SYLLABUS

2021/2022

Centrale Marseille

Semester 8

Contents

Alternative CEA 4

Prerequisites: No

Learning Objectives

The alternating skills module aims to train alternates in a specific mission in an enterprise. Alternatives are followed during the periods of alternation by a "professional tutor" and a "school tutor". The objective is to familiarise oneself with a particular environment, to learn the codes, to understand how the structure works, to develop innovative solutions enabling the progress of the project.

For semester 8, the objective is to integrate the skills, the knowledge aggregated during the first three semesters. Semester 8 can be the opportunity for the apprentice to face new structures, new ways of working, new work organisations through international mobility.

Description of the programme

During this period, the apprentice must also make regular points with his "tutor school", to keep him informed of his mission and his evolution. The module ends with two evaluations, an evaluation of the school through a defence and an evaluation of the "business tutor".
The important points are:
- Training (basic knowledge, acquisition skills, sense of analysis, sense of synthesis, creativity and level of innovation)
- Work and results (quality level, quantity, effectiveness, achievement of objectives, respect of deadlines, taking subject's hand, subject's mastery)
- Personality (initiative, sociability, contacts, interests, motivation, sense of responsibility, method and organisation, communication, openness, judgement and realism)

Target generic centrale-specific field-related skills and knowledge

The defence of semester 8 is individual. It lasts 20 minutes in September (beginning 3A) and covers the presentation of the work done in relation to the report, highlighting the issues, the context, the solutions envisaged, the solution chosen, the implementation and the results.

Knowledge Control Procedures

The module consists of a group of 5 to 6 alternates and an evaluation of the "professional tutor". Both evaluations are in the form of a letter (A: Excellent, B: All right, C: Good, D: Pretty good, E: Fair, F: Failure).
The final evaluation is done by means of the two evaluations, when the average is difficult (A and B, for example) the evaluation of the "business guardian" prevails.

Bibliography

This unit is very specific to each alternation, so there is no bibliography and there can be no bibliography.

Teacher

The Team is made up of ECM tutors: they assist the alternates in case of problems.

Distribution of hours
Total: 4
Other: 4

Language(s) used during the course: French

Sustainable Energy

Sustainable Energy Project

Prerequisites: No

Learning Objectives
- Understanding the complexity of implementing a sustainable energy project in a city in the South
- Understanding the local, departmental, regional, national and even European

decision-making mechanisms - Taking into account the energy, socio-economic and financial issues of this type of project
- Implementing the knowledge gained from all the lessons learned

Description of the programme

By group, students are assigned a city in the Southern Region to propose a sustainable energy project.
They will have to conduct a local energy analysis, take stock of available resources, take into account the finances of the current and future city.

Cities have different typologies (tourism, industry, particular geographical location, size, finance, etc.).

Several milestones are proposed to serve as a point of step in the implementation of their project. In some cases, contacts can be made with the services of the cities concerned.

The return of the project is an opportunity to implement communication skills, but also critical analysis skills for the students who will join the jury.

Target generic centrale-specific field-related skills and knowledge

- C1: The Central Engineer creates value through scientific and technical innovation.
- C2: The Central Engineer has mastered the complexity of the systems and the problems he encounters.
- C3: The Central Engineer conducts programmes.
- C4: The Central Engineer manages in an ethical and responsible manner.
- C5: The Central Engineer is part of a strategic vision and knows how to implement it.

Knowledge Control Procedures

Group Report and Presentation

Bibliography

Regional Energy Atlas

Teacher

- Thierry Gaidon
- Pascal Denis

Distribution of hours

Total: 30
Projects: 30

Language(s) used during the course: French

Sustainable Energy

Transverse energy concepts: transport, conversion, storage and power

Prerequisites: No

Learning Objectives

- Present the various transversal aspects such as different forms of energy conversion, energy transport, consumption and smart grids
- master the basic elements of primary energy conversion to electric energy through transport, storage, consumption and smart grids
- Understand the principle of operation of electric machines in motor and generator operation. Present the main topologies of power electronics converters to power an electrical equipment (motor, alternator, electronic card...) from a given source of energy (alternative network, battery...)
- Present the various means of storing the electric energy and the technical and economic challenges for the future

Description of the programme

- Conversion of electrical energy to mechanical energy (electric motors): synchronous engine, asynchronous engine, operating principle, modelling, equivalent scheme, torque calculation - Conversion of mechanical energy to electric energy (electric generators, wind turbines): asynchronous and synchronous generator (alternator)
- Conversion of electric energy to electric energy: sources, switches, connection rules, switchgear, static converter family (AC/DC), continuous-continuous (DC/DC), continuous-alternating (DC/AC), principles, advantages and disadvantages of structures, three-phase transformer)
- Transport of electric energy - Use of electric energy (railway traction, transport [land, aeronautics, maritime], industrial processes, pumping, household appliances, lighting, buildings, etc.)
- Electrical energy storage (chemical accumulators, fuel cell, super capacitor, inertia steering wheel, etc.)
- Presentation of Smart grids intelligent distribution networks, which allow the coupling of the various forms of energy located (power plant) or distributed (photovoltaic panels or other) on a distribution network, and " feed a complex typology of consumption patterns (housing, industrial, tertiary...)

Target generic centrale-specific field-related skills and knowledge

- C1: The Central Engineer creates value through scientific and technical innovation.
- C2: The Central Engineer has mastered the complexity of the systems and the problems he encounters.
- C3: The Central Engineer conducts programmes.
- C4: The Central Engineer manages in an ethical and responsible manner.

Knowledge Control Procedures
Duties monitored

Bibliography
Course Copies

Teacher
- Mohamed Boussak
- Thierry Gaidon

Distribution of hours
Total: 20
Magistrates: 20

Language(s) used during the course: French

Sustainable Energy

Sustainable Energy - Nuclear Energy

Prerequisites: No

Learning Objectives
Provide the elements for a complete understanding of the nuclear industry, its role in the current and future energy landscape, its strengths and weaknesses. Taking into account the different aspects associated, scientific, technological, environmental and societal.

Description of the programme
- Introduction: Nuclear physics, fission reactions, fusion reactions

Module Fission:
- Architecture and operation of nuclear reactors REP and RNR (JC. Klein)
- Basic principles of nuclear systems (JC. Klein)
- Fuel of nuclear reactors (Y. Pontillon)
- A review of the 3 major nuclear accidents: TMI, Chernobyl and Fukushima - Lessons for Nuclear Safety (Y. Pontillon)
- Nuclear Safety (J.C. Klein)

Fusion module:
- Introduction of controlled fusion (C. Grisolia)
- Nuclear fusion physics and quantification of reactor performance (C. Grisolia)
- Plasma physics and magnetic confinement (F. Schwander)
- Scale laws for the design of a fusion reactor (F. Schwander)
- Plasma/wall interaction physics (G. Ciraolo)
- Current situation of fusion research - the objectives and challenges of ITER (G. Ciraolo)"

Target generic centrale-specific field-related skills and knowledge
- C1 The Central Engineer creates value through scientific and technical innovation - C2 The Central Engineer masters the complexity of the systems and the problems he encounters
- C3 The Central Engineer conducts programmes
- C4 The Central Engineer manages in an ethical and responsible manner

Knowledge Control Procedures
Duties monitored

Teacher
Y. Pontillon
J.C. Klein
C. Grisolia
F. Schwander
G. Ciraolo

Distribution of hours

Total: 60
CM: 30
TD: 10
TP: 20

Language(s) used during the course: French

Sustainable Energy

Sustainable Energy Marine, wind and hydro energy

Prerequisites: No

Learning Objectives
Identify, understand and master the challenges and criteria for the sizing and optimisation of technologies and devices involving marine, wind and hydraulic energy.

Description of the programme
Generally speaking, the course is divided into three parts: the one on ocean energy (waves, hydrolienne...), the one on hydro/hydroelectricity, and the one on wind turbines. For each of these three parts, the sessions combine lectures (which set the theoretical framework and the physical laws that underlie the functioning of the various devices) and directed exercises/works (which make it possible to design and size installations). Among the concepts to be considered, specific criteria related to the coupling between mechanical devices and electrical devices must be taken into account in the sizing. Also, the power range targeted or required (which can range from a few watts to several gigawatts) impacts the choice of optimal technology.

Target generic centrale-specific field-related skills and knowledge
- C1: The Central Engineer creates value through scientific and technical innovation.
- C2: The Central Engineer has mastered the complexity of the systems and the problems he encounters.
- C3: The Central Engineer conducts programmes.
- C4: The Central Engineer manages in an ethical and responsible manner.

Knowledge Control Procedures
Duties monitored

Bibliography
D. Le Gouriérès, The Small Hydropower Plants: Design and calculation, Éditions du Moulin Cadiou, 2009. Available at the documentation centre of the school.

Teacher
- Fabien Anselmet
- Michel Benoit
- Mohamed Boussak

Distribution of hours
Total: 50

Language(s) used during the course: French

Sustainable Energy

Sustainable Energy Introduction to Energy Issues and Transverse and Societal Aspects

Prerequisites: No

Learning Objectives
- Awareness of the importance of sustainable energy for society
- Developing a general culture around energy
- Knowledge of the economic mechanisms linked to the energy environment
- Discover, through industrial visits, the reality of energy installations

Description of the programme
- Introduction on the concept of energy
- Energy
classification - Energy
deposits and resources - Geopolitical importance of different energy
resources - Specific economic mechanisms and models in the energy
sector - Industrial visits: CEA Cadarache, hydroelectric plant

Target generic centrale-specific field-related skills and knowledge
- C1: The Central Engineer creates value through scientific and technical innovation.
- C2: The Central Engineer has mastered the complexity of the systems and the problems he encounters.
- C3: The Central Engineer conducts programmes.
- C4: The Central Engineer manages in an ethical and responsible manner.
- C5: The Central Engineer is part of a strategic vision and knows how to implement it.

Knowledge Control Procedures
Continuous control and supervised homework

Bibliography
A.V. da Rosa, Fundamentals of Renewable Energy Processes, Academic Press, 2012.

Teacher
- Thierry Gaidon
- Pascal Denis
- Nicolas Clootens

Distribution of hours
Total: 34
Magistrates: 34

Language(s) used during the course: French

Environment: Management and Technology

Environment: Management and Technology - Circular Economy

Prerequisites: No

Learning Objectives

The EU relies on sustainable chemistry (technological tools) and environmental management (managerial tools), it provides the tools for eco-design, the whole enabling waste to be transformed into new resources, and beyond that, it builds industrial ecology. That's really the current trend in the economy.
This EU involves cross-cutting skills in the training of the ECM engineer. The various disciplines involved are Process Engineering, Industrial Engineering and Chemistry, as well as the Life Cycle Analysis (LCA) methods that have developed significantly in recent years.
The main objective is to understand the environmental, societal and economic issues related to industries that transform resources into products.

Description of the programme

- Discover the carbon balance tool of ADEME, a tool for assessing the emissions of Greenhouse Gases (GHGs) of a company or a site and also, a tool to help define an energy management strategy with a view to saving energy costs.
- Know the multi-criteria, multi-stage structure of an eco-design approach (according to the French standard of The same name) and the difficult constraints that environmental considerations add to the usual technical and economic design.
- Discover the ASIT method, an applied and affordable extraction developed more recently by Roni Horowitz based on the TRIZ principles.
- Know the standard evaluation method "Life Cycle Analysis" of the impacts of an industrial system on the environment.
- Go from a transformation chain resource-product-waste to processes in which waste is a new resource is one of the major challenges of the $^{21st\ century}$ processing industry.
- In the section entitled "Value", a global approach to the processes of processing of the material helps to understand the integration of the sectors and provides elements of choice for the different modes of recycling or recovery of the effluents or wastes. Industrial examples of waste recovery provide opportunities for sustainable chemistry and industrial ecology.

Target generic centrale-specific field-related skills and knowledge

- C1: Scientific and
technical innovationIn connection with the lessons of the other EU countries of this S8 journey, know how to make a diagnosis and then propose processes for the manufacture or the recovery/treatment of waste to establish a more virtuous cycle in the direction of the circular economy (C1)
- C2: Control of Complexity and Systems:
- Control of methods for assessing the environmental impact of a manufacturing or design process or process (C2)
- Interpret the results of such analyses and identify steps or processes that could significantly improve (C2)
- Model and analyse a manufacturing or design process or process (C2))

Knowledge Control Procedures

Ecodesign - Continuous Control: 30 %Lifecycle
Analysis - Continuous Control: 30 %
Industrial Symbols - Project in Bandom: 40%

Bibliography

Numerous articles in the journal Engineering

Teacher

- C. Jalain (ECM)
- External stakeholders

Distribution of hours

Total: 53
Magistrates: 25
Directed work: 12
Practical work: 12
Project: 4

Language(s) used during the course: French

Environment: Management and Technology

Environment: Management and Technology - Circular Economy

Prerequisites: No

Learning Objectives

The EU is based on sustainable chemistry (technological tools) and environmental management (managerial tools); it provides the tools for eco-design, enabling waste to be transformed into new resources, and beyond that, to build industrial ecology. That's really the current trend in the economy.
This EU involves cross-cutting skills in the training of the ECM engineer. The various disciplines involved are Process Engineering, Industrial Engineering and Chemistry, as well as the Life Cycle Analysis (LCA) methods that have developed significantly in recent years.
The main objective is to understand the environmental, societal and economic issues related to industries that transform resources into products.

Description of the programme

- Discover the carbon balance tool of ADEME, a tool for assessing the emissions of Greenhouse Gases (GHGs) of a company or a site and also, a tool to help define an energy management strategy with a view to saving energy costs.
- Know the multi-criteria, multi-stage structure of an eco-design approach (according to the French standard of The same name) and the difficult constraints that environmental considerations add to the usual technical and economic design.
- Discover the ASIT method, an applied and affordable extraction developed more recently by Roni Horowitz based on the TRIZ principles.
- Know the standard evaluation method "Life Cycle Analysis" of the impacts of an industrial system on the environment.
- Go from a transformation chain resource-product-waste to processes in which waste is a new resource is one of the major challenges of the $^{21st\ century}$ processing industry.
- In the section entitled "Value", a global approach to the processes of processing of the material helps to understand the integration of the sectors and provides elements of choice for the different modes of recycling or recovery of the effluents or wastes. Industrial examples of waste recovery provide opportunities for sustainable chemistry and industrial ecology.

Target generic centrale-specific field-related skills and knowledge

- C1: Scientific and
technical innovation in connection with the lessons of the other EU countries of this S8 journey, know how to make a diagnosis and then propose processes for the manufacture or the recovery/treatment of waste to establish a more virtuous cycle in the direction of the circular economy (C1)
- C2: Control of Complexity and Systems:
- Control of Methods for Assessing the Environmental Impact of a Process or a Manufacturing or Design Process (C2)
- Know how to interpret the results of such analyses and identify steps or processes that could significantly improve (C2)
- Know how to model and analyse a manufacturing or design process or process (C2)

Knowledge Control Procedures

Ecodesign - Continuous Control: 30 %Lifecycle
Analysis - Continuous Control: 30 %
Industrial Symbols - Project in Bandom: 40%

Bibliography

Numerous articles in the journal Engineering.

Teacher

- C. Jalain (ECM)
- External stakeholders

Distribution of hours

Total: 53
Magistrates: 25
Directed work: 12
Practical work: 12
Project: 4

Language(s) used during the course: French

Dynamics - Changes - Crises

Dynamics - Mutations - Crises - Beyond the Model

Prerequisites:

Mathematics: probability/statistics

Learning Objectives

- Understanding and analysing the inherent limitations of each model
- Being able to detect situations in which a model no longer seems to fit
- Being able to analyse and master a complex system without using a modelAt a more general level, this EU aims to provide students with the skills and knowledge to become aware of the limitations of modelling complex systems.

Description of the programme

Trend modelling, uncertainty quantification and sensitivity analysis (10:00: 5-3-2-0)
- Multiple regression: linear and non-parametric methods - trend modelling: models Holt-Winters, ARMA, ARIMA...
- Quantification of uncertainties: parametric, non-parametric methods, small samples (quick evocation of Bayesian, Wilks methods...)
- Sensitivity analysis: local methods, global methods (GSA) monotonous, non-monotonous, qualitative/quantitative (screening, decomposition of variance)

Blurred command (4pm: 6-2-8-0)
The approach to modelling and its use to control a system can be difficult to implement if the system is too complex: it is therefore a question of presenting an alternative approach and possibly comparing them. Based on the examples of applications considered in the S8, a blurred logic approach (no complex system model) is proposed to control the behavior of a complex system modelling

limitations. Scientific and technical, philosophical, cultural and political aspects (4h: 4-0-0-0)
This module aims to highlight - in several multidisciplinary aspects - the limitations of modelling and the always partial nature of a model. This module is designed in the form of lectures given by experts outside the School. Its exact content will therefore depend on the guest speakers.

Target generic centrale-specific field-related skills and knowledge

- Ability to invent creative, ingenious, original solutions - Ability to mobilise a scientific/technical culture (transdisciplinarity and/or specialisation)
- Ability to understand and formulate the problem (hypotheses, orders of magnitude, etc.)
- Ability to propose one or more resolution scenarios

Knowledge Control Procedures

- CC1: Trends Modelling (Project): 40%
- DC2: Blurry Command (Report): 30%
- CC3: Blurry Command (Programme): 30%

Bibliography

Course Documents
Polycopied by performer

Teacher

- Alain Kilidjian
- Nadia Pérot (CEA)

Distribution of hours

Total: 30
CM: 15
TD: 5
TP: 10

Language(s) used during the course: French

Dynamics - Changes - Crises

Dynamics - Mutations - Crises - Mathematical and statistical modelling of complex systems

Prerequisites: Mathematics: theoretical analysis, probability/statistics

Learning Objectives

- Know the theory of dynamic systems in discrete and continuous time - Know the theory of stability
- Know the theory of differential equations - Know the theory of estimation and detection for extreme phenomena - Be able to choose the appropriate tools for the modelling of a phenomenon
- Be able to implement a model with evaluation of parameters and to illustrate the different behaviours through Simulations
- Know how to use or develop appropriate numerical methods to effectively solve a problem
- Know the IT tools needed for the digital implementation of models

Description of the programme

Mathematical modelling of complex systems I and II (30 h: 9-7-14-0)
- Discrete models, continuous dynamic systems, associated numerical methods; partial differential equations, numerical methods and examples of applications in biology.

The Lorenz system: a simple model in meteorology (3 pm: 10-5-0-0)
- General introduction (meteorology, Lorenz discovery, Rayleigh-Bénard convection and Lorenz system); instability of Rayleigh-Bénard (linear stability theory; fundamental equations and approximation of Boussinesq; basic flow and serialisation of equations; dimensionless equations: Rayleigh and Prandtl numbers transition from conduction to convection); Chaos (notion of attractors and sensitivity to initial conditions; study of the Lorenz system. Digital simulations of the Lorenz system).

Extreme values (7 pm: 6-6-7-0)
- Extreme values, order statistics, areas of attraction of a distribution of extreme values, Hill estimator, Pickands estimator, tails of distribution, behaviour of excesses, Pareto law, Gumbel law, Weibull law. Use of R or Matlab software.

Target generic centrale-specific field-related skills and knowledge

Competence 2 - Complexity
- Define a problem in a simple system, position it in its environment and propose a relevant model - Understand and use a given complex model (multi-component and multi-dimensional)
- Model a multidimensional system with interdependent and/or non-deterministic components. Ascertain assumptions and conditions of validity.
- Experiencing the unpredictability of a complex system (disturbances, potential risks...)

Knowledge Control Procedures

DS1 - Dynamic Systems: 25%
CC1 - Dynamic Systems (Home Duty): 15%
CC2 - Dynamic Systems (TP): 10 %
DS2 - Lorenz Model: 17%
CC3 - Lorenz Model (TP): 8%
CC4 Extreme Values (Queries): 25%

Bibliography

English course copy

Teacher

- Malek Abid (Aix-Marseille University)
- Guillaume Chiavassa
- Jacques Liandrat
- Christophe Pouet

Sustainable development objectives (SDO)

13-Combating climate change

Distribution of hours

Total: 64
Magistrates: 25
Directed work: 18
Practical work: 21

Language(s) used during the course: French

Dynamics - Changes - Crises

Dynamics - Mutations - Crises - Optimisation and enforcement

Prerequisites: Mathematics: differential calculation

Learning Objectives

Optimisation methods are applied in many fields related to engineering sciences, whether as simple numerical analysis tools or from a dynamic point of view, such as optimal control problems.
The objective of this course is to present the theoretical aspects of static optimisation without constraint, then with constraints (Lagrangian, KKT, saddle points and duality), as well as the main optimisation algorithms (the gradient, the conjugated gradient, Newton, quasi-Newton...)
The stochastic aspects of optimisation will be addressed with the use of annealing, cross-entropy.
This first part aims to introduce the notions of static optimisation, in order to extend them to dynamic optimisation and optimal control problems in a second part. The latter will be dedicated to the Hamilton equation, to the principle of Pontryagin minimum, to the principle of Bellman optimality. This will lead to the Riccati equation and the resolution of the algebro-differential equations. Different illustrative examples will be covered.

Description of the programme

The course is composed of two parts.
Part I deals with static optimisation, which aims to acquire the following concepts:
- mathematical notions, definition and choice of criteria, unconstrained optimisation, definition of constraints and optimisation with constraints, numerical algorithms/methods, stochastic aspects, towards identification.
Part II deals with dynamic optimisation and optimal control; It aims to acquire the following concepts:
- choice of criteria, dynamic constraints, Hamilton equation, Pontryagin optimality principle, Bellman dynamic programming and optimality, Riccati equation, towards optimal control.

Target generic centrale-specific field-related skills and knowledge

Continuous monitoring shall aim at the acquisition of the following skills:
- C1 Theme 1: intermediate level
- C1 Theme 2: novice/intermediate level continuous evaluation and monitoring shall aim at the acquisition of the following skills:
- C2 Theme 1: Competent level
- C2 Theme 2: intermediate

Knowledge Control Procedures

The CMCs are divided into two parts:
- 66% written evaluation of 2 hours without document, calculator allowed
- 34% reports of the two Practical works (static optimisation and dynamic optimisation)

Bibliography

G. Allaire and S.M. Kaber, Digital Linear Algebra, Ellipses, 2002
P.G. Ciarlet, Introduction to Matrix Digital Analysis and Optimisation, Dunod, 1998
M. Bergounioux, Optimisation and Control of Linear Systems, Dunod, 2001
B. d'Andréa-Novel and M. Cohen de Lara, Automatic course, linear dynamic systems control, École des Mines de Paris, 2000

Teacher

- Guillaume Graton
- Samia Mellah
- Dima El Jamal

Distribution of hours

Total: 38
Magistrates: 14
Directed work: 10
Practical work: 14

Language(s) used during the course: French

Dynamics - Changes - Crises

Dynamic - Mutations - Crises - Dynamic instabilities and chaotic transport

Prerequisites:

MechanicalMathematical modelling of complex systems

Learning Objectives

- Know how to apply the concepts discussed in the course "Mathematical Modelling of Complex Systems" to examples of dynamic systems derived from the mechanics of fluids and solids
- Know the concept of instability, identify its appearance through several applications
- Know the properties of a Hamiltonian system, identify critical points in the space of phases, apprehend the deterministic chaos In a Hamiltonian system, understanding transportation
in a chaotic system

Description of the programme

Based on the general equations of the mechanics of continuous media (MMC, 1A), the equations of the movement of the system in question are drawn up, and discrete in space to return to a dynamic system, usually of small dimensions. The instabilities and their consequences are described using the basic concepts seen in the course "Mathematical Modelling of Complex Systems".

Some examples from the mechanics of solids (16 h):

- Collapse of a structure by flaming
- Criss of a brake disk or clutch
- Auto-oscillations in musical instruments (rubbed strings, winds, (drunk)
- Aeroelastic instability of a wing, a bridge; ground instability of a helicopter

Some examples from fluid mechanics (10 p.m.):

We study the behaviour of a chaotic hamiltonian system and the phenomena of transport. Transport pitch is illustrated by digital applications exploiting the analogy between hamiltonian systems and incompressible fluids.
- Melting plasma (magnetic line dynamics and chaos, paradric particle diffusion ExB)
- Neutral fluids: dynamics and mixing in fluids

Target generic centrale-specific field-related skills and knowledge

Control of complexity and systems. The EU provides the theoretical tools needed to understand the instabilities of chaotic systems. It helps students to understand the rich behaviors of a dynamic system, to give them the tools to describe them through applications derived from mechanics.

Knowledge Control Procedures

- CC1 - Dynamic Instability in Continuous Environments (TP): 40%
- CC2 - Chaotic transport and control strategies: Fluid Applications (TP): 30%
- DS1 - Chaotic Transportation: 30%

Bibliography

Polycopies of courses.

Teacher

- Guido Ciraolo (CEA)
- Bruno Cochelin
- Emmanuelle Sarrouy
- Frédéric Schwander

Distribution of hours

Total: 38
Magistrates: 10
Directed work: 6
Practical work: 22

Language(s) used during the course: French

Dynamics - Changes - Crises

Dynamic - Mutations - Crises - Economic Modelling: growth and sustainable development

Prerequisites

Mathematical
ModelingDynamic Optimisation

Learning Objectives

Part I: Environmental, Resource and population economics. This course provides an introduction to environmental and natural resource economics issues. By mobilising the dynamic optimisation tools studied in the other courses of the course, we are exploring a set of common problems in the field: the problem of mine management, predator-prey models, fishery models. In addition, a more "static" part of the course focuses on the need for regulation (and the tools available) to correct externalities.

Part II: Growth and economic crises this course aims to introduce students to the main factors that explain a country's long-term economic growth. The presentation of these factors is made through empirical evidence and stylised facts, which serve to establish the elements of reflection mobilised during the theoretical modelling of economic growth.

Description of the programme

Part I: Resource Economics
1. Introduction
2. Optimal Management of a Non-Renewable Resource Stock
3. Population Models
4. Fisheries dynamics
5. Environmental policy needs and instruments
6. Management of a pollutant stock, theoretical and digital analysis
7. An Epidemiological Model with Economic Decision-Making: the SIR-Macro

Part II model: Economic growth and crisis
1. Introduction: empirical regularities and stylised facts of economic growth
2. Exogenousgrowth models
3. Introduction to endogenous growth models

Target generic centrale-specific field-related skills and knowledge

The main generic competencies of the Central Profile developed by this teaching are the C2, C3 and C5 skills.
The subject of the course, and more broadly of the course, is the C2 competence.
The use of economic theory contributes to the C5 competence.

Knowledge Control Procedures

Continuous control - homework: 100 %
The EU evaluation is a group project. Part of the project is closer to a DM that summarises the two EU courses. The second part of the project invites students to pursue DM through the development of mini-research.

Bibliography

Hotelling, H. (1931), The Economics of Exhaustible Resources, Journal of Political Economy, 39(2), 137-175. https://doi.org/10.1086/254195
Shone, R. (2003), *Economic Dynamics: Phase Diagrams and their Economic Application (2th ed.), Cambridge University Press.*

Teacher

- Nicolas Abad (University of Rouen-Normandy)
- Nicolas Clootens

Sustainable development objectives (SDO)

1-Eradication of poverty
12-Responsible consumption and production
13-Combating climate change
14-Aquatic Life
15-Earth Life

Distribution of hours

Total: 40
Magistrates: 36
Directed work: 4

Language(s) used during the course: French

SIS: Information Sciences and Digital Society

Information Sciences and the Digital Society - Digital Strategic Issues

Prerequisites: Common Trunk Course

Learning Objectives

This module is based on different disciplines to present the strategic challenges of digital. The aim of this course is to give students a good knowledge of the issues, orders of magnitude, evolution and performance in digital and industrial computing. The representation and modelling of knowledge and reasoning are also studied, as they are widely used, especially in AI.

Description of the programme

- Randomness and Determinism in Science and Technology

Reminder of the introduction of randomness in twentieth century physics, its consequences and discussion of its role in information processing technologies.

- Learning and Deep Learning

The strategic issues of Deep Learning and Learning are presented.

- Computational Neurosciences

Opening Sessions the main issues related to the modelling of information processing in the brain.

- Human visual perception

What factors can explain our perception of the world around us? Various aspects will be studied: Anatomical, psychological, cognitive.

- Cryptography Technical and historical

panorama- Problematic of the representation of knowledge

Working on symbolic representations of knowledge and using the notion of heuristics, Artificial Intelligence (AI) systems allow correspondence with the real world.

- Material processing of information

Faced with the extremely rapid evolution of electronic components and their technology, all They must have a general culture in this field that enables them to anticipate and adapt to technological change.

- Seminars: Outdoors

Target generic centrale-specific field-related skills and knowledge

This module aims to give a broad view of the economic, scientific and technological issues in the field of digital,

it aims to develop the capacity to define a long-term strategy and to identify the interactions between the elements.

Knowledge Control Procedures

Continuous Control:
CC1 - Random and Determinism in Science and Technology and Human Visual Perception - 1 average of 2 writings: 26%
CC2 - Computational Neurosciences - 1 report: 18%
CC3 - Cryptography - 1 report: 12%
CC4 - Knowledge representation issue - 1 average of 3 writings: 26%
CC5 - Material Information Processing: 1 report: 18%

Bibliography

Teacher

- T. Artieres
- E. Daucé
- C. Fossati
- C. Jazzar
- P. Préa
- Ph. Ref
.- Mr. Roche

Distribution of hours

Total: 42
Magistrates: 40
Directed work: 2

Language(s) used during the course: French

DMC: Dynamics - Changes - Crises

Dynamics - Changes - Crises - Crisis management: physical and chemical applications

Prerequisite Statistical

Physics - Chemistry - Process Engineering

Learning Objectives

Know when and how to use random techniques and sciences, statistics and complexity.
Illustrate these notions around applications of different kinds.
Open your mind, have a certain knowledge of the concepts of information sciences, physics, chemistry and that answer the problems posed. Link to related mathematical tools. Develop the desire to be a player in the field. Develop a global vision.

Description of the programme

Component 1: Statistics, Information and Physics of Complex Systems. (CM 20 - TD 8 - TP 0 - TA 6)

Part A: "Statistics, Information"
- Recalls on Probabilities and Classical Statistical Theory
- Statistical Theory of Risk for Decision or Estimation
- Elements of Information Theory
- Complexity and Applications

Part B: "Physics of Complex Systems"
- Phase Transitions, Landau Model and Disasters
- Percolation and Fractals
- Complex Physical Systems and

Information Processing ApplicationComponent 2: Modelling of chemical and biological processes (2 h CM + 10 h TD + 4 h TP)

When sizing industrial installations and evaluating their performance, it is necessary to have relevant models, making the right compromise between precision and simplicity. Unfortunately, chemical and biological processes are often subjected to non-linear processes. Several case studies will illustrate the proposal for sound simplifications and the resolution of the equations obtained (EDO, EAD, etc.).

Target generic centrale-specific field-related skills and knowledge

- Understand the usefulness of statistical tools for analysing data from industrial, physical or management systems (C5)
- Understand the essential factors in complex systems (C2)
- Select a relevant resolution method and take a critical look at the result (C2)

Knowledge Control Procedures

Stream 1 - Continuous Monitoring - 2 Reports 2 × 35%: 70%
Pane 2 - Continuous Monitoring - Personal Work Report: 30%

Bibliography

Ph Refréger, Noise theory and application to physics, Springer 2003.
P.H. Garthwaite, I.T. Jolliffe and B. Jones, *Statistical Inference, Prentice Hall 1995.*
T.M. Cover and J.A. Thomas, *Elements of information theory, Wiley 2006.*
D. Stauffer, H.E. Stanley, A. Lesne, *Physics Course: From Newton to Mandelbrot, Springer 1999.*

Teacher

- Nelson Ibaseta
- Philippe Réfrégier

Distribution of hours

Total: 50
Magistrates: 23
Directed work: 18
Practical work: 3
Applied Jobs: 6

Language(s) used during the course: French

Environment: Management and Technology

Environment: Management and Technology - Environmental Quality Monitoring

Prerequisites: Common Trunk Course

Learning Objectives

The EU brings together tools for measuring water quality, the atmosphere and the sound environment. In relation to environmental management (standards, monitoring of the territory) and clean effluents and pollution (treatment of effluents and pollution and modelling of pollution diffusion).
The goal is to give the future engineer methods and tools for geosurveillance (in natural and urban environments) and detection of pollution, regardless of the scale of analysis. These tools will allow the company to understand/develop the full range of environmental monitoring chains, from data acquisition by dedicated sensors to information processing that takes into account the modelling of physical phenomena. The areas of monitoring covered range from chemical air pollution to urban noise prediction and reduction and the condition of continental surfaces (vegetation) by imaging.

Description of the programme

This EU deals with pollution indicator detection tools, both locally and globally, with environmental sensors and measurements and geosurveillance. It also addresses issues related to environmental acoustic pollution, in order to achieve improvements in the sound environment (linked to the concept of a sustainable silent city).

1. Environmental sensors and measurements (J. Bittebierre and D. Nuel)
Measurements with independent sensors or networks allow precise monitoring, in real time, on closed sites or on larger spaces. The focus is on sensors that are most used for localised precision measurements, and on components for imaging (optical sensors, including LIDAR (laser-based optical surveillance radars) and hyperspectral camera (camera that provides the composition of its spectrum for each point of the image entered), chemical sensors and gas sensors).

2. Remote sensing (R. Marion and A. Roueff)Remote sensing
methods for geosurveillance and pollution characterisation. Relevant information on the state of vegetation, soils and seas can be extracted from on-board sensors (multispectral, hyperspectral or radar). We will see how remote sensing works and how to implement algorithms for mapping through several examples of application.

3. Acoustic pollution (C. Maury and D. Mazzoni)
We will look at acoustic pollution in outdoor or in buildings, relying in particular on the characterisation of the acoustic field and sources, and on the treatment with acoustic screens.
Also included is a conference on acoustic technology for the prevention of risks of CO2 storage.

Target generic centrale-specific field-related skills and knowledge

- Scientific and technical innovation:
 - Being able to follow the development (especially at the level of the computerised processing of data) of new or better methods

- Being able to frame the implementation of a monitoring technique in a new context
- Mastering complexity and systems:
- Knowing how to analyse a problem linked to pollution
- Mastering the methods for these types of situations so as to propose an appropriate follow-up method, using the most relevant detection and monitoring techniques
- Know how to interpret experience results, and know how to identify problematic situations (breakdowns, abnormal background noise, various malfunctions)

Knowledge Control Procedures

CC1 (Remote sensing part) - an average of reports: 40%
CC2 (part "Sensors") - Exposition + bonus on Directed Jobs: 30%
CC3 (part "Acoustics") - Project rendering: 30%

Bibliography

Georges Asch et col., Les Senseurs en instrumentation industrielle, 5th edition, Dunod, 1999.
Frédéric P. Miller, Acoustique Environnementale, Alphascript Publishing, 2010.
Numerous articles in *Engineering Techniques.*

Teacher

- F. Anselmet
- J. Bittebierre
- R. Marion
- C. Maury
- D. Mazzoni
- D. Nuel
- A. Roueff
- External stakeholders (CEA, LMA/CNRS, South Atmo)

Sustainable development objectives (SDO)

13-Combating climate change
14-Aquatic Life
15-Earth Life

Distribution of hours

Total: 60
Magistrates: 36
Directed work: 8
Practical work: 16

Language(s) used during the course: English

Environment: Management and Technology

Environment: Management and technologies - Environmental management

Prerequisites: It is expected that the student will know the basics of economic science as covered by the 1A course.

Learning Objectives

Environmental management is part of a sustainable development perspective. The EU integrates the technical, regulatory, behavioural and economic components at enterprise level and positions the role and tasks of the engineer. It has strong links with the EU on the circular economy. In terms of regulatory aspects, particular attention is paid to corporate (or social) social responsibility (CSR) and ISO 14000, which are the pillars of environmental management. Economic issues are approached from the perspective of economic science applied to environmental economics and sustainable development (in order to, for example, analyse economic mechanisms, understand the evolution of a society in the face of scarcity of resources, anticipate the effects of environmental policies...).

Description of the programme

The management and regulatory part aims to make the everyday understanding and integration of the environmental aspects that are essential for any manager in a company, in its technical, regulatory, behavioural and economic components. The goal is to be able to prioritise key environmental issues for a company, build environmental approaches and conduct environmental audits. The aim is to be able to build, implement and improve an environmental management system.
The EU section on environmental economics is structured around five main points: introduction to environmental economics; integration of environmental issues into decision-making; evaluation of public policies and implementation of indicators and consumer sensitivity to environmental issues; study of sustainable development reports and presentation of work (the aim of this collective work is to study the sustainable development policy of some major French companies, with an oral synthesis in progress of 15 minutes and a written report to give at the last course). A duty on the table completes this evaluation.
These courses are supplemented by a cycle of lectures given by specialists in their field.

Target generic centrale-specific field-related skills and knowledge

- C1: Scientific and Technical Innovation
- C2: Control of Complexity and Systems
- C3: Program direction
- C5: Strategic vision - Know how to perform an analysis or diagnosis of a company in relation to environmental management problems (C1 + C2 + C3 + C5)
- Be aware and well aware of the main regulatory constraints related to environmental management (C1 + C2 + C3 + C5)

Knowledge Control Procedures
Project 50% + Duty on table 50%

Bibliography
M-P. Gcoated and L. Vaute, At the heart of ISO 14001:2015: The environmental management system at the centre of the strategy, AFNOR (2015).
L. Abdelmalki and P. Mundler, Economy of the Environment and Sustainable Development, De Boeck (2015).
T. Tietenberg et al., Economy of the Environment and Sustainable Development, Pearson (2013).
Articles in the journal *Engineering.*

Teacher
- N. Clootens
- External stakeholders

Sustainable development objectives (SDO)
7-Use of renewable energy
12-Responsible consumption and production
13-Combating climate change
14-Aquatic Life
15-Earth Life

Distribution of hours
Total: 42
Magistrates: 32
Directed work: 6
Other: 4

Language(s) used during the course: English

Sustainable Energy

Sustainable Energy - Solar Energy

Prerequisites
Basics in photometry, electricity, differential equations

Learning Objectives
Among the sustainable energies available, solar energy is very abundant and renewable. This resource can be used directly as heat (solar thermal) or converted into electricity (thermal power plants or direct transformation into electricity by photovoltaic effect). With its abundance, solar energy is taking an increasingly important part in the world's resources.
In this EU, we will study the characteristics of this resource, the technologies associated with it, to have all the tools necessary for the sizing of electrical and thermal installations. The knowledge provided throughout the course of education is also aimed at understanding current socio-economic and scientific issues.
This EU is at the crossroads of several disciplines: electronic, optical, optronic, physical, thermal.

Description of the programme
General introduction:
- Social issues
- Economic and technical problems, challenges solar deposit:
- Physical aspect
- Principle of solar operation, atmospheric absorption and local, temporal and spectral dependence of light, photometry
- Optimisation of light: solar concentrators. Energy balance (solar energy received, thermal radiation, greenhouse effect)

Photovoltaic sensors
- Operating principle:
- Calculation of a photovoltaic installation, semiconductors, diodes and photovoltaic effect; cells cell matrices, impedance adaptation, challenges (cost, yield, storage)
- Technology:
- Crystal Silicum: mono and polycrystalline (Mono-Si, Poly-Si) - cells in mineral thin layers: a-Si: H, CdTe, CIS, SIGS, a-Si: H, µ-Si, HIT, GaAs
- Organic and hybrid cells: principles of organic cells, particularity of perovskite cells- Advanced concepts:
- Surface structure, photonic crystals, plasmonics, quantum structures, concentration...
- Conclusions and perspectives on photovoltaics: What hopes, what future uses?

Thermal
- Solar thermal sensors
- The sensor plan: structure, performance, test standard - Vacuum sensors: operation, service life, applications
- Other sensors: without glazing, common applications- Concentration sensors: calculation of the concentration factor, sun monitoring,

boiler temperature, efficiency, the different types of thermal power plants with concentration in the current world and their capacity for electricity generation
- Dimensioning of thermal installations, application of solar energy to habitat:
- Positioning (need/input)
- Main components (sensors, storage, transmitters, regulation)
- Calculation of the coverage rate (case of ECS and heating)

Target generic centrale-specific field-related skills and knowledge

- C1: The Central Engineer creates value through scientific and technical innovation. In particular, knowledge of the various technologies and their historical developments allow for a step backwards on future innovations.
- C2: The Central Engineer has mastered the complexity of the systems and the problems he encounters. In particular, the socio-economic aspects and the different disciplines of physics respond to a complex need for energy.
- C3: The Central Engineer conducts programmes. In particular, when sizing solar installations.
- C4: The Central Engineer manages in an ethical and responsible manner. In particular, by being aware of the needs and impacts of technological choices in solar energy.

Knowledge Control Procedures

Continuous monitoring: 2 bonus points (average of small 5-minute evaluations or document analysis)
Supervised: 50 % (deposit, photovoltaic), 50 % (thermal)

Bibliography

Courses
Yves JANNOT, Solar Thermal (2007).
*Michel Villoz, Anne Labouret, Solar photovoltaic energy, 4*th edition (2009).
P. Jayarama Reddy, *Solar Power Generation, 1*st edition, 2021.
*Chetan Singh Solanki, Solar Photovoltaics: fundamentals, technologies and applications, 3*rd edition, 2015.

Teaching team:

- Læ titia Abel-Tiberini
- Jean Bittebierre
- Daniel Roux
- David Duche
- Judikael Le Rouzo

Sustainable development objectives (SDO)

7-Use of renewable energy
9-Building Resilient Infrastructure
11-Sustainable cities and communities
12-Responsible consumption and production
13-Combating climate change

Distribution of hours

Total: 36
Magistrates: 28
Directed work: 8

Language(s) used during the course: French

Common Trunk

Languages - International Cultures

Prerequisites: no

Learning Objectives

LCI education is part of the training of · citizens · s and · engineers and · international engineers · and · .

The Engineer · Central · Marseille will have to be able to interact accurately and effectively with partners of different languages and/or cultures, especially in a professional environment. He/she will be able to mobilise linguistic, conceptual, cultural and communicational knowledge and skills. To do this he/she will acquire knowledge of historical, cultural, social, economic and political practices, events and/or phenomena. He/she will stimulate his/her imagination through cultural discovery and awareness of difference by varying his/her representations. He/she will develop his/her critical mind.

Description of the programme

LCI education comprises two separate lessons per semester: English (LV1) 20h and another language (LV2) 20h.
Attention: students enrolled in Double Degree will follow 2 FLE lessons (LV1 and LV2) at S5 and S6.
These 40 hours of face-to-face courses are completed by 10 hours of personal work (autonomous work, research, exercises...) per language and per semester.
LCI is taught at a rate of 2 hours per language per week. Level groups are formed following evaluation tests in English, French, German and Spanish.

Target generic centrale-specific field-related skills and knowledge

Training in Languages and Cultures is essential to the identity of the · Engineer · Central American who will be able to communicate and interact internationally. The skills of the Central Engineer repository specifically targeted by LCI's teachings will be related to:
- C1: the Central Engineer creates value through scientific and technical innovation.
-C2: ICR has mastered the complexity of the systems and the issues it faces.
-C3: the IC conducts programmes.
- C4: IC manages in an ethical and responsible manner.
-C5: ICR is part of a strategic vision and knows how to implement it.

Knowledge Control Procedures

2 languages (50% each of the average). Minimum of 7/20 for each language.

The 5 skills of CECRL will be evaluated (modalities specified by the teacher ・ e).

Attention: required attendance: more than 2 absences will compromise the validation of the semester.
Sessions 2 will address unvalidated skills in session 1 and will be managed individually by teachers ・ s ・.

Bibliography

According to the courses chosen.

Teacher

- English: P. Atkinson, J. Airey, V. Durbec (Head of EU), G. Marquis, M. McKimmie
- Spanish: C. Enoch (responsible for LV2), S. Duran, S. Carmoni, E. Munoz, K. Pinchenet
- German: D. Ortelli van Sloun
- FLE: V. Hamel, D. Betton
- Chinese: J. Dong
- Japanese: K. Yoshida
- Italian: S. Canzonieri
- Arabic: B. Zoubir
- Russian: Y. Yurchenko
- Portuguese: S. Almeida

Sustainable development objectives (SDO)

5-Gender equality
7-Use of renewable energy
10-Reducing Inequality
12-Responsible consumption and production
16-Justice and peace

Distribution of hours

Total: 40
Directed work: 40
Applied Jobs: 20

Language(s) used during the course: English

ENE Sustainable Energy

Sustainable Energy - More Energy for Tomorrow? Examples of biomass and hydrogen

Prerequisites: no

Learning Objectives

Identify, understand and address issues and challenges for the use of biomass and bioenergy technologies, hydrogen and fuel cells for the general public. In both cases, these are potentially very interesting energy sources for the future, but the actual development and impact of these sources is still quite uncertain, both in terms of scale and in terms of time-scale implementation.

Description of the programme

The course includes bioenergy and hydrogen and fuel cell components equally. For bioenergy, an introductory course helps to position the problem and the issues. The other sessions focus on case studies and personal work framed around specific related points, including biofuels (global process analysis, pre-treatments, distillation processes, associated energy balances...). For the hydrogen and fuel cells part, the course sessions combine lectures and exercises/assignments. In particular, the underlying thermodynamic aspects related to the oxydorabduction reactions will be presented, which allow a clear understanding of the operation of the batteries and the technological issues involved in their optimisation. The safety and standardisation aspects being developed for these systems will also be discussed, as well as examples of existing installations and devices for both transport and stationary applications.

Target generic centrale-specific field-related skills and knowledge

- C1: The Central Engineer creates value through scientific and technical innovation.
- C2: The Central Engineer has mastered the complexity of the systems and the problems he encounters.
- C3: The Central Engineer conducts programmes.
- C4: The Central Engineer manages in an ethical and responsible manner.

Knowledge Control Procedures
Duties monitored: 50 %Continuous
Control: 50%

Bibliography
A.V. da Rosa, Fundamentals of Renewable Energy Processes, Academic Press, 2012.
M. Boudellal, *The Fuel Stack, Hydrogen and its Applications, Dunod, 2012.*

Teacher
- F. Anselmet
- P. Denis

Sustainable development objectives (SDO)
7-Use of renewable energy
9-Building Resilient Infrastructure
11-Sustainable cities and communities
12-Responsible consumption and production
13-Combating climate change

Distribution of hours
Total: 30
Magistrates: 18
Directed work: 12

Language(s) used during the course: French

ENV: Environment: Management and Technology

Environment Project

Prerequisites: No

Learning Objectives

- Implement the different knowledge and skills learned during the course of the training, whether technical or organisational
- Know how to tackle a real problem and its different constraints
- Know how to complement your knowledge and skills according to the needs of the project
- Find this information beyond the circle usually implemented at school
- Work as a team and in interface with a representative
- Structure your work in time

Description of the programme

- Different subjects are offered in mid-semester (March) and treated each by a group of two to three students. These topics are points of interest for the worlds of academic (and/or industrial) research and industry.
- Coaching is provided by one or two teachers or collaborators.
- About half a day a week is dedicated to them for 10 weeks (38 h in all).
- The project ends with an oral defence and the submission of a report.

- Some examples of topics from previous years :
- Acoustic impedance of a micro perforated plate
- Tiny Houses - A new approach to the concept and the eco-responsibility of constructions
- Environmental impact of remote teaching at Centrale Marseille: production and recycling of digital equipment
- Wind energy availability predictions using GIS data and land use information
- Life Cycle Analysis of the environmental impact of the IRPHE laboratory
- Ecological footprint of the Epicurious sailboat
- Study of a low-head water wheel
- Carbon footprint of PV solar power plants

Target generic centrale-specific field-related skills and knowledge

- Know how to approach and break down a complex problem (C2)
- Know how to propose innovative but realistic solutions (C1)
- Know how to divide the tasks to be carried out according to the desires or skills of each member of the group (C3)
- Know how to structure their work over time (C3)
- Know how to report on their work (C3)
- Know how to find an organisation within a group and interface of external collaborators (C4)

Knowledge Control Procedures

Final Report: 34%
Support: 33 %
Work performed: 33% (opinion of manager(s))

Bibliography

S8 courses that correspond to the subject and any other documents available at the doc centre or online (Engineering techniques, in particular).
Course of other semesters on project management and management (if necessary, to remember the important points).

Teacher

- ECM
Teachers - Outside Staff (industrial or other)

Sustainable development objectives (SDO)

7-Use of renewable energy
9-Building Resilient Infrastructure
11-Sustainable cities and communities
12-Responsible consumption and production
13-Combating climate change

Distribution of hours

Total: 38
Projects: 38

Course Language: English

SIS: Information Sciences and Digital Society

Information Sciences and Digital Society Project

Prerequisites: Common Trunk Course

Learning Objectives:

The objective of this EU is to provide S8-SISN students with the opportunity to conduct a technical study or an analysis on the issues of a given issue. This teaching promotes teamwork because students work in groups. Teams can be formed with students from the IEP of Aix-en-Provence.
Students learn to use their knowledge to solve a problem technically or to think about issues related to a problem that may be societal or related to data law.

Description of the programme:

The subjects of the projects can be proposed by a teacher of the Centrale, by an outside person (association, company, lab...) or by the students themselves. Each project is carried out as a team of at least 2 students. For each project, a tutor is appointed from the teaching team to guide students in their choices. Recent topics include:
- Installation of a connected statue for the underwater museum of Marseille
- Analysis of issues related to 5G/6G networks - Implementation of an artistic project - Statistical modelling in epidemiology
- Study of networks of self-normalising neurones

Target generic centrale-specific field-related skills and knowledge:

- Ability to analyse context and present results
- Ability to mobilise a scientific/technical culture to situate the issues
- Ability to invent creative, ingenious, original solutions - Ability to propose one or more resolution scenarios - Ability to identify the interactions between elements

Knowledge Control Procedures:

CC1: 1 support that contributes to 33% of the
final gradeCC2: 1 report that contributes to 33% of the
final scoreCC3: 1 rating of the tutor who contributes 33% of the final score

Bibliography

None

Teacher

- Essentially teachers of the SISN course

Distribution of hours

Total: 30
Projects: 26
Other: 4

Language(s) used during the course: French

SIS: Information Sciences and Digital Society

Statistical Analysis of Information

Prerequisites: Common Trunk Course

Learning Objectives

The objective is to enable students to acquire the fundamentals of information theory, methods for analysing physical and statistical information and classification techniques (supervised and not supervised). The fields of application are digital, physics and pattern recognition. Students will be familiar with the essential elements of statistics applied to the description and analysis of data for a wide variety of applications.

Description of the programme

- *Extraction of physical and*
statistical informationStatistical techniques are particularly suitable methods for retrieving information. *Special attention is given to digital data and physical quantities. The topics covered are based on applied probability, statistics and optimisation methods. The techniques for characterising fluctuations, estimating and analysing data are thus discussed both on their foundations and their applications.*

- Foundations of information theory and
classificationInformation theory provides a quantitative measure of the notion of information brought about by a message or an observation. *The fundamental elements of information theory will be presented not only for its applications in the field of information processing, but also by showing links with other scientific fields, in particular with those of data classification, physics and, more generally, statistics. The concepts of entropy, information and complexity will thus be approached from a broad perspective.*

- Recognition of statistical forms.
The objective of this module is to present the problem of statistical decision around the objectives of detection, classification with or without *a priori probabilistic model.* This teaching is structured around practical work to illustrate from examples how performance analysis makes it possible to choose from different techniques.

Target generic centrale-specific field-related skills and knowledge

- Develop technical and scientific innovations (ability to stimulate imagination, ability to analyse context, ability to expand a tool or concept to other uses, ability to collect and analyse information logically and methodically, ability to mobilise a scientific/technical culture).
- Resolve complex and transdisciplinary problems (ability to understand and formulate the problem, ability to recognise the specific elements of a problem, ability to identify interactions between elements, to take into account the uncertainty generated by complexity).
- Develop and conduct international scientific and technical projects (ability to rapidly deepen a field).

Knowledge Control Procedures

CC1 (part "Extracting physical and statistical information"): 1 writes that contributes 37% of the final score.
CC2 (part "Foundations of Information and Classification Theory"): 1 writing that contributes 26% of the final note.
CC3 (part "Recognition of statistical forms"): a sturdy average of reporting that contributes 37% of the final score.

Bibliography

Ph. Réfréger, Noise theory and application to physics, Springer 2003.
T.M. Cover, J.A. Thomas, *Elements of information theory, Wiley 2006.*
R.O. Duda, P.E. Hart, D.G. Stork, *Pattern Classification, Wiley 2 001.*

Teacher

- G. Bérardi
- Ph. Ref
.- A. Roueff

Distribution of hours

Total: 60
Magistrates: 36
Directed work: 8
Practical work: 16

Language(s) used during the course: French

ENV: Environment: Management and Technology

Effluents and pollution

Prerequisites: 1A Mechanical and Chemistry-GP

Learning Objectives

The EU is concerned with effluent treatment and modelling its environmental release. It has strong links with the EU Monitoring (detection and measurement of pollution) and the EU Circular Economy (recovery of waste). The EU's objective is to have a broad overview of effluent treatment techniques, particularly waste water, where possible for reuse, as well as methods for monitoring river pollution.

In detail, the EU is organised around the following themes:

- Effluent treatment: (33 h)
- Water treatment
- Membranes
- Phytotechnologies: Soil and water
- Site visit (STEP Marseille)

- Dissemination in the environment: (13 h)
- Modelling of pollutant dispersion in rivers
- Transfers of radionuclides into rivers

Description of the programme

After an introduction concerning water (resources, demands, quality and main pollutants), the traditional water treatment process is presented. Special focus will then be given to the following unit operations: settling, coagulation - flocculation, filtration, and barometric membrane separations. The second part of the EU presents first of all, by combining courses and exercises, the main characteristics of flows in rivers or canals, as well as various problems related in particular to the erosion or stability properties of solid grains (especially sediments) that make up the bottom and banks. These theoretical modelling elements form the basis of the methods used in the numerical model of radionuclide transfer/dispersion in rivers, which is then presented as a case study, with the sedimentary dynamics part playing a major role in this type of pollutant, which is largely fixed on sediments smaller than about 50 microns.

Target generic centrale-specific field-related skills and knowledge

- C1: Scientific and Technical Innovation
- Development of new processes that are more economical and/or efficient, based on a detailed knowledge of the basic principles
- C2: Control of complexity and systems
- Better management of the waste production/treatment chain with the aim of getting as close as possible to the objectives of sustainable development and, where possible, effluent recovery (circular economy process)

Knowledge Control Procedures

Supervised Duty 1: Process Effluent - Written Examination 2 h (50%)
Continuous Control 1: TP GP Practical Work (20%)
Supervision 2: Modelling (Rivers) - Written exam 1 h 30 (30%)

Bibliography

Numerous articles in the journal Techniques de l'Engineeur.

Teacher

- P. Guichardon, N. Ibaseta, F. Anselmet (ECM)
- Patrick Boyer (IRSN Cadarache)

Sustainable development objectives (SDO)

6-Access to safe water and sanitation
14-Aquatic Life

Distribution of hours

Total: 46
Magistrates: 26
Directed work: 14
Practical work: 4

Language(s) used during the course: English

Bioengineering

Planet BIO

Prerequisites: No

Learning Objectives
The purpose of this EU is to allow students to move beyond the school setting to open up more broadly to the industry. The S8 Bioengineering offers them a very broad overview by going to meet the biology and health community of Aix-Marseille. This EU offers many opportunities to interact with the sector. The realisation of a project is also possible, but left to the initiative of the students themselves.

Description of the programme
Bioengineering is the prime example of a sector of activity that constantly feeds on scientific and technological discoveries from research laboratories. With an exceptional number of researchers and clinicians, with a wealth of laboratories to cover a very wide spectrum, the Aix-Marseille site is ideal to understand the stakes of this sector, for those who agree to leave the walls of the school. The programme is updated annually during the fall, possibly in consultation with the students who come forward.Detailed
content of the lessons in the online documentation on the school's website (in French and English).

Target generic centrale-specific field-related skills and knowledge
The objective is to open up the socio-economic sector by offering students the opportunity to interact with the professional community. Its positioning is therefore outside the boundaries of the usual academic training, even if multidisciplinary training is the basis on which to build more complex skills of knowing how to be.

Knowledge Control Procedures
This includes the ability to communicate with the media.
The form can be considered in consultation with the students who express their interest in it before the semester. This work is accompanied by a media professional. Basic training is offered at the beginning of the semester, resulting in a roadmap. The debriefing is held at the end of the semester, with a mid-term review.

Teacher
- Marc Jaeger
- Sylvain Jaeger

Distribution of hours
Total: 48
Magistrates: 28
Applied Jobs: 20

Language(s) used during the course: French

Bioengineering

Biotechnologies and Chemical Therapies

Prerequisites: No

Learning Objectives
The development of a drug is a multi-parameter project that includes regulatory, temporal, societal and innovation constraints. In addition, there is a complex set of specifications to integrate (effectiveness, availability, safety, etc.). It is therefore an area par excellence where solutions emerge from the ability to mobilise complementary skills and address a multiparameter problem. The study of the development and life cycle of a pharmaceutical compound illustrates the required multidisciplinary approach in the sector and shows the value of generalist training for new scientific, technological and societal challenges.

Description of the programme
The heart of this EU is the creation and placing on the market of new active ingredients and biotechnological devices. It's about stimulating the ability to invent creative, ingenious, original solutions through what was produced in the past and is being developed today. In addition, much of the teaching is devoted to bioinformatics and biotechnology, which aim to use genomes, biomolecules, cells and tissues to create innovative devices that meet the human challenges of the future. The EU is thus divided into four parts:
- Molecular Therapeutic Strategy
- Pharmaceutical Processes
- Bioinformatics
- Inorganic Biochemistry and Bioinspired ChemistryDetailed content of the teaching in the online documentation on the school's website (in French and English).

Target generic centrale-specific field-related skills and knowledge
This EU mobilises knowledge in process and chemistry engineering for pharmaceutical aspects and for the bioinorganic study of living systems leading to biomimetic chemistry. They also mobilise skills in discrete mathematics and basic computing for bioinformatics. The knowledge provided complements that already acquired in these disciplines, and is useful in itself. The field itself is conducive to stimulating the imagination since it is in direct contact with the world of living, which by its long-lasting creativity of millions of years of evolution is the richest source of inspiration for man.

Knowledge Control Procedures
Continuous control in each party, contributing 35%, 15%, 30% and 20% respectively

Bibliography
Ng. Rick, Drugs: from discovery to approval, Wiley-Liss, 2004.
J. W. Mullin, *Crystallisation, Butterworth Heineman, 2001.*
O. Papini, H. Prade, *Artificial Intelligence: borders and applications, Cépaduès, 2014.*
J. E. Huhey, E. A. Keiter, R. L. Keiter, *Inorganic Chemistry, Boeck, 2004.*

Teacher

- Karine Alvarez
- Stéphane Betzi
- Stéphane Canaan
- Philippe Roche
- Nelson Ibaseta
- Anaïs Baudot
- Maxime Lucas
- Élisabeth Rémy
- Thien Vu Manh
- Alexandre Martinez

Sustainable development objectives (SDO)

Distribution of hours

Total: 68
Magistrates: 78
Practical work: 10

Language(s) used during the course: French

Bioengineering

Imaging and Wave Therapies

Prerequisites: None

Learning Objectives

At the end of this EU, students will have a good knowledge of the foundations and possibilities offered by medical imaging (from the wave-matter interaction to data processing). A thorough understanding of the physiological properties and metabolisms targeted by the different modalities, and of the numerical techniques used, specific to each modality. This skills base will enable effective response to diagnostic and therapeutic needs, with an appreciation of medical constraints.

Description of the programme

Medical imaging is a multifaceted issue. In the health field, non-invasive body observation provides morphological, metabolic and functional information, leading to significant advances in public health care (screening). From an industrial point of view, the development of new modalities results in the manufacture of increasingly sophisticated and more specific equipment. Through broad dynamics (from the cellular to the macroscopic scale), we describe the models of wave-tissue interactions and their use in imaging and therapy. The various imaging modalities, from the most conventional to the most advanced, and associated therapies are put in perspective. The processing of digital images is a key step in diagnostic and therapeutic monitoring. In particular: notions of image quality, data analysis, tracking objects in sequences and decision support. The aim is to be trained on the most advanced imaging methods by considering the physical foundations in order to be able to offer the best innovation potential for medical purposes. The EU is thus divided into three parts:
- Cellular and subcellular
 microscopy- Medical imaging and therapy
-
Image processingDetailed content of the teaching in the online documentation on the school's website (in English and French).

Target generic centrale-specific field-related skills and knowledge

This course allows the basic concepts of physics, mechanics or image processing to be extended to imaging and wave therapy (applied to life). These techniques involve the analysis of information from the interaction between waves and matter in order to obtain an image and/or effect on the material useful for therapy, and then the treatment of information useful for diagnosis, reconstruction or follow-up. Students will be able to analyse the socio-economic context of medical imaging and therapy by presenting the issues related to each technique and thus measure the potential for innovation. Practical work will also make these different concepts a reality.

Knowledge Control Procedures

Continuous control in each party, contributing 30%, 35% and 35% respectively

Bibliography

Mr. Locquin, Mr. Langeron, Handbook of Microscopy, Butterworth-Heinemann, 1983.
V. Tuchin, *Tissue optics: Light scattering methods and instruments for medical diagnosis, SPIE Press, 2015.*
J. Beutel, R Van Metter, H. Kundel, Handbook of Medical Imaging: Physics and Psychophysics, SPIE Press, 2000.
I.N. Bankman, *Handbook of Medical Image Processing and Analysis, Academic Press, 2009.*

Teacher

- Hervé Rigneault
- Anabela Dasilva
- Carine Guivier-Curien
- Philippe Lasaygues
- Serge Mensah
- Salah Bourennane
- Caroline Fossatti
- Thierry Gaidon

Distribution of hours

Total: 70
Magistrates: 53
Practical work: 17

Language(s) used during the course: French

Bioengineering

Bricks of life

Prerequisites: No

Learning Objectives
The complexity of living matter emerges from its multi-scale organisation and it is the purpose of this EU to give a global vision of it. A multidisciplinary approach is essential to achieve this. Approaching the study of an object, a material, a system, with the vision of different disciplines shows the value of multidisciplinary training for new scientific, technological and societal challenges.

Description of the programme
The object of this EU is the biological material in a multi-scale vision, from the nanomolecular and cellular scale to the human scale, through the mesoscopic scale of the circulation of biofluids and macroscopic tissues. It is thus divided into four parts:
- Basic bricks: that describes living matter at the molecular and cellular scale
- Soft and microfluidic: which, by integrating the molecular organisation into a statistical thermodynamic approach, leads to a description of the medium field and finally of the continuous material medium
- Tissue modelling: which integrates structural data of tissues of the microscopic scale on a human scale, in a description of biomechanics of continuous media
- Anatomy and pathology: which describes the biomechanical functioning and dysfunction of the human body Detailed information in the on-line documentation on the school's website (in English and French).

Target generic centrale-specific field-related skills and knowledge
The disciplines involved are chemistry, physics, mechanics, and mathematical and numerical modelling. This course complements other lessons about the structure of matter and its behaviour. Living matter is widely recognised today as a promising source of inspiration. We usually talk about biomimicry or bioinspired materials.

Knowledge Control Procedures
Continuous control in each of the four parties, counting equally for the EU grade.

Bibliography
B. Alberts, A. D. Johnson, J. Lewis, D. Morgan, M. Raff, K. Roberts, P. Walter, Molecular Biology of the Cell, Garland Science, 2015.
J. N. Israelachvili, *Intermolecular and interface forces, Academic press, 2011.*
S. C. Cowin, *Tissue mechanics, Springer, 2007.*
A. I. Kapandji, *Functional Anatomy, Maloine, 2018.*

Teacher

- Karine Alvarez
- Anaïs Baudot
- Stéphane Betzi
- Stéphane Canaan
- Alexandre Martinez
- Thien Vu Manh
- Marc Jaeger
- Jean-Marie Rossi
- Stéphane Bourgeois
- Serge Measure

Distribution of hours

Total: 74
Magistrates: 70
Directed work: 20
Practical work: 4

Language(s) used during the course: French

ENV: Environment: Management and Technology

Sustainable chemistry

Prerequisites: No

Learning Objectives

Sustainable chemistry concerns the process industry. This module provides the essential foundations of chemistry and green processes, and helps to understand the possibilities of recycling and industrial symbiosis, which are presented in the EU "Circular Economy". This means discovering and appropriating methods based on the development of associated innovative and clean chemical technologies, based on the desire to implement clean processes (less polluting and/or less consuming raw materials or energy), but also on the use of biosourced materials. Sustainable chemistry is underpinned by European chemical regulation, REACH, and concepts or principles based on ecodesign and the circular economy are of course directly related to sustainable chemistry.

Description of the programme

The EU programme addresses sustainability aspects, the 12 principles of green chemistry, homogeneous and heterogeneous phase catalysis, biocatalysis, new reactive environments, renewable raw materials, and new concepts guiding research and development in this field (such as biomimicry).
More specifically, the EU is structured around the following themes:
- Introduction to green chemistry, towards a bio-based economy?
- Health and environmental security: REACH, new European chemical regulation
- agro resources
- Reduction of material quantities. Alternative Solvents
- Catalysis (organocatalysis/biocatalysis/homogeneous catalysis)
- Practical work
- Green processes: cells as living plants, intensification and energy saving

Target generic centrale-specific field-related skills and knowledge

- C1: Scientific and Technical Innovation
- Development of new processes that are more economical and/or efficient, based on a detailed knowledge of the basic principles
C2: Control of complexity and systems
- Better management of the production chain, use of resources, waste treatment, circular economy

Knowledge Control Procedures

Green Chemistry Assessment: 25%
Green Chemistry - Continuous Control: 25%
Green Chemistry - Practical Work: 30 %
Green Processes - Continuous Control: 20%

Bibliography

S. Antoniotti, Green Chemistry Sustainable Chemistry, Ellipses Marketing (2013).
J. Augé and M., C. Scherrmann, *Green Chemistry: concepts and applications, EDP Sciences/CNRS (2016).*

Teacher

- D. Hérault
- D. Nuel
- P. Guichardon
- A. Soric
- External stakeholders

Sustainable development objectives (SDO)

6-Access to safe water and sanitation
7-Use of renewable energy
9-Building Resilient Infrastructure
11-Sustainable cities and communities
12-Responsible consumption and production

Distribution of hours

Total: 42
Magistrates: 28
Directed work: 6
Practical work: 8

Course Language: English

SIS: Information Sciences and Digital Society

Coding and Information Search

Prerequisites: Common Trunk Course

Learning Objectives

Information coding and retrieval is a system capable of retrieving information (structured, textual, visual, audio) in order to meet a user's expressed need. This EU aims to introduce students to the main methods of research, recognition, extraction, formatting, information flow, being able to model, choose and implement the whole system to obtain relevant information.

Description of the programme

- Images (4h CM + 8h TP): Mr. Roche): Human visual perception and TP in image tattoo and image quality using human vision aspects.

- Quantum information (6 h CM: T. Durt): The theory of Quantum Information results from the mixing of two major theories of the twentieth century, namely quantum theory and information theory. The aim of the course is to give a brief overview of this new discipline and to balance things between theoretical utopias and practical achievements so as to understand new concepts and a non-classical vision of information.

- Cryptography (6 h CM: P. Préa, 2h CM: T. Durt): Since its invention in antiquity, cryptography has been constantly evolving. It has even recently experienced a profound paradigm shift with the introduction of public key methods. This course is the continuation of the EU ESN cryptography course, where we presented
a panorama of different techniques.

- Language C (6 h CM, 8 h TP: F. Galland): This module aims to give students an experimental methodology in digital sciences:
- Quality, validity and effectiveness in programming (application in C)
- Introduction and awareness of numerical computation problems

Target generic centrale-specific field-related skills and knowledge

- Developing technical and scientific innovations (ability to stimulate imagination, ability to analyse the context, ability to mobilise a scientific/technical culture, ability to invent creative, ingenious, original solutions)
- Solving complex and transdisciplinary problems (ability to understand and formulate the problem, ability to take account of the uncertainty generated by complexity, ability to converge towards an acceptable solution)
- Developing and conducting international scientific and technical projects (ability to rapidly deepen a field)
- Perform a personalised analytical work related to the course content, which aims to develop its critical thinking and strategic vision

Knowledge Control Procedures
Continuous monitoring: 1 CC (written + debriefing) 100% of final mark

Teacher
- N. Bertal
- T. Durt
- F. Galland
- P. Préa
- M. Roche

Sustainable development objectives (SDO)
4-Access to quality education
8-Access to decent jobs

Distribution of hours
Total: 40
Magistrates: 24
Practical work: 16

Language(s) used during the course: French

SIS: Information Sciences and Digital Society

Telecommunications, Learning and Information Technology

Prerequisites: Common Trunk Course

Learning Objectives

The purpose of this module is to present applications, advanced technologies for processing, analysis, transmission and display of digital data in the broad sense and general principles on statistical learning and neural networks. The aim is therefore to present in a cross-cutting vision the main technologies of components and systems, statistical learning techniques and concrete applications of information theory in the field of digital and telecommunications. Practical and conceptual consequences in other areas of science and in particular in those of physics will also be addressed (propagation, transmission).

Description of the programme

- Digital Microelectronics: In a context of continuous evolution of microelectronic technologies, the study of information processing architectures, regardless of their origin, is an important aspect of engineering training.

- Information theory - Applications: The aim of this course is to implement the main concepts of information theory by considering applications such as data compression, data transmission, storage and data processing. A review of the various advanced applications of information theory in telecommunications will also be presented.

- Telecommunications
- Fibre optic telecommunications: Network capacity and physical effects during propagation (distortion, noise).
- Network protocols. The OSI model and the IP protocol (v4 & v6) will be presented.
- Telecommunications networks: Wireless networks (mobile telephony; local, personal and extensive networks; wireless optics) and wires (ADSL, PLC); smart grids Internet of Things for smart-city and smart-home.

- Display system: Presentation of the essential concepts on screen science and technology.

- Neurone learning and networks: This module introduces the general principles of statistical learning and neural networks (multilayer perceptron and convolutionary models) for supervised classification and data generation.

Target generic centrale-specific field-related skills and knowledge

- Develop technical and scientific innovations (ability to stimulate imagination, ability to analyse context, ability to mobilise a scientific/technical culture, ability to invent creative, ingenious, original solutions)
- Resolve complex and transdisciplinary problems (ability to recognise the specific elements of a problem, ability to propose one or more resolution scenarios, ability to identify the interactions between elements, ability to take into account the uncertainty generated by complexity)

Knowledge Control Procedures

Continuous monitoring: 1 CC in each part of the course that contributes 25% of the final grade
CC1 (Digital Microelech): average of 2
CC2 writings (Info Theory. - App): average
CC3 (Telecom and Syst. display): average of
CC4 reports and writings (Learning and neural networks): 1 project rendering

Teacher

- J.C. Antonna
- T. Artieres
- S. Bourennane
- C. Fossati
- L. Gallais
- A. Khalighi
- P. Préa

Sustainable development objectives (SDO)

4-Access to quality education
8-Access to decent jobs
12-Responsible consumption and production

Distribution of hours

Total: 50
Magistrates: 40
Directed work: 4
Practical work: 6

Language(s) used during the course: French

SIS: Information Sciences and Digital Society

Issues and Regulation

Prerequisites: EU SHS Trunk Common Engineer

Learning Objectives

Develop a culture in social sciences and law that enables the general engineer to assess the societal challenges of information and digital sciences and technologