scale between 1 and 4. C4 is validated for a rating of 3 and more.
The skill C8 is assessed by the supervisors.

Course support, bibliography

Presentation slides, scientific articles and a start guide to cell culture will be provided during the course.

Resources

- Teaching staff: H. Duval (Professor, CS, MEP Department, LGPM), B. Taidi (PR, CS, MEP Department, LGPM), B. David (CNRS Associate scientist, LMPS)

-Maximum enrolment: 28

-Software, number of licenses required: Imagej (Public Domain)

-Equipement, specific classrooms (department and room capacity): biology preparation room (MSSMat), 14 students at the same time

Learning outcomes covered on the course

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

- identify the different time and space scales taking place in a given process;
- select the most appropriate scale to solve a given problem;
- identify and keep the predominant phenomena;
- reduce the dimensionality and the complexity of a problem;
- establish a multiphysics model by aggregating knowledge from different scientific fields (biology, transport phenomena, biochemical engineering, materials science, image analysis);
- perform cultivation to estimate the proliferation kinetics of a cell line;
- write a program to implement a mathematical model;
- keep a critical eye on a model and its limitations.
- provide a comprehensive presentation of a modelling approach.

Description of the skills acquired at the end of the course

C1: Analyze, design, and implement complex systems made up of scientific, technological, social, and economic dimensions
C4: Create value for companies and clients
C7: Strengthen the Art of Persuasion
C8: Lead a team, manage a project

1SC2292 – Biofilm: a hindrance to electricity production coupled with environmental and health risks

Instructors : **François Puel**
Department : **DOMINANTE - VIVANT, SANTÉ, ENVIRONNEMENT**
Language of instruction : **FRENCH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

Biofouling an obstacle to electricity production coupled with an environmental risk is one of the 4 courses (**EI)** that ends the Thematic Sequence (ST2) **Bioengineering: Produce, Protect, Repair.** This course illustrates how bioengineering may contribute to **Produce energy and Protect a natural ecosystem.**

A problem related to energy production and its health and environmental impact.
Nuclear power plants have three cooling circuits in series. The tertiary circuit is based on the withdrawal of water from the environment (river or sea) of the plant and aims to remove a significant amount of heat from the secondary circuit. Practically it consists of condensing a steam. This water taken from the natural environment returns directly to it, so it should not be modified in a way that is too important from a thermal, physicochemical and biological point of view. Due to its natural origin, this cooling water contains microorganisms. These latter can develop in the condenser tubes and form a biofilm. The problem faced by the operating team are on three levels:
(i) this biofilm will hinder the heat exchange capacity between the secondary and tertiary circuits, thus limiting the productivity of the plant (biofouling phenomenon). There is an operational limitation. The operator must use additional cooling capacities, which has an additional financial cost. This is an issue of energy production coupled with a financial issue
(ii) the water released into the environment must not be allowed to rise too highly its temperature, otherwise it is too harmful for the aquatic ecosystems at the place of release. Increasing the flow rate is possible. Nevertheless the periods of intense drought are more frequent. This is an environnemental issue
(iii) Chemical treatment of this water is possible, but in return there is a chemical discharge into the environment that is detrimental to aquatic ecosystems and may interact with local poulations. This is a double environmental and health issue.
The proposed subject aims at modelling the loss of efficiency of a heat exchanger in the tertiary water circuit, caused by this biofouling phenomenon (fouling by biofilm, inevitable due to water withdrawal in the natural environment). This modeling will be used to propose operating and investment scenarios according to situations proposed by the electricity plant manufacturer (production capacity, characteristic of the environment where the water intake is carried out, etc.).These scenarios must take into account environmental and health constraints. Key performance indicators(KPIs) will allow to classify scenarios and quantify the created value

Modelling of the heat exchanger

The course focuses on limiting heat exchange due to the biological growth of the biofilm. The proposed approach is in three stages (i) Formulation of the problem, resulting in the writing of the model describing the phenomena involved, without forgetting to clearly define the system under consideration, the initial and boundary conditions (ii) Simulation implementation by coding and its validation. In general, a simple reference case ("Toy problem") is used to validate the simulation code, the calculated results must correspond to the results already established for this configuration. This step allows to have the orders of magnitude of the phenomena (temperature drift, biofilm thickness) and to make a sensitivity study of each of the parameters, to determine which ones are critical for the representation of the phenomena involved (iii) Application of the modeling to the industrial study case. By combining the simulation results with other technical and economic data, it is then possible to design equipment and propose operating strategies depending on the location of the plant on the seashore (Europe or Asia) and according to health and environmental discharge criteria

Quarter number ST2

Prerequisites (in terms of CS courses) None

Syllabus

Day 1: Implementation of the problem formulation. Context of electricity production and its environmental and health impact, reading of the bibliography provided on the subject of heat exchange and biofilm growth; writing of the energy efficiency model (two slides to be returned by 4pm to supervisors)

Day 2: Performing the simulation: Programming the growth of the biofilm by assuming a temperature profile in the fluid inside the tube); Programming the temperature profile for a biofilm thickness; Joint programming of the temperature profile and the growth of the biofilm. Validation of the simulation by considering a baseline study. Sensitivity study of the parameters; discussion of the results. Writing a written note of no more than 2.5 pages (1st part of the final technical note)

Day 3 a.m : Travel to the EDF research center in Chatou (78). Visit of the experimental biofouling study systems; Discussion of the results already obtained; Presentation of the methodology for calculating investment costs (CAPEX) and operating costs (OPEX)

Day 3 p.m & Day 4 a.m: Simulation of the case study supplied by EDF by integrating cost aspects. Establishment of different investment and production management scenari. Finalization of the calculation note, preparation of the oral for the project manager and the oral for the experts

Day 5 morning: Finalization of the written note, preparation of two orals for the project manager and for the jury of experts
Day 5 p.m : two oral meetings with the project manager and experts / discussions / self-assessment

Class components (lecture, labs, etc.)

Biofouling an obstacle to electricity production coupled with an environmental risk is a course dedicated to **Problem solving**. Students will confront the multiphysics and multiscale aspects (heat exchange, biology) of of an industrial problem, by implementing the concepts introduced in the basic courses of **ST2 Bioengineering** and in the common courses of mathematics and computer science. Finally, the student is in the position of a young engineer who must produce a technical simulation note and present his work to technical experts and a project manager as part of an industrial investment.
The course is scheduled over 5 consecutive days. It begins with a half-day project launch (Monday morning) with the client. During the week, students work in groups of 4 to 6 students, supervised by a team of teacher-researchers from the LGPM laboratory. The students visit a research and development laboratory dedicated to this problem at the cclient site to see how to obtain reliable data and thus validate the simulations carried out.
Updates will be held daily: sharing of information, methodological input, additional courses. The week ends with a debriefing session on Friday afternoon in the presence of an expert and a project manager from the client (EDF).

Grading

The evaluation will take into account: individual assiduity, group involvement, model relevance, numerical implementation, programming quality (code), oral presentations and discussions (Q&A), quality of the technical report.

Course support, bibliography

Slides of the various presentations, handout of courses in Thermal Transfer, scientific articles will be provided during the course.

- Client presentation: file "20191203 EI02 Biofouling EDF presentation"
- Extract from the Heat Transfer Course on Exchangers: "TT-Chapter 5-Exchangers Course"
- Techniques de l'ingénieur P. Lemoine, Refroidissement des eaux Techniques de l'Ingénieur, b2480, 1986
- Article Melo et al. 1997 "Biofouling in water system" Experimental Thermal and Fluid Science 1997; 14:375-381

- Article Nebot et al. 2007 "Model for fouling deposition on power plant steam condensers cooled with seawater: Effect of water velocity and tube material" International Journal of Heat and Mass Transfer 50 (2007) 3351-3358
- Article Huang et al. 2011 "Effect of temperature on microbila growth rate-Mathematical analysis : The Arrhenius and Eyring-Polanyi Connections"
- EDF document ""Centrales Nucléaires et Environnement : prélèvements d'eau et rejets " EDP Sciences 2014
- Presentation by Mrs. M. Lorthioy on 02/12/2019 "CS-Centrale nucléaire environnement".
- A first set of data (Figure 1, Nebot et al. 1997) in.txt and Excel files

Resources

Teaching staff : F. Puel (Professor, CS, MEP Department, LGPM), V. Pozzobon (Associate Professor, CS, CEBB Industrial Chair of Biotechnology, LGPM), T. Neveux (Research and Development Engineer, EDF Chatou), N. Jourdan (Engineer, PhD student EDF Chatou)
Maximum enrolment : 24 to 28
Software tools and number of licenses required: Sypder-Python (free software)

Learning outcomes covered on the course

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

- Identify the different time and space scales taking place in a given process
- Select the most appropriate scale to solve a given problem;
- iIentify and keep the predominant phenomena;
- Reduce the dimensionality and the complexity of a problem;
- Establish a multiphysics model by aggregating knowledge from different scientific fields (biology, transport phenomena, technical and economic analysis);
- Write a program to implement a mathematical model;
- Keep a critical eye on a model and its limitations.
- Provide a comprehensive presentation of a modelling approach.

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 et 3

C1.2 : Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when addressing a problem, milestone 1: learning outcomes 2, 4 et 5

C1.2, : Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when addressing a problem milestone 2: learning outcome 2
C1.2 : Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when addressing a problem, milestone 3: learning outcome 5
C1.3, : Apply problem-solving through approximation, simulation and experimentation. milestone 1B: learning outcome 2, 3 et 4
C1.3 : Apply problem-solving through approximation, simulation and experimentation. milestone 2B: learning outcome 7
C6.1 : Identify and use the necessary software for one's work (including collaborative tools) and adapt digital responses according to the context. milestone 1: learning outcome 76
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 milestones 1 et 2: learning outcome 9

1SC2293 – Microalgae production using a biofilm-based photobioreactor

Instructors : **Filipa Lopes**
Department : **DOMINANTE - VIVANT, SANTÉ, ENVIRONNEMENT**
Language of instruction : **FRENCH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

" Microalgae production using a biofilm-based system" is one of the 4 courses (EI) that ends the Thematic Sequence (ST2) Bioengineering: Produce, Protect, Repair.
This course illustrates how bioengineering may contribute to Produce industrial compounds.

Micro-algae are sun-light driven cell factories that convert carbon dioxide into food, feed and high-valuable molecules (pigments, polyunsaturated fatty acids, proteins, ...) with a broad of industrial applications (chemical, pharmaceutical, cosmetics,...).

They are mostly cultivated as planktonic cells suspended in liquid nutrient medium mainly in open raceways before being harvested for molecules extraction. These production systems are generally located outdoors and therefore subject to significant daily and seasonally variations in light and temperature. These systems are though characterized by low productivities, high energy demand and high operating costs associated to the production and harvesting steps. In this context, the interest of using immobilized microalgae (biofilm-based microalgae cultivation) has increased lately and presented as a very promising technology to overcome the major challenges of the conventional systems. Higher productivities (algal biomass and molecules of interest) and lower energy consumption are therefore reported compared to those of suspended cultures and the biomass is easily harvested by scraping.

A biofilm is an assemblage of microbial cells that are associated with a surface. They are ubiquitous in nature, covering all kinds of surfaces in seawater and freshwater environments, representing therefore the prevailing mode of microbial life. In addition, biofilm-based systems are widely used in bioremediation and industrial bioprocesses.

The use of biofilm technologies is at the heart of the activity of Inalve, a company that industrializes a process for the production of microalgae, in agreement with sustainable development in its social, economic and environmental dimensions.

This course aims to improve the microalgae production system developed by this start-up. The objective is thus to develop a multiphysical model (thermal and biological) able of predicting the productivity of the bioprocess subjected to variations in light intensity and temperature. This modelling tool combined with numerical simulation will make possible to optimize the bioprocess system and finally to propose new strategies for its exploitation.

Bioprocess modeling:

This course focuses on the modelling of the bioprocess used by Inalve.

The approach to be implemented will be as follows:

- First, a thermal model will be developed and calibrated to predict the evolution of the biofilm temperature in the process subjected to the solar radiative flux. The resulting thermal profile will be compared with the data.
In parallel, a biological model will be developed to predict the dynamics of biofilm formation under the different process operating conditions, in particular as a function of the incident light and the temperature of the biofilm.
- Thermal and biological models will be combined. This will make possible to predict the evolution of algal biomass productivity over an annual cycle.
- The dynamics of the process will be evaluated in a "qualitative" (i.e. trend) way to make recommendations for the design and operation of the Inalve technological device.

Quarter number ST2

Prerequisites (in terms of CS courses) None

Syllabus

Presentation of the project by the industrial partner

- **Comprehensive analysis of the problem**

Bibliographical review
Identification of the model objective (thermal/biological)
Identification of the required data
Writing the model equations (thermal and mass balances)

Coupling the thermal and biological models

- **Numerical implementation**

Programming

Validation of the model on test configurations

- **Parametric study**

o Assessment of the impact of process operating conditions on productivity

- **Presentation of the deliverable**

Report writing and oral presentation.

Class components (lecture, labs, etc.)

"Production of microalgae by a biofilm-based system" is a course dedicated to Problem solving. Students will be confronted to the multiphysics aspects (thermal transfer, biology) of an industrial problem, by implementing the concepts introduced in the basic courses of ST2 Bioengineering and in the common courses of mathematics and computer science. Finally, the student is in the position of a young engineer who must produce a technical report and present his work to experts and an industrial partner in an industrial context.

The course is scheduled over 5 consecutive days. It begins with a half-day project launch (Monday morning) with the client. During the week, students work in groups of 4 to 6 students, supervised by a team of researchers from the LGPM laboratory and INRIA. Each group addresses one of the issues of the multiphysics modeling (thermal or biological model) and have to interact with a second team working on the complementary model.
Updates will be held daily: sharing of information, discussion of the results, methodological input. The week ends with a debriefing session on Friday afternoon in the presence of the industrial partner.

Grading

The evaluation will take into account: individual assiduity, group involvement, relevance of the model, numerical implementation, programming quality (code), oral presentation and discussions, quality of the report.

Course support, bibliography

The handout of courses in Thermal transfer and scientific articles will be provided during the course.

Resources

- Teaching team : F. Lopes (PR, CS, MEP Department, LGPM), O. Bernard (DR, INRIA Biocore Team), industrial (inalve)
- Maximum enrolment: 24 to 28
- Software tools and number of licenses required: Sypder-Python (free software).

Learning outcomes covered on the course

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

Identify the different time and space scales taking place in a given process;
Select the most appropriate scale to solve a given problem;
Identify and keep the predominant phenomena;
Reduce the dimensionality and complexity of a problem;
Establish a multiphysics model by aggregating knowledge from different disciplinary fields (biology, transport phenomena, process and bioprocess engineering);
Write a program to implement a mathematical model;
Keep a critical eye on a model and its limitations;
Provide a comprehensive presentation of the modeling approach

Description of the skills acquired at the end of the course

C1: Analyze, design, and implement complex systems made up of scientific, technological, social, and economic dimensions
C4: Create value for companies and clients
C7: Strengthen the Art of Persuasion
C8: Lead a team, manage a project.

1SC2294 – Controlled release systems for pharmaceutical agents

Instructors : **Morgan Chabanon**
Department : **DOMINANTE - VIVANT, SANTÉ, ENVIRONNEMENT**
Language of instruction : **FRENCH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

The design of a pharmaceutical solution requires to consider the kinetics of release of its active agent into the bloodstream or tissue, and to maintain the adequate drug concentration over a specific period. Indeed, a too slow release of the active agent leads to an underdose and renders the drug ineffective, while a too fast release can lead to a toxic overdose for the patient. For this reason, active agents are usually formulated in specific forms to control their release.

Despite the variety of controlled drug release systems, their operating principles are based on the physics of mass transfer. Thus, in the design phase, modeling tools are particularly useful for scaling and predicting drug release dynamics before entering the more expensive stage of production and testing. This leads the pharmaceutical industry to call upon engineers to design systems that increase drug efficacy and facilitate patient use, while reducing the frequency of administration and dosage-related side effects.

Quarter number ST2

Prerequisites (in terms of CS courses) None

Syllabus

Presentation of the project
Analysis and formulation of the problem
- Bibliographic research
- Identification of the objectives of the model (transfers, concentrations, kinetics)
- Identification of the required data
- Writing of the model equations (mass balances, geometry)

Analytical resolution for a simple case
Implementation of numerical method in a more complex case
- Programming of the model
- Validation of the model on test configurations
- Presentation of case studies by the customer
- Development of a solution for the customer
- Presentation of the solution to "decision takers"
- Presentation of the solution to "engineers"

Class components (lecture, labs, etc.)

The teaching focuses on the spatiotemporal modeling of the concentration of a pharmaceutical active agent released by different drug delivery systems. The proposed approach is incremental: (i) Study of a simple classical case (e.g. intravenous free agent), formulation of the problem, modelling, analytical resolution, and scaling for a specific active agent. (ii) Adaptation of the model to a more complex case for which the analytical solution is not available (e.g. multiple organs, nanocarriers). Development of a numerical resolution code and exploitation for scaling. (iii) Application of the approach to a case study presented by the client (researcher at the Galien Institute, Faculty of Pharmacy of UP Saclay, restitution of the recommended solution and implementation strategy in the form of a presentation.

Grading

The evaluation will take into account: individual attendance, group involvement, relevance of the model, its digital implementation, quality of programming, oral presentation and discussion (question/answer).

Course support, bibliography

Slides of the various presentations, scientific articles and websites will be provided during the course.

Resources

Teaching team: Morgan Chabanon (MCF, CS, EM2C laboratory), Eloisa Barbel-Manaia (Researcher at Institut Galien, Faculty of Pharmacy, Université Paris-Saclay, CNRS)

Software tools: Matlab and/or Python.

Learning outcomes covered on the course

Upon completion of the course, students will be able to:
Estimate the different time and space scales involved in a process;
Choose the most relevant scale to solve the problem at hand;
Discriminate and conserve the most important phenomena;
Reduce the dimensions and complexity of a problem in a relevant way;
Establish a multiphysics model by aggregating knowledge from different disciplinary fields (medicine, chemistry, transfer science);
Numerically implement a mathematical model;
Have a critical look at a model and its limitations;
Present a modeling approach in a structured and argued manner.

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
C4 Have a sense of value creation for his company and his customers
C7 Know how to convince
C8 Lead a project, a team

ST2 - 23 - TELECOMMUNICATION SYSTEMS

Dominante **: SCOC (Connected Systems and Communicating Objects)**

Langue d'enseignement **: French**

Campus où le cours est proposé **: Paris-Saclay**

Engineering problem

This topic deals with the sizing of wireless communication systems in the context of civil systems (cellular networks 4G, 5G) or systems for crisis management (vital emergencies, law enforcement, civil security, armed forces, events, coverage of desert areas, interventions in case of natural disasters, resistance to failures, accidents, attacks ...). Coverage and continuity of service are critical. The rapid deployment of a transmission system in case of crisis when no infrastructure is available can rely on several networks and/or on complementary components such as ground relays, drones, balloons, satellites...
In order to design these communication systems, it is necessary to model all the elements of the transmission chain and the network architecture. These models allow the construction of simulation platforms which, together with test scenarios, allow engineers to understand the behavior in case of failure or incident.
In this sequence, students will be made aware of the choice of models and their uncertainties, the quality of service with coverage and availability requirements close to 100%.

Adviced prerequisites

None; having taken at least one of the science courses for the "Networks and Security" or "Electromagnetics" engineer in SG1 would be a plus.

Context and issue modules :

These modules aim to give a vision of the theme from several angles, in particular

- An introduction on telecommunication systems followed by a conference "telecom and society

- A conference on technological barriers (frequencies, ad hoc networks, turbo receivers, ...)

- A round table at the end of the sequence on the theme "telecom and industry", allowing to understand the contribution of the 5G for the industry, by experts of Thales, Orange, EDF, SNCF, ...

Specific course (40 HEE) : Principles of wireless telecommunications

Short description :

The objective of this course is to give students the keys to choose the right models in the context of an engineering problem which is here to be able to transmit an information with full fidelity/security taking into account regulatory constraints (frequency, power), physical constraints (antennas, propagation, disturbances), quality constraints (bit error rate, coverage) and traffic constraints (Erlang's law). This course also presents the theoretical and applicative elements that have enabled the development of smart antennas (antennas and array antennas), ranging from antenna technologies specific to wireless and mobile communications, to signal processing techniques that make these antennas capable of adapting to severe transmission conditions, and which are currently the focus of the development of 5G and pervasive communications.

Challenge week:

Sizing of a communication system mixing modeling, experimentation, simulation, measurement, identification of parameters

- Associated partners: Thales, Nokia, Bouygues Telecom

- Location: Paris-Saclay campus

- Short description:

The three challenge week of the ST2 SCOC will consist in dimensioning a set of wireless links to establish (or restore) wireless communications. Several scenarios could be considered: establishing communications in a developing country, re-establishing communications in an island after a hurricane, forecasting the sizing of a national cellular network by 2025, ... Students will design a communication network based on the technical characteristics of our industrial partners' equipment (power, frequency, etc.), propagation models (topography, distance, etc.) and traffic models (number of communications, throughput, etc.). Each AR will focus on a particular issue: economic constraints, speed of deployment (use of drones), antenna sizing, channel modeling from measurements, ... During the CW, the students will be supervised by teachers and researchers from the school as well as by engineers from partner companies (Thales, Nokia, Bouygues Telecom).

1SC2310 – Principles of wireless telecommunications

Instructors : **Jacques ANTOINE**
Department : **DÉPARTEMENT SIGNAL, INFORMATION, COMMUNICATION**
Language of instruction : **FRENCH**
Type of course : **Specific course**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **19,50**

Description

This course is an introduction to wireless communication systems. From Chappe's telegraph (1794) to current cellular systems (2G/3G/4G) and the 5G now being deployed, the problem of exchanging information between a source and a receiver in a reliable and efficient manner is a constant source of innovation. In order to design, test and optimize wireless communication systems it is fundamental to understand the role of all its parts, and to be able to model their individual responses as well as the entire system.

This course deals with wireless communication modeling from different complementary perspectives, taking into account physical phenomena (antennas, wave radiation and propagation, noise, link budgets), information processing (coding, modulation, amplification, diversity, spectral efficiency) and a system-oriented perspective (network architectures, spectrum and power management, data throughput, quality of service).

This course will introduce the main concepts, models and tools required for understanding these topics, used for the analysis and design of real-life wireless communication systems.

Quarter number ST2

Prerequisites (in terms of CS courses)

None; having taken at least one of the science courses for the engineer « Réseaux et sécurité », « Rayonnement et propagation » or « Physique des ondes » in SG1 would be a plus.

Syllabus

Antennas :

- Antenna macromodels from radiation theory
- Main antenna families for communications
- Antenna arrays

Propagation models :

- Wave propagation in free space
- Link budget (Friis equation)
- Deterministic and semi-empirical propagation models
- Propagation models for complex media
- Fading and diversity

Data transmission :

- Building blocks of a wireless communication link
- Data coding, modulation, amplification
- Spectral efficiency and figures of merit (sensitivity threshold, bit rate)
- Reliability (error rates, availability ratio)

Wireless systems

- Long-distance wireless communications
- Cellular networks
  - Architecture, cell coverage models, spectrum management, interference models
  - Data flow management et traffic models (Erlang laws), quality of service (voice, video, file download)

During tutorial classes students will apply the models introduced during lectures to the analysis and design the main building blocks found in wireless communication systems, in particular for long-distance and cellular communications, highlighting the design criteria applied when choosing among antennas and propagation models, modulations and codes, traffic models and network topologies.

Class components (lecture, labs, etc.)

9 hours of course and 9 heures of Practice Session

Grading

Final exam (80%) : written exam (1h30). Intermediate exam (20%) : one MCQ during one of the tutorial classes.

Course support, bibliography

Lecture slides

- S. R. Saunder, A. A. Zavala ; Antennas and Propagation for Wireless Communication Systems
- K.L. Du et al., Wireless Communication Systems: From RF Subsystems to 4G Enabling Technologies, Cambridge University Press, 2010
- Réseaux GSM-DCS ; X. Lagrange, P. Godlewski, S. Tabbane ; Hermes

Resources

- Lecturers : Jacques Antoine, Andrea Cozza, Salah-Eddine Elayoubi, S. Hoteit, F. Jouvie, D. Lecointe, D. Picard, A. Wautier

- Size of tutorial classes : 25
- Software used : Matlab

Learning outcomes covered on the course

The objective of this course is to provide students with concepts enabling them to choose the most suitable models to solve an engineering problem, namely the design of a communication system subject to multiple constraints, such as regulatory (frequency, power), physical (antennas, propagation), quality of service (error rate, coverage, blocking) and trafic (Erlang distribution).

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

- Model physical phenomena involved in wireless communications
- Choose the most suitable propagation models, depending on the nature and complexity of the environment (free space, urban and indoor, etc.)
- Take into account legal and physical constraints
- Know the main modulations currently used in modern communications
- Compute a link budget and assess its quality of service (bit-error rate, radio coverage)
- Estimate the benefits of using smart antenna solutions in order to counter/take advantage of certain characteristics of complex media
- Understand the phenomena leading to fading and the available solutions at hand to control it
- Understand how trafic affects the design of communication systems
- Choose the most suitable trafic model depending on the type of information to be transmitted (voice, video, 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 problem
C1.4 : Design, detail and corroborate a whole or part of a complex system.

1SC2391 – Restoring telecommunications after a natural disaster

Instructors : **Raul De Lacerda**
Department : **DOMINANTE - SYSTÈMES COMMUNICANTS ET OBJETS CONNECTÉS**
Language of instruction : **FRENCH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

The project "Restoring Wireless Communications Infrastructure after Natural Disaster" is one of the 3 Integration projects that conclude Thematic Sequence 2 (ST2) SCOC: Communicating Systems and Connected Objects. It sheds concrete light on the implementation of a wireless communication network after the passage of a hurricane. The implementation of a resilient solution takes into account the geographical and human factors of the island.

"Relief operations are based on a fast communication network to be implemented"

This topic deals with the real case of a natural disaster taking place on the island of Saint Martin. Located in the Caribbean, this island, like those surrounding it, is subject to numerous hurricanes from mid-May to the end of November. These hurricanes, of varying strength, can be powerful enough to destroy all installations linked to the communication network. This was the case with Hurricane Irma in 2017. This is the framework within which we will place ourselves. The entire wireless communications infrastructure on the island was wiped out by the hurricane. Your job is to study the characteristics of the island and to propose a solution in order to set up a resilient telecommunications network throughout the island for long-term use.

The dimensioning of the network will have to take into account the distribution of populations on the island to ensure a service adapted to the main areas of demographic concentration. The quality of communications is an essential factor in ensuring 4G coverage for all users. Your solution will have to include the dimensioning of a hertzian link between the network of the island of Saint Martin and the neighbouring island (spared by the hurricane) which is connected to the mainland by means of an optical fibre. Your study should be based on realistic data. It will use simple propagation models seen in the specific course of the thematic sequence. The use of simulation software to check the quality of radio coverage and the relevance of the distribution of base stations is one option among others to argue your architectural choices.

"The realization of your mission will take into account the time dimension".

Several milestones essential to your project will be defined:
(i) It is necessary to propose the characteristics of the emergency communication network to be set up. This solution must ensure coverage of the island's two airports and the capitals Marigot and Philipsburg. This solution must be set up within 12 hours after the passage of the hurricane in order to organize rescue operations on the island. The key word is "emergency".
(ii) The second solution is to propose an intermediate network providing radio coverage for the entire population of the island. The capacity of the network is a parameter to be taken into account in the sizing of the proposed solution. All solutions must be costed and justified.
(iii) The proposed solutions must support backhall links between cells. This is essential for the operation of the communication network.
(iv) It is necessary to provide a microwave link with the neighbouring island in order to maintain contact with the rest of the world. This link must support the capacity of the entire island of Saint Martin.
(v) The sustainable solution must be resilient and economically viable. The partner of this EI is Nokia. It will provide you with the various technological solutions in its catalogue. The energy supply of your solutions is your responsibility. Nokia has solar solutions that you should take into account.

The subject thus proposed is intended to put you in the position of the technical sales engineer who has to size a wireless communication network according to the geographical location of transmitters and users, the antennas used or the nature of the propagation model used. Depending on the propagation model chosen, you will need to readjust your solution and its impact on resilience and cost. Depending on the choice of propagation model, you

can negotiate the final cost of your solution. Your strategy is to quantify the different options according to the coverage-resilience-cost trade-off. You will have two Nokia experts who will accompany you throughout the week to evaluate your proposals and guide your choices towards a concrete solution.

Quarter number ST2

Prerequisites (in terms of CS courses) None

Syllabus

Day 1
(i) Problem identification and analysis of technological solutions proposed by Nokia.
(ii) Identification of the island context and formulation of a coverage proposal for the airports on the island of Saint Martin and the capitals Marigot and Philipsburg.
(iii) An initial costing is expected by the end of the day (4 p.m.) for a first deliverable: 5 slides describing the problem and the first coverage solution for the emergency services.

Day 2
(i) Identification of the needs of each zone of the island to size the capacities of each node of the network.
(ii) Assessing radio frequency signal levels to test radio coverage according to the propagation model used and the geographical positions of the nodes of the proposed network. Validation of the calculation assumptions via simulation software. A discussion with a Nokia expert should be scheduled at the end of the day to explain your strategy.
(iii) Coverage and capacity; a balance to be found

Day 3
(i) Sizing of the capacities of the different nodes of the network
(ii) dimensioning of the radio-relay system with the neighboring island

Day 4
(i) Preparation of an assessment of the solution to be presented to Nokia experts at the end of day 3.
(ii) The morning of Day 4 should allow you to refine your final presentation.

Day 5
Your oral presentations are ready. Auditions will take place in the morning in front of Nokia-Sacaly experts and prizes will be distributed.

Class components (lecture, labs, etc.)

This course "**Restoring Wireless Communications Infrastructure after Natural Disaster**" is a **Problem-Solving** learning activity. It allows students to confront a concrete telecommunication problem. The student must work in teams to carry out a mission that the group must present and argue according to technical and economic criteria. The teaching is programmed over a "blocked" week. During the week, students work in groups of 5 to 6 students, supervised by a team composed of experts from Nokia and teacher-researchers from CentraleSupelec. The communication with the management team is horizontal and requests are taken care of throughout the week.

Progress points will be made on a daily basis.

Grading

The evaluation will take into account: individual attendance, involvement in group work, relevance of technical-economic choices, oral presentations and discussions with experts (questions/answers).

Course support, bibliography

«Antennas and Propagation for Wireless Communication Systems», Simon R. Saunders, Alejandro Aragón-Zavala

Resources

Teaching team:
A. Wautier (PR, CS, L2S),
S. Hoteit (MCF, CS, L2S),
R. de Lacerda (MCF, CS, L2S)

Experts from Nokia-Saclay:
E. Preira
S. Chabbouh

Taille de l'effectif : 30 à 35
Outils logiciels : CloudRf

Learning outcomes covered on the course

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

- Understand the stakes of the implementation of a telecommunication network for exceptional situations
- Selecting network components based on the technical characteristics imposed by a customer
- Building a technical argument and fine-tuning a commercial offer
- Prioritize the constraints of a modeling problem
- Establish technical reasoning on the basis of complex and different kinds of parameters
- Build a solution from a simple model and propose alternatives based on more complex models
- To take a critical look at a solution and justify its limits
- Presenting a problem-solving approach in a well-argued manner

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
C4 Have a sense of value creation for his company and his customers
C7 Know how to convince
C8 Lead a project, a team

1SC2392 – Mobile network design for crisis management

Instructors : **Andrea Cozza**
Department : **DOMINANTE - SYSTÈMES COMMUNICANTS ET OBJETS CONNECTÉS**
Language of instruction : **FRENCH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

The integration teaching projects for the ST2 SCOC will consist in the design of a wireless communication network.

Several scenarios will be presented, among which the deployment of a new wireless communication network in a developing country and the reconstruction of a network for disaster relief on a hurricane-hit island.

Students will design the networks using the technical data provided by our industrial partners, based on their current wireless communication products (power consumption, frequencies, ...), wireless propagation models (ground features, distance, ...), as well as traffic models (number of calls, data throughput, ...).

Each project will emphasize a specific aspect of the design process: cost constraints, lead time (use of drones for fast relief operations), antenna design, communication channel modeling based on measurements, ...

During the week-long integration teaching, each group of students will be coached and advised by CentraleSupelec lecturers and engineers from our industrial partners (Thales, Nokia, Bouygues Télécom,...)

Quarter number ST2

Prerequisites (in terms of CS courses) none

Syllabus

Days 1-2: "First aid" phase
1. taking control of the problem and analysis of the technological solutions proposed by Thales
2. Identification of the island's context and formulation of a coverage proposal for the priority areas of the airport and the capital.
3. Exchanges with Thales experts will be organised, in order to ask your questions and validate your technical solution.

Day 2: Consolidation phase
1. identification of the needs of each zone of the island to size the capacities of each node of the network
2. Evaluate radio-frequency signal levels for testing radio coverage based on the propagation model used and the geographical positions of the nodes of the proposed network.
3. Coverage and capacity; a balance to be found.

Days 3-4: antenna design and visit of the Thales LAS site.
1. design of a microwave link to the island of St. Martin
2. design of a base station antenna for mobile cell coverage.

Day 5: defense
The project presentations will take place in front of Thales experts.

A visit to the Thales LAS site (Limours) will be organised in the afternoon of the third day. It will allow to discover the activities of Thales around the antennas and radars.

Class components (lecture, labs, etc.)

This course is a problem-solving pedagogical activity. It is an opportunity to deal with a real-life telecommunication problem. Students must work as a team to carry out a mission that the group must present and defend according to technical and economic criteria.

Teaching is scheduled over a "blocked" week. During the week, the students work in groups of 5 to 6. students, supervised by a team composed of experts from Thales and teacher-researchers from CentraleSupelec.
Progress reports will be made on a daily basis. The communication with the management team is horizontal and solicitations are taken care of during the whole week.

Grading

The evaluation will take into account: individual attendance, involvement in group work, relevance of choices, etc. technical-economic, oral presentations and discussions with industrial experts (questions/answers).

Course support, bibliography

Handouts and documents from the specific course.

Presentation of the partners in challenge week

Resources

- Teaching staff: J. Antoine, A. Cozza, D. Lecointe
- Thales experts team
- Staff size: 30 to 35
- Software tools: Matlab, Excel, CloudRf

Learning outcomes covered on the course

At the end of the course, students will be able to :
1. Understand the issues involved in the implementation of a telecommunication network for exceptional situations
2. Selecting network components from the technical characteristics imposed by a customer
3. 3. Building a technical argument and refining a commercial offer
4. Prioritize the constraints of a modeling problem
5. Establish technical reasoning on the basis of complex and different kinds of parameters
6. Build a solution from a simple model and propose alternatives based on more complex models
7. Take a critical look at a solution and justify its limitations
8. Detail their problem-solving approach

Description of the skills acquired at the end of the course

Four skills will be assessed during the week:

C1 : Analyze, design and build complex systems with scientific, technological, human and economic components
C4 : Have a sense of value creation for one's company and customers
C7 : Know how to convince
C8 : Lead a project, a team

1SC2393 – Predicting the size of an operator's national network

Instructors : **Salah-Eddine El Ayoubi**
Department : **DOMINANTE - SYSTÈMES COMMUNICANTS ET OBJETS CONNECTÉS**
Language of instruction : **FRENCH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

This module is one of the three challenge weeks of the thematic sequence on Communicating Systems and Connected Objects. It consists in dimensioning a 4G/5G cellular network in a medium-sized city. This starts by the estimation of the needed radio radio capacity for ensuring the Quality of Service (QoS). A detailed analysis determines then the spectrum to be deployed in each site, and the placement of new sites in the city for achieving the target performance.

Quarter number ST2

Prerequisites (in terms of CS courses) course of ECT2

Syllabus

Day 1 :
(i) Problem statement and choice of the city for the network deployment
(ii) Visit to Bouygues Telecom premises
Day 2 :
(i) dimensioning of the 4G access network.
(ii) backhaul design
Day 3:
(i) prediction of 5G spectrum needs based on traffic projections
(ii) proposition of a plan for 4G site upgrades towards 5G in the next 5 years.
Day 4 : solution refinements
Day 5 : Oral presentations

Class components (lecture, labs, etc.)

This course is a Problem Solving pedagogical activity. It allows you to face a concrete telecommunication problem. The student must work in a team to carry out a mission that the group must present and argue according to technical and economic criteria.

The teaching is programmed over a "blocked" week. During the week, students work in groups of 5 to 6 students, supervised by a team composed of experts from Bouygues Telecom and teacher-researchers from CentraleSupelec.

Progress points will be made daily. Communication with the management team is horizontal and requests are handled throughout the week.

Grading

Will be evaluated the individual motivation, the collaboration quality and the adequacy of the proposed technical solutions to the scenario.

Resources

Supervision by professors from CentraleSupélec and by engineers from Bouygues Telecom

Learning outcomes covered on the course

Understand the general principles for deploying a cellular network in a practical scenario.

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
C1.2 Use and develop appropriate models, choose the right scale of modelling and relevant simplifying assumptions to address the problem
C1.3 Solving the problem with a practice of approximation, simulation and experimentation
C1.4 Specify, design, build and validate all or part of a complex system
C8 Leading a project, a team
C8.1 Work in team/collaboration.
C8.4 Work in project mode by implementing appropriate project management methods

ST2 - 24 – ENERGY TRANSITION

Dominante : **ENE (Energy)**

Langue d'enseignement : **French - One tutorial session is in English for Specific course.**

Campus où le cours est proposé **: Paris-Saclay**

Engineering problem

The objective of this subject is twofold: on the one hand, to present the major issues of the energy transition (global and French context, technical and scientific barriers, economic, human and climatic issues), and on the other hand, to discover and implement the concepts and methods of modeling in engineering. The challenge week will implement the modeling of energy transfers in two key sectors of the energy transition: transportation (contactless recharging) and building (energy modeling of a neighborhood).

Adviced prerequisites

No prerequisites, but it is recommended to have taken Electrical Energy or Transfer Science

Context and issue modules :

They will include a series of introductory conferences and round tables in which a panorama of the major issues of the energy transition will be drawn up, and several thematic presentations by various players in the energy sector where the economic, geopolitical and societal issues of the theme will be examined more specifically. A review will be made of the major technological and scientific obstacles related to the energy transition, and technological innovation workshops will be led by professionals in this field.

Specific course (40 HEE) : Study and modeling of electromagnetic conversion systems and unsteady heat transfer

Brief description : In a first part, this course will provide students with a set of knowledge necessary to approach the challenge week on the modeling of a coupler for contactless charging. It will focus on the principle of electromagnetic conversion and the different modeling approaches to solve a problem in the energy domain. It is based on the electrical and magnetic circuits, the electromagnetic coupling and the different modeling approaches.

In the same way, in a second part, this course will provide students with all the knowledge necessary to carry out the challenge week devoted to the modeling of the energy consumption of a group of buildings. Theoretical elements related to mathematical modeling and numerical simulation of unsteady energy transfers will be presented. The course will conclude with the presentation of a dynamic thermal simulation software of buildings; during the last session, students will use this software to solve simulation problems of unsteady energy behavior in simple configurations.

Challenge week n°1 : Study, modeling and experimental validation of a non-contact energy transfer system

Associated partners: VeDeCoM, Renault

Location: Paris-Saclay campus

Brief description: The technique of contactless recharging has been gaining momentum in recent years. The principle consists in transferring energy between two systems without any electrical connection between them. This technique is of interest in various fields ranging from cell phones to electric vehicles. During this integration course, students will work on the modeling of a contactless charging system by induction.

After understanding the principle of energy transfer, the first step of the study will be devoted to the implementation of a modeling approach of an electromagnetic coupler in order to determine the electrical parameters. To achieve this objective, the students will use an electromagnetic modeling tool "COMSOL" and the results obtained by modeling will be validated experimentally. To reduce the electromagnetic radiation, the students will also have to predict the magnetic field radiated by the coupler and propose solutions to make it comply with the standards.

The second step will be to determine the compensation capacitors and to set up the associated electronics to adapt the system to the power source and the load. The whole chain, from the source to the load, will be simulated in matlab/simulink in the frequency and time domains. In this step, the students will have to quantify the electrical quantities (currents, voltages, efficiency,...).

Finally, a validation of the whole modeling process will be performed on an experimental model.

Challenge week n°2 : Modeling the energy consumption of a group of buildings

Associated partners: EDF

Location: Paris-Saclay campus

Brief description: The students will approach an engineering problem involving the modeling of energy transfers in an existing neighborhood and the definition of a renovation strategy to transform this neighborhood into a positive energy neighborhood. The first step of the work will be to collect the data necessary to evaluate the energy of the different buildings in the neighborhood. The software presented in the specific course n°2 will then be used to make a thermal diagnosis of the buildings, averaged over the day/night alternation and over the whole year. An analysis of the critical points that have a strong impact on the energy consumption of the buildings will then allow to make choices for the energy renovation of the buildings, and these choices will be evaluated with the software. At the end of this integration activity, the students should be able to propose a set of energy renovation actions, and they will have quantified the gain of these measures in terms of reduction of the energy bill of the whole building.

1SC2410 – Studying and modeling electromagnetic conversion systems and unsteady thermal transfer

Instructors : **Mohamed Bensetti**
Department : **DÉPARTEMENT SYSTÈMES D'ÉNERGIE ÉLECTRIQUE**
Language of instruction : **FRENCH**
Type of course : **Specific Course**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **19,50**

Description

This course will provide students with a knowledge base that will be necessary for them to complete the project in the end of this sequence. It focuses on the development of models to study electromagnetic conversion systems and unsteady heat transfer. The course will on one hand adress basic concepts of electrical and magnetic circuits as well as the principles of magnetic coupling to ensure the students' understanding of the functioning of electromagnetic systems, and on the other hand, the fundamental concepts of unsteady heat transfer (problem formulation, solving some typical academic problems, highlighting characteristic lenghts and times). Several modeling approaches (analytical, semi-analytical and numerical) will be presented to solve the electromagnetic and/or thermal problems.

Quarter number ST2

Prerequisites (in terms of CS courses)

The SPI courses " electric energy" and " Introduction to heat, mass and momentum transfer" are recommended

Syllabus

Electromagnetic part:

- Basic principle of electric and magnetic circuits (calculation of electric power, calculation of magnetic field, self and mutual inductance, magnetic energy ...).
- Different modellig approaches (analytical and numerical) to solve an electromagnetic problem
- Wireless power transmission by induction
    - Different approaches for modelling of a magnetic coupler to determine the element of an electric equivalent circuit
    - The electromagnetic radiation and reduction of the magnetic field
    - Compensation of reactive energy
    - Power converters (inverter/rectifier)
    - Calculation of losses and the energy efficiency
- Tutorial 1: Analytical study of an electromagnetic energy conversion system
- Tutorial 2 and 3 : Modelling of magnetic system by COMSOL software
- Tutorial 4 : Study of electromagnetic radiation

Thermal part:

Energy balance, boundary conditions, thermal diffusivity, superposition theorem, Π theorem; Response of a semie-infinite medium (response after a short time): imposed temperature, imposed heat flux, periodic excitation.
Response of a finite medium, diffusion characteristic time, conducto-convection characteristic time, Biot number, Fourrier number; Analytical and numerical methods for unsteady heat conduction.

- Tutorial 5 : Cooling of a transparent ball + thermal inertia of a building (beginning)
- Tutorial 6 : Thermal inertia of a building (end) and semi-analytical analysis and numerical solve of the problem "Thermal inertia of a building"

- Tutorial 8 : Presentation of the BuildSysPro model libraray: structure, modularity, assembly of elementary models to build a complete building model, presentation of existing building libraries, introduction to new building models.
- Tutorial 9 : Use of the model library: choice of a building model, change of building properties, integration of new models, building simulations and post-processing.

Class components (lecture, labs, etc.)

4 courses of 1,5h
8 tutorials sessions of 1,5h (group with 25 students) - one tutorial session is in Eglish.

Grading

Two 10-minute continuous tests in a tutorials sessions. The final mark for the continuous control is the average of the two marks.
1 written exam of 1h30: 45 min for the electromagnetic part and 45 min for the thermal part. The final mark is the average of the grades obtained in each of the parts : 20% for the continuous control and 80% for the final exam.

Course support, bibliography

Course materials in ppt form
Principles and components of electrical engineering - course material - G. PIERRON.
Comsol software website: https://www.comsol.fr/models.
J. Taine, F. Enguehard, E. Iacona, "Heat Transfer - Introduction to Energy Transfers", 5th edition, Dunod 2014.
F. Incropera, D. Dewitt, T. Bergman, A. Lavine, "Fundamentals of heat and mass transfer", 6th edition, Wiley, 2007
BuildSysPro software installation website and tutorials to use the software: https://github/edf-enerbat/BuildSysPro

Resources

Teaching team:

- Courses: Mohamed Bensetti (CentraleSupélec) & Laurent Soucasse (CentraleSupélec)
- Tutorials 1, 2, 3 and 4: Mohamed Bensetti (CentraleSupélec), Amir Arzandé (CentraleSupélec) et Mike Kirkpatrick (CentraleSupélec)
- Tutorials 5 and 6 : Mehdi Ayouz (CentraleSupélec), Fabien Bellet (CentraleSupélec), Mathieu Niezgoda (CentraleSupélec) et Gabi Stancu (CentraleSupélec)
- Tutorials 7 and 8 : Research Engineer from EDF (R&D - Centre des Renardières)

TD class size: 25 students
Software tools: Comsol and Matlab

Learning outcomes covered on the course

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

- Study, analyse and model electromagnetic and/or thermal
- Apply the fundamental concepts of unsteady heat transfer to study the energy performance of a building
- Modelling of a wireless power transfer charging system and determination of its electrical and magnetic parameters
- Use and implement appropriate models to solve electromagnetic and/or thermal problems
- Use multi-physics software Tools (electromagnetic and thermal)
- Validate and analyse the results obtained by modelling.

Description of the skills acquired at the end of the course

C1.1: Study a problem as a whole and an overall situation
C1.2 : Identify, formulate and analyse a problem in its scientific, economic and human dimensions
C1.3 : Use and develop appropriate models, choose the right modelling scale and the relevant simplifying hypotheses to deal with a problem

1SC2491 – Study, modelling and experimental validation of a wirless energy transfer system

Instructors : **Mohamed Bensetti**
Department : **DOMINANTE - ENERGIE**
Language of instruction : **FRENCH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

This course was created in collaboration with the company Renault and theVedecom institute. The subject matter is the modelling and sizing of an inductive wireless power tranfer charging system. Emphasis is made on the magnetic coupler. In parallel to the functional aspects of the charging system, the problem of user exposure to magnetic fields will also be explored. This public safety issue will be treated by proposing solutions which may reduce the magnetic field emitted by the system in order to conform to the applicable norms. The envisaged modelling approach must take into account the different aspects of the posed problem (system geometry, material properties, sheilding, alignment, environment, ...). The proposed methodology will take advantage of a combination of modelling tools for electromagnetism (COMSOL) and other software for circuit analysis (LTSpice and matlab/Simulink).

Quarter number ST2

Prerequisites (in terms of CS courses)

The elective course "electric energy" is recommended

Syllabus

- Modelling of a magnetic coupler
  - Use of comsol to model a magnetic coupler taking into account its physical and geometrical properties
  - Establish a modelling method for the determination of the parameters of the equivalent electric circuit
  - Experimental validation
- Construction of a model circuit for wireless power transfer system
  - Determination of the compensation mode and calculation of the values for capacitors
  - Analysis of the results obtaiend by simulation - LTSpice or Matlab/Simulink
  - Study of the power converter (inverter)
  - Analysis and validation of the results
  - Determination of the energy efficiency
- Study of electromagnetic radiation
  - Determination of electromagnetic radiation using Comsol
  - Study of the impact of the field on health
- Experimental Study
  - Utilisation of a test bench for validation of the results obtained from the modelling
  - Measurement of the magnetic field

Class components (lecture, labs, etc.)

This course will take place in the format of a student project with groups being constituted during the first session. Session 1 and 9 will be take place in the classroom while the other sessions will be held in the nergy department's teaching laboratory.

Session 1: Presentation of the subject and project specifications
Session2 : Literature search on inductive wireless power transfer systems and the different approaches to modelling those systems

Session 3-4: Modelling (both analytical/numerical) of the coupler
Session 5-6: Study the compensation of the reactive power and the type of the converter to be employed.
Session 7 : Study the electromagnetic radiation
Session 8: Experimental validation
Session 9 : Delivery of final report and student presentations before the teaching team and industrial partners

Grading

The students will be evaluated based on their final reports and their oral made in the final session.

Course support, bibliography

handhout

Resources

Teaching team : Mohamed Bensetti (CentraleSupélec), Amir Arzandé (CentraleSupélec), Mike Kirkpatrick (CentraleSupélec), Bruno Lorcet (CentraleSupélec), Ingénieurs de recherche (Renault et Vedecom).
Software tools: Comsol, matlab and LTSpice
Laboratory equipement: test bench + measuring devices (LCR Meters, Impedance analyzer, scope, ...)

Learning outcomes covered on the course

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

- Modelling of magnetic coupler for the determination of electrical parameters.
- Use and implement appropriate models to solve electromagnetic problems.
- Study of electromagnetic radiation of a magnetic coupler.
- Modelling of wireless power tranfer charging system from the source to the load.
- Validate and analyze the results obtained by modelling with experimental results.

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.
C4-Create value for companies and clients
C7- Strengthen the Art of Persuasion
C8- Lead a team, manage a project

1SC2492 – Modeling the energy consumption of a group of buildings

Instructors : **Sean MCGUIRE**
Department : **DOMINANTE - ENERGIE**
Language of instruction : **FRENCH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

Design and develop software tools for the simulation of the energy consummation of an existing building complex. Determine the primary sources of energy consumption and device methods for reducing energy consumption.

Quarter number ST2

Prerequisites (in terms of CS courses)

Be enrolled in and pursuing courses specific to ST2 « Transition énergétique ».

Syllabus

The work for this course will be done by teams of 3-5 students each (14 groups total). The students will receive a Google Earth image of a suburban district (18 buildings). 6 of the 7 groups must separately treat 3 buildings. The remaining group will be in charge of developping and testing a model for a photovoltaic system. The goal of the study is to transform the neighborhood into an « energy positive » area through a combined approach of renovation and the integration of a photovoltaic solar power system. For this, the students will construct a model for each building in the zone ; they must identify appropriate hypotheses used and develop a model based upon these. The groups are expected to discuss amongst one another to develop a unified strategy for making the zone « energy positive » (e.g. identification of most and least efficient buildings in the neighborhood, primary sources of energy consumption, …) They must then integrate this strategy into their models and use their simulations to argue for its use in making the neighborhood « energy positive ».

Class components (lecture, labs, etc.)

Project-based learning

Grading

Oral presentations with Powerpoint supports

Course support, bibliography

Presentation slides discussing the functionality and use of BuildSysPro, direct use of the open source code BuildSysPro (https://github.com/edf-enerbat/BuildSysPro) during courses specific to ST2 and during the week of the EI.

Resources

Team of professors: 2 engineers from EDF R&D, 1 professor from CentraleSupélec
Software tools and licenses : BuildSysPro (gratuit)

Learning outcomes covered on the course

- Realistic data analysis and interpretation
- Develop a coherent and practical model using the tools given
- Data analysis and presentation of results

Description of the skills acquired at the end of the course

- Study a problem in its entirety. Identify, formulate and analyze a problem with an eye towards both its scientific and human dimensions.
- Develop and utilize models tailored to the particular situation, identify the appropriate level of model complexity and simplifying hypotheses appropriate for the problem
- Solve a problem us

ST2 - 25 - MODELING, SIMULATIONS AND EXPERIMENTS FOR THE DESIGN OF VEHICLES AND STRUCTURES

Major**: CVT (Construction, City and Transportation)**

Language: **English, except a couple of conferences by external experts that might be in French**

Campus where the course will take place **: Paris-Saclay**

Engineering problem

When developing a new project, whether it concerns a car, an airplane, or an infrastructure, modeling plays a key role. Indeed, it is necessary to evaluate the relevance of the concept at all stages of a project, not just at the final stage for obvious cost reasons. Several levels of modeling are therefore required. In the pre-conception phase, very simple modeling tools (e.g. a spreadsheet) allow to specify the orders of magnitude and the main levers of improvement at a lower cost, often on the basis of empirical correlations. In a more advanced phase of evaluation of technological choices, experimental or numerical models are used. In both cases, modeling is required either to measure the relevant data experimentally or to define the physical model to be simulated numerically. At this stage, the engineers have at their disposal a wide range of solutions, from reduced models to the real system, or from the simple and fast numerical simulation – but not very accurate – to the high-fidelity numerical simulation – accurate but costly in computing time.

In this thematic sequence, these different modeling aspects will be presented. An emphasis will be put on the "transportation" component of the course, although "construction and city" will also be touched upon. The societal and economic context, as well as the diversity of modeling tools used by the engineer will be the subject of "Introductory Lectures". The "Specific Courses" will allow the implementation of experimental and numerical simulation approaches, with an emphasis on validation. Finally, based on relevant modeling choice, it will be shown in the context of the "Engineering Challenge Week" how to model the performance of a complex system to a first approximation, particularly in a hybridization approach.

Recommended prerequisites

S.I., programming notions in Matlab

Introductory lectures:

These lectures will allow, through contact with actors concerned by the pre-dimensioning aspects of complex systems and multiphysics modeling, to have an overview of the CVT theme from several angles, including economic and industrial constraints. In addition to these lectures, students will participate in bibliographic workshops, during which they will have to produce a group study on the topic of their choice within the CVT major.

Specific course (40 HEE): Modeling, simulations and experiments

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

- follow a modeling approach via experimentation. By giving them a model adapted to the description of the studied phenomenon at the beginning, they will build an experimental approach making sure to answer the objective by controlling the uncertainty and to implement this experimental approach iteratively between the model and the acquired data.

- follow modeling approach via numerical simulation. We wish to make a numerical prediction of a given problem from a model. By giving them a model adapted to the description of the phenomenon, they will build a simulation approach making sure to answer the objective by controlling the uncertainty and implement this numerical approach.

This course is divided into 4 sub-sections: numerical simulation in fluid mechanics or in solid mechanics, and experiments in fluid mechanics or in solid mechanics. Students will have to choose two of the 4 courses at the beginning of the sequence.

Engineering challenge week: Performance and hybridization of a vehicle by functional modeling

- Industrial partner: Renault

- Location: Paris-Saclay campus

For this Challenge Week, the objective is to position the students as the partner's design team. The partner will impose specifications for a hybrid car from Renault. The students will have to carry out a market study, define the product and carry out a pre-design. The pre-design will require the creation of a global model of the vehicle, including not only the aerodynamic aspects but also the motorization aspect. In addition, they will have to work as a team to meet the CO2 emission limits.

1SC2510 – Modeling, simulations and experiments

Instructors : **Morgan Chabanon**
Department : **DÉPARTEMENT MÉCANIQUE ENERGÉTIQUE PROCÉDÉS**
Language of instruction : **ENGLISH**
Type of course : **Specific Course**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **19,50**

Description

The objective of this course is to provide students with a modelling approach through numerical simulation and/or experimentation, in the fields of fluid mechanics or solid mechanics.
By giving a model that will be adapted to the description of specific phenomenon, the students will have to set up a numerical or experimental approach that will answer the initial objective while managing physical uncertainties. They will finally implement their methodology, using an iterative process between the model and the acquired data (experimental or numerical).

Quarter number ST2

Prerequisites (in terms of CS courses) no prerequisite

Syllabus

For this course, the students will have to choose at the beginning of the sequence two activities among the four proposed:

- numerical simulation in fluid mechanics: students will use MATLAB and Ansys Fluent to simulate basic engineering flows, like channel flow or flow past a cylinder.
- numerical simulation in solid mechanics: the students will use COMSOL multiphysics in order to compare models as well as different types of geometry, in the scope of deriving conception rules.
- experiments in fluid mechanics: the students will measure forces and velocities in fluid flows (liquid or gaseous) using diagnostics based on different physical principles (particle image velocimetry, hot wire, dynamometer, Pitot probe). Acquisition and data analysis will be done using NI LabView and Matlab.
- experiments in solid mechanics: Students will have to use a mechanical test machine to identify certain parameters of the law of behaviour (linear elasticity model) of a material of their choice (steel, aluminium, bone tissue, wood...).

Grading

The evaluation is based on the work performed during each of the two activities followed by the students. The evaluation takes the form of a group report or presentation depending on the activity. The final grade of the specific course is the average between the two marks. Attendance is mandatory, and any unjustified absence will lead to a penalty on the final grade.

Resources

Teaching team:
-Numerical simulation: Ann-Lenaig Hamon, Camille Gandiolle (Solid mechanics), Morgan Chabanon (Fluid mechanics).
-Experiments: Jan Neggers (Solid mechanics), Antoine Renaud (Fluid mechanics).

Experimental rooms of MMSMAT and EM2C laboratories.
Numerical tools COMSOL Multiphysics (Solid mechanics), Matlab et Ansys Fluent (Fluid mechanics).

Learning outcomes covered on the course

Being able to use numerical tool or experimental diagnostic to validate or build a model.

1SC2590 – Performance and hybridization of a vehicle by functional modeling

Instructors : **Morgan Chabanon**
Department : **DOMINANTE - CONSTRUCTION VILLE TRANSPORTS**
Language of instruction : **ENGLISH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

During this challenge week, an automotive powertrain will be pre-dimensioned in order to adapt it optimally to a specific vehicle category taking into account performance, consumption, pollutant and price criteria.

Quarter number ST2

Prerequisites (in terms of CS courses) No prerequisite

Syllabus

After an introduction presenting the different elements making up a powertrain, students will have to model and optimize a vehicle according to different constraints.
A benchmark will be made to position itself according to the performance of the competition.
The study will first focus on the performance of the vehicle and then the homologation cycles from the point of view of consumption.
Students have a budget to buy different technologies to achieve the objectives required by their segment (performance, economy, low emissions ...).

Class components (lecture, labs, etc.)

Students will work in groups, each responsible for a segment of a general automaker's lineup. The speakers offer support and challenge the students in relation to their technological choices.

Grading

The evaluation has two components:
- continuous observation of the general behavior of the group during the course of the teaching and the answers during discussions
- short final defense presenting the final result and justifying the selected choices

Resources

All sizing will be done using an Excel spreadsheet (or equivalent). Useful data and features will be provided by stakeholders. The use of a spreadsheet will allow us to obtain quickly representative results without the problem of handling more specialized software.

Learning outcomes covered on the course

- Knowing the components of a hybrid automotive powertrain.
- Knowing what impacts different technological choices have on pollutant emissions and performance.
- Pre-dimensioning a powertrain under constraints.

ST2 - 26 - EARTH OBSERVATION FOR OUR ENVIRONMENT AND SAFETY

Dominante **: PNT (Physics and Nanotechnology)**
Langue d'enseignement : **French**
Campus où le cours est proposé **: Paris-Saclay**

Engineering problem

Earth observation by means of measuring instruments embarked on drones, airplanes or satellites is a fairly recent discipline but one that is experiencing exceptional development because of its role in major environmental and security issues. The recent satellites launched by the European, American, Canadian and Chinese space agencies ... all have the following objectives

- land security (border observation, troop movements, nuclear activities ...) and sea security (piracy, smuggling ...),

- a better understanding of the phenomena that affect the environment (deforestation, ice melting, desertification, monitoring of wetlands ...),

- the protection of populations against natural or man-made disasters (earthquakes, floods, fires, pollution...),

- studying the impact of our activities, for example by monitoring the growth of metropolises.

The growing share of private players (Airbus DS, Thales Alenia Space, MDA ...) in this field also reflects the commercial issues related to this theme. Whether for insurance companies, civil security actors, or urban planning, the processing and analysis of this data opens the way to numerous applications and new activities.

The number of sensors is increasing and data is abundant. The challenge is first to correctly interpret the images acquired by these different sensors, and then to develop tools that can be applied automatically. Modeling the interactions between waves (radar, optical, hyperspectral, ...) and the environment is a key step for the analysis of these images.

Whatever the type of sensor, the key point is to identify the useful information in the image. To do this, the very first step is to model the object of interest. Using the physical knowledge of the scene, we will identify the relevant model or develop a new model. Then, detection / classification tools will be used. They can be based on "traditional" or machine learning methods.

The specific course will first address some elements of wave physics in order to understand the interactions between waves and objects. Then, the commonly used models and the analysis techniques corresponding to these models will be covered. Throughout the course, great importance will be given to the manipulation of images by the students.

Adviced prerequisites None

Context and issue modules

Earth observation is a major challenge for the European Commission, which has financed the Copernicus project (series of satellites with various sensors). The ambition of the Commission is to allow the development of new economic activities. This topic will be discussed at the beginning of these modules.

The European Space Agency has the mission to implement the Paris agreements. Representatives of French and European agencies will present in more detail the actions underway.

Companies are also strongly involved in this field, representatives will discuss technical and commercial issues.

Finally, an overview of new scientific developments will be given.

Specific course (40 HEE): Physical models for radar and optical image analysis

- Brief description: This course will provide a first understanding of the physical phenomena in wave-object interactions, give basic modeling techniques and explain how to use them to process data. The main topics covered are propagation and remote sensing, radar sensors, other types of sensors (optical, hyperspectral...), classification, change detection

Challenge week #1: biomass and deforestation

- In partnership with : ESA & CNES & Environment Canada

- Location: Paris-Saclay campus

- Brief description Forests are an important ecosystem from an environmental and climatic point of view. Their protection but also the control of their contribution in terms of CO2 regulation are fundamental. Protection involves both detecting and monitoring sources of deforestation (clear-cutting to sell wood, conversion into agricultural land, etc.) and assessing their health (e.g. infestation of pine trees by butterfly larvae in Canada). The CO2 absorption capacity is a function of the biomass. In 2022, ESA will launch a BIOMASS mission whose objective is to allow the inventory of the world biomass.

- Students will be able to choose to work on one of these aspects, either to estimate the biomass of forests, to detect deforested areas or to follow the evolution of an area infested by insects.

Challenge week #2: Classification of agricultural areas

- In partnership with : CS-SI

- Location: Paris-Saclay campus

- Brief description: Detailed and accurate knowledge of land cover is crucial for many scientific and operational applications, and as such, it has been identified as an essential climate variable. Iota2 is the processing chain that allows the fully automatic production of land cover maps at the country scale using time series of high resolution optical images that are based on supervised classification and use existing databases as reference data for model learning and validation. This chain is triggered once a year in the CNES computing center to produce the land cover maps.

Challenge week #3: Glacier monitoring

- In partnership with : ONERA

- Location : Paris-Saclay campus

- Brief description: Mapping glaciers and studying their change on a global scale is very useful for predicting sea level changes, water resources in certain regions, mountain developments and for studying climate change and associated natural hazards. In this project, we propose to observe the dynamics of glaciers, through the observation of surface state changes, and the calculation of their displacement speed, by flow calculation and interferometry techniques.

Challenge week #4: Automatic land cover classification

- **In partnership with :** Preligens (formerly EarthCube)

- Location: Paris-Saclay campus

- **Short description:** This project is an opportunity to use machine learning while getting familiar with satellite imagery. Gohar and her team will first introduce the relevant machine learning and remote sensing concepts, as well as the tools needed to get started with the project. You will then apply the algorithm of your choice to analyze the type of land cover on images from the Sentinel 2 mission. On each image, you will have to decide on the nature of each pixel: is it an artificial area, cultivated, grassy, aquatic, or forested?

1SC2610 – Physical models for radar and optical image analysis

Instructors : **Laetitia Thirion-Lefevre, Regis Guinvarc'H**
Department : **DÉPARTEMENT PHYSIQUE**
Language of instruction : **FRENCH**
Type of course : **Specific course**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **19,50**

Description

The observation of the Earth using spaceborne or airborne sensors is a rather recent topic, which has recently known an exceptional development as it plays a major role for the environmental and safety challenges we have to face. What is the speed of ice melt at North Pole? How many refugees are present in camps? What is the extent of oil palm plantations? Could we survey the rise of sea level?

Quarter number ST2

Prerequisites (in terms of CS courses) none

Syllabus

1/ Propagation and remote sensing
2/ Radar sensors
3/ Other types of sensors (optical and hyperspectral)
4/ Classification and inversion
5/ Change detection

Class components (lecture, labs, etc.)

5 lectures (90 min each), 7 tutorials (90 min each), one 90 min final examen

Grading

Continuous assesment and final exam One final written examination of 1h30 with document Weighting: 20% continuous assesment and 80% final exam.
Sub-skill C1.1 and C1.2 are evaluated in two questions of the final exam. If the average mark of the 2 questions is above 50%, then C1 is validated.

Course support, bibliography

Lecture notes and reference textbook available on the Learning Management System.

Resources

- Faculty members for lectures : Laetitia Thirion-Lefevre (CS), Régis Guinvarc'h (CS) and Elise Colin-Koeniguer (ONERA)
- Size of tutorial classes : 35 students.

1SC2691 – Biomass and deforestation

Instructors : **Regis Guinvarc'H, Laetitia Thirion-Lefevre**
Department : **DOMINANTE - PHYSIQUE ET NANOTECHNOLOGIES**
Language of instruction : **FRENCH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

Forests are an important ecosystem from an environmental and climatic point of view. Their protection but also the control of their contribution in terms of CO2 regulation are fundamental. Protection involves both detecting and monitoring the sources of deforestation (clear cuts to sell wood, transformation into agricultural areas, etc.) and estimating their health (infestation of pines by butterfly larvae in Canada for example) . The CO2 absorption capacity is a function of the biomass. In 2022, ESA will launch a BIOMASS mission, the objective of which is to enable the inventory of global biomass.
Students can choose to work on one of these aspects, either to estimate the biomass of forests, to detect deforested areas or to follow the evolution of an area infested by insects.

Quarter number ST2

Prerequisites (in terms of CS courses) none

Syllabus

To understand the physical links between the signal measured by a radar and a forest (biomass in particular).
To propose a model to link the two.
To study the robustness of this model according to the type of forest, topography and polarization.

Grading

The session will be evaluated with an oral presentation.
Skills C4, C7 and C8 are evaluated during the oral defense.

Resources

ESA computing platform

Learning outcomes covered on the course

To understand the physical links between the signal measured by a radar and a forest (biomass in particular).
To propose a model to link the two.
To study the robustness of this model according to the type of forest, topography and polarization.

Description of the skills acquired at the end of the course

C4-1 Identify and reformulate the need
C4-2 Define and present one or more solutions
C7-1 Structure your ideas and arguments, be synthetic (assumptions, objectives, expected results, approach, and value created)
C7-2 Understand in an evolving way the needs and expectations of your interlocutors. Encourage interactions, be an educator, and create a climate of trust.
C7-4 Master spoken, written, and body language and master basic communication techniques

1SC2692 – Classification of agricultural areas

Instructors : **Regis Guinvarc'H, Laetitia Thirion-Lefevre**
Department : **DOMINANTE - PHYSIQUE ET NANOTECHNOLOGIES**
Language of instruction : **FRENCH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

Detailed and accurate knowledge of land cover is crucial for many scientific and operational applications, and as such, it has been identified as an essential climate variable. Iota2 is the processing chain that enables the fully automatic production of country-wide land cover maps using time series of high-resolution optical images that are based on supervised classification and use the basics of existing data as reference data for training the models and their validation. This chain is triggered once a year in the CNES data center to produce the land use maps.

Quarter number ST2

Prerequisites (in terms of CS courses) none

Syllabus

Autonomous research (library and visualizations) on the different sources and platforms for downloading data and on spectral indices
To identify the physical characteristics of signals from different land covers.
Propose and test classification algorithms.
To model the performances

Grading

The session will be evaluated with an oral presentation.
Skills C4, C7 and C8 are evaluated during the oral defense.

Resources

ESA computing platform

Learning outcomes covered on the course

autonomous research (library and visualizations) on the different sources and platforms for downloading data and on spectral indices
To identify the physical characteristics of signals from different land covers.
Propose and test classification algorithms.
To model the performances

Description of the skills acquired at the end of the course

C4-1 Identify and reformulate the need
C4-2 Define and present one or more solutions
C7-1 Structure your ideas and arguments, be synthetic (assumptions, objectives, expected results, approach, and value created)
C7-2 Understand in an evolving way the needs and expectations of your interlocutors. Encourage interactions, be an educator, and create a climate of trust.
C7-4 Master spoken, written, and body language and master basic communication techniques

1SC2693 – Glacier monitoring

Instructors : **Laetitia Thirion-Lefevre, Regis Guinvarc'H**
Department : **DOMINANTE - PHYSIQUE ET NANOTECHNOLOGIES**
Language of instruction : **FRENCH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

The mapping of glaciers and the study of their change on a global scale are very useful for predicting changes in sea level, water resources in certain regions, mountain developments and for studying climate change and risks. natural associated. In this project, we propose to observe the dynamics of glaciers, through the observation of surface state changes, and the calculation of their speed of movement, by flux calculation and interferometry techniques.

Quarter number ST2

Prerequisites (in terms of CS courses) none

Syllabus

- Guided bibliographical research on glacier sites with particular recent dynamics (ice break, glacier surge)
- State of the art techniques dedicated to glacier analysis: estimation of snow cover, estimation of displacements by optical flow/interferometry, analysis of temporal evolution.
- application to real data sets and critical analysis of results

Grading

The session will be evaluated with an oral presentation.
Skills C4, C7 and C8 are evaluated during the oral defense.

Learning outcomes covered on the course

Applying the differential interferometry technique seen in progress on the city of Semarang.
Evaluate the sinking depth over the interval of available data estimate the sinking speed.
Propose a model to predict the level and the sinking speed for the next 10 years.

Description of the skills acquired at the end of the course

C4-1 Identify and reformulate the need
C4-2 Define and present one or more solutions
C7-1 Structure your ideas and arguments, be synthetic (assumptions, objectives, expected results, approach, and value created)
C7-2 Understand in an evolving way the needs and expectations of your interlocutors. Encourage interactions, be an educator, and create a climate of trust.
C7-4 Master spoken, written, and body language and master basic communication techniques

1SC2694 – Automatic land cover classification

Instructors : **Regis Guinvarc'H, Laetitia Thirion-Lefevre**
Department : **DOMINANTE - PHYSIQUE ET NANOTECHNOLOGIES**
Language of instruction : **FRANCAIS**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

This project is an opportunity to use machine learning while learning about satellite imagery. Preligens team will first introduce the relevant machine learning and remote sensing concepts, as well as the tools needed to get started with the project. You will then apply the algorithm of your choice to analyze the type of ground cover on images from the Sentinel 2 mission. On each image, it will be a question of deciding on the nature of each pixel: is it an area artificial, cultivated, herbaceous, aquatic forest?

Quarter number ST2

Prerequisites (in terms of CS courses) none

Syllabus

autonomous research (library and visualizations) on the different sources and platforms for downloading data and on spectral indices
To identify the physical characteristics of signals from different land covers.
Propose and test classification algorithms.
To model the performances

Class components (lecture, labs, etc.)

Project-based, the students work in small teams for the whole week. Regular discussions are planned with the custormers/supervisors.

Grading

The session will be evaluated with an oral presentation.
Skills C4, C7 and C8 are evaluated during the oral defense.

Description of the skills acquired at the end of the course

C4-1 Identify and reformulate the need
C4-2 Define and present one or more solutions
C7-1 Structure your ideas and arguments, be synthetic (assumptions, objectives, expected results, approach, and value created)
C7-2 Understand in an evolving way the needs and expectations of your interlocutors. Encourage interactions, be an educator, and create a climate of trust.
C7-4 Master spoken, written, and body language and master basic communication techniques

ST2 - 27 - VIRAL PROPAGATION

Dominante **MDS (Mathematics and Data Science)**

Language**: English**

Campus: **Paris-Saclay**

Subject

This engineering challenge term uses viral propagation as a pretext to develop students' modeling skills and to help them discover several fields of application where viral propagation must either be slowed down (e.g. epidemic, attack on a computer system) or amplified (e.g. diffusion of a message on a social network).

Context and challenge modules**:** Students will discover different contexts in which virality is important, among them epidemiology, information systems and marketing. Speakers will present the key elements of these topics and students will put them into practice in workshops.

Specific courses (Workload: 40 hours): Viral propagation

Abstract: The modeling of propagation has seen great progress in its formalization in recent decades. It applies to various contexts: populations, dynamics, computer networks, social networks, etc.. The goal of this class is to acquaint students with the usual techniques to model, predict and anticipate the effects of a virus in real-life situations.

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Challenge Week – Option #1 **– 1SC2791**

Epidemic: model, predict, communicate

Campus: Paris-Saclay

Abstract: You have just been hired at the Pasteur Institute to reinforce the modeling teams. In teams of four, you will have two days to build up your expertise on four infectious diseases, develop models to represent their propagation in different contexts, and set up methods to efficiently perform their analysis and parametric estimation. One morning, an epidemic crisis breaks out somewhere in the world, for one of these four diseases. Your team has been called to work on it.

Challenge Week – Option #2 **– 1SC2792**

Response to a viral attack on an information system

Industrial Partner: Will be announced on the first day of the challenge.

Campus: Paris-Saclay

Abstract: For five days and 24 hours a day, you will have to deploy your knowledge, creativity, and organizational skills to best respond to a crisis related to the propagation of malware on an information system.

In 2019, it was a viral attack on a large bank.
In 2020, it was a virus attack on a water treatment facility.
In 2021, it was a virus attack on NATO.
In 2022, it was a virus attack on a satellite control center.
In 2023, it was a virus attack on a hospital.

The 2023 topic will be revealed on the first day of the EI.

Challenge Week – Option #3 – 1SC2793

Modeling, development, and management of a viral marketing camp

Industrial Partner: Artefact

Campus: Paris-Saclay

Abstract: As a young engineer, you have just joined Artefact, an international services company at the intersection of marketing, consulting, and data science. You are on a team of six people. A client needs Artefact's help to spread a message on social networks by leveraging virality and maximizing the campaign's impact. The CEO of Artefact asks your team to take the case. You will have to understand the dynamics and the functioning of the viral diffusion of information on the Internet and, in particular, social networks. Artefact will provide you with data from social networks (who follows who, who retweets what, who likes what, etc.). Your mission: to make action-oriented recommendations that lead to the highest impact.

1SC2710 – Viral propagation

Instructors : **Véronique Le Chevalier, John Cagnol**
Department : **DÉPARTEMENT MATHÉMATIQUES**
Language of instruction : **ENGLISH**
Type of course : **Specifc Course**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **19,50**

Description

Who should we immunize, to prevent an epidemic? Who should we target in order to run an effective promotional campaign for our product? How do opinions or rumors form and spread in social media?

Modeling propagation in various contexts (populations, computer networks, social networks) has made great progress over the past decades. The objective of this class is to familiarize students with the now classic techniques that will allow them to model, predict and optimize its effects in concrete situations.

Two types of models can be used: continuous (based on differential equations) and discrete (generally based on graphs). Students will be introduced to these models and invited to work on the modeling approach.

Quarter number ST2

Prerequisites (in terms of CS courses)

CIP

1. PDE
2. SIP
3. Modeling
4. Algorithms and Complexity

Syllabus

- Concepts of descriptive and analytical epidemiology (incidence, prevalence, types of epidemiological surveys and associated risk measures, odds ratios, etc.)
- Compartmental models and their analysis
- Propagation modeling on graphs and their properties
- Some notions on graph inference

Class components (lecture, labs, etc.)

Lectures and labs

Grading

Lab (TP) - Mandatory Evaluation (EO) $\alpha_0 = 0.3$.
Exam - (split on three parts) a_f = 0.7

Resources

- Theoretical lectures, exercises, programming

Learning outcomes covered on the course

- We expect that by the end of the course, the students will :
- Understand various data analysis tasks related to graphs and information spreading.
- Formulate and solve problems that involve propagation phenomena on homogeneous domains or on networks.

Description of the skills acquired at the end of the course

- By the end of the course, we expect that students will have acquired skills on:
- Compartmental models (e.g., SIR, SIR).
- Graph theory and network analysis.
- nformation and influence spreading on graphs .
- Implementation of graph algorithms for information propagation on networks in Python.

1SC2791 – Epidemic: model, predict, communicate

Instructors : **Véronique Le Chevalier, John Cagnol**
Department : **DOMINANTE - MATHÉMATIQUES, DATA SCIENCES**
Language of instruction : **ENGLISH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

The importance of modeling in epidemiology is no longer in question: everyone has been able to feel the stakes and the consequences on daily life, whether in terms of model use for prediction,choice of interventions or communication.
This week course on modeling in epidemiology puts students in the role of a committee of modeling experts in an organization such as the WHO or the Pasteur Institute, faced with an epidemic situation to be analyzed and controlled.
The objective is to have students put into practice the modeling approach in life sciences and the mathematical methods associated with it, particularly in terms of analysis and evaluation of models.

Quarter number ST2

Prerequisites (in terms of CS courses)

None except courses from the ST2 viral propagation

Syllabus

During this course, the students will dwelve into the domain of epidemiology, by working as a team of modelling experts in the context of an international health service such as the WHO or Pasteur Institute. During the first part of the week, they will learn about epidemic models and constitute their expertise for a given set of infectious diseases, mainly by the means of bibliographic research and conference by an epidemiologist. They will also implement different mathematical methods for model development, parametric estimation and evaluation. The second part of the week consists in a "WHO challenge": the teams compete to deal with the situation of an epidemic crisis about wich they periodically receive some datasets. Adapting their models prealably developed to the given situation, they have to make prediction of the future trends of the epidemy, to simulate possible public interventions in order make recommendations to the government, and to communicate using different types of media (press release, scientific report, etc). Epidemiology is an interesting playground for this kind of course since experimentation is impossible at the population scale, thus emphasising the importance of mathematical modelling.

Class components (lecture, labs, etc.)

Work in teams of 4, each team building an expert on a given disease and then sharing during the challenge. Warm-up exercise on data from an epidemic in class. Flash" course on small reminders of modeling tools. Interventions by various experts (crisis communication, epidemiologist, etc.).

Grading

- press release - dossier for public health decision-makers - report for scientists - Oral presentation - challenge score (prediction and effectiveness of recommended interventions) - quizz (bonus) -

Course support, bibliography

A nice introductive paper: "Covid-19 : ces modélisateurs qui anticipent la pandémie - By David Larousserie. "Le Monde", Published January 5th 2021, 04h04".

Resources

Teacher : Véronique Letort - Le Chevalier + others

Learning outcomes covered on the course

Understand epidemiology basics
Understand dynamic epidemic propagation models based on ordinary differential equations (SIR, SIS, etc.) or multi-agent models. Critical thinking regarding the model best adapted to a given situation, and above all, implementation of the iterative approach of building a model based on information, often fragmentary, on a real system and its evolution.
Implementation of the methodological chain for model analysis, parameter estimation and selection. Application of models for prediction and decision support (recommendation of interventions). Understand basics of communication for different audiences (general public, public health decision-makers, scientific community)

Description of the skills acquired at the end of the course

C1.1 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.
C1.2 Model: use and develop appropriate models, choose the right scale of modeling and relevant simplifying assumptions

C7.4 On communication techniques : master spoken, written and body language, and master basic communication techniques
And C4, C8.

1SC2792 – Response to a viral attack on an information system

Instructors : **John Cagnol, Remi Geraud**
Department : **DOMINANTE - MATHÉMATIQUES, DATA SCIENCES**
Language of instruction : **ENGLISH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

In this course you will be facing a cyber crisis, not unlike those that sometimes undergo large companies and industrial sites. Harnessing an ongoing incident, you will assist a client in figuring out the best course of action.

You will be tasked with understanding the nature and impact of the incident ; then communicate this to different stakeholders, and ultimately come up with realistic and concrete countermeasures, along with talking points, for the decision-makers to consider.

In particular you are expect to clarify the nature of the threat, taking into account the uncertainty and stakes at hand, and support your analyses with convincing and rigorous scientific experiments.

Quarter number ST2

Prerequisites (in terms of CS courses)

Information systems and programming
Algorithms and complexity
Modeling
CIP

Syllabus

During five whole days, 24h a day, you'll be expected to invest your technical knowledge, creativity, and organizational skills to respond as best as possible to a cyber crisis situation.

· In 2019, the attack targeted a major international bank
· In 2020, the attack targeted a water treatment facility.
· In 2021, the attack targeted NATO delegations.
· In 2022, the attack targeted a satellite constellation.
- In 2023, the attack targeted a large hospital center
The 2024 topic will be revealed on the first day of the EI.

Grading

The capstone project is graded through observation of your work and behavior during the week, your intermediate reports, your report and your defense.

Resources

Instructors:
Rémi Géraud-Stewart
Hugo Waltsburger

Learning outcomes covered on the course

At the end of this teaching you will be able to
- Taking a step back from an industrial issue and placing it in its technological, economic and social context
- Modelling a propagation phenomenon on the basis of partial information
- Choose one or more models to meet a given objective
- Adjusting your speech to different people in the business world
- Developing language elements for crisis communication
- Present your results with rigour, precision, conciseness and honesty

Description of the skills acquired at the end of the course

This EI term contributes to the **acquisition** of several CentraleSupélec engineer competencies, including C1, C4, C6, C7, C8 and C9.

The integration capstone project will be a place for the **evaluation** of C1, C4, C7 and C8 competencies.

1SC2793 – Modeling, development, and management of a viral marketing camp

Instructors : **John Cagnol**
Department : **DOMINANTE - MATHÉMATIQUES, DATA SCIENCES**
Language of instruction : **ENGLISH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

In this challenge week, you will understand and model the viral propagation of a message on social networks.

You will work with Artefact (www.artefact.com), a digital marketing agency created in 1998 with more than 25 offices in 18 countries and headquartered in Paris.

You will help them maximize the impact of a marketing campaign by using mathematical models and you will program these models, mainly using Python.

Quarter number ST2

Prerequisites (in terms of CS courses)

Information Systems and Programming
Convergence, Integration, Probability
Partial Differential Equations (first part of the class)
Algorithms and complexity
Modeling

Syllabus

Your team of six individuals will work for the digital marketing agency Artefact. Artefact has just launched a campaign on social networks and the initial pieces of information are now available. Your mission will be to develop models and simulations to produce a set of recommendations to maximize the impact of the campaign. You will start by understanding the dynamics of viral broadcasting of information on the Internet in general and social networks, in particular. You will use the tools from the courses indicated as prerequisites to model the propagation and find its characteristic elements. You will also need to use common sense and inventiveness. You will propose a communication strategy based on the models you have developed. This strategy should boost the impact of the campaign.

Class components (lecture, labs, etc.)

Challenge week

Grading

Preliminary results will be required from the students.
A defense and a report will conclude this class.

Resources

CentraleSupélec professors
Client and industrial partner (Artifact)
Software (Python and associated libraries)

Learning outcomes covered on the course

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

- Model a propagation phenomenon.
- Choose the relevant model(s) for a given objective.
- Structure hypotheses and respond quantitatively.
- Discuss with the client the issues, needs, and ideas for reflection and analysis.
- Be customer-sensitive. Identify and analyze the needs, issues, and constraints of the stakeholders.
- Make decisions in an uncertain environment, manage the unexpected, and take risks.
- Assemble a broad, scientific and technical base within the framework of a transdisciplinary approach.
- Use the appropriate visual representation modes for your data and its analysis.
- Present your results with rigor, precision, and conciseness.

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.
C2 : Acquire and develop broad skills in a scientific or academic field and applied professional areas
C3 : Act, engage, innovate within a scientific and technological environment
C4 : Create value for companies and clients
C6 : Advance and innovate in the digital world
C7 : Strengthen the Art of Persuasion
C8 : Lead a team, manage a project
C9 : Think and act as an accountable ethical professional

As a reminder, these refer to the CentraleSupélec statement of objectives available at bit.ly/CS-eng

ST2 - 28 - MODELING OF STRATEGIC INTERACTIONS THROUGH GAMES

Dominante **: INFO&NUM (Computer and Digital)**

Langue d'enseignement **: French**

Campus où le cours est proposé **: Paris-Saclay**

Engineering problem

Artificial intelligence is booming, bringing innovation (in all senses of the word) and a source of actual, solid and potential growth. Since the beginnings of AI, games have been used as "showcases" of scientific and technological advances in this field, such as, for example, A. Samuel's checkers game in 1952, Deep Blue for chess in 1997, Watson for Jeopardy in 2011 or more recently, in 2016, AlphaGo for the game of Go. Computerized games are suitable environments because they are simplified to test AI methods before applying them to other fields. Typically, today, many platforms allowing the development of artificial agents and their tests on strategic games are made available by players whose core business is not gaming.

In this challenge term, we propose to study the techniques of modelling (discrete low state models and graphs of states, variables, and constraints) and algorithmic resolution of games, considered in general as representative of the problems treated by the techniques of Artificial Intelligence and which implement the paradigm of modelling/inferring/learning, and to apply them to real problems of modelling strategic interactions between agents.

A game is a universe in which each agent (player) has a set of possible actions determined by the game's rules and acts according to its goal of winning but also in reaction to the actions of other agents (players). It is, therefore, a question of modelling rational agents interacting with other agents and/or with their environment, each pursuing a goal of its own. Game theory is a set of mathematical and computational tools to model, analyze and simulate this type of strategic interactions. Applications will be discussed (resource sharing games, auctions, programming a simple player AI, etc.). Game theory is concerned with the optimal choice that an agent must make, anticipating the possible decisions of other agents, which are themselves dictated by the objectives of these other agents. It was initially motivated by economic questions, but it now has many practical applications beyond economics. First and foremost, it has its place in the field of games of reflection, board games, and card games with one or more players. In addition to strategic games, game theory has also mainly been motivated by questions of an economic nature. It now has many practical applications: modelling competitive relationships between companies and strategic management, especially in oligopoly situations, understanding voting in political science, evolution and survival in biology, or the study of the coordination of the electrical charge of a fleet of vehicles.

The relationship between games and Artificial Intelligence is, therefore, twofold: on the one hand, the foundations of game theory provide strategies for solving Artificial Intelligence problems, and on the other hand, the modelling and solving of reasonably complex games require the implementation of Artificial Intelligence techniques.

At the crossroads of modelling and solving techniques in AI and those used in game theory, this thematic sequence aims to address these two fields' main concepts and implement them in concrete cases of modelling strategic interactions between agents provided by industrial partners.

Advised prerequisites.

The course of algorithmic and complexity common to all during this sequence

Context and issue modules: These modules, with conferences involving different actors (academic and industrial) of this field, will allow to discover the perimeter of this topic under the scientific, technological and economic angles; in particular:

- Game theory and social choice theory;
- Game theory in economics: from Nash equilibrium to the Nobel prizes;
- Application of game theory in computer science: artificial intelligence, Go game, stable marriage problem;
- Game theory and cooperation.

Specific course (40 HEE) : Computational approach to games

Brief description: Game theory is the formal study of the interaction between rational systems or agents defined by the goals they seek to achieve and by the strategic options available to them to achieve them, strategies that may eventually be interdependent (i.e., situations in which the fate of each participant depends not only on the decisions he makes but also on the decisions made by the other participants). In this course, we will focus on the computational approach to games, which is based on computer models of game situations (state and graph-based models, constraint-based models, etc.) and aims to automate the search for strategies and to analyze their performance (optimality). This course will cover the theory and practice of finding optimal and satisfying solutions for multi-player combinatorial games, such as popular games like Soduku, Sokoban, Othello, and Checkers... It will include the following points: relevant information representation, intelligent (i.e., satisfying, near-optimal, or optimal) decision making, modeling of action sequences, consideration of payoffs and information structure and experience capitalization, aggregation of conflicting preferences, algorithms for traversing combinatorial game spaces.

Challenge week n°1: Adversarial games for software design

- Associated partner: CEA

- Location: Paris-Saclay campus

- Short description: Computer systems open to their environment (networks, web, sensors, users) evolve independently and concurrently. In terms of game theory, specifying a program is equivalent to characterizing a game whose parts consist of infinite sequences of interactions between two players, the system and the environment; and verifying or synthesizing a program is equivalent to computing a winning strategy according to all or part of the game defined by the specification. Depending on the systems modeled and the objectives, different families of games (accessibility, parity, Büchi), defined in terms of automata theories, are brought into play.

Challenge week n°2: Strategic games for the economy

- Associated partner: Consulting firm BCG

- Location: Paris-Saclay campus

- Short description: Game theory is a standard tool for analyzing competition between firms in oligopoly situations, auction mechanisms, ... By modeling the actors as rational agents, game theory allows to model the different possible scenarios and to help in strategic decision making.

Challenge week n°3: Congestion games for transportation

- Associated partner: IRT SystemX, chaire Anthropolis, EPAPS

- Location: Paris-Saclay campus

Brief description: Transport systems induce strategic interactions between users. Individual strategies (choice of mode of transport, departure time, route, etc.) are likely to create congestion that runs counter to the collective interest. The price of non-coordination is measured by the loss of welfare due to the sub-optimality of aggregating individual behaviour. It can be improved by network management policies (pricing, road opening or closing).

Challenge week n°4: Evolutionary games

Associated partner: Genopole actor

Location: Paris-Saclay campus

Brief description: Evolutionary games are the declination of game theory for the study of the evolution of populations. Individuals meet and reproduce according to certain rules related to their characteristics (phenotype, gene, ...). According to Darwin's theory of natural selection, the gain is expressed in terms of fitness. Evolutionary algorithms are bio-inspired algorithms that evolve a population of candidate solutions, with selection and mutation mechanisms defined from an evaluation function (fitness).

1SC2810 – Computational approach to games

Instructors : **Pascale Le Gall**
Department : **DÉPARTEMENT INFORMATIQUE**
Language of instruction : **FRENCH**
Type of course : **Specific Course**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **19,50**

Description

Game theory is the formal study of the interaction between rational systems or agents defined by the goals they seek to achieve and by the strategic options available to them to achieve them, strategies that may eventually be interdependent (i.e., situations in which the fate of each participant depends not only on the decisions he makes but also on the decisions made by the other participants). In this course, we will focus on the computational approach to games, which is based on computer models of game situations (state and graph-based models, constraint-based models, etc.) and aims to automate the search for strategies and to analyze their performance (optimality). This course will cover the theory and practice of finding optimal and satisfying solutions for multi-player combinatorial games, such as popular games like Soduku, Sokoban, Othello, and Checkers... It will include the following points: relevant information representation, intelligent (i.e., satisfying, near-optimal, or optimal) decision making, modelling of action sequences, consideration of payoffs and information structure and experience capitalization, aggregation of conflicting preferences, algorithms for traversing combinatorial game spaces.

Quarter number ST2

Prerequisites (in terms of CS courses)

The course of algorithmic and complexity common to all during this sequence

Syllabus

Game theory

Terminology (game, payment, strategies, etc.), Modeling and different representations of a game (strategic form - extensive form), application domains: economics, pricing, auctioning, routing, etc.

Game in normal (or strategic) form: Dominated, cautious strategies, social welfare, Pareto Optimum. Representative examples: Prisoner's dilemma, Battle of sexes, Beauty contest, Cooperative games. Pure and mixed strategies, Nash equilibria. Competitive games, repeated games. Bayesian games.

Games in extensive form: definition, modeling (game tree), with perfect or imperfect information, with hazard, strategy selection, backward induction, subgame perfect equilibrium, equivalent representation in strategic form

Sequential games for 2 players: theoretical study, practical resolution and search for a winning strategy. This part will be illustrated by typical examples of combinatorial games such as the Nim game. Algorithms for strategies by adversarial (minmax, alphabeta) or approximate method (Monte Carlo, Algorithm A*...)

Games with incomplete information: Bayesian games and equilibria.

Puzzle games (Soduku, Nongram,...) : introduction, modeling using constraints - Algorithms for solving constraint satisfaction problems (propagation, arc consistency)

Class components (lecture, labs, etc.)

Sessions organized into lectures, tutorials and practical works

Grading

compulsory assessment: 1 or 2 practical works (Programming exercices in Python)
1h30 written exam, with documents.
The written exam and the compulsory assessment account for 60% and 40% of the final grade respectively

Course support, bibliography

Course slides - Handout - Handout - Topics and answers for tutorials

Resources

Personal labtop

1SC2891 – Adversarial games for software design

Instructors : **Marc Aiguier**
Department : **DOMINANTE - INFORMATIQUE ET NUMÉRIQUE**
Language of instruction : **FRENCH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

During this week of integration teaching will be addressed the problem of testing software and cyber-physical systems (embedded systems,analog-digital ...). It will be proposed an exploration of the links that can be made between the test based on models and the game theory, specifically the theory of adversarial games. The goal is to be able to exploit game theory concepts and results as part of the test.

Quarter number ST2

Prerequisites (in terms of CS courses)

Have taken courses in algorithmic and complexity and modeling.

Syllabus

Conformance testing consists of verifying the conformity of an implementation with respect to its specification.

In conformance testing, both implementation and specification are defined using the formalism of Input Output Symbolic Transition System (IOSTS).

We can then systematically re-express IOSTS as two-player games with perfect information. Indeed, we can consider that the 2 players are respectively the tester and the system under testing, the shots played by these 2 players being: for the tester the inputs, and for the system the outputs.

The objective of this EI is to be able to implement a test tool based on the theory of the adversarial games, and to apply this tooling on a system under testing (which can be a small real program or that simulates a physical system). The 25 students will then be divided into 3 groups of 8 to 9 students. One group will be in charge of describing and implementing the system under test representing a concrete case, while a second group will describe the specification of the system. Finally, the 3rd group will be in charge of implementing algorithms to generate tests from techniques from adversarial games to ensure the conformity of the implementation against its specification.
At the end of the week, the whole will be integrated to make it possible to check the conformity of the concrete case with respect to its specification, and this by means of the tooling developed by the 3rd group.

Grading

The afternoon of Friday (the last day of the EI) an evaluation will be made by a presentation of each group in front of the entire promotion having followed this thematic sequence.

Resources

- Teaching team: Marc Aiguier, Erwan Mahé and Arnault Lapître (CEA-List)
- Size of the classes: maximum 25 students
- Software tools and number of licenses required: python language and Diversity software developed by CEA that students will install on their personal machine.

Learning outcomes covered on the course

Being able to model a problem for a computer solution, and knowing how to check its behavior by conformance testing techniques by means of results from the theory of adversarial games.

1SC2892 – Strategic Games for the Economy

Instructors : **Mehdi SENOUCI**
Department : **DOMINANTE - INFORMATIQUE ET NUMÉRIQUE**
Language of instruction : **FRANCAIS**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

This Challenge Week involves treating a strategic case in groups of 6 students, in collaboration with the consulting firm BCG which shall propose a case study similar to the ones that the BCG treats day-to-day. Students will be asked to conduct an investigation and make strategic recommendations to a certain "client" organization. The final defense will be held in front of BCG members. The subject will be presented on the first day of the Challenge Week.

Quarter number ST2

Prerequisites (in terms of CS courses) None.

Class components (lecture, labs, etc.) Team work.

Grading Final presentation by each group. Individual grade.

Learning outcomes covered on the course

Shall depend on the case chosen by the BCG.

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
C3.4 Take decisions in an environment that may not be fully transparent, embracing the unexpected and calculating risk.
C4.1 Think in client terms, identify and analyse customer needs, the constraints of other stakeholders including societal challenges.
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
C8.1 Work collaboratively in a team.

1SC2893 – Congestion Games for Transportation

Instructors : **Pascale Le Gall**
Department : **DOMINANTE - INFORMATIQUE ET NUMÉRIQUE**
Language of instruction : **FRENCH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

This integration course aims to address the challenges of modelling and simulating transport systems in relation to the individual choices expressed by users with regard to transportation modes (public transportation, personal vehicles). Users are in a position to share resources (road, public transport) so that their choice and gain in terms of transportation time or price are determined by the number of other users and their choices. In some configurations, users make individual choices, which lead to congestion situations, which are not desirable for the general interest. This observation characterizes the so-called congestion games, for which individual and collective interests are difficult to reconcile.

In this context, policy makers aim to plan public transport systems and land-use planning with a view to optimising the balance between the cost of public infrastructure and the balances resulting from individual user choices.

Quarter number ST2

Prerequisites (in terms of CS courses) none

Grading

The evaluation will be based on an oral presentation and a written report (each accounting for half)

Course support, bibliography

Document will be given during the course

Resources

Integration education will be developed through a special case study, for example, that of the Moulon district, including the Centrale-Supélec Gif campus.

Partners
- AnthroPOLIS chair (https://www.chaire-anthropolis.fr/) of the IRT SystemX
- EPA Paris-Saclay (EPAPS https://epa-paris-saclay.fr/)

1SC2894 – Evolutionary Games

Instructors : **Paolo Ballarini**
Department : **DOMINANTE - INFORMATIQUE ET NUMÉRIQUE**
Language of instruction : **FRENCH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

The theory of evolutionary games is the application of game theory to the study of the evolution of populations in biology and more generally to the study of biological phenomena with applications in many different fields including sociology, anthropology and economics. Evolutionary game theory is based on Darwinian evolution and comprises three main stages: competition (play), natural selection (replicator dynamics) and heredity.
In this context we are interested in genetic algorithms (which are part of evolutionary algorithms) deal with optimization problems and search parameters using bio-inspired operators such as mutation, crossing and selection.

Quarter number ST2

Prerequisites (in terms of CS courses)

Having attended the ST2 course "Theorie des jeux"

Syllabus

The subject of this EI aims to apply evolutionary algorithms to a bioinformatics problem. The project consists in 1) designing the evolutionary operators; 2) parameterizing the designed operators bearing in mind that several parameters have to be finely tuned to obtain good results and that there is no methodology for this adjustment which must be carried out according to the data and the objective to to reach; 3) to combine them through the execution of an (evolutionary) game in order to obtain a solution approaching as much as possible the fixed objective, knowing that the objective is not necessarily attainable. As a consequence, several parameters for several operators must also be tested in order to improve the proposed solution. For example, the question: "What happens if you re-inject evolution history into operators?" Requires many executions to compare trends.

Class components (lecture, labs, etc.)

Students must be able to organize themselves into working groups in order to segment the work to be done. Two approaches are possible: collaboration or competition. A third way would be to combine the approaches, either at the same time or in different times during the project. What is the capacity of the group to organize itself, to make leaders emerge, to accept its emergence? What is the ability of leaders to bring the group to the desired goal?

Grading

The evaluation consists of a seminar session where each student's group is going to present the project done

Resources

Development and analysis of genetic algorithms baased optimisation framework through the Python programming language.

Description of the skills acquired at the end of the course

Students will have acquired basic notions for the conception, implantation and solution of an optimization problem trough the methodology of genetic (evolutionary) algorithms.

SCIENCE AND ENGINEERING CHALLENGE N°4 COURSES

ST4 - 41 - SYSTEMS MONITORING AND PROGNOSTICS FOR RISK MANAGEMENT

Major: : **GSI (Grands Systèmes en Interaction)**
Langue d'enseignement **: English**

Campus où le cours est proposé **: Paris-Saclay**

Engineer related topic

Today, complex industrial systems are all integrated into risk management processes. These processes aim to prevent serious failures, to limit their effects, and to optimize protection measures or return to service procedures. They encompass fields of expertise that are both numerous and varied, such as applied statistics, management, modeling, simulation, decision support, etc. The general objective of this thematic sequence is to show how specific areas related to information processing (Applied statistics and Signal processing) can be used to contribute to risk management.

Let us take the example of railway, land or air transport systems. The infrastructures, vehicles and devices welcoming users are equipped with a large number of sensors that continuously collect data relating to their state of health. The processing of this monitoring data collected online makes it possible to detect the aging or malfunction of certain components and to update the prognostics of breakdowns or accidents. If problems are detected early enough, we are able to anticipate and adapt maintenance plans and operational modes. We will then speak about predictive maintenance. If the problems are detected too late, we will be more likely to manage a crisis situation and reduce its effects. We will then speak about resilience.

In order to optimize predictive maintenance or resilience strategies upstream, we will use so-called "historical" data collected by the same types of sensors in the past or from additional studies (on similar systems, in the laboratory, etc.). These data will be used to build models and calculate performance indicators such as maintenance costs or return to service times after an accident.

These "online" detection/prognostics and upstream optimization approaches are applicable to other sectors such as manufacturing industry, energy production and distribution, extraction of petroleum resources, etc. It is all the more important in sectors activity requiring a high level of safety, such as nuclear or aeronautics.

Two fundamental questions are addressed in this ST:

- What are the benefits, both economic and in terms of safety, that can be obtained by optimizing predictive maintenance and the resilience of industrial systems and infrastructures?
- What steps need to be considered to establish relevant predictive maintenance and resilience?

Prerequisite Main statistics and probability courses.

Introductory period: this sequence aims to give a vision of the theme from several angles:

- Introductory lectures on the issue of resilience, risk analysis and predictive maintenance and the associated economic issues
- Highlighting interest in advanced methods for maintenance, risk analysis, diagnosis
- Presentation related to the social, economic and geopolitical environment, in the context of the industry 4.0

Specific course (60 HEE): **Systems monitoring and prognostics for risk management**

Brief description: Industrial systems monitoring, prognosis and decision-making encompass several areas of expertise, from data analysis to management, including modeling and decision support. The content of this course is designed to be integrated into the thematic sequence: "Information processing for the resilience of systems and infrastructures" and to meet the challenges proposed by industrial partners during the integration week.

The general objective of the course is to show how statistical and data- driven approaches (probabilistic modeling, parametric estimation, hypothesis tests, classification, machine learning, stochastic processes) can contribute to

the monitoring of systems, to the prognosis of their failure and decision support for maintenance or risk management in the broad sense.

The first focus is to estimate the probability that a technical system will not fulfill its main function. We present a set of methods which allows:

- to predict the instant of failure for an isolated element, or a set of interconnected elements (called a system),
- to predict online the evolution of a degradation phenomenon based on monitoring data.

The next focus is how the processing of available system health information can help the decision-maker minimizing the delay before resumption of service and the effects of a failure. We present a set of methods which allow:

- to diagnose a failure,
- to evaluate the performance of a maintenance strategy
- to make a decision under uncertainty.

based on historical data and online monitoring data.

Challenge week n°1: Algorithms for monitoring and decision of the state of health of aircraft engines. Application to the diagnosis of the oil circuit of a turbojet.

In partnership with: Safran

Location: Paris-Saclay campus

Brief description: The availability and safety of aircraft have been at the heart of air transport since their creation. Failures, particularly in flight, may result in the aircraft being diverted to an airport other than the destination or delayed on arrival. They can also significantly degrade the engine. The extra costs generated can be significant for the company or the manufacturer. In collaboration with Safran, this integration course focuses on the monitoring of the state of health of aircraft engines by limiting the study, because of the complexity of the general problem, in the case of the oil circuit of a turbojet. The oil circuit plays a vital role in the lubrication of the engine bearings of an aircraft. Several failure modes can lead to a degradation of the lubrication efficiency inducing the damage of the bearing and then the engine and subsequently a stopping of the engine in flight. This has important consequences in economic terms: availability of the engine or repair if the engine is repairable.

- Failures can occur for example due to leaks or coking (deposits on pipes or sprinklers). One of the paths explored for detecting a failure of this system is to monitor a number of circuit parameters such as pressure or temperature.
- In this case study, the goal is to be able to detect a drift. The direct use of the pressure is insufficient due to the dispersions of the flight scenarios.
- The question of finding the influencing parameters on the oil pressure become primordial by means for example of a statistical modeling. Subsequently, algorithms need to be design to follow-up and help the decision process.
-

Challenge week n°2: Flood risk management for an electricity production system

In partnership with: EDF R&D

Location: Paris-Saclay campus

Brief description:

The operator of electricity production facilities EDF's mission is to make the best use of its system, over time, in order to produce the electricity required in its load plan as profitably as possible and in complete safety.

One of the major challenges of risk management in this sector of activity is the forecasting and anticipation of the effects of natural disasters, and more generally, rare events having an impact on the proper functioning of infrastructures. Optimal risk management involves predicting hazards, that is to say initiating events likely to create dysfunctions, analyzing their consequences and implementing barriers to mitigate their effects.

The objective of this project is to reproduce the optimization of a risk management approach on a use case. This involves dimensioning the height of a dike which constitutes a protective barrier against the risk of flooding for a nuclear power plant located along a river.

The risk analysis is carried out on the basis of historical flood data and a physical flow model making it possible to calculate the height of the overflow. Decision-making regarding the height of the dike is optimized from a cost model taking into account investment costs, maintenance costs, and costs in the event of flooding.

Challenge week n°3: Data driven approaches to help to default detection and diagnosis.

In partnership with: EDF

Location: Paris-Saclay campus

Brief description: Supporting fault detection and diagnosis is a key point in the context of after-sales safety and customer satisfaction for Stellantis. In this context, this project aims to evaluate different data-driven approaches to assist monitoring and diagnostic procedures in garages.

The objective of this project, based on a set of simulated and partially labeled data (time series), is to implement digital solutions making it possible to detect the abnormality of situations, to classify known defects and to notify and group unknown defects while minimizing the need for technical expertise.

Challenge week n°4: Data-driven reliability estimation and optimal operation planning for health care equipment.

In partnership with: GE health care

Location: Paris-Saclay campus

Brief description:

Health care equipment in general has high reliability requirements: its failure might directly endanger the lives of patients. At the same time, health care equipment also has high availability requirements: the hospitals in general could not afford too-long downtime as they have to keep serving patients. Understanding the reliability of health care equipment is, thus, an important topic in medical care industries.

In this project, we work with GE Healthcare (GE HC), one of the leading supplier to health care equipment globally. GE HC has to satisfy the high reliability and availability requirements for their products. For this, they have to maintain a large-scale aftersales(service) supply chain supporting over one million systems installed globally in the world. More than 400,000 spare part references, including~10,000 repairable parts are potentially necessary to maintain the installed based (IB). How to effectively manage so many products, while satisfying the high reliability and availability requirements, is, thus, a very challenging problem. At the same time, during the product design, development, and, more importantly, the operation phases, there are a large number of data available. Although these data might be noisy and contain large degree of missing information and uncertainty, they are valuable sources that could provide some insights to the reliability of the products, which could be further used to improve the efficiency of the operation of the after-sale supply chain.

The aim of this project is, then, to provide tools and processes to leverage the reliability information from the data and to enrich decision making process in the operations of the after-sale supply chain. In this project, you will be able to:

- Work with the real dataset provided by GE HC;
- Develop data-driven reliability models for health care equipment, on both the component and system level;
- Experience how to deal with the “imperfectness” of a practical dataset;
- Experience how to improve a current process with the help of data analytics on the reliability data.

1SC4110 – Systems monitoring, prognosis and risk analysis

Instructors : **Anne BARROS**
Department : **DÉPARTEMENT GÉNIE INDUSTRIEL ET OPÉRATIONS**
Language of instruction : **ENGLISH**
Type of course : **Specific course**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **60**
On-site hours (HPE) : **30,00**

Description

Industrial systems monitoring, prognosis and decision-making encompass several areas of expertise, from data analysis to management, including modeling and decision support. The content of this course is designed to be integrated into a thematic sequence dedicated to information treatment for industrial systems monitoring and to meet the challenges proposed by industrial partners during the integration week.

The general objective of the course is to show how statistical and data-driven approaches (probabilistic modeling, parametric estimation, hypothesis tests, classification, machine learning, stochastic processes) can contribute to the monitoring of systems, to the prognosis of their failure and decision support for availability or risk management in the broad sense.

The first focus is to estimate the probability that a technical system will not fulfill its main function. We present a set of methods which allows:

- to predict the instant of failure for an isolated element, or a set of interconnected elements (called a system),
- to predict online the evolution of a degradation phenomenon based on monitoring data.

The next focus is how the processing of available system health information can help the decision-maker minimizing the delay before resumption of service and the effects of a failure. We present a set of methods which allow:

- to evaluate the availability of a system,
- to diagnose a failure,
- to make a decision under uncertainty.

based on historical data and online monitoring data.

Quarter number ST4

Prerequisites (in terms of CS courses) Basic knowledge in probability, statistic and modélisation

Syllabus

The course is organized around 6 chapters, the proportion of time dedicated to every chapter being adapted every year according to the industry challenges.

1. Lifetime models (Chapter 1): This chapter is a direct application of the course "Data analytics" . Classical data and statistical analysis are applied to data sets containing failure times. In addition, specific censoring problems related to failure time analysis are presented. At last, some metrics very used in decision under uncertainty for the reliability, the availability and the risk management of technical systems are presented.
2. System analysis (Chapter 2): The goal is to define performance metrics at the system level for decision under uncertainty, when several items are put altogether.

3. Prognostics and health management (Chapter 3): This chapter is to be linked to the course "Signal processing". Signals related to vibrations, temperature, pressure, etc, are considered as "health indicators". They are used to fit and to update degradation models in order to make on-line failure prognostics.
4. Maintenance assessment (Chapter 4): the objective is to model the degradation of a component / system and the impact of a monitoring / inspection / maintenance strategy on its availability or on its time to return to service.
5. Fault diagnosis (Chapter 5): This chapter is to be linked to the courses "Signal processing" and "Data analytics". Results and tools coming from statistics are combined with signal processing concepts to develop different methods related to the diagnosis of the health condition of an item.
6. Decision analysis for risk (Chapter 6):This chapter is specific to this course and will be useful to all challenges to deal with decision problems under uncertainties in the strict framework of the challenge or to propose solutions and inputs beyond what is strictly asked by the industry partner.

For every chapter, we propose only a selection of existing methods and theoretical concepts. All the chapters do not cover all the aspects of monitoring, pronostic and decision making. However they constitute a good basis to start with and to develop solutions related to the industrial challenges. References to the challenges will be done all over the lectures.

Class components (lecture, labs, etc.)

Lectures and tutorials in equal proportion.
Possibility of progressing to an inverted class.

Grading

Final written exam of 1h30.

Course support, bibliography

Polycopié de cours, Recueil de transparents, Video, Textbook Website Companion
Bibliographie:

- Marvin Rausand, Anne Barros, Arnljolt Hoyland,"System Reliability Theory", Models, Statistical Methods and Applications Third Edition, Wiley, 2020.
- Zio E. “An introduction to the basics of reliability and risk analysis”. World Scientific, 2007.
- Kroger W. and Zio E. “Vulnerable Systems”. Springer, 2013.
- Blanke, M., Kinnaert, M., Lunze, J., and Staroswiecki, M. (2015). Diagnosis and Fault-Tolerant Control. Springer Berlin Heidelberg.
- Byington,C.,Roemer,M.,andGalie,T.(2002).Prognostic enhancements to diagnostic systems for improved condition- based maintenance. In IEEE Aerospace Conference Proceedings.
- Zio E., “Computational Methods for Reliability and Risk Analysis”, World Scientific Publishing, 2009.
- Baraldi P., Cadini F. and E. Zio, “Basics of Reliability and Risk Analysis: Worked Out Problems and Solutions”, World Scientific Publishing, 2011.
- Shapiro, Alexander, Darinka Dentcheva, and Andrzej Ruszczyński. Lectures on stochastic programming: modeling and theory. Society for Industrial and Applied Mathematics, 2009.
- Powell, Warren B. "A unified framework for optimization under uncertainty." In Optimization Challenges in Complex, Networked and Risky Systems, pp. 45-83. INFORMS, 2016

Resources

- Teaching team: Anne Barros, Yiping Fang
- Tools: Python/Matlab

Learning outcomes covered on the course

At the end of this course, the student should be able to:

- Have a general knowledge of fundamental concepts involving diagnosis, prognosis and decision support under uncertainty (typically for availability maximisation or risk reduction)
- Understand the principles of useful data analysis techniques to support reliability and risk analyzes.
- Understand the basic methods of PHM (Prognosis and Health Management).
- Understand basic probabilistic modeling methods to assess the availability and the level of resilience of a system.
- Understand the principles of statistical and data-based approaches for diagnosing the state of a system.
- Use computer tools and software (Matlab, for example) to facilitate the application of theoretical methods.

- Apply theoretical methods to support monitoring, prevention of failures and associated risks for real engineering systems.

Description of the skills acquired at the end of the course

- Understand basic concepts for monitoring systems, predicting their failure and making decisions under uncertainty. It corresponds to milestone C1.1.
- Know the major families of statistical and data-driven approaches that optimize decisions relating to the diagnosis and anticipation of failures in an industrial system. It corresponds to milestone C1.5 (jalon 2).
- Know how to apply theoretical methodological frameworks to the resolution of a real problem. It corresponds to milestone C1.2 (jalons 1 et 2).
- Know how to implement these approaches on simple cases with computer tools (Matlab, Python for example). It corresponds to milestone C1.3 (jalons 1B, 2B).

1SC4191 – Algorithms for monitoring and decision of the state of health of aircraft engines. Application to the diagnosis of the oil circuit of a turbojet.

Instructors : **Sorin Olaru**
Department : **DOMINANTE - GRANDS SYSTÈMES EN INTERACTION**
Language of instruction : **ENGLISH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

The availability and safety of aircraft have been at the heart of air transport since their creation. Failures, particularly in flight, may result in the aircraft being diverted to an airport other than the destination or delayed on arrival. They can also significantly degrade the engine. The extra costs generated can be significant for the company or the manufacturer. In collaboration with Safran, this integration course focuses on the monitoring of the state of health of aircraft engines by limiting the study, because of the complexity of the general problem, in the case of the oil circuit of a turbojet. The oil circuit plays a vital role in the lubrication of the engine bearings of an aircraft. Several failure modes can lead to a degradation of the lubrication efficiency inducing the damage of the bearing and then the engine and subsequently a stopping of the engine in flight. This has important consequences in economic terms: availability of the engine or repair if the engine is repairable.
Failures can occur for example due to leaks or coking (deposits on pipes or sprinklers). One of the paths explored for detecting a failure of this system is to monitor a number of circuit parameters such as pressure or temperature. In this case study, the goal is to be able to detect a drift. The direct use of the pressure is insufficient due to the dispersions of the flight scenarios.
The question of finding the influencing parameters on the oil pressure become primordial by means for example of a statistical modeling. Subsequently, algorithms need to be design to follow-up and help the decision process.

Quarter number ST4

Prerequisites (in terms of CS courses) Statistics and probability

Syllabus

- Economic context: importance of availability and resilience in the rail sector.
- Meaning of these concepts in this context. Implications for design and maintenance.
- The principles and tools of classification, decision maing and PHM ("Predictions & Health Management") and their application in the context.
- The contributions of digital transformation.
- Link to operational safety.
- Normative standards.
- Performance indicators.
- Concrete applications.
- Perspectives and challenges.
- Obstacles to adoption and support for change.
- Implications for the business and the actors in maintenance, design and operation.

Part 1: Introduction to concepts and issues (a participant from Safran).
Part 2: Implementation on a practical example (rolling stock, signaling or infrastructure).
Part 3 (group - one week): work of one or two groups of students on data provided by our industrial partner, Safran.

Class components (lecture, labs, etc.)

Project-based learning
Modalities of participation of the partner involved
- Participation of Saran speakers in the introductory session.
- Presence of an Safran expert in coaching mode during group work.

During this work, industrial data (possibly anonymized) will be provided to students. Some will be labelled, others not. Some will include historical information from the maintainers: types of defects or degradations identified, maintenance actions carried out), others will not.
Students will be asked to combine knowledge of physical systems and data processing algorithms to extract useful information from the raw data and make recommendations for use by maintainers.

Two modalities are envisaged:
- Either divide the tasks into small groups of students;
- Either give the same tasks to two or three groups that will work in parallel, in challenge mode.

Grading

Oral presentation and evaluation of the project along the week.
With respect to the competencies C4,6,7,8 , the evaluation will be done jointly with the industrial partners at regular meetings, by means of data challenges and during the final presentation.

Resources

1 room for 30 élèves, overhead projectr, partition by groups
Software : Matlab/Simulink (network licence – wifi preferably) on individual PCs for each student; Python, …

2 academic supervisiors + 1 expert from Safran
Involvement of Safran over the entire week

Learning outcomes covered on the course

At the end of this course the students will be able to:
- to understand the issue of resilience and predictive maintenance as well as the potential benefits of such an approach
- to analyse a complex system and develop the elements of reflection leading to a representation model (physical, statistical, etc.) of the phenomena whose identification is the subject of the study
- to conduct the modelling process with an appropriate choice of modelling assumptions and to understand the limits of the models
- apprehend and use machine learning algorithms to extract information useful for predictive maintenance from raw data
- conclude and decide on the relevance of the approach and on the performance of the algorithms evaluated

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
C.1.1: The aim is to understand and analyse a complex system and study the problem as a whole for decision-making where the economic and human dimensions are important
The cost and human impact aspects are important for decision-makers, who will have to convince them of the economic benefits of such a solution while maintaining a high level of security or even improving it depending on the project, and to convince users of the viability and reliability of the solutions envisaged.
C1.2: Use and develop appropriate models, choose the right modeling scale and relevant simplifying assumptions to address the problem
In all projects it will be necessary to recover a large volume of data from an industrial company and from different sources. This will raise the problem of data aggregation, assumptions for eliminating outliers and model(s) for selecting the appropriate scale and level of accuracy required.
C4: Ability to create value for your company and its customers
In this context, it will be a question of creating value for the customer by increasing availability time by assessing the risk of failure and optimizing maintenance phases (periodicity, critical equipment, etc.).
C6: Being comfortable and innovative in the digital world
C6.5 Use any type of data, structured or unstructured, including massive data.
This will involve processing massive data provided by the manufacturer. This data, exploited using algorithms to be developed, will provide information on the risks of failure. The use of data for diagnosis will require prior treatment to eliminate outliers.
C7: Collect relevant and reliable information to support an argument (e. g. to retrieve relevant data).
– C8 Lead a project, a team

1SC4192 – Flood risk management for an electricity production system

Instructors : **Sorin Olaru**
Department : **DOMINANTE - GRANDS SYSTÈMES EN INTERACTION**
Language of instruction : **ENGLISH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

The operator of electricity production facilities EDF's mission is to make the best use of its system, over time, in order to produce the electricity required in its load plan as profitably as possible and in complete safety.

One of the major challenges of risk management in this sector of activity is the forecasting and anticipation of the effects of natural disasters, and more generally, rare events having an impact on the proper functioning of infrastructures. Optimal risk management involves predicting hazards, that is to say initiating events likely to create dysfunctions, analyzing their consequences and implementing barriers to mitigate their effects.

The objective of this project is to reproduce the optimization of a risk management approach on a use case. This involves dimensioning the height of a dike which constitutes a protective barrier against the risk of flooding for a nuclear power plant located along a river.

The risk analysis is carried out on the basis of historical flood data and a physical flow model making it possible to calculate the height of the overflow. Decision-making regarding the height of the dike is optimized from a cost model taking into account investment costs, maintenance costs, and costs in the event of flooding

Quarter number ST4

Prerequisites (in terms of CS courses) 1SC4110 - System Monitoring, Pronostics and Risk Analysis

Syllabus

The project contains two main elements on which the study should be based:

• A physical description of the bank, the dike and the overflow phenomenon

• Incomplete flood data over a period of 30 years

The study is divided into three work-packages (WP):

• A first WP concerns the use of historical data to predict the possible level of the river over a period of 30 years. From the point of view of the engineer in charge of the study, it is necessary to manage the fact that the data are incomplete and to be able to assess the quality of the predictions, in particular for the occurrence of extreme and rare events (very high levels of floods).

• A second WP concerns the use of a physical model to size the dike by propagating the uncertainties on the parameters of the model and on the possible flood levels. From the perspective of the engineer in charge of the study, it is necessary to set up a Monte Carlo simulation procedure and assess its quality.

• A third WP concerns the use of a cost model. From the perspective of the engineer in charge of the study, it is necessary to provide reliable decision indicators (optimal height of the dike) with associated uncertainties.

Class components (lecture, labs, etc.)

Projet-based learning
· Part 1: Introduction to concepts and issues (an EDF speaker).
· Part 2: implementation of statistical methods on flood data and physical models and Monte Carlo simulation

Grading

Oral presentation and evaluation of the project along the week.
With respect to the competencies C4,6,7,8 , the evaluation will be done jointly with the industrial partners at regular meetings, by means of data challenges and during the final presentation.

Resources

1 room for 30 élèves, overhead projectr, partition by groups
Software : Matlab/Simulink (network licence – wifi preferably) on individual PCs for each student; Python, …

2 academic supervisiors + 1 expert from EDF
Involvement of EDF over the entire week

Learning outcomes covered on the course

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

• understand the issue of risk management and decision-making under uncertainty

• to analyze a complex system and develop the elements of reflection allowing to provide a representation model (physical, statistical ...) of the phenomena whose demonstration is the object of the study

• to carry out the modeling process with an appropriate choice of modeling assumptions and to understand the limits of the models

• to conclude and decide on the relevance of the approach and on the performance of the proposed modeling solutions

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

C.1.1: The aim is to understand and analyse a complex system and study the problem as a whole for decision-making where the economic and human dimensions are important.The cost and human impact aspects are important for decision-makers, who will have to convince them of the economic benefits of such a solution while maintaining a high level of security or even improving it depending on the project, and to convince users of the viability and reliability of the solutions envisaged.

C1.2: Use and develop appropriate models, choose the right modeling scale and relevant simplifying assumptions to address the problem

C4: Ability to create value for your company and its customers
In this context, it will be a question of creating value for the customer by optimizing security margins

C6: Being comfortable and innovative in the digital world

C6.5 Use any type of data, structured or unstructured, including massive data.

C7: Collect relevant and reliable information to support an argument (e. g. to retrieve relevant data).

1SC4194 – Data driven approaches to help to default detection and diagnosis

Instructors : **Anne BARROS**
Department : **DÉPARTEMENT GÉNIE INDUSTRIEL ET OPÉRATIONS**
Language of instruction : **ENGLISH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **60**
On-site hours (HPE) : **24,00**

Description

Supporting fault detection and diagnosis is a key point in the context of after-sales safety and customer satisfaction for Stellantis. In this context, this project aims to evaluate different data-driven approaches to assist monitoring and diagnostic procedures in garages.

The objective of this project, based on a set of simulated and partially labeled data (time series), is to implement digital solutions making it possible to detect the abnormality of situations, to classify known defects and to notify and group unknown defects while minimizing the need for technical expertise.

Quarter number ST4

Prerequisites (in terms of CS courses)

1SC4110 - System Monitoring, Pronostics and Risk Analysis

Syllabus

The project is based on a set of data (time series) simulated from a command control system (setpoint signal and signal for measuring the regulated quantity). The data is partially labeled: normal situation and different types of fault (eg actuator fault, sensor fault, etc.). The objective is to develop a detection system to recognize normal situations from abnormal situations. Once the detection has been carried out, a second classification system must make it possible to group together similar faults (diagnosis). One of the key elements is that not all defects are labeled and that a “dynamic” approach is required to group similar unlabeled defects. In this context, the use of an oracle to label a situation is possible but should be minimized.

Class components (lecture, labs, etc.)

Projet-based learning

- Part 1: Introduction to concepts and issues (an EDF speaker).
- Part 2: implementation of statistical methods simulates data
-

Grading

Oral presentation and evaluation of the project along the week

Ressources

1 room for 30 élèves, overhead projectr, partition by groups
Software : Matlab/Simulink (network licence – wifi preferably) on individual PCs for each student; Python, …

2 academic supervisiors + 1 expert from EDF
Involvement of EDF over the entire week

Learning outcomes covered on the course

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

- understand the issue of risk management and decision-making under uncertainty

- to analyze a complex system and develop the elements of reflection allowing to provide a representation model (physical, statistical ...) of the phenomena whose demonstration is the object of the study

- to carry out the modeling process with an appropriate choice of modeling assumptions and to understand the limits of the models

- to conclude and decide on the relevance of the approach and on the performance of the proposed modeling solutions

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

C.1.1: The aim is to understand and analyse a complex system and study the problem as a whole for decision-making where the economic and human dimensions are important.

The cost and human impact aspects are important for decision-makers, who will have to convince them of the economic benefits of such a solution while maintaining a high level of security or even improving it depending on the project, and to convince users of the viability and reliability of the solutions envisaged.

C1.2: Use and develop appropriate models, choose the right modeling scale and relevant simplifying assumptions to address the problem

C4: Ability to create value for your company and its customers

In this context, it will be a question of creating value for the customer by optimizing security margins

C6: Being comfortable and innovative in the digital world

C6.5 Use any type of data, structured or unstructured, including massive data.

C7: Collect relevant and reliable information to support an argument (e. g. to retrieve relevant data).

1SC4195 – Data-driven reliability estimation and optimal operation planning for health care equipment

Instructors : **Sorin Olaru**
Department : **DÉPARTEMENT GÉNIE INDUSTRIEL ET OPÉRATIONS**
Language of instruction : **ENGLISH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

Health care equipment in general has high reliability requirements: its failure might directly endanger the lives of patients. At the same time, health care equipment also has high availability requirements: the hospitals in general could not afford too-long downtime as they have to keep serving patients. Understanding the reliability of health care equipment is, thus, an important topic in medical care industries.

In this project, we work with GE Healthcare (GE HC), one of the leading suppliers to health care equipment globally. GE HC has to satisfy the high reliability and availability requirements for their products. For this, they have to maintain a large-scale aftersales(service) supply chain supporting over one million systems installed globally in the world. More than 400,000 spare part references, including~10,000 repairable parts are potentially necessary to maintain the installed based (IB). How to effectively manage so many products, while satisfying the high reliability and availability requirements, is, thus, a very challenging problem. At the same time, during the product design, development, and, more importantly, the operation phases, there are a large number of data available. Although these data might be noisy and contain large degree of missing information and uncertainty, they are valuable sources that could provide some insights to the reliability of the products, which could be further used to improve the efficiency of the operation of the after-sale supply chain.

Quarter number ST4

Prerequisites (in terms of CS courses) Statistics and probability

Syllabus

The project will apply tools and processes to leverage the reliability information from the data and to enrich decision making process in the operations of the after-sale supply chain. In this project, the students will be able to:
- Work with the real dataset provided by GE HC;
- Develop data-driven reliability models for health care equipment, on both the component and system level;
- Experience how to deal with the “imperfectness” of a practical dataset;
- Experience how to improve a current process with the help of data analytics on the reliability data.

Class components (lecture, labs, etc.)

Project-based learning

Modalities of participation of the partner involved
- Participation of speakers GE within the introductory session.
- Presence of an expert from GE in coaching mode during the week.

For the project, industrial data (possibly anonymized) will be provided to students. Some will be labelled, others not. Some will include historical information from the maintainers: types of defects or degradations identified,

maintenance actions carried out), others will not.
Students will be asked to combine knowledge of physical systems and data processing algorithms to extract useful information from the raw data and make recommendations for use by maintainers.

Two modalities are envisaged:

- Either divide the tasks into small groups of students;
- Either give the same tasks to two or three groups that will work in parallel, in challenge mode.

Grading
Oral presentation and evaluation of the project along the week.

With respect to the competencies C4,6,7,8 , the evaluation will be done jointly with the industrial partners at regular meetings, by means of data challenges and during the final presentation.

Course support, bibliography
References of the ST4 GSI lectures

Resources
1 room for 40 students, overhead project, partition by groups
Software : Matlab/Simulink (network licence – wifi preferably) on individual PCs for each student; Python, …
2 academic supervisiors + 1 expert from GE
Involvement of GE over the entire week when needed (upon request)

Learning outcomes covered on the course
At the end of this course the students will be able to:
- to understand the issue of resilience and predictive maintenance as well as the potential benefits of such an approach
- to analyse a complex system and develop the elements of reflection leading to a representation model (physical, statistical, etc.) of the phenomena whose identification is the subject of the study
- to conduct the modelling process with an appropriate choice of modelling assumptions and to understand the limits of the models
- apprehend and use machine learning algorithms to extract information useful for predictive maintenance from raw data
- conclude and decide on the relevance of the approach and on the performance of the algorithms evaluated

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
C.1.1: The aim is to understand and analyse a complex system and study the problem as a whole for decision-making where the economic and human dimensions are important.
The cost and human impact aspects are important for decision-makers, who will have to convince them of the economic benefits of such a solution while maintaining a high level of security or even improving it depending on the project, and to convince users of the viability and reliability of the solutions envisaged.
C1.2: Use and develop appropriate models, choose the right modeling scaleand relevant simplifying assumptions to address the problem
In all projects it will be necessary to recover a large volume of data from an industrial company and from different sources. This will raise the problem of data aggregation, assumptions for eliminating outliers and model(s) for selecting the appropriate scale and level of accuracy required.
C4: Ability to create value for your company and its customers
In this context, it will be a question of creating value for the customer by increasing availability time by assessing the risk of failure and optimizing maintenance phases (periodicity, critical equipment, etc.).
C6: Being comfortable and innovative in the digital world
C6.5 Use any type of data, structured or unstructured, including massive data.
This will involve processing massive data provided by the manufacturer.This data, exploited using algorithms to be developed, will provide information on the risks of failure. The use of data for diagnosis will require prior treatment to eliminate outliers.
C7: Collect relevant and reliable information to support an argument (e. g. to retrieve relevant data).
– C8 Lead a project, a team.

ST4 - 42 - BIG DATA & HEALTH : FROM DATA ACQUISITION TO DECISION MAKING

Dominante **: : : VSE (Living-Health Environment)**

Langue d'enseignement **: French**

Campus où le cours est proposé **: Paris-Saclay**

Engineering problem

Health, and more generally the field of living organisms, is undergoing a veritable technological revolution that is making it possible to acquire increasingly large amounts of data (signals, images, measurement results, etc.). For example, genomic data can now be used to explore the multi-scale activity of a cell in ever greater detail. Another example is medical imaging, which is one of the pillars of medicine, whether in conventional medicine and surgery or in the neurosciences. The "data revolution" is impacting all areas of life and we propose, within the framework of this thematic sequence, to explore the consequences in epidemiology, oncology and in the context of neurodegenerative diseases. This thematic sequence is resolutely positioned on the processing of biomedical data and offers an area for meetings and exchanges between doctors/biologists from various backgrounds and engineers. This thematic sequence offers a field of application where statistics and machine learning find all their meaning.

Adviced prerequisites None

Context and issue modules: This introduction to the thematic sequence will discuss the place of data in the health field and highlight the engineer's position in this context. Data collection, whether for large cohort studies or clinical trials, requires innovative equipment: on-site visits to one of our partners will be offered to enable you to understand this important aspect prior to any statistical study. The different integration lessons will also be presented by the partners.

Specific course (60 HEE) : Biology and Statistics

Brief description: The cell is a complex multi-scale system that biologists have been studying for several centuries. The development of new technologies now allows us to explore it and measure its activity more and more finely. The objective of the first part of the course is to present the various facets of the cell to better understand its global functioning. The technologies of measurement will also be approached.

The second part of the course presents the statistical methods widely used in the biomedical field. At the end of this part, the students will have a useful toolbox to answer the various questions raised by the analysis of biomedical data.

This course will be largely illustrated on medical applications in order to allow students to acquire the knowledge and vocabulary necessary to understand the applications proposed in IE (bases in biology, genomics, etc.), to understand the origin of the enormous volume of data related to medical applications. For this reason, about half of the overall volume of this course will be reserved for our physician/biologist partners.

Challenge week n°1: Sleep analysis by electroencephalogram

Associated partner: DREEM & Institut du Cerveau et de la moelle épinière (ICM)

Location: Paris-Saclay campus

Brief description. In the framework of this integration course, we propose to implement signal processing and machine learning methods to address neurological disease issues. In particular, we will be interested in the study of sleep disorders through the analysis of electroencephalogram (EEG). These disorders are generally early signs of neurological disease (such as Parkinson's disease), hence the importance of monitoring them. This is therefore

a problem of EEG signal processing and machine learning where we will try to produce reliable biological/medical knowledge from massive noisy and incomplete high dimensional data.

Course of action : The students involved in this project will be divided into sub-groups which will compete in a "challenge mode": The sub-groups will analyse the data through the different techniques and compete to produce the best model. The models will be evaluated in real time and a live ranking will be provided and visible to all. A collaborative platform will be used to share scores, results and scripts. As the data and the problem are provided by our external partners from DREEM and ICM, the students will have to meet them several times. Finally, they will have to present their results in front of all the actors of the project (all the students involved in the project, partners, supervisors).

Challenge week n°2: E3/E4N cohort data for the identification of major trends

Associated partner: INSERM/Gustave Roussy

Location: Paris-Saclay campus

Short description : In this integration course, we propose to implement statistical/machine learning methods to answer epidemiological problems. In particular, we will be interested in the data of the E3N/E4N cohort (Epidemiological Study of MGEN women), which concerns hundreds of thousands of women (https://www.e4n.fr). This is therefore a problem of statistical analysis of a "Big Data" dataset where we are trying to identify major trends at the population level from massive noisy and incomplete data.

- Process. The students involved in this project will be divided into sub-groups. The subgroups will analyse the data using the techniques of their choice. The data and the problem being provided by members of INSERM, the students will have to meet them several times. Finally, they will have to present their results to all the actors of the project (all the students involved in the project, partners, supervisors).

Challenge week n°3: Infectious diseases: The indoor environment project

Associated partner: Institut Pasteur

Location: Paris-Saclay campus

Brief description: The "Milieu Intérieur" project, coordinated by the Institut Pasteur, has been developed to better understand the diversity of immune reactions in the population with the broader aim of contributing to the development of precision medicine. In the framework of this project, a cohort of 1000 individuals was constituted and several large datasets were generated, including socio-demographic and clinical data, blood cell composition data, as well as gene expression data under different immune stimulation conditions for each individual. During this IR, we propose to analyse and cross-reference these data in order to identify factors that differentiate individuals in their responses to immune stimuli and eventually to explain and predict these responses. The objective will be to apply descriptive and predictive statistical analysis methods to extract relevant biological information from these data.

Procedure. The students involved in this integration course will be divided into subgroups. The subgroups will analyse the data using the different techniques discussed in class. As the data and the problem are provided by the Pateur Institute, the students will have to meet this partner several times. Finally, they will have to present their results to all the actors of the project (all the students involved in the project, the partner, the supervisors).

Challenge week n°5: Using innovative methods to predict health and disease in exposome studies

Associated partner: one of the institutes involved in the European ATLHETE project (https://athleteproject.eu)

Location: Paris-Saclay campus

Brief description. The exposome, described as "the totality of human environmental exposures from conception onwards", recognises that individuals are exposed simultaneously to a multitude of different environmental factors and takes a holistic approach to the discovery of etiological factors of disease. The main advantage of the exposome over traditional "one exposure-one disease" approaches is that it provides an unprecedented conceptual framework for the study of multiple environmental risks (urban, chemical, lifestyle, social) and their combined effects. The objective of this AR is to promote statistical, data science or other innovative quantitative approaches to study the effects of exposure indicators (exposome) on health. The dataset will include multiple health phenotypes (quantitative or qualitative), multiple exposures, -omics and additional non-exposure variables (e.g. potential confounders).

- Process. The students involved in this project will be divided into subgroups. As the data and the problem are provided by our partners in the European ATHLETE project (see https://athleteproject.eu/consortium), one of these

partners will participate in the supervision of the project. The students will have to meet him several times. Finally, they will have to present their results in front of all the actors of the project (all the students involved in the project, partners, supervisors).

Challenge week n°6 : Epidemiology & Biostatistics on a Hospital Health Data Warehouse

Associated partner: AP-HP (Assistance Publique - Hôpitaux de Paris)

Location: Paris-Saclay campus

Brief description: The Health Data Warehouse (EDS) of the Assistance Publique -Hôpitaux de Paris (AP-HP) integrates the administrative and medical data of more than 8 million patients hospitalised or consulted in one of its 39 institutions. This warehouse allows for the improvement of hospital activity management and the advancement of scientific research in the field of health by promoting the implementation of studies on real-life data, the setting up of clinical trials and the development of decision support algorithms. In this Integration Course, we propose that you discover the AP-HP's EDS and its specificities through the prism of epidemiological and biostatistical analysis. In particular, you will have the opportunity to process structured data (medico-economic data - diagnoses & procedures, demographic data, patient pathways and biological analyses) and unstructured data (medical reports), integrated into a synthetic database largely inspired by the structure of the EDS. You will have to answer two research questions (epidemiological surveillance study and analysis of predictive factors for lung cancer), while deciphering and correcting the biases inherent in routine clinical data.

Process. The students involved in this project will be divided into subgroups. The subgroups will analyse the data using the different techniques discussed in class. As the data and the problem are provided by the AP-HP, the students will have to meet several times with this partner. Finally, they will have to present their results in front of all the actors of the project (all the students involved in the project, partner, supervisors).

Challenge week n°7 : Diagnosis of liver cancer using imaging techniques-

Associated partner: Radiology Department, Hôpital Henri Mondor

Location: Paris-Saclay campus

Brief description: Liver cancer is the third leading cause of cancer deaths worldwide, and a growing public health problem. The two most common types of primary liver cancer are hepatocellular carcinoma (HCC) and intrahepatic cholangiocarcinoma (ICHC). A third type, hepato-cholangiocarcinoma (HCC-CCA), is a rare variant that can present as a mixture or coexistence of the first two types of cancer. While HCC can be reliably diagnosed on imaging in cases of known liver disease (cirrhosis), the diagnosis of CCA or CHC-CCA is often more difficult, with equivocal aspects on imaging. However, these types of cancer have completely different treatment strategies and prognoses, so it is essential to identify them correctly. The aim of this project is to differentiate between these three types of cancer on the basis of quantitative parameters reflecting tumor heterogeneity on contrast-enhanced magnetic resonance imaging (MRI).

Process. The students involved in this project will be divided into subgroups. The subgroups will analyse the data using the different techniques discussed in class. As the data and the problem are provided by radiologists of AP-HP, the students will have to meet several times with this partner. Finally, they will have to present their results in front of all the actors of the project (all the students involved in the project, partner, supervisors).

1SC4210 – Biology and statistics

Instructors : **Laurent Le Brusquet, Arthur Tenenhaus**
Department : **DOMINANTE - VIVANT, SANTÉ, ENVIRONNEMENT**
Language of instruction : **FRENCH**
Type of course : **Specific Course**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **60**
On-site hours (HPE) : **30,00**

Description

The cell is a complex multi-scale system that biologists have been studying for several centuries. The development of new technologies now makes it possible to explore it and measure its activity more and more finely. The objective of the first part of the course is to present the different facets of the cell to better understand its overall functioning. Measurement technologies will also be discussed.
The second part of the course presents the statistical methods widely used in the biomedical field. At the end of this section, students will have a useful toolbox to answer the various questions raised by the analysis of biomedical data.
This course will be widely illustrated on medical applications to enable students to acquire the knowledge and vocabulary necessary to understand the applications proposed during the EI (basics in biology, genomics, etc.), to understand the origin of the huge volume of data related to medical applications. For this reason, approximately one third of the total volume of this course will be reserved for our physician/biologist partners.

Quarter number ST4

Prerequisites (in terms of CS courses) Statistics and Learning

Syllabus

PART I: INTRODUCTION TO CELLULAR and MOLECULAR BIOLOGY (12h)
The cell is a complex multi-scale system that biologists have been studying for several centuries. The development of new technologies now makes it possible to explore it and measure its activity more and more finely. The objective of this module is therefore to present the different facets of the cell in order to better understand its overall functioning. Measurement technologies will also be discussed.

I.1. CELL BIOLOGY & MOLECULAR GENETICS

- General organization of the eukaryotic cell
- Nucleic acids (DNA and RNA)
- Proteins
- The cell cycle of the eukaryotic cell
- DNA replication in eukaryotes:
- The regulation of gene expression in eukaryotes
- Genetic engineering tools

I.2 GENOMIC

I.2.1. Structural genomics
- Definition of genomics - the rise of bioinformatics
- Inventory of genome sequencing
- Genome structure and organization
- Genome sequencing methods

I.2.2. Functional Genomics: Gene expression
- The transcriptome
- Transcriptional & epigenetic regulation

I.2.3 Data Integration

- Omics: interests in biology and difficulties in bioinformatics
- Post-analysis integration: supervised or unsupervised integration
- Pre-analysis integration: towards network inference
- Applications in basic research and personalized medicine

I.2.4. Conclusion & perspectives: evolution of the notion of gene & modifications of classical models of transcription regulation. Information provided by the single-cell genomic.
Each part of the course will be associated with practical work under R

PART II: BIOSTASTICS (12h)

At the end of Part II, students will have a useful toolbox to answer the various questions raised by the analysis of biological data.

- Univariate approach and multiple tests (Bonferonni, False Discovery Rate...) ;
- Linear model, ANOVA and mixed effects models.
- GLM (regression, logistic regression,...)
- Principale Component Analysis & Hierachical Clustering

PART III: DIRECTED WORK/TP (9h)

A large part of the concepts covered in the biostatistics section will be implemented in R.

Class components (lecture, labs, etc.)

5*3h lectures for the biology part.
6*3h lectures for the statistics part.
The presented methods will be assessed on real biomedical data with R.

Grading

written exam (1H30)

Resources

- Teaching team : Arthur Tenenhaus and Marie-Anne Debily (MCF Evry)
- Size of the TDs: 25 for the TDs with computer.
- Software : R

Learning outcomes covered on the course

Two main objectives:

1. Introduction to molecular and cellular biology
2. Biostatistics: to provide additional statistical information (useful for the analysis of bomb data) in addition to the "Statistics and Learning" course.

1SC4291 – Sleep analysis by EEG

Instructors : **Arthur Tenenhaus, Laurent Le Brusquet**
Department : **DOMINANTE - VIVANT, SANTÉ, ENVIRONNEMENT**
Language of instruction : **FRENCH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

Brief description. As part of this project, we propose to implement signal processing and machine learning methods to predict the different sleep phases from electroencephalogram (EEG) data. This is therefore an EEG signal processing and machine learning problem in which we will seek to build precise prediction models from large noisy massive data.

The students involved in this project will be divided into sub-groups which will be put in “competition in challenge mode”: The sub-groups will analyze the data through different techniques and will compete to produce the best model. Models will be evaluated in real time and a live ranking will be provided and visible to all. A collaborative platform for sharing scores, results and scripts will be used.

The data and the problem being provided by our DREEM partners, students will have to meet them several times.

Associated partner. DREEM
Location. Paris-Saclay Campus

Quarter number ST4

Prerequisites (in terms of CS courses)

Statistics and Learning Course
Signal Processing Course

Class components (lecture, labs, etc.)

The students involved in this integration teaching will be divided into sub-groups which will be put in "competition in challenge mode": The sub-groups will analyze the data through different techniques and will compete to produce the best model. Models will be evaluated in real time and a live ranking will be provided and visible to all. A collaborative platform for sharing scores, results and scripts will be used. The data and the problem being provided by our external partners of DREEM, the students will have to meet them several times. Finally, they will have to report their results to all the students involved in the project, partners and supervisors.

Grading

The final score will be built from the score obtained in the challenge and the score obtained at the final defense.

Learning outcomes covered on the course

Students will be able to define, understand, choose a machine learning method and implement it in line with the problem at hand

1SC4292 – Data from the E3N / E4N cohort for trending identification

Instructors : **Laurent Le Brusquet, Arthur Tenenhaus**
Department : **DOMINANTE - VIVANT, SANTÉ, ENVIRONNEMENT**
Language of instruction : **FRENCH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

As part of this integration teaching, we propose to implement statistical/machine learning methods to address epidemiological issues. In particular, we will focus on the data of the E3N/E4N cohort (Epidemiological Study of Women in the MGEN), which therefore concerns hundreds of thousands of women (https://www.e4n.fr). This is therefore a problem in the statistical analysis of a "Big Data" dataset in which we try to identify major population trends based on massive, noisy and incomplete data.

- Associated partner: INSERM

1. Location: Paris-Saclay Campus

Quarter number ST4

Prerequisites (in terms of CS courses) Statistics and Learning

Class components (lecture, labs, etc.)

The students involved in this project will be divided into sub-groups that will analyze the data using different techniques. As the data and the problem are provided by INSERM members, students will have to meet them several times. Finally, they will have to present their results to all the actors of the project (all the students involved in the project, partners, supervisors).

Grading

Oral defense and/or written report at the end of the integration course.

Course support, bibliography

The Elements of Statistical Learning: Data Mining, Inference, and Prediction. Second Edition. February 2009. Springer.
https://web.stanford.edu/~hastie/Papers/ESLII.pdf

Learning outcomes covered on the course

At the end of this course, students will be able to define, understand, choose a statistical/machine learning method and implement it in accordance with the problem at hand.

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.
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
C3.5 Put forward new tools with either continual progress or disruptive solutions as the goal
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.
C6.1 Identify and use the necessary software for one's work (including collaborative tools) and adapt digital responses according to the context.

1SC4293 – Data analysis for Biology : Leveraging omics data to unravel functional pathways

Instructors : **Laurent Le Brusquet, Arthur Tenenhaus**
Department : **DOMINANTE - VIVANT, SANTÉ, ENVIRONNEMENT**
Language of instruction : **FRENCH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

Description. This project, coordinated by the Institut Pasteur, was developed to better understand the diversity of immune reactions within the population with the broader aim of contributing to the development of precision medicine. As part of this project, a cohort of 1000 individuals was formed and several large datasets were generated, including socio-demographic and clinical data, blood cell composition data, as well as gene expression data in different immune stimulation conditions for each individual.
During this session, we suggest to analyze and this heterogeneous data in order to identify the factors that differentiate individuals in their responses to immune stimuli and possibly to explain and predict these reactions. The objective will be to apply descriptive and predictive statistical analysis methods in order to extract relevant biological information from these data.
Associate partner: Pasteur
Location: Paris-Saclay Campus

Quarter number ST4

Prerequisites (in terms of CS courses)

Statistics and Learning
Biology and Statistics

Class components (lecture, labs, etc.)

The data and the problem being provided by Pasteur, students will have to meet this partner several times. Finally, they will have to report their results to all the students involved in the project, partners and supervisors.

Grading

Oral defense at the end of the project

1SC4295 – Use of innovative methods to predict health and disease in exposome studies

Instructors : **Arthur Tenenhaus, Laurent Le Brusquet**
Department : **DOMINANTE - VIVANT, SANTÉ, ENVIRONNEMENT**
Language of instruction : **FRENCH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

Summary. The exposome, described as "the totality of human environmental exposures from conception onwards", recognizes that individuals are exposed simultaneously to a multitude of different environmental factors and takes a holistic approach to the discovery of etiological factors for disease. The exposome's main advantage over traditional 'one-exposure-one-disease' study approaches is that it provides an unprecedented conceptual framework for the study of multiple environmental hazards (urban, chemical, lifestyle, social) and their combined effects.

The objective of this EI is to promote innovative statistical, data science, or other quantitative approaches to studying the health effects of complex high-throughput measurement of exposure indicators (exposome). In this EI, you will be offered an opportunity to test your statistical methods of choice on a real case scenario exposome dataset and later exhibit their findings at the workshop. The dataset will include multiple health outcomes (continuous and categorical), multiple exposures, -omics and additional non-exposure variables (e.g., potential confounders).

Place. Campus Paris-Saclay

Link to ATLHETE project. https://athleteproject.eu

Quarter number ST4

Prerequisites (in terms of CS courses)

Statistics and Machine Learning
Biology and Statistics

Class components (lecture, labs, etc.)

The students involved in this project will be divided into sub-groups that will analyze the data using different techniques. As the data and the problem are provided by the ATHLETE partners (see https://athleteproject.eu/consortium), students will have to meet them several times. Finally, they will have to present their results to all the actors of the project (all the students involved in the project, partners, supervisors).

Grading

Report and oral defense

Resources

The data and the problem being provided by the ATHLETE Project, students will have to meet this partner several times. Finally, they will have to report their results to all the students involved in the project, partners and supervisors.

1SC4296 – Epidemiology & Biostatistics on a Hospital Health Database

Instructors : **Laurent Le Brusquet, Arthur Tenenhaus**
Department : **DOMINANTE - VIVANT, SANTÉ, ENVIRONNEMENT**
Language of instruction : **FRENCH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **25,00**

Description

partner : Assistance Publique - Hôpitaux de Paris.
The Health Data Warehouse (EDS) of the Assistance Publique - Hôpitaux de Paris (AP-HP) integrates the administrative and medical data of more than 8 million patients hospitalized or consulted in one of its 39 institutions. This warehouse allows to improve the management of hospital activity and to advance scientific research in the field of health by facilitating studies on real life data, the implementation of clinical trials and the development of decision support algorithms.
During this Integration Course, we propose to discover the AP-HP EDS and its specificities through the prism of epidemiological and biostatistical analysis. You will have the opportunity to process structured data (medico-economic data - diagnoses and procedures, demographic data, patient pathways and biological analyses) and unstructured data (medical reports), integrated into a synthetic database largely inspired by the structure of the EDS. You will have to answer two research questions (epidemiological surveillance study and analysis of predictive factors of lung cancer), while deciphering and correcting the biases inherent in routine clinical data.

Quarter number ST 4

Prerequisites (in terms of CS courses)

Statistics and Learning
Biology and Statistics

1SC4297 – Diagnosis by imaging of liver cancers

Instructors : **Laurent Le Brusquet, Arthur Tenenhaus**
Department : **DOMINANTE - VIVANT, SANTÉ, ENVIRONNEMENT**
Language of instruction : **FRENCH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **25,00**

Quarter number ST 4

ST4 - 43 - THE IoT (INTERNET OF THINGS) AND RELATED INFORMATION PROCESSING

Dominante **: SCOC (Systèmes Connectés et Objets Communicants)**
Langue d'enseignement **: English**

Campus où le cours est proposé **: Paris-Saclay**

Engineering problem statement

The IoT (Internet of Things) is the next Internet evolution. It stands at the crossroads of telecommunications, computer science, electronics, signal processing, big data and artificial intelligence. Connected objects are only the early stage of the IoT as major evolutions are going to happen. The IoT, the future of the Internet, is sometimes coined as the Internet 4.0, ambient intelligence, or ubiquitous Internet… It is one of the main domains of investment for the European policy in science and technology, and for countries and companies in the rest of the world as well. The IoT is going to bring major changes in everyday life and in the industry.

During this sequence, we will deal with transmission, storage, and processing of information together with Artificial Intelligence in communication systems for IoT.
Students will meet main actors of the IoT who will share with them their vision and their road maps.

A workshop will be organized where students exploit their acquired knowledge during the sequence for designing an IoT service from technical and business model perspectives.

During the challenge week, students will tackle the different aspects of IoT from the deployment of a sensor network to the processing of the data for a final application, related to a real actual case presented by a company in the sector.

Prerequisite

Core curriculum CIP-EDP, EIP

Context and challenge modules

Major companies in the domain will share their point of view and road maps. Different usage cases will be presented to understand the expectations and tradeoff in terms of information gathering, network architecture in relation with the required performances (robustness, security, bitrate, latency, energy consumption, density, availability, coverage...), and information processing (prediction, help for the decision, alerts…). Students will have the key to understand the economical and societal impact and to evaluate the value brought by the IoT. During the workshop, groups of students will position themselves as startups in the domain of IoT and will propose a service based on IoT sensor deployment and data processing, together with its technical design and business model.

Specific course (60 HEE): From Information Theory to IoT

Short description:

The first part of the course will deal with Shannon Information and will give the prerequisite and the skills to understand the concept of information and its measures; to understand the fundamental limits and the concepts for the representation and the compression of different kinds of signal models; to understand the effect of analogic source compression, the loss or lossless reconstitution of a digital signal; to understand the tradeoff between the bitrate and the distortion; to design the compression and transmission chain.

The second part presents different wireless communication systems for IoT, short or long range (Zigbee, SigFox, LoRA, LTE-M, NB-IoT, etc.). It will deal with the main concepts behind a telecommunication system, with their design at the radio level for an efficient collect of data. The learning outcomes and skills brought by this course are:

- understanding the mechanisms and communication protocols to transmit information with low cost sensors and high consumption constraints.
- dimensioning a wireless network for IoT applications with specific coverage and capacity requirements.
-

Challenge Week: sensor networks deployments and data processing for IoT

Industrial partners: Bouygues Telecom, EDF, Fifteen, Zettascale.

Location: Paris-Saclay Campus

Short description: The aim of the challenge week is to deploy an IoT network and/or to process the IoT collected data for a given application. The students will choose between various topics proposed by partners (Wind farm monitoring, smart city/smart building security, distributed robot control, safety monitoring for connected bikes, etc.). Various machine learning algorithms will be used for detecting patterns in the data and making the appropriate decisions.

1SC4310 – Principles of information theory and communication networks for IoT

Instructors : **Richard Combes, Salah-Eddine El Ayoubi**
Department : **DÉPARTEMENT SIGNAL, INFORMATION, COMMUNICATION**
Language of instruction : **ENGLISH**
Type of course : **Specific course**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **60**
On-site hours (HPE) : **30,00**

Description

This course will first present the theoretical foundations and fundamental limits in information theory and then study concrete cases of network standards and protocols for the Internet of Things.

Information theory, fruit of the work of scientists such as Hartley, Shannon, Wiener and Kolmogorov, is a major tool to solve fundamental problems of the digital world such as: implementation of large-scale broadband communication networks, storage and processing of massive data or cryptography. The first part of the course introduces the fundamental concepts and results of this theory, as well as the algorithms that can be used to solve problems. This course will also serve as introduction for more advanced courses in communications and statistics.

The various wireless communication systems for IoT, short or long range (Zigbee, SigFox, LoRA, LTE-M, NB-IoT, etc.) will then be presented. We will be interested in their design at the radio level for efficient data collection but also for storage and centralized or distributed data processing architectures, adapted to application requirements (execution time, security, etc.).

Quarter number ST4

Prerequisites (in terms of CS courses) CIP EDP

Syllabus

I. Information Theory

1) Introduction: motivations (communication networks, processing and storage of massive data), probabilistic tools.

2) Information measures: entropy, relative entropy and mutual information for discrete alphabets. Properties of information measures: string rule, informational inequalities (Fano, Log-sum, Data Processing etc.).

3) Data Compression: source encodings, prefix codes, unencrypted codes, and Kraft inequality. Coding of Huffman, Fano-Shannon and Lempel-Ziv. Fundamental limits. Optimality and complexity of Huffman coding. Typical sequences.

4) Data Transmission, Discrete Channels: channel coding, coding and decoding. Examples of discrete channels. Shannon's theorem, channel capacity. Return on typicity, attached typicity. Complexity and coding.

5) Data Transmission, Continuous Channels: information measurements for continuous alphabets, source and capacity coding theorems. Gaussian channels and models for communications, modulations. Fundamental limits, Shannon-Hartley's theorem. Extensions: parallel channels, colored noise. Coding for Gaussian channels. Multi-user communication.

6) Quantization: quantization of continuous valued signals, rate distortion theory, optimal quantization schemes.

II. Wireless telecommunications networks for IoT

7) Presentation of different wireless communication standards for IoT, low or long range

8) Radio mechanisms for IoT (modulation, coding, retransmissions, access to the canal)

9) Data Collect and Storage Architecture

10) Impact of application requirements for security, resilience and geolocation on the design of the collect and processing system.

Class components (lecture, labs, etc.)

Lectures, Tutorials, Homework

course : 24h00, tutorials : 5h30, a written exam : 1h30

Grading

Written exam : 1h30

Course support, bibliography

Detailed PDF slides available on edunao.

Learning outcomes covered on the course

Understand the algorithms and fundamental limitations for data transmission, storage and data processing.
Understand the physical meaning of information measures
Implement algorithms to apply the concepts of information theory to real problems,
Evaluate the performance of these algorithms.
Understand communication mechanisms and protocols that allow low-cost sensors with high energy consumption constraints to transmit their information.
Calculate the dimension a wireless network for IoT applications with special coverage and capacity requirements.
Design a secure storage and data processing system for IoT tailored to application requirements.

Description of the skills acquired at the end of the course

Understand the algorithms and fundamental limitations for data transmission, storage and data processing.
Understand the physical meaning of information measures
Implement algorithms to apply the concepts of information theory to real problems,
Evaluate the performance of these algorithms.
Understand communication mechanisms and protocols that allow low-cost sensors with high energy consumption constraints to transmit their information.
Dimension a wireless network for IoT applications with special coverage and capacity requirements.
Design a secure storage and data processing system for IoT tailored to application requirements.

1SC4391 – Deployment of a fog computing platform for video processing

Instructors : **Richard Combes, Salah-Eddine El Ayoubi**
Department : **DOMINANTE - SYSTÈMES COMMUNICANTS ET OBJETS CONNECTÉS**
Language of instruction : **ENGLISH**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description
This challenge week aims at deploying a fog computing solution for IoT. The students will deploy an experimental network connecting objects to processing nodes. The target scenario is mobile robots that are automatically guided by distributed Artificial Intelligence techniques. These techniques will be deployed on the fog and compared to centralized solutions.

Quarter number ST4

Prerequisites (in terms of CS courses) none

Syllabus
- Manipulation of the hardware and software components provided by the supervision team
- Deployment and test of a communication network between nodes.
- Creation of a distributed storage solution for information gathered from objects
- Implementation of an AI algorithm for processing the collected information
- Comparison of distributed versus centralized solutions
- Demonstration of the platform and defense before a jury

Class components (lecture, labs, etc.) One week of practical work in project mode

Grading Report and defense before a jury

Resources
The challenge week will be supervised by professors from CentraleSupélec and engineers from Zettascale.
The students will manipulate objects and robots equipped with Turtlebots.

Learning outcomes covered on the course
This challenge week will help students acquire the following competences:
- deploy a network composed of connected objets and processing nodes ;
- implement distributed AI methods and compare them to centralized ones understand the interplay between processing capacity and communication bandwidth.

Description of the skills acquired at the end of the course

C1 - Analyse, design and build complex systems with scientific, technological, human and economic components
C7.1 - Structure ideas and arguments, summarise (hypotheses, objectives, expected results, approach and value created)
C8.1 - Build a team to work as part of a team
C8.2 - Mobilise and motivate a team by demonstrating leadership skills
C8.4 - Work in project mode using project management methods appropriate to the situation

1SC4392 – Prediction of wind farm production using IoT data

Instructors : **Jocelyn Fiorina**
Department : **COMMUNICATION, DOMINANTE - SYSTÈMES COMMUNICANTS ET OBJETS CONNECTÉS**
Language of instruction : **English**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description
After an introduction about the importance of capturing data, coming from IoT sensors or by other means, and their processsing for EDF, algorithms will be developped in order to process the data collected in order to monitor and predict the energy production of a wind farm, and the consumption prediction based on real data.

Quarter number ST4

Prerequisites (in terms of CS courses)
Signal Processing
From information theory to IoT networks
Statistic and Machine Learning

Syllabus
- Context Presentation by industrial in this field
- dimensionning for the deployment of a sensor network
- data processing for monitoring and predicting the production of a windfarm and th user consumption

Class components (lecture, labs, etc.)
team working with practical exercises with ponctual help from the teaching team.
theoretical and methodogical briefs by the teaching team

Grading report and final presentation

Resources
Teaching team composed of professors and external industrial partners
The students will work in small teams
Tools: computers and servers adapted for massive data processing, Python

Learning outcomes covered on the course
The objective is to acquire the competencies resulting from the practice of the notions learnt during the ST4, in particular:
- For understanding the mechanisms to collect their data.
- Data processing for analysis and prediction

Description of the skills acquired at the end of the course
The objective is to acquire the competencies resulting from the practice of the notions learnt during the ST4, in particular:
- For understanding the mechanisms to collect data.
- Data processing for analysis and prediction
Team working and presentation of the results will also contribute to the related competencies.

The corresponding reference competencies are: C1, C2, C3, C4, C6, C7 et C8

1SC4393 – Detection of anomalies in networks using IoT data processing

Instructors : **Alexis Aravanis, Sahar Hoteit**
Department : **DOMINANTE - SYSTÈMES COMMUNICANTS ET OBJETS CONNECTÉS**
Language of instruction : **English**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

This challenge week focuses on data science and anomaly detection in networks, its objective is to exploit IoT data to detect anomalies in a network. Data is captured from Bouygues Telecom

Prerequisites (in terms of CS courses) none

Syllabus

- Manipulation of the software components provided by the supervision team
- Implementation of an AI algorithm for processing the collected information
- Demonstration of the platform and defense in front of a jury

Class components (lecture, labs, etc.)

One week of practical work in project mode

Grading

Report and defense in front of a jury

Resources

The challenge week will be supervised by professors from CentraleSupélec and engineers from Bouygues Telecom.

Learning outcomes covered on the course

At the end of this week, students will be able to handle distributed artificial intelligence methods for processing information and detecting anomalies in networks.

Description of the skills acquired at the end of the course

C4.1 Interact with the customer (industrial partner or supervisor) during the integration week

C4.2 Propose at least 2 solutions, with advantages and limitations

C6.1 Model the problem and apply algorithmic solutions

C6.3 Propose a methodology for processing IoT data and making subsequent decisions

C7.1 - Structure his/her ideas and arguments, be concise (hypotheses, objectives, expected results, approach and value created)
C7.4 Quality of the final presentation

C8.1 - Build a team to work as a team
C8.2 - Mobilise and train a team by demonstrating leadership skills

C8.3 - Interact with supervisors and customers, identify the necessary resources

C8.4 - Work in project mode using project management methods appropriate to the situation

1SC4394 – Sensor data for fault detection

Instructors : **Jose Picheral**
Department : **DOMINANTE - SYSTÈMES COMMUNICANTS ET OBJETS CONNECTÉS**
Language of instruction : **English**
Type of course : **Challenge week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **0**
On-site hours (HPE) : **24,00**

Description

The objective of this project is to utilize the signals collected by the connected measurement systems that are integrated into the bike-sharing fleet of the Zoov brand, operated by the company Fifteen. The main application aims to detect bike falls by utilizing the measurements from the inertial sensor's sensors (accelerometers and gyroscopes).

Prerequisites (in terms of CS courses) none

Resources

The project will be supervised by professors and researchers from CentraleSupélec, with the involvement of a data scientist from Fifteen company.
The labeled dataset of the trips will be provided by Fifteen company.
The development will be done in Python (Pandas, Scikit-Learn...).

Learning outcomes covered on the course

- Being aware of the limitations associated with IoT for data analysis.
- Defining and extracting relevant features from the signals to address a classification problem.
- Using machine learning classification methods.
- Evaluating the performance of the classification methods.

Description of the skills acquired at the end of the course

C4, C6, C7 and C8

ST4 - 44 - TIME SERIES AND AGENT – BASED MODEL IN FINANCE

Major: : MDS (Mathematics, Data Sciences)
Langue d'enseignement **: English**

Campus où le cours est proposé **: Paris-Saclay**

Engineering problem statement:

Financial markets have been deeply transformed by mathematical pricing methods and the computerization of exchanges. Engineers and scientists with maths/physics/computer science backgrounds have thus gained prominent roles on financial markets.

One of the goals of this course sequence is to use standard statistical tools, time series modeling, econometric models, and agent-based models to describe contemporaneous financial markets, and understand how the analysis of price series can be at the core of trading strategies. Besides the mastering of statistical tools and econometric models, courses of this sequence will also try to show how a better use of empirical results may usefully question some standard modeling assumptions.

Prerequisite: Core curriculum CIP-EDP and Algorithmique & Complexité

Context and challenge modules: Some introductory conferences will present financial markets, credit in finance, statistical modeling in finance, challenges linked to large databases in finance, learning methods, etc.

Specific course (60 HEE): Time series and agent-based modeling in finance

- *Econometrics of financial time series:* Stylized facts of financial time series. Stationarity, covariance, correlation. ARMA linear models. Estimation. Prediction. Introduction to non-linear ARCH/GARCH models. Introduction to portfolio theory. - *Agent-based models:* Design of agent-based models. Simulation of financial markets. Reproduction of financial stylized facts

Challenge week: Statistical analysis of financial markets

Students in this course will analyze real data from modern financial markets and assess the relevance of time series models or agent-based approach to model this data.

-

List of recent subjects : VARMA models for commodities ; Autoregressive models and high-frequency financial data ; Calibration of agent-based models on financial market data and price prediction ; Developing a Bitcoin trading bot ; French regional electricity load forecasting ; Structural analysis of VAR models in finance

-

Recent industrial partners : BNP Paribas, Cap Gemini, SIA Partners

Academic CS partner : Quantitative Finance Team, MICS Lab

1SC4410 – Time series and agent-based modeling in finance

Instructors : **Damien Challet, Christian Bongiorno**
Department : **DÉPARTEMENT MATHÉMATIQUES**
Language of instruction : **ENGLISH**
Type of course : **Specific Course**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **60**
On-site hours (HPE) : **30,00**

Description

This course provides an extensive exploration into the realms of financial markets, primarily focusing on the modeling of asset prices through two distinctive approaches: Econometrics of financial time series and Agent-based modeling. The course, conducted entirely in English, has a strong emphasis on application and numerical methods.

The Econometrics module of the course emphasizes a robust application-oriented approach rather than delving deep into the intricacies of mathematics. The primary objective of this module is to equip students with the skills required to autonomously implement time-series analyses on a computer. Students will learn to analyze real data and characterize the prominent features of financial markets effectively.

The Agent-based modeling module shows how investment strategies and learning shapes price dynamics. Even if simple econometric strategies are used, learning causes the nonlinearities that produce realistic price dynamics.

Please note that a high level of confidence in Python programming is necessary as this course heavily relies on it for labs and the final examination.

Quarter number ST4

Prerequisites (in terms of CS courses) CIP EDP, Algorithmique and Complexité

Syllabus

- Econometrics of financial time series:
  - -Stylized facts of financial time series.
  - -Portfolio Optimization.
  - -Stationarity, covariance, correlation.
  - -ARMA linear models.
  - -Estimation/Prediction.
  - -Introduction to volatility ARCH/GARCH models.
- Agent-based models:
  - -Design of agent-based models.
- Simulation of financial markets.
  - -Reproduction of financial stylized facts.

Class components (lecture, labs, etc.)

Temporal Series: CM (9h) + TD/MCQ (7.5h)

Agent-based Models: CM (6h) + TP (6h)

The course requires high confidence to code in Python.
Labs are in Python. The final exam is in Python in an exam room under time constraints.

Grading

The final grade will be made up of a final examination (CF) related to the econometrics module and four compulsory continuous assessments (EO) concerning the agent-based models module. There will be the possibility to carry out multiple-choice tests during the econometrics module (CCF).

The final grade will be calculated according to the following formula:

Max(0.5 CF + 0.5 EO, 0.4 CF + 0.5 EO + 0.1 CCF)

Both the labs and the final exam will be checked with anti-plagiarism algorithms.

Course support, bibliography

- Brockwell, P.J. and Davis, R.A. (1991) Time Series : Theory and Methods, Second edition, Springer Series in Statistics.
- Tsay, R.S. (2010) Analysis of Financial Time Series, Third edition, Wiley.

Resources

Teaching faculty : Christian Bongiorno (CentraleSupelec) Damien Challet (CentraleSupelec).

1SC4490 – Statistical analysis of financial markets

Instructors : **Damien Challet, Christian Bongiorno**
Department : **DOMINANTE - MATHÉMATIQUES, DATA SCIENCES**
Language of instruction : **ENGLISH**
Type of course : **Challenge Week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description
Students in this course will analyze real data from modern financial markets and assess the relevance of time series models or agent-based approach to model this data.

Quarter number ST4

Prerequisites (in terms of CS courses)
Time Series and Agent-based Models in Finance (ST4 MDS)

Syllabus

Data handling. Reading of scientific articles. Python implementation of time series or agent-based models. Analysis and technical presentation.

List of recent subjects (subjects may differ in 2023):
- Autoregressive Conditional Duration Models (FiQuant, CentraleSupelec, 2023): investigate the statistical properties of financial durations, to assess the modelling performances of ACD models on various financial durations (equities, cryptocurrencies)
- Information flow on Order-Books (FiQuant, CentraleSupelec, 2022, 2023): investigates cross-sectional asynchronous led-lag relationship in order-books of multiple stocks, trying to identify and charcterize short-term predictors.
- *VARMA models for commodities* (BNP Paribas, 2020).
- *Autoregressive models and high-frequency financial data* (FiQuant, CentraleSupelec, 2019, 2020, 2021)
- *Calibration of agent-based models on financial markets* (FiQuant, CentraleSupelec, 2020, 2021, 2022) : build and calibrate agent-based models with methods including generalized methods of moments and Kalman filters ; compare the model behaviour to real financial timeseries.
- *Developing a Bitcoin trading bot* (Cap Gemini, 2020, 2021, 2022) : explore Blockchain time series, model the time series with classical models using AR/MA/ARIMA or GARCH, and neural networks, compare and contrast both approaches and finally propose a trading strategy.
- *French regional electricity load forecasting* (SIA Partners, 2021) : forecast the electricity consumption of several french administrative regions, using multiple years of past observations timeseries, as well as meteorological features.
- *Structural analysis of VAR models in finance* (FiQuant, CentraleSupelec, 2021, 2022) : model financial time series with vector autoregressive models ; analyze dependencies on multiple markets and data (equity or bitcoin, low or high-frequency) using structural analysis.
- Predicting National Electricity Demand (Cap Gemini, 2023): explore and predict the time series of electricity consumption by comparing classical models (ARIMA, GARCH) and RNN.

Class components (lecture, labs, etc.)
Project work in groups of students.

Grading
Oral presentation with detailed technical support. Absence from daily meetings will result in evaluation penalties.

ST4 - 45 - ADAPTING INFRASTRUCTURES TO CLIMATE CHANGE ENGENEERING ISSUES

Dominante **: : CVT (Construction, City and Transport)**

Langue d'enseignement **: English**

Campus où le cours est proposé **: Paris-Saclay**

Engineering problem

Infrastructures are key assets for mobility (roads, railways, airports), energy (power plants, dams), or health (hospitals). They can be exposed to various environmental hazards such as earthquakes, floods, droughts, fires, storms, heat waves. In the occurrence of one of these phenomena, infrastructures can suffer damage, losses, casualties, service interruptions. The impact can range from null to catastrophic depending on the intensity of the event and on the vulnerability of the infrastructure to the event. With the effects of climate change, both the frequency of occurrence and the intensity of some environmental events have been increasing, while human and economic losses keep on increasing due to growth in wealth, complexity of the production system, population, and urbanization. In France, natural disasters cost insurers 10 billion euros in 2022, which is three times the mean annual cost between 2017 and 2021.

Adapting infrastructures to climate change is necessary for achieving sustainability. There are many different types of actions that can be taken. For instance, dikes can be constructed to reduce the exposure of infrastructures to sea-level rise, construction codes can be implemented to reduce the vulnerability of buildings to hurricanes, response plans can be designed to recover quickly after damages have occurred.

Digital twins of urban areas and of their assets provide a virtual representation of the physical world that can be used to simulate the impact of environmental disasters, to compare the performance of adaptation strategies before they are implemented, and to alert the populations.

Digital twins carry and maintain different sources of information. Hazard maps show georeferenced historic environmental event intensity measures (say the water-level history of the Seine under Pont-Neuf in Paris). Vulnerability maps show georeferenced measures of the impact of a given natural event on the assets (say the buildings that collapsed in the event of a hurricane with a peak speed of 200 km/h). Risk maps combine hazard with vulnerability.

Digital twins also integrate numerical simulation capabilities that can be used to provide additional information for adaptation when recorded data are absent or scarce, geographically – few recorded points in space – or historically – few recorded points in time. Simulations are based on the physics of the problem, on data, or both.

Advised (but bot compulsory) prerequisites:

Programming in Matlab or Python; Continuum Mechanics course.

Context and issue modules:

Conferences will be delivered to introduce and illustrate:

- social and economic impacts of climate change on the built environment,
- the concept of digital twins and how numerical simulation can support decision-making for adapting infrastructures to climate change effects.

Specific course: Environmental hazards and structural risks simulation.

This course introduces the fundamental concepts needed to assess environmental hazards and simulate risks in structural systems exposed to these hazards.

Structural systems such as infrastructures or buildings are expected to achieve performance criteria in terms of safety and serviceability. As a structure is exposed to environmental hazards, there can be a risk that some performance criteria are not satisfied.

The course introduces various hazards including seismic, flooding, and landslides. Approaches based on physical laws are introduced to model the actions induced by these hazards on the structures. Also, as environmental actions are generally represented by time series, signal processing techniques can be used to characterize and to model environmental actions.

The course also introduces continuous and discrete models of the structural behavior in environmental actions. Analytical and numerical methods are introduced to solve the partial differential equations that govern the structural behavior and to simulate the vulnerability of structures exposed to environmental actions.

Combining hazards and structural vulnerability, practical approaches are presented for effectively communicating environmental risks in structural systems.

Challenge week: Digital twins for managing infrastructures in the presence of environmental risks.

During the challenge week, the students are placed in the situation of a team of engineers in charge of managing risks associated to a bridge exposed to environmental hazards. The team has the mission to develop a digital twin of the bridge for virtually comparing different risks management strategies.

To model environmental actions as well as to model the behavior of the bridge in these actions, the students team can use models built from physical laws, models built from machine learning algorithms and data sets, as well as signal processing methods.

1SC4510 – Environmental hazards and structural risks simulation

Instructors : **Karim Tarbali, Pierre JEHEL**
Department : **DÉPARTEMENT MÉCANIQUE ENERGÉTIQUE PROCÉDÉS**
Language of instruction : **English**
Type of course : **Specific course**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **60**
On-site hours (HPE) : **30,00**

Description

Structural systems such as infrastructures (bridges, dikes, tunnels) or buildings are expected to achieve performance criteria in terms of safety and serviceability all along their lifespan. As a structure is exposed to environmental hazards such as earthquakes, hurricanes, floods…, there can be a risk that some of these performance criteria are not satisfied. Simulating and assessing these risks is key in the structural design process, especially today where hazards due to climate change need to be accounted for.
This course introduces the fundamental concepts needed to assess environmental hazards and to assess the vulnerability of structural systems exposed to these hazards.
Various hazards including seismic, flooding, and landslides are introduced along with various structural models for simulating the vulnerability of structures in dynamic environmental actions. Combining hazards and structural vulnerability, practical approaches are presented for effectively communicating environmental risks in structural systems.
Computational tools are introduced and used for solving engineering problems.

Quarter number ST4

Prerequisites (in terms of CS courses)

Continuum mechanics; Programming with Matlab or Python.

Syllabus

The course is divided into 10 sessions of 3 hours each.

3 sessions focus on understanding the fundamental concepts of environmental hazards and risks. They delve into the methodologies to quantify various natural hazards, including seismic, flooding, and landslides. The topics discussed are:
- Hazard and risk concepts and their underlying components; risk-informed design and importance of accurate hazard modelling; and catastrophe modeling workflow.
- Scenario and probabilistic hazard assessment methods.
- Physics of the seismic, flooding, and landslide phenomena.
- Modeling components of the scenario and probabilistic hazard assessments.
- Example case studies and a hands-on session of seismic hazard assessment.
- Physics-based approaches to improve hazard modeling.
- Loss assessment methodology and risk-informed decision-making for disaster risk management and reduction.
- Multi-hazard and insurance perspectives on environmental hazards.

6 sessions are dedicated to the fundamental structural dynamics concepts to model and simulate structural vulnerability in environmental actions using numerical tools (finite element software). The topics discussed are:
- Dynamic response of a beam structures in harmonic loading: continuous beam model, and discrete single and multi-degree-of-freedom systems.

- Dynamic response of structures in environmental actions: Duhamel integral, Fourier transform of the environmental actions, structural response spectrum.
- Beam formulation and finite element implementation.
- Engineering case studies with hands-on session using the software Pythagore.

1 session introduces methodologies for structural model updating and structural health monitoring in case the structure modeled is equipped by sensors that collect data about the actual structural behavior in dynamic loading.

Class components (lecture, labs, etc.)

Lectures, analytical and numerical hands-on sessions.

Grading

Final exam.
Some of the hands-on sessions may be graded and multi-choice questionnaires may be organized occasionally (will be announced in the beginning of the course).

Course support, bibliography

Bibliographical lists and documents with methodological notes will be provided during the course.

Resources

Software: professional finite element program Pythagore.
Office hours.

Learning outcomes covered on the course

At the end of this course, students:
- Know how to use the concepts of environmental hazard and structural vulnerability for assessing risks in structural systems.
- Are able to communicate risks to a non-specialist audience.
- Understand the rationale for establishing risk mitigation strategies.

Description of the skills acquired at the end of the course

C6 – Being operational, responsible, and innovative in the digital world

1SC4590 – Digital twins for managing infrastructures in the presence of environmental risks

Instructors : **Pierre JEHEL**
Department : **DOMINANTE - CONSTRUCTION VILLE TRANSPORTS**
Language of instruction : **English**
Type of course : **Challenge Week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

This challenge week aims at putting students in the position of an engineer in charge of designing a railway bridge. More specifically, students will have to design a preliminary project for a railway bridge built in a seismic zone so that it meets certain constraints and a certain level of performance.

As a starting point, students will be given an example of a digital model containing the geometric data and mechanical properties of a bridge as well as specifications presenting the point to be designed and the performance criteria to be met. The partner company of this challenge week plays the role of the client of the design mission in front of teams made up of 5 students.

At the end of this challenge week, each team will present to the client (the partner company) its design project for the bridge as well as its advances in the development of automated and integrated engineering design approach. The client will then evaluate the various solutions proposed.

Quarter number ST4

Prerequisites (in terms of CS courses)

The course *Continuum Mechanics* would be a plus.

Syllabus

1) Day 1:

- Presentation of the bridge project by the client commissioning the mission: geometry, materials, densities, photos or 3D model if available. Data recovery on the bridge.
- Statistical analysis of a database of bridge projects already completed. Methods such as linear regression, random forest, or neural networks can be considered to learn physical and non-physical data collected during projects already completed and to give indications on the choices to be made in the case of the mission to be carried out.

2) Day 2:
Geometric, mechanical, and seismic modeling of the bridge with digital continuity. The following developments are expected:

- a parametric modeling of the bridge geometry from CAD tools,
- a seismic modeling of a bridge from a finite element analysis software, and
- an interface making it possible to export the geometries generated by the CAD software in a format that can be used directly by the numerical simulation software.

3) Day 3:
Recovery of seismic data and estimation of the seismic hazard:

1. measurements of the seismic intensity, probability of occurrence of an earthquake, dimensioning spectrum adapted to the considered hazard,
2. selection of accelerograms compatible with a design spectrum,
3. critical analysis of uncertainties in seismic loading (variability of seismic forces as a function of the seismic signal considered).

4) Day 4:
Synthesis of the 3 previous days, improvement of the weak points identified, production of a first version of the final presentation of the project.

5) Day 5:

-Morning: design of the bridge (calculation of the data of interest for the design engineer, comparison with limit states, iterative approach for optimizing the bridge geometry towards meeting the expected performance criteria).
-Afternoon: final jury (presentation of the bridge project to the client).

Class components (lecture, labs, etc.)

-Work in a team of 5 students.
-Work in project mode.
-Reminders or introductions of theoretical elements (3h in the week).
-List of daily expectations distributed to the teams at the beginning of each day.
-Progress report to be produced at the end of each day.
-Supervision by a multi-disciplinary team.

Grading

1) Evaluation Jury:At the end of the integration course, each team presents its project to a jury.20 minutes of presentation followed by 10 minutes of exchanges with the jury.The jury is made up of the client who is the sponsor of the completed mission and a teacher-researcher.The jury evaluates the teams.
2) Continuous assessment: Each day concludes with the writing of a short report (1 or 2 pages) showing the successful acquisition of the skills expected to be developed.

Course support, bibliograph

Bibliography and materials distributed according to the progression of the course.

Resources

1) Software:

-Rhinoceros3D Grasshopper for CAD
-Pythagore for the numerical simulation of the dynamic behavior of civil engineering structures with the finite element method
-Python / Matlab

2) Databases:

-Bridge projects
-Seismic demands

3) Teaching materials:

-Course to remind or introduce useful theoretical elements (3h total in the week)
-List of daily expectations distributed to the teams at the beginning of each day
-Research, technical or vulgarization articles

4) Multi-disciplinary team:

-Faculty members
-Engineers-architects experts in Rhinoceros3D and Grasshopper software

- Engineers developers of the Pythagore software
- Structural engineers from a bridge design company

Learning outcomes covered on the course

-Hold a design engineer position adapted to the collaborative context in a digital setting (identification of the actors, understanding of the respective responsibilities / perimeters of action, adapted communication / respect of a certain protocol).
-Analyze and process the geometrical and mechanical information from the digital model of the bridge to propose a simplified but relevant mechanical model at a pre-project stage.
-Analyze and process statistical information from databases.
-Manipulate CAD tools.
-Manipulate numerical and analytical tools for modeling dynamic structural behavior.
-Initiate a process of automating the design of a bridge.

Description of the skills acquired at the end of the course

C4 – Having a sense of value creation for your company and its customers
C6 – Being operational, responsible, and innovative in the digital world
C7 – Knowing how to convince
C8 – Leading a project, a team

ST4 - 46 - ENERGY AND CLIMATE

Dominante : ENE (Energy)

Langue d'enseignement : French

Campus où le cours est proposé : Paris-Saclay

Engineering problem

In the face of climate change, the energy transition is now inevitable. CentraleSupélec engineers can contribute to these challenges by contributing their skills in processing huge quantities of data. Indeed, the acquisition, statistical analysis and integration of climate data into predictive models make it possible to assess the impact of GHG emissions on the climate and the measures to be implemented to limit these changes. The same applies to economic data used to anticipate the economic consequences of climate change.

At the same time, the digitalisation and computerisation of energy systems (e.g. smart meters) is resulting in an increase in the volume of data collected, the exploitation of which opens up new opportunities for optimising the production of renewable energy and controlling consumption.

This thematic sequence is an opportunity for the future CentraleSupélec engineer to apply data processing and analysis tools to respond to specific climate and energy issues: modelling climate change and its economic impacts, identifying and analysing uses to control electrical energy consumption, or estimating the production of an offshore wind farm.

Adviced prerequisites

No CentraleSupélec course is required. It is recommended to have taken the elective courses Electrical Energy and Transfer Sciences.

Context and issue modules:

The conferences and round tables will provide an opportunity to take stock of climate change and the need to reduce GHG emissions, particularly in the field of energy, as well as the major economic consequences that must be anticipated and managed. They will be addressed by academic experts in climatology and economics, industrial experts on the production of renewable energy, and entrepreneurs in the energy sector.

Specific course (60 HEE) : Climate and Energy Transition

Brief description: The objective of this course is :

- provide the physical basis for the energetics of the global climate system (role of the vertical temperature profile in the atmosphere, effect of water vapor, albedo, feedback mechanisms). Particular attention will be paid to climate models.

- present how climate models can be applied to power generation, particularly intermittent energies. The first part is devoted to the main systems for generating electricity from renewable sources. A second part deals with the integration, management and storage of energy within transmission and distribution systems.

- present how climate models can be applied to electrical energy consumption. The aim is to understand the operation and models of components used in domestic applications: generators, converters, loads.

Challenge week n°1: Prediction of climate change and its economic impacts

- Associated partners: IPSL

- Location: Paris-Saclay campus

- Brief description: the objectives of this engineering challenge are to

Students can choose between physical or economic modeling. The two sections deal with :

understanding the issues linked to climate change: impact on energy needs (air conditioning, new modes of transport, etc.), societal and economic impact, etc.

The physical modeling component enables you to:

-Implement global models integrating fluid dynamics and energy balances

-Analyze climate data using Python

-Examine the challenges of global warming in a selected region of the world.

The economic modeling section enables you to :

-Implement an economic model incorporating a physical component representing global warming (Python)

-Analyze and understand the economic, social, environmental and human impacts on certain regions of the globe, chosen by the students according to their interests.

-Challenge week n°3: Estimation of the production of an offshore wind farm

-Associated partner: EDF

- Location: Paris-Saclay campus

- Brief description: The aim of this engineering challengeis to use a dataset derived from a climate model to estimate the production of a future offshore wind farm and the associated energy cost. In particular, we'll be looking at wind studies (understanding a complex dataset), the wake effect, the wind turbine conversion chain, cabling and energy costs

1SC4610 – Climate and energy transition

Instructors : **Simon Meunier**
Department : **DÉPARTEMENT SYSTÈMES D'ÉNERGIE ÉLECTRIQUE**
Language of instruction : **FRENCH**
Type of course : **Specific Course**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **60**
On-site hours (HPE) : **30,00**

Description

This course is divided into 3 parts which prepare each corresponding "enseignement d'intégration ".

Part I

The goal of this course is to present the main physical-chemical principles that determine the climate of the Earth. The first part is dedicated to the account of past climates and of the mechanisms behind climatic changes, in particular orbital variations, greenhouse gases concentration changes linked to perturbations of the carbon cycle, or the evolution of life on Earth. The second part will present the different numerical modeling strategies used in climatology. The equations and approximations used to simulate the atmosphere and oceans, and the couplings between the different components of the climate system.

Part II

Variables/intermittent renewable energy sources are renewable energy sources whose availability varies strongly without any possibility of control. Some have regular variations and predictable as tidal energy, others are more fluctuating as photovoltaics or wind energy. The goal of this course is to present the potential of variable sources of renewable energy. The first part is dedicated to the main features of production of energy from these sources. The second part concerns the integration and management of energy in the transportation and distribution grid. The conversion and storage elements used in this framework will be addressed.

Part III

The energy transition with its efficiency goals associated to rethink the way in which users will have access to electric power. To establish new consumption patterns, it is necessary to analyse behaviours of consumers to organize the new means of production and supply of the network. The course focuses on the description of the operation of main electrical appliances used for domestic and industrial sites to characterize these charges in order subsequently to identify the presence of these devices by the analysis of consumption data.

Quarter number ST4

Prerequisites (in terms of CS courses)

SPI course Electric Energy adviced

Syllabus

Session 1 (3h): D. Paillard (courses carried out in collaboration with IPSL (LSCE))

Introduction, paleoclimates

General presentation of the diversity of climates that our planet has known in its history, since the recent era (meteorological measurements) to the early ages of the Earth (geological and geochemical information). Emphasis will be on the main physicochemical principles responsible for climate change: astronomical variations for Quaternary cycles; episodes Earth-snowball and ice-albedo feedback. the young Sun paradox; evolution of the carbon cycle, geology and evolution of life; etc...

Session 2 (3h): D. Paillard (courses carried out in collaboration with IPSL (LSCE))

Radiative balance, greenhouse, the carbon cycle

The main determinant of the climate on a planet is the balance between incoming solar radiation and outgoing infrared radiation. "The greenhouse effect" stems from the fact that looking generally at the surface temperature while the outgoing infrared radiation is emitted at high altitude. It will look at the role of CO2 on the radiation balance, but also to the carbon cycle: the time constants of the carbon on Earth, the main tanks, the role of global thermostat via the erosion of silicates.

Session 3 (3h): M. Kageyama (courses carried out in collaboration with IPSL (LSCE))

Introduction to the climate modeling

General presentation of the models: the components of the system (atmosphere, ocean, continental surfaces, biogeochemical cycles, calottes ice,...); the various couplings and combinations of components used in modelling of the climate, the hierarchy of models. Description and main principles of the atmospheric circulation, equations of motion, usual approximations. Simulation of climates past, present, future.

Session 4 (3h): M. Kageyama (courses carried out in collaboration with IPSL (LSCE))

The example of the fast simulation of climate events

Description and main principles of ocean circulation. Phenomenology of abrupt events (corner-Oeschger and Heinrich), model Stommel and multiple equilibria. Coupled simulations and disturbances in flow of fresh water.

Session 5 (1h30) : S. Meunier (CS)
Sources and variable production from renewables ½
Wind energy, marine energy

Session 6 (3h) : S. Meunier (CS)
Sources and variable production from renewables 2/2
Solar PV
Session 7 (3h) : E. Odic (CS)

Integration and management of variable renewable energy sources
Means of storage, principles and implementation

Session 8 (3h): M. Hennebel (CS)
Integration and management of variable renewable energy sources
Impact of renewables on the grid, electricity market

Session 9 (3h): T.D. Le (CS)
Presentation of electrical quantities in the field of electrical consumption, the general operation principles of electrical devices and power electronics. Study of the waveforms of currents absorbed by electrical devices and methods of recognizing these waveforms by Data Science. Introduction of smart meters for measuring power consumption. Use of power consumption data in Smart Grids. Introduction of load forecasting.

Session 10 (3h): D. Tourin-Lebret (Smart Impulse)

Introduction, challenges and issues of the analysis of the electric consumption in a network. After a reminder of the context of the energy demand, the global warming situation and the supply / demand balance on an energy distribution network, the challenge of automatically identifying unnecessary electrical consumption is tackled with an engineering vision : finding a simple and robust solution to a complex problem that is a priori intractable.

Session 11 (1h30): Written exam (QCM)

Class components (lecture, labs, etc.)

10 lectures + written exam (QCM)

Grading

Written examination of 1h30 (QCM)
The grades are homogenized to reach the target average grade that is set by the school office.

Resources

classroom (120 pers.)

Learning outcomes covered on the course

-Understand the physical basis of Earth’s climate and its changes.
-Master the various components for the generation, conversion and gestion of the renewable energy.
-Understand the difficulties related to the integration of renewable energy to the electrical grid.
-Solve simple problems dealing with the alimentation of residential/industrial sites from from renewable energy.
-Evaluate the economic aspects.

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 scientific, economic and human dimensions.
- C1.2 - Use and develop suitable models, choose the right scale of modelling and assumptions relevant to deal with the problem.
- C4.2 - Know how to identify the value of a solution for a customer, the market. Know how to discern opportunities, opportunities business and enter them.

1SC4691 – Climate change forecasting

Instructors : **Stella BOURDIN, Pascal DA COSTA**
Department : **DOMINANTE - ENERGIE**
Language of instruction : **FRENCH**
Type of course : **Challenge Week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

In this "Enseignement d'Intégration", you will find the latest IPCC special reports "PLANT HEATING OF 1.5°C"... " OCEAN AND CRYOSPHERE IN THE CONTEXT OF CLIMATE CHANGE" published in 2018 and 2019, as well as the work of the Nobel Prize for Economics 2018, WILLIAM NORDHAUS, on climate economics.

The aim is either to understand how the iLOVECLIM model works and analyse its simulations using Python (time series, anomalies, regional studies, etc.), or to discover and use (again using Python) the NORDHAUS DICE model (for Dynamic Integrated model of Climate and the Economy). Exchanges between the two groups are scheduled during the week.

Quarter number ST4

Prerequisites (in terms of CS courses) No.

Syllabus

Students will be able to choose between physical or economic modelling. Both options cover understanding the problems associated with climate change: impact on energy requirements (air conditioning, new modes of transport, etc.), societal and economic impact.

The physical modelling component enables students to:

- implement a global model integrating fluid dynamics and energy balances

- analyse climate data using Python

- explore the issues surrounding global warming in a selected region of the world.

The economic modelling section enables students to:

- Implement an economic model incorporating a physical component representing global warming (Python).

- Analyse an economic or geopolitical issue by experimenting with the model.

Class components (lecture, labs, etc.)

Climatic or economic simulations under python.

Grading

Team project and defense.

Resources

Speakers:
Laboratory of Environmental and Climate Sciences CEA-CNRS-UVSQ-IPSL;
Industrial Engineering Laboratory / Sustainable Economy Team CentraleSupélec.

Learning outcomes covered on the course

Recreate the climatic and economic simulations of chapters 1 and 3 of the IPCC report: Assessing and Negotiating Pathways to Combat Global Warming.

Description of the skills acquired at the end of the course

C4 C6 C7 C8

1SC4692 – Power consumption analysis using data science techniques

Instructors : **Amir Arzandé, Jing Dai, Trung-Dung Le**
Department : **DOMINANTE - ENERGIE**
Language of instruction : **FRENCH**
Type of course : **Challenge Week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

To successfully realize the energy transition, it is essential not only to develop renewable energy sources but also to know how to adjust the consumption and thus make energy savings. With the development of data science and the availability of massive consumption data (big data), new solutions are possible to achieve the objective of consumption reduction.

The purpose of this EI is:

- To become familiar with data science methods applied to the field of electricity consumption
- To use data science methods for the recognition of electric loads and the forecast of power consumption

Quarter number ST4

Prerequisites (in terms of CS courses) Basic knowledge of programming in Python.

Syllabus

The week is divided into two parts:

- During the first 3 half days, the students do case studies to apply machine learning methods to the processing of data on electricity consumption. In this way, the students learn how to use Python libraries specially designed for data science.

- The following days are devoted to a project where students work in groups on the problem of forecast of electrical consumption based on consumption histories.

Class components (lecture, labs, etc.)

During the case studies of the first 3 half days, the students are supervised by the teachers to master Python libraries for data science.

For the project, the students work in small groups. The teachers and the industry expert in data science are available to answer any technical questions.

Grading

- The students are assessed based on:

-Reports for the case studies (20%)

-Presentation and project report (80%)

Course support, bibliography

DataCamp, E-learning sur data science.
R.Arghandeh et Y. Zho, Big Data Application in Power Systems, Elsevier Science, 2018
T.Hastie, R. Tibshirani, et J. Friedman, Element of statistical learning:
Data Mining.
Inference and Prediction, Springer, 2017.

Resources

Computer with Python installed.
Classroom with video projector and Wifi

Learning outcomes covered on the course

Understand the procedure of use the data science to process massive data on electricity consumption.
Learn to use IT tools like Python to implement data science methods.
Learn to analyze the consumption curve in order to draw useful information

Description of the skills acquired at the end of the course

At the end of this week, the students will have acquired the knowledge to apply the popular methods of data science in the field of electricity consumption, for example to forecast electrical consumption.

Programming skills in Python, in particular data science packages.

1SC4693 – Estimate the output of an offshore wind farm

Instructors : **Loïc Queval**
Department : **DOMINANTE - ENERGIE**
Language of instruction : **FRENCH**
Type of course : **Challenge Week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

The goal of the EI is to estimate the production of an offshore wind farm. We will consider several factors, such as the variability of the wind, the wake effect, the parameters of the energy conversion chaine, the cabling and the costs.

Quarter number ST4

Prerequisites (in terms of CS courses) none

Syllabus

The students are divided into 12 groups of 3 students (= 36) who work in "competition". The goal is to design an offshore wind farm by taking into account certain technic and economic constraints. The input data is a set of weather data and the parameters of the conversion chain (measured in TL for some). The constraints are the geographic boundaries of the park, the point of connection to the power grid and the size of the cables. The students have to determine the optimal number of turbines, their location and estimate the park's production.

Grading

At the end of the week, each group presents their analysis. The optimized park data for each group is used by the supervising team to evaluate the work of each group.

Course support, bibliography none

Resources

Classroom (50 pers) reconfigurable with videoprojection and WiFi.

Learning outcomes covered on the course

- Assess the wind energy ressource of a given site.
- Master the various steps of the energy conversion from wind energy to electric energy.
- Understand the difficulties related to the integration of this production mean to the electrical grid.
- Evaluate the levelized cost of wind energy.

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.

ST4 - 47 - BLACK SWANS DETECTION IN PARTICLE PHYSICS AND COSMOLOGY

Dominante : : **PNT (Physics and Nanotechnology)**

Langue d'enseignement **: French**

Campus où le cours est proposé **: Paris-Saclay**

Engineering problem statement:

Particle Physics and Observational Cosmology are fields which have significantly progressed in recent years, substantially improving our understanding of the Universe and its content. This research requires considerable human, scientific and technological efforts to detect rare events and/or of very low intensity, thus difficult to detect. The simple observation of those sparse events can however greatly change our understanding paradigm. They are therefore called "*Black Swans*", a metaphor remembering the fragility of our system of thoughts where a single rare event can potentially largely change our posterior understandings. In order to get a real scientific meaning, these measurements have to be reported with an acute awareness of their limitations (statistical and systematical uncertainties).

From an economic perspective, Particle Physics and Observational Cosmology data are collected thanks to several tens of millions to billion dollars facilities. These high costs lead scientists to maximally exploit these data. Engineering designs behind these activities are often far beyond the scientific goal alone. They require optimising data storage, memory allocation, CPU usage and algorithms *etc.*

These fundamental research efforts have always required complex data analysis rationales. The quick growth of the Internet giants (GAFA, BATX) has considerably accelerated Artificial Intelligence (AI) revival. Scientists have recently sought to incorporate these developments back in their data analyses. These algorithms gradually become new standards for the exploitation of considerable amounts of data from Particle Physics facilities and astrophysical observatories.

This course addresses Fundamental Physics issues as well as a some of the scientific rationales used by this community to analyse the data of the most recent instruments (LHC, Planck, SDSS, …). It is focused on giving students a view on technical activities in this intense field of research.

Prerequisite

First semester Statistical and probability course. Computer programming skills: Python (Anaconda), GitHub.

Context and challenge modules: these modules will give to the engineering students a first sight with nowadays scientific context in Particle Physics and Cosmology. It will also lead to point out needs and challenges of these research fields in Big Data, High Performance Computing (HPC), High Throughput Computing (HTC) and Artificial Intelligence. Beyond scientific and technological facets, social and economic aspects will be addressed, among which funding of fundamental research.

Specific course (60 HEE): Data Analysis in Particle Physics and Cosmology

Short description: This course will give a short overview of modern Particle Physics and Cosmology research through data analyses. The objective is to give to students a synthetic and technical view of research activities which exploit data from the most recent instruments (such as LHC, Planck, SDSS,…). However, the technics and skills introduced in this course could largely serve a wider scope for data analysis technics since many former PhD students in Particle Physics and Cosmology have also secured Data Scientist positions in private companies.

Challenge week: Black Swans detection in Particle Physics and Cosmology.

Industrial partner: CNRS/CEA

Location: Paris-Saclay Campus

Short description:

Application of signal processing, statistical analysis and machine learning methods to the analysis of Particle Physics and Cosmology experimental data.

- The students will be divided into two groups, one working on a Particle Physics problem (Higgs group), the other on Cosmology (Cosmology group). The organisation of the two groups will be very similar, the differences will be indicated when necessary.
- Higgs group. The activities will involve searching for Higgs bosons in data provided by the ATLAS collaboration (LHC). The data sample contains Higgs bosons but also distortions of experimental origins. The goal is to find a maximum of Higgs bosons using different techniques, robust to experimental distortions.
- Cosmology group. The working frame will be an end-to-end analysis of public data from the three main probes of contemporary Observational Cosmology: Type Ia Supernovæ (SNIa), Cosmic Microwave Background (CMB) and Baryon Acoustic Oscillations (BAO). The goal is to obtain constraints on the ΛCDM cosmological model by a Bayesian approach based on the Markov Chain Monte Carlo technique with each probe and to combine them.

The learning objectives are: consistency checks, performance evaluations and optimisation of machine learning methods, of image and catalogs analysis, output results combination, treatment of statistical and systematical uncertainties and scientific interpretation.

1SC4710 – Data Analysis in Particle Physics and Cosmology

Instructors : **Jean-Christophe Hamilton, Guillaume Mention**
Department : **DÉPARTEMENT PHYSIQUE**
Language of instruction : **ENGLISH**
Type of course : **Specific Course**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **60**
On-site hours (HPE) : **30,00**

Description

Particle Physics and Observational Cosmology are two fields which experienced considerable advances over the last few years, improving in a significant manner our understanding of the Universe and its content. These topics require considerable human, scientific and technological efforts in order to be able to detect rare events or very weak signals, therefore hard to detect which we call "Black Swans". In order to be scientifically meaningful, these measurements need to be reported with an accurate consciousness of their limitation s(statistical and systematic uncertainties).
This course will cover the fundamental physics questions as well as a wide variety of algorithms used within the scientific community in order to analyse data from the most recent instruments (LHC, Planck, SDSS, ...). It aims at giving the students both a synthetic and a technical view of the scientific activities in these research fields. It will give an overview and basic knowledge of the challenges in particle physics and cosmology data analysis.

Quarter number ST4

Prerequisites (in terms of CS courses)

Cours dispensé en anglais: une bonne maîtrise de la langue est donc nécessaire.
CIP PED course

Syllabus

1 Particle Physics (Neutrinos, Dark Matter, Higgs, Supersymmetry) - 20 HEE
Scientific Introduction - 10 HEE
Standard model of particle physics
Basic knowledge of particle physics (interaction probability, cross section, event identification)
Overview of experimental detection methods in particle physics
Simulation tools developed by the community (Monte Carlo, ...)
Current research in particle physics

Specific Data Analysis Techniques - 10 HEE
Counting rate, detection efficiency, event classification, uncertainties. Signal / Noise Ratio, Statistical Significance.
Signal, background noise, classification, performance.
Systematic, nuisance, ...
Experimental uncertainties, theoretical. Balance sheets of uncertainties. Propagation of uncertainties.
Statistical inference, adjustments with $\chi 2$, Likelihood, Likelihood profile, confidence contours, p-value.
Combination of results and suitability tests
2 Cosmology- 20 HEE
General introduction 10 HEE
Pillars of cosmology (General Relativity, Expansion of the Universe, Cosmological Principle)
Big-Bang model: cosmological parameters
Cosmological Probes: Type Ia Supernovae, Acoustic Baryon Oscillations, Cosmic Microwave Background
Opening to the primordial Universe, inflation

Specific Analysis Techniques - 10 HEE
In astronomy: Imaging, photometry, spectroscopy, CMB map, spherical harmonics, pixelation
In statistics: Adjustments with $\chi 2$, Likelihood, marginalization, Bayes theorem, posterior, Monte-Carlo-Markov-Chain
3 Automatic Learning- 20 HEE
General Introduction
Classifiers: principles
Nearest Neighbor
Decision trees
OCR curves, learning curve
Overtraining, cross validation
Neural network, principles
General principles of optimization
Building tips and optimization of neural networks
Some architectures and their applications: dense network, convolutional network, recurrent network, adversary network

Class components (lecture, labs, etc.)

The "séquence thématique" starts with 4 half day of introduction with seminars from external people and round tables.
The courses proper are 8 half day (3 hours) of courses, 3 half days (3 hours) of exercices.
The séquence thématique end with the week long "enseignement d'intégration" . The students are split in 4 groups, 2 in cosmology and 2 in particle physics.
Each group has to put in place and optimise a data analysis pipe line, resulting in a scientific measurement (including uncertainties), each group divided in teams focussing on a particular aspect.

Grading

Combination of several methods. Synthetic notes on the introduction seminars. 1H30 final exam for the specific course. Enseignement d'integration : grade combining the notebooks written and the final presentation.

Course support, bibliography

- F. James, Statistical Methods in Experimental Physics: 2nd Edition
- G. Cowan, Statistical Data Analysis
- I. Narsky et F. C. Porter, Statistical analysis techniques in particle physics: fits, density estimation and supervised learning
- G. D'Agostini, Bayesian reasoning in data analysis: a critical introduction
- J. Rich, Fundamentals of Cosmology, Springer
- S. Serjeant, Observational Cosmology, The Open University
- C. Giunti, C. W. Kim, Fundamentals of Neutrino Physics and Astrophysics
- D. Griffiths, Introduction to Elementary Particle Physics.

Resources

- Teaching team : Jean-Christophe Hamilton (CNRS-APC), Guillaume Mention (CEA-IRFU)
- Practice work: 100 students on their laptops
- Software and licenses : iPython Notebooks (Jupyter, JupyterHub on a dedicated serve). No specific licence.

Learning outcomes covered on the course

Applying knowledge of statistics and machine learning to scientific issues

1SC4791 – Black swans detection in particle physics and cosmology (Higgs)

Instructors : **David Rousseau, Guillaume Mention**
Department : **DOMINANTE - PHYSIQUE ET NANOTECHNOLOGIES**
Language of instruction : **ENGLISH**
Type of course : **Challenge Week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

This Enseignement d'Intégration / Challenge Week is a week-long project where students are grouped in collaborations of about 25, split into 5 teams.
The goal of each collaboration is to build an analysis pipeline to arrive at a piece of evidence for the existence of the Higgs boson with Machine Learning, using open data from the CERN ATLAS experiment. The five teams are: Feature Engineering, Boosted Decision Tree, Neural Networks, Statistical analysis, Systematics effects. An elected spokesperson is making sure the collaboration as a whole delivers the expected outcome.

Quarter number ST4

Prerequisites (in terms of CS courses)

Basic knowledge in Particle Physics, Statistical Analysis, Machine Learning, coding in the Machine Learning python ecosystem.

Syllabus

We provide an introduction to the work to be done on the morning of the first day.
Students are divided into two collaborations and work independently. They are participating in team works and should share workload and tasks, identify difficulties, and brainstorm together. Adjustments on workload and sharing have to be managed within the week to ensure a global collaborative effort.
Regular updates on progress and difficulties encountered have to be provided in order to improve the students' progress. Discussions with teachers happen all along the week. Small daily reports have to be provided.
Students work on shared notebooks. We ask for a presentation of the work done and the results obtained by the end of the EI week.
This challenge week ends with a half-day of oral presentations by the students.

Class components (lecture, labs, etc.)

We provide support materials to read and understand. Basic notebooks are also provided. The instruction framework follows practice sessions from which students can draw inspiration to get started. Their work must then go well beyond the framework seen in class and leave room for their personal understanding and initiative.

Grading

The week of the EI ends with a 45' presentation followed by 15' of questions. The presentation is split between 5 randomly selected speakers in addition to the spokesperson. In addition, the collaboration should deliver notebooks with all their computation. The final grade is a combination of the performance of the whole collaboration, the performance of the team, and individual contributions.

Resources

Python Colaboratory notebooks (seen during the main course).

Learning outcomes covered on the course

- Set up standard statistical tools
- Use of machine learning libraries
- Computation of quantities using special relativity
- Numerical data analysis
- Team working
- Work sharing
- Presentation of methods and results

Description of the skills acquired at the end of the course

[C6] Be operational, responsible, and innovative in the digital world:
- C6.3 Process data;
- C6.1 Solve a problem numerically;
- C6.2 Design software

[C7] know how to convince:
- C7.1 Structure your ideas and arguments, be synthetic (assumptions, objectives, expected results, approach, and value created);
- C7.4 On communication techniques: Master spoken, written, and body language, and master basic communication techniques

[C8] Lead a project, a team:
- C8.1Build the collective to work as a team ;
- C8.4 Work in project mode by implementing project management methods adapted to the situation

[C1] Analyze, design, and build complex systems with scientific, technological, human, and economic components:
- C1.4: Design: specify, implement and validate all or part of a complex system
- C1.3: Solve: solve a problem with a practice of approximation, simulation, and experimentation

[C2] Develop in-depth skills in an engineering field and in a family of professions
- C2.1 Deepen a field of engineering sciences or a scientific discipline

1SC4792 – Black swans detection in particle physics and cosmology (Cosmology)

Instructors : **Jean-Christophe Hamilton**
Department : **DOMINANTE - PHYSIQUE ET NANOTECHNOLOGIES**
Language of instruction : **ENGLISH**
Type of course : **Challenge Week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

This Enseignement d'Intégration / Challenge Week is a week long project where students are grouped in collaborations of about 25, split into 6 teams corresponding to various tasks.
The goal is to come up with cosmological constraints from a simulated dataset (Type Ia supernovae and Cosmic Microwave Background) corresponding to a Universe with distinct (and unknown) cosmological parameters.
Each collaboration has to build an analysis pipeline to arrive to the relevant cosmological constraints. Tasks to achieve include:

-Supernovae detection from images
-Supernovae photometry and light curve building
-Cosmological constraints from Supernovae
-CMB time ordered data filtering and mapmaking
-CMB Angular Power spectrum extraction
-Cosmological constraints from CMB Angular Power Spectrum
-Joint cosmological constraints from CMB and Supernovae data

An elected spokesperson is making sure the collaboration as a whole deliver the expected outcome.

Quarter number ST4

Prerequisites (in terms of CS courses)

Basic knowledge in Cosmology, Statistical Analysis, coding in python.

Syllabus

We provide an introduction to the work to be done on the morning of the first day.
Students are divided into two collaborations and work independently. They are participating in team works and should share workload and tasks, identify difficulties and brainstorm together. Adjustments on work load and sharing has to be managed within the week to ensure a global collaborative effort.
Regular updates on progress and difficulties encountered have to be provided in order to improve the students' progress. Discussions with teachers happen all along the week. Small daily reports are to be provided.
Students work on shared notebooks. We ask for a presentation of the work done and the results obtained by the end of the EI week.
This week ends with a half day of oral presentations by the students.

Class components (lecture, labs, etc.)

We provide support materials to read and understand. Basic notebooks are also provided. The instruction framework follows practice sessions from which students can draw inspiration to get started. Their work must then go well beyond the framework seen in class and leave room for their personal understanding and initiative.

Grading

The week of the EI ends with a 45' presentation followed by 15' of questions. The presentation is split between 6 randomly selected speakers in addition to the spokesperson. In addition, the collaboration should deliver notebooks with all their computation. The final grade is a combination of : the performance of the whole collaboration, performance of the team, individual contributions.

Resources

Python Colaboratory notebooks (seen during main course).

Learning outcomes covered on the course

- Set up standard statistical tools
- Numerical data analysis
- search for available public librairies for specific tasks
- Team working
- Work sharing
- Presentation of methods and results

Description of the skills acquired at the end of the course

[C6] Be operational, responsible, and innovative in the digital world:
- C6.3 Process data;
- C6.1 Solve a problem numerically;
- C6.2 Design software
[C7] know how to convince:
- C7.1 Structure your ideas and arguments, be synthetic (assumptions, objectives, expected results, approach, and value created);
- C7.4 On communication techniques: Master spoken, written, and body language, and master basic communication techniques
[C8] Lead a project, a team:
- C8.1Build the collective to work as a team ;
- C8.4 Work in project mode by implementing project management methods adapted to the situation
[C1] Analyze, design, and build complex systems with scientific, technological, human, and economic components:
- C1.4: Design: specify, implement and validate all or part of a complex system
- C1.3: Solve: solve a problem with a practice of approximation, simulation, and experimentation
[C2] Develop in-depth skills in an engineering field and in a family of professions
- C2.1 Deepen a field of engineering sciences or a scientific discipline

ST4 - 48 - Data@Web : Web Data Intelligence “Value creation around of web data”

Dominante: : **Info&Num (Computer and Digital)**

Langue d’enseignement **: French**

Campus où le cours est proposé **: Paris-Saclay**

Engineering problem

This thematic sequence deals with the problem of exploiting WEB data, which are massive, high-speed (for example, in 60 seconds, Google must process more than 3 million requests for its search engine, LinkedIn manages the creation of 120 new accounts, etc.), unstructured (textual or multimedia data) and very heterogeneous. This data is also obviously valuable, as shown by the success of the web giants, and exploiting it raises more and more engineering challenges (like the MapReduce paradigm proposed by Google's engineers for the distributed processing of its search engine data). Another very important aspect of this data is that we are both producers and consumers of it and that it therefore has a strong social impact.

In this thematic sequence, we therefore propose to address the main concepts of web data analysis, from their collection to their interpretation, through at least 3 applications: e-reputation, e-marketing and e-commerce. In addition to the aspects of data processing and information extraction, this thematic sequence will also be an opportunity to address issues such as digital life, ethics, the right to privacy, data protection and a reflection on the web we want for tomorrow.

Adviced prerequisites

Common course 1A, SIP, Algorithms

Context and issue modules:

They include a series of conferences, roundtables and innovation workshops:

The (r)evolutions of the Web planet, looking at some of the past, current, and future changes of the Web, emphasising the complexity of this artefact which makes it an object of multidisciplinary research

The Web giants, looking at the new practices, uses and technologies introduced by the web giants and how the GAFA members have revolutionised the way computing is done

Conference and round table on the theme of digital life, personal data, its protection, the GDPR, its impact on the market and society

Algorithmic recommendation and information diversity: how to analyse the impact of online algorithms?

Specific course (60 HEE) :

Processing and analysis of massive unstructured data - the case of web data

Brief description: How can we automatically and quickly find information relevant to a particular need from a large amount of information? This is typically what search engines such as Google or Baidu do efficiently when they answer the 4 million queries they each receive every second. The objective of this course is to describe the foundations and techniques of Information Retrieval (IR) on which these search engines rely. The course will also address current challenges in the field such as the contributions of machine and deep learning to IR or personalization and recommendation (collaborative filtering).

Integration course: Web datackathon challenge the data of the web!

The objective is to implement, on concrete data from the Web, several of the approaches discussed in the ST with the aim of a web data intelligence application (e-reputation, e-marketing, e-vigilance ...)

- Analysis and translation of the need

- Construction of the data analysis chain: from collection (enrichment) to interpretation and visualisation

- Design of the underlying technical architecture

- Evaluation, validation and hindsight on the implemented solution.

The IE will be built as a mini datackathon around several themes built with the ST partners. The themes envisaged are :

- e-reputation of a brand or a product in social networks

- e-marketing

- e-commerce: developing a film recommendation platform

Challenge week n°1: e-reputation: sentiment analysis and NLP

- Associated partners: Mazars

- Location: Paris-Saclay campus

- Brief description : Mazars offers to share its business experience on the development of a Data Science model for client needs. The aim is to familiarise you with the important stages of data collection, modelling using machine learning algorithms and putting the model into practice by participating in the development of a complete model project: from the choice of objective to the critical presentation of your results. Mazars suggests the following area of application: "the e-reputation of a company, a brand or a personality by analysing feelings based on data from social networks or the Web, in this case Twitter".

It will also be an opportunity for you to discover how to scrape data on a network that has 'blocked' free access to its data. The project will involve the following stages:

1. Understand the customer's problem and translate the need
2. Identify the Data Sets required for the model
3. Collect, clean and qualify the data
4. Build a model using the arsenal of data science algorithms
5. Validate the model

Challenge week n°2: e-marketing

- Examples of Associated partners: HeadMind Partners

- Location: Paris-Saclay campus

- Brief description: In an ever-changing digital world, search engines play a crucial role in enabling us to explore, analyze and discover relevant information from the mass of online data. An in-depth understanding of how these engines work is therefore becoming an essential skill for those who aspire to shape the future of information retrieval. The aim is to implement a semantic search engine by following the steps below:

- Data mining (retrieval, exploration, and visualization of data)

- Creation of the search engine (indexing, search method, ranking, etc.)

- Improving the search engine (performance metrics)

Challenge week n°3: e-commerce

- Associated partner: Theodo

- Location: Paris-Saclay campus

- Brief description: Theodo develops bespoke web applications to solve its customers' business problems. With offices in Paris, Lyon, Nantes, London and New York, we work with both large groups (RATP, Bpifrance, Carrefour) and scale-ups/start-ups (Qonto, Sunday, ManoMano). The aim is to develop a web platform where users can rate films and receive automatic recommendations. Several technologies can be used to achieve this: React JS for the graphical interface, Express JS for the server side, SQL for the database, etc.

1SC4810 – Processing and analysis of massive unstructured data - the case of web data

Instructors : **Wassila Ouerdane, Céline Hudelot**
Department : **DÉPARTEMENT INFORMATIQUE**
Language of instruction : **FRENCH**
Type of course : **Specific Course**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **60**
On-site hours (HPE) : **30,00**

Description

How can we automatically and quickly find relevant information to a particular need, based on a large amount of information? This is typically what search engines such as Google or Baidu do effectively when they respond to the 4 million queries they each receive every second. The objective of this course is to describe the foundations and techniques of Information Retrieval (IR) on which these search engines are based. The course will also address some current challenges in the field such as the contributions of automatic and deep learning to IR or personnalisation and recommendation (collaborative filtering).

Quarter number ST4

Prerequisites (in terms of CS courses)

Information systems and programming (ISP) - Algorithms design and Complexity.

Syllabus

Breakdown of the course into chapters:

-Introduction to Information Retrieval - Basics: indexing and inverted index.
-Boolean and vectorial search models.
-Probabilistic and language models.
-Evaluation of Information Retrieval Systems.
-Web search: crawling - case of large collections - distributed indexing (MAP REDUCE - Hadoop)
-Web search : link analysis
-Personalization: e.g. Recommendation systems
-Machine Learning for Information retrieval : categorization
-Machine Learning for Information retrieval : Learning to Rank

Contents of the Laboratories (practical work on machine and TDs)

-Indexing - Building of an inverted index
-Search Models : boolean and vectorial search models
-Search Models : probabilistic search models
-Evaluation of IR Systems
-Web search : MapReduce
-Web search : Link analysis -PageRank
-Recommandation systems
-Learning to Rank : point-wise approaches
-Learning to Rank : pair-wise approaches

Class components (lecture, labs, etc.)
9 sessions of 1h30 of classes, 13 sessions of 1h30 of Laboratories

Grading
Final control in the form of a written exam (1,30 hours) with calculator, handouts and course notes of the student authorized

Course support, bibliography
Introduction to Information Retrieval, by C. Manning, P. Raghavan, and H. Schütze (Cambridge University Press, 2008)
1. Information Retrieval: Implementing and Evaluating Search Engines, by S. Büttcher, C. Clarke, and G. Cormack.
2. Search Engines: Information Retrieval in Practice, by B. Croft, D. Metzler, and T. Strohman.
3. Modern Information Retrieval, by R. Baeza-Yates and B. Ribeiro-Neto.
4. Recherche d'information - Applications, modèles et algorithmes - Data mining, décisionnel et big data - Messa-Aminih Reza et Gaussier Eric - Eyrolles

Resources
- Teaching team : Céline Hudelot, Wassila Ouerdane, Myriam Tami, Bich-Liên Doan.
- Size of the Lab groups: 40 (3 or 4 groups)
- Software tools:

-Programming language: python
-Development tools : jupyter notebooks

Learning outcomes covered on the course

At the end of this course the student will have acquired a good understanding of the basic concepts of Information Retrieval and will be able to apply these concepts in practice. More precisely, it will be able to:

-Understand the problems of modeling, indexing and information processing related to Information Retrieval (IR).
-Understand how statistical text models and machine learning can be used to solve IR problems.
-Understand and make recommendations on the importance of data structures for effective access to information in large corpora.
-Apply the main concepts of Information Retrieval to the design and implementation of real applications of ad-hoc information retrieval.
-Analyze and evaluate the performance of information retrieval systems using test collections.
-Understand the current challenges of Information Retrieval such as large scale data processing or personnalisation.

Description of the skills acquired at the end of the course

- Understand the problems of modeling, indexing and information processing related to Information Retrieval (IR), Apply the main concepts of Information Retrieval for the design and implementation of real ad-hoc information system applications and Understand the current challenges of Information Retrieval such as large-scale date processing or personnalisation are part of **C1 "Analyze, design and build complex systems with scientific, technological, human and economic components"** and **C2 "Develop an in-depth competence in an engineering field and in a family of professions".**

- Understanding how statistical text models and learning can be used to solve IR problems and Understanding and making recommendations on the importance of data structures to enable effective access to information in large corpora are part of **C6 : "Be operational, responsible and innovative in the digital world"**

- Analyzing and evaluating the performance of information retrieval systems using test collections is part of **C3.3 "To concretely implement innovative ideas and commit to their decisions, to evaluate the solutions, to move to industrialization to deliver tangible results".**

1SC4891 – E-reputation

Instructors : **Bich-Lien Doan**
Department : **DOMINANTE - INFORMATIQUE ET NUMÉRIQUE**
Language of instruction : **FRENCH**
Type of course : **Challenge Week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

EI-1: E-reputation: sentiment analysis and NLP

Information management is strategic for Octopeek. Its importance is measurable by the volume of information processed, by the speed of information evolution as well as by the time spent in the activity of information research. This issue has led to the emergence in recent years of new businesses around Data Science and Big Data. Context and objective :

Mazars proposes to share its business experience on the development of a Data Science model for customer needs. The aim is to qualify the e-reputation of a company, a brand, a personality by analyzing feelings on data from social networks or the Web.

The objective is to make an analysis of feelings about a company, a group or simply a phenomenon in order to determine the causality of these feelings on the future of the entity concerned. Example: analysis of feelings on a television channel "HBO" which proposes a trend series currently "Game Of Thrones". At the business level, the channel's managers are trying to find out whether it would be interesting to launch a spin-off of this series soon or not. To do so, they need to conduct a study on how fans feel about their series. The best approach is to collect the reaction of fans on a source that ensures we have access to so-called "hot" or real-time data. The data collections used for testing will be either public collections available on the web (Twitter) or collections provided by Mazars.

Quarter number ST4

Prerequisites (in terms of CS courses) none

Syllabus

In this project, students choose a topic on which to conduct a study on users' feelings, analysing the feelings related to their comments. The first step is to collect tweets from real-time data sources. Then, after cleaning up the collected data, the students experiment with algorithms to get the best recommendation and use the precision measures to evaluate the chosen model. The implementation of the project will be in the form of a challenge between the teams, which will allow them to confront the best algorithm at the end of the project.

Class components (lecture, labs, etc.)

project work
real-life setting

Grading

continuous checking
oral defense

Learning outcomes covered on the course

Understand the customer's problem and translate the need
Identify Data Sets needed for the model
Collect, cleanse and qualify data
Elaborate a model using the arsenal of datascience algorithms
Validate the model

1SC4892 – E-Marketing

Instructors : **Céline Hudelot, Pierre COLOMBO**
Department : **DOMINANTE - INFORMATIQUE ET NUMÉRIQUE**
Language of instruction : **FRENCH**
Type of course : **Challenge Week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

Web datackathon: web data challenge!

E-Marketing - With an industrial partner (2019 : Doctolib - 2020-2021 : Procter & Gamble - 2022 : Rakuten - **2023 HeadMind Partners)**

The objective is to implement, on concrete data provided by the partner and enrich with web-based data, several of the approaches discussed in the ST with the aim of an application in marketing. It will consist in :

-Analyzing and translating the needs
-Building the data analysis chain: from collection (enrichment) to interpretation and visualization
-Designing the underlying technical architecture
-Evaluating, validating and taking a step back from the product on the solution developed.

Quarter number ST4

Prerequisites (in terms of CS courses)

Information systems and programming- Algorithms design and complexity - Statistics and machine learning

Syllabus

The precise content of this EI may be subject to change each year, depending on the industrial partner involved. The contents of the three previous editions of this EI are given for information only.

EI Procter&Gamble, 2020
OralB is a leading brand in Powered tooth brush category with 20% of people in France using powered tooth brush. Based on the research, powered tooth brush gives a better plaque removal by 21% as compared to manual toothbrush. To be able to attract more consumers to try powered tooth brush, we need a marketing campaign that is able to target the right audience at the right time. Using the data on the consumers that have tried the toothbrush, we could develop the algorithms to find the consumers that have a high likelihood to buy Powered tooth brush. The project aims at leveraging data science to make the BEST business decision regarding precision marketing.

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EI Procter&Gamble, 2021

Procter & Gamble (P&G) is an American multinational corporation that sells consumer products. P&G offers many well-known brands such as Gilette, Braun, OralB, Ariel, Lenor, Pampers, Always, Head & Shoulders, Herbal Essence, Febrez, Mr Propre, Vicks ... They are currently launching a new product in France called Fairy pods for Auto dishwashers.
In this EI, the goal is to identify, using machine learning algorithms, consumers who are very likely to have automatic dishwashers. This will allow the P&G marketing team to target them in media campaigns and attract as many consumers as possible to try the Fairy Pods, while spending the lowest possible budget. Based on the demographic / behavioral characteristics and web actions of consumers, part of which is provided via a database format, the goal is to predict whether or not they have an automatic dishwasher. Students are thus both encouraged to develop strategies for enriching the databases provided but also for managing missing data and any other problem that a data scientist is confronted with when working on real data.

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EI Rakuten, 2022

Rakuten Institute of Technology (RIT) is the incubation center of AI research and technologies that fuel Rakuten's innovation. It is the core AI research wing of Rakuten, is spread across six geographical locations including Tokyo, Singapore, Boston, San Mateo, Bengaluru, and Paris. RIT does applied research on three major verticals, customer understanding, natural language processing, computer vision. RIT also engages in moonshot initiatives includes programs like curing cancer using AI, quantum computing, and building a fully autonomous mobile network.

Context

This challenge focuses on the topic of large-scale product type code (possibly, multimodal using text and image) classification where the goal is to predict each product's type code (which defines the category of the product) as defined in the catalog of Rakuten France.

The cataloging of product listings through title and image categorization is a fundamental problem for any e-commerce marketplace, with applications ranging from personalized search and recommendations to query understanding. Manual and rule-based approaches to categorization are not scalable since commercial products are organized in many classes. Deploying multimodal approaches would be a useful technique for e-commerce companies as they have trouble categorizing products given images and labels from merchants and avoid duplication, especially when selling both new and used products from professional and non-professional merchants, like Rakuten does. Advances in this area of research have been limited due to the lack of real data from actual commercial catalogs. The challenge presents several interesting research aspects due to the intrinsic noisy nature of the product labels and images, the size of modern e-commerce catalogs, and the typical unbalanced data distribution.

Task definition

Participants are required to design a classifier to categorize products in the Rakuten France catalog into product type codes.

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EI headMind Partners, 2023

Founded on cutting-edge expertise, HeadMind Partners AI & Blockchain is the AI and Blockchain Consulting entity of the HeadMind Partners Group. Its 30 employees reveal the data potential of Key Account Companies from all sectors by supporting them in the realization of their AI projects: from ideation to AI transformation through to the industrialization phase. All areas of AI are covered: NLP, Computer Vision & Time Series!

Context

In a constantly evolving digital world, search engines play a crucial role in enabling us to explore, analyze and discover relevant information from the mass of data available online. An in-depth understanding of how these engines work is therefore becoming an essential skill for those aspiring to shape the future of information retrieval.

Beyond their apparent simplicity, these systems are in fact complex, calling on sophisticated artificial intelligence models and advanced semantic analysis techniques. You will have the opportunity to explore the underlying architectures that enable search engines to interpret user queries and deliver relevant results in real time.

You will work on projects involving emerging technologies, real datasets and realistic scenarios. You'll have the opportunity to develop your skills in programming, natural language processing and artificial intelligence model design.

Class components (lecture, labs, etc.)

The work will be done, in competition or challenge mode. Students will be divided into groups of 4 to 6 people and will work in groups to propose the best prediction model and a product view of the proposed model. The proposed model will be evaluated on a test set that will be provided at the end of the week to the different groups.

Grading

The evaluation of the EI is composed of :

- a control of the presence and involvement of the different students in the group's work
- a defense of the final solution in front of engineers and product managers of the partner during which the deliverables will be evaluated
- the delivery of clean, executable and commented Python code.

Course support, bibliography

+ Data Science : fondamentaux et études de cas - Machine Learning avec Python et R. E. Biernat, M. Lutz - Eyrolles
+ Introduction to Information Retrieval, by C. Manning, P. Raghavan, and H. Schütze (Cambridge University Press, 2008).
+ Massih-Reza Amini, Gaussier Eric. Recherche d'Information - applications, modèles et algorithmes. Eyrolles. Eyrolles, pp.1-233, 2013, Algorithmes, Muriel Shan Sei Fan, 978-2-212-13532-9
+ Python Data Science Handbook : https://jakevdp.github.io/PythonDataScienceHandbook/

Resources

Teaching team : Céline Hudelot and Pierre Colombo and several partner employees.
Software tools :

1. Python and its data science libraries: numpy, pandas, scikit-learn, nltk, spacy,...
2. IDE left to the students' choice.
3. Git and code sharing tool (Visual Studio Code with live share option , google colab, Kaggle)
4. Group messaging: slack and Mteams

Learning outcomes covered on the course

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

-Apply and use a set of knowledge and information processing methods to answer and propose a solution to a real problem.
-Take a step back on an information processing problem in a real context.
-Work as a team independently and interdependently towards a common team goal.
-Defend and convince a jury of professionals.

Description of the skills acquired at the end of the course

-Applying and using a set of knowledge and information processing methods to solve a real problem is part of ***C1.1 "Studying a problem as a whole", C1.5 "Mobilizing a broad scientific and technical base as part of a transdisciplinary approach", C6.4 "Solving problems in a computational thinking approach" and C6.5 "Exploiting all types of data".***
-Taking a step back from information processing work is part of ***C4.1 "Customer Thinking", C6.6 "Understanding the Digital Economy" and C9.4 "Demonstrating rigour and critical thinking".***
-Working as a team in an autonomous and interdependent way towards a common objective for the team is part of ***C8 "Leading a project, a team".***
-Defending and convincing a jury of professionals is part of ***C7 "Knowing how to convince".***

1SC4893 – E-Commerce

Instructors : **Wassila Ouerdane**
Department : **DOMINANTE - INFORMATIQUE ET NUMÉRIQUE**
Language of instruction : **FRENCH**
Type of course : **Challenge Week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **40**
On-site hours (HPE) : **24,00**

Description

-The objective of 'E-commerce' teaching is to put into practice one of the facets of information retrieval, namely "personalization" to respond to the problem of "information overload". The idea is to implement a platform which aims to provide relevant information to a user on the basis of his profile and preferences. More specifically, we will discuss several technical topics:
-A web development part in Serveless AWS in JS & Vue during which we will implement an authentication, a search bar and a REST API
-A Machine Learning part to establish the recommendation. This part is based on the notions and concepts seen during the recommendation course (course Data @ Web: web Data Intelligence: Creation of values around web data).

Quarter number ST4

Prerequisites (in terms of CS courses)

- Have taken the course of Data @ Web: web Data Intelligence: Creation of values around the data of the Web and the course of Machine Learning.

Class components (lecture, labs, etc.)

The work will be done in groups of 2/3 people to offer on the one hand the best interface and on the other hand an implementation (a demonstration) of the platform for recommendation, on the basis of data chosen by the group. .

Grading

The assessment includes:

1. a control of the presence and the implication of the different students in the group work.
2. a presentation defense of the final solution in front of a jury made up of our participants from the industrial partner.

Resources

-Teaching Team: Wassila Ouerdane and several participants from the industry partner

-Different tools and software:

-for web development: Serveless AWS in JS & Vue, REST API
-Git and code sharing tools
-Group messaging: Slack.

Learning outcomes covered on the course

-At the end, the student will be able to:
-Apply and use a set of knowledge and methods of implementing web platforms and information processing.
-Take a step back on information retrieval domain in general and recommendation process in particular.
-Work as a team in an autonomous way towards a common goal.
-know how to defend a proposal to real problem in a rigorous and justified manner in from of a jury of professionals.

Description of the skills acquired at the end of the course

-C1.1 : étudier un problème dans sa globalité, la situation dans son ensemble.
-C1.4: Spécifier, concevoir, réaliser et valider tout ou partie d'un système complexe
-C1.5: mobiliser un large socle scientifique et technique dans le cadre d'une approche transdisciplinaire.
-C3.1: Etre proactif, prendre des initiatives, s'impliquer
-C3.6: Evaluer l'efficacité, la faisabilité et la robustesse des solutions proposées.
-C8.1: Travailler en équipe/en collaboration

INTENSIVE COURSES

1IN1000 – Start-Up Week

Instructors : **Annie Le Vey, Jean-François Gallouin**
Department : **DÉPARTEMENT SCIENCES HUMAINES ET SOCIALES**
Language of instruction : **FRENCH**
Type of course : **Intensive Week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **30**
On-site hours (HPE) : **18,00**

Description

The objective of Startup Week is to
- to allow students to discover in a concrete way what an "entrepreneurial posture" is. Entrepreneurship should be understood in its broadest definition: business creation, intrapreneurship, launching a new activity, self-entrepreneurship.
- to provide students with initial entrepreneurial skills: business model, finance, market analysis, etc.
The students, divided into teams before the start of the SUW, have 4 days to start validating (or invalidating) a product/activity/business idea of their choice, and to convince themselves of the quality of their entrepreneurial approach. The aim of the startup week is for them to learn how to
- Formulate a value proposition
- Define a business plan
- Acquire initial knowledge: business model, finance, market analysis, pitch technique, teamwork, prototyping, etc
.- Make progress on teamwork

Quarter number

Intensive week at the end of the ST2

Prerequisites (in terms of CS courses)

None

Syllabus

Day 1 :
- 13H30-14H30 (in plenary): Presentation of the SUW in plenary
- 14h30-15H: Presentation of the Business Model Canvas
- 15H30 - 17H00 (in workshops of 40, in teams of 6): Ideation, problematisation

Day 2 :

- 9H-12H30 (in workshops): Exchanges with the coaches and Adjustments based on the work prepared the day before by the students
- 14H00-15h00 (in plenary): Financial elements
- From 15.00: Students develop their work on the dimensions (Offer, Market, Business Model) and support exchanges with the facilitators for the next day

Day 3 :
- 9H- 12H30 (in workshops): Exchanges with the coaches and Adjustments based on the work prepared the day before by the students
- 14:00 - 15:00 (in plenary); Pitching techniques
- From 15:00: Students continue to improve their work, prepare a pitch deck and practice oral communication for the next day

Day 4:
- 9.00 - 12.00 (in workshops): Exchanges with the coaches and adjustments based on the work prepared the day before by the students

Day 5:

- 9.00-11.00 (in workshops): Presentations by all the teams of the finalised Pitch Deck
- 11.00-12.00 (in workshops): Individual feedback from the coaches to each team on the quality of the achievements during the week (Offer, Market, Business Model, Pitch Deck) - And evaluation of the teams by the coaches
- 14H00-15H30: Pre-selection jury for the Final
- 16H-17H30 (in plenary): Presentation in Pitch Deck format by the pre-selected teams - Final

Grading

students will be evaluated on :Their involvement throughout the 4 days
The quality of the achievements at the end of the week
The quality of the TD Pitch Deck group presentation on the weekend

Resources

- Teaching team (names of lecturers): Jean-François Gallouïn, Maxime Guymard-
Group size in workshops: 40 students, in teams of +-6 students, supervised by 2 experts in business creation-
Rooms (department and capacity): 22 rooms of 40 for the workshops and the Michelin amphitheatre for the plenary sessions

Learning outcomes covered on the course

At the end of this teaching, the student will be able to :
Formulate a value proposition
Analyze a market Formalize a Business Model Canvas
Synthesizing and pitching a project

Description of the skills acquired at the end of the course

C3.1 Be proactive, take initiatives, get involved
C3.2 Question one's initial hypotheses and certainties. Overcome failures.Make decisions
C4.1 Think customer. Identify/analyse the needs, issues and constraints of otherstakeholders, especially societal and socio-economic ones.
C4.2 Know how to identify the value of a solution for a client, the market.
C7.3 Know how to discern and seize opportunities, good business opportunities.
C7.4 Convince by working on communication techniquesMaster spoken, written and body language. Master the basic techniques ofcommunication
C8.1 Work in a team/collaboration

1IN2000 – Project Management - The Fundamentals

Instructors : **Ludovic-Alexandre VIDAL**
Department : **SCIENCES ENTREPRISE, DÉPARTEMENT GÉNIE INDUSTRIEL ET OPÉRATIONS**
Language of instruction: **ENGLISH, FRENCH**
Type of course : **Intensive week**
Campus : **CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **10**
On-site hours (HPE) : **6,00**

Description

Master the basic concepts and tools of project management.
Distance Learning on Edunao.

Quarter number SG1

Prerequisites (in terms of CS courses) none

Syllabus

- Understanding the project management process, the different phases of a project and project management vocabulary.
- Identifying project stakeholders, objectives, deliverables and value creation.
- Build a project organisation with a task-oriented architecture (WBS).
- Plan a project in terms of Schedule and know the associated concepts (free and total floats, critical path, PERT and Gantt models,...).
- Plan the ressources and costs of a project (workload diagram, project budget,...).
- Identify, analyse and control project risks.

Class components (lecture, labs, etc.)

Class with industrial and student project examples. Edunao exercise.

Grading Pass/Fail validation.

Course support, bibliography

PROJECT MANAGEMENT INSTITUTE. (2004). A guide to the project management body of knowledge (PMBOK guide). Newtown Square, Pa, Project Management Institute.
FRANCK MARLE, LUDOVIC-ALEXANDRE VIDAL (2016). Managing Complex, High Risk Projects. A Guide to Basic and Advanced Project Management. Springer.

Resources

- Teacher : Ludovic-Alexandre VIDAL, maybe some industrial practitioners.
- Software : Microsoft Project.

Description of the skills acquired at the end of the course

- Understanding the project management process, the different phases of a project and project management vocabulary.

- Identifying project stakeholders, objectives, deliverables and value creation.

- Build a project organisation with a task-oriented architecture (WBS).

- Plan a project in terms of Schedule and know the associated concepts (free and total floats, critical path, PERT and Gantt models,...).
- Plan the ressources and costs of a project (workload diagram, project budget,...).

- Identify, analyse and control project risks.

1IN3000 – Coding Weeks

Instructors : **Paolo Ballarini, Marc-Antoine Weisser**
Department : **DÉPARTEMENT INFORMATIQUE**
Language of instruction: **ENGLISH, FRENCH**
Type of course : **Intensive week**
Campus : **CAMPUS DE METZ, CAMPUS DE PARIS - SACLAY, CAMPUS DE RENNES**
Workload (HEE) : **80**
On-site hours (HPE) : **48,00**

Description

The objective of this module is to enable students to consolidate their knowledge in programming and software engineering through coding projects, on the one hand, and, on the other hand, to get familiar with the practices and methodologies of collaborative computer science projects development within a group of developers. Following a "learning-by-doing" approach, students will be initiated to the fundamentals of software craftsmanship.

Quarter number

Infill week at the end of SG1

Prerequisites (in terms of CS courses)

Information systems and Programming (ISP)

Syllabus

This module is organized in two consecutive weeks of programming in bootcamp mode.

During a first part (3 days), students will work in pairs and groups of 4 to 5 persons to develop a typical project organized in different progressive iterations (sprints). The pairs could be renewed every day (i.e. "pair programming", one of the computer development methods considered as a good practice of "extreme programming"). Short methodological and technical contributions will also be provided in the form of conferences and mini-tutorials (version managers, APIs, Test Driven Development and code quality, agility) and implemented during the development of this model project. This first part will give rise to an evaluation taking into account a knowledge test of the concepts introduced during this first part, a presence test and a participation mark.

During the second part (5 days), students will work in groups of 4 to 5 on a thematic project with the objective of moving from idea to product. The aim will be to implement the previously acquired methodologies and practices. This project will give rise to a group evaluation by a jury during a defense.

Class components (lecture, labs, etc.)

This module is organised over two consecutive weeks
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Week 1 - Day 1: 1h30 amphi (presentation and skills input) + EL/TP work in groups of 25-35
Week 1 - Day 2: EL/TP work in groups
Week 1 - Day 3: EL/TP work in groups
Week 1 - Day 4: work on the project
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Week 2 - Day 1: work on the project
Week 2 - Day 2: work on the project
Week 2 - Day 3: work on the project
Week 2 - Day 4: work on the project - Final defense during the last half-day.

Grading

- The first three learning outcomes will be assessed both by the work on the typical project in the first part and by the work on the free project in week 2 (defence - delivery and documentation of the project on Gitlab or Github).The fourth learning outcome will be more specifically assessed in the part 2 project.

Course support, bibliography

Programming Languages

- Python

Think Python 2nd Edition - Allen B. Downey - GreenTeaPress.
Python Cookbook, 3rd Edition - Recipes for Mastering Python- B. Jones - D.Beazley - O'Reilly
Test-Driven Development With Python: Obey the Testing Goat- Harry J.W. Percival- O'Reilly
Autres : RealPython : https://realpython.com/

- Java

Core Java Volume I—Fundamentals, Eleventh Edition - Cay S. Horstmann. Prentice Hall

- Software craftmanship

Clean Code - A Handbook of Agile Software Craftmanship- Robert C. Martin
Apprenticeship Patterns: Guidance for the Aspiring Software Craftsman- Dave Hoover et Adewale Oshineye - O'Reilly
OCTO - Culture Code - https://www.octo.com/publications/culture-code/

Resources

Teaching Team : Paolo Ballarini (responsable), Marc-Antoine Weisser (responsable), Lina Yé, Gianluca Quercini, Wassila Ouerdane, Myriam Tami and a team of temporary staff.

- Group size: 25 to 50 students.
- Programming languages: mainly Python and its many modules and according to groups: java, unity...
- Software tools: VisualStudioCode, git and for some groups Android Studio, Unity

Learning outcomes covered on the course

Through this module the student will be able to:

- Know and Apply good programming practices and methods of software development at a simple project level: structuration of a set of programs in a clear and meaningful way, use of existing libraries or modules, build the project in a modular way, test, and allow the readability, understanding and use of the project source code (software quality).
- Know how to build a coding project in an iterative (from idea to product) and collaborative approach.
- Know and know how to use the main tools of software development.
- Work in team/collaboration.

Description of the skills acquired at the end of the course

- This course will provide a first milestone in competency **C6: " Be operational, responsible and innovative in - the digital world**"

-Knowing and applying good programming practices and methods of computer development at the scale of a simple project is covered in **C6.2: "Software Design" and C6.3: "Data Processing".**

-Knowing how to build a computer project in an iterative (from idea to product) is part of **C6.1: "Solve a problem numerically"**

- Knowing and knowing how to use the main tools of software development is part of C6.2: "Software Design"
Teamwork/collaboration is part of **C8: "Leading a project, a team".**

-Skills **C1.1, C3 and C7** will also be mobilized.

LANGUAGE AND CULTURE COURSES

LC0100 – English

Instructors : **Mark Pitt**
Department : **DÉPARTEMENT LANGUES ET CULTURES**
Language of instruction : **ENGLISH**
Type of course : **Language**
Campus : **CAMPUS DE PARIS - SACLAY, CAMPUS DE RENNES, CAMPUS DE METZ**
Workload (HEE) : **30**
On-site hours (HPE) : **21,00**

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.

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**
Type of course : **Language**
Campus : **CAMPUS DE METZ, CAMPUS DE RENNES, CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **30**
On-site hours (HPE) : **21,00**

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 : **GERMAN**
Type of course : **Language**
Campus : **CAMPUS DE RENNES, CAMPUS DE METZ, CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **28**
On-site hours (HPE) : **21,00**

Description

General German courses from level A0 to C1, with specialization (thematic courses) possible from level B1+.
Possibility of E-Tandem with the RWTH Aachen for advanced students

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:A0, 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
Written and oral assessment of the required exit level at the end of the language course in 3A: A2- for those who have started German at CS, B1 or higher for those who have studied German before

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 adapted to the interests and needs of the learners and focused on the major themes and trends of our societies, the culture and economic, political and social current events in German-speaking countries as well as interculturality

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 engineer's skills C5 and C7 (intercultural skills, arguing and convincing)

LC0400 – Spanish

Instructors : **Antonio Barrejon Lopez**
Department : **LANGUES ET CULTURES, DÉPARTEMENT LANGUES ET CULTURES**
Language of instruction : **SPANISH**
Type of course : **Language**
Campus : **CAMPUS DE RENNES, CAMPUS DE METZ, CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **28**
On-site hours (HPE) : **21,00**

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 : **ITALIAN**
Type of course : **Language**
Campus : **CAMPUS DE METZ, CAMPUS DE RENNES, CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **28**
On-site hours (HPE) : **21,00**

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.

LC0600 – Portuguese

Instructors : **Claude Mezin-Wilkinson**
Department : **DÉPARTEMENT LANGUES ET CULTURES, LANGUES ET CULTURES**
Language of instruction : **PORTUGUESE**
Type of course : **Language**
Campus : **CAMPUS DE PARIS - SACLAY, CAMPUS DE RENNES, CAMPUS DE METZ**
Workload (HEE) : **28**
On-site hours (HPE) : **21,00**

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 : **CHINESE**
Type of course : **Language**
Campus : **CAMPUS DE RENNES, CAMPUS DE METZ, CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **28**
On-site hours (HPE) : **21,00**

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 : **JAPONESE**
Type of course : **Language**
Campus : **CAMPUS DE PARIS - SACLAY, CAMPUS DE METZ, CAMPUS DE RENNES**
Workload (HEE) : **28**
On-site hours (HPE) : **21,00**

Description

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 : **RUSSIAN**
Type of course : **Language**
Campus : **CAMPUS DE RENNES, CAMPUS DE METZ, CAMPUS DE PARIS - SACLAY**
Workload (HEE) : **28**
On-site hours (HPE) : **21,00**

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 : **ARABIC**
Type of course : **Language**
Campus : **CAMPUS DE PARIS - SACLAY, CAMPUS DE METZ, CAMPUS DE RENNES**
Workload (HEE) : **28**
On-site hours (HPE) : **21,00**

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 : **HEBREW**
Type of course : **Language**
Campus : **CAMPUS DE RENNES, CAMPUS DE PARIS - SACLAY, CAMPUS DE METZ**
Workload (HEE) : **28**
On-site hours (HPE) : **21,00**

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.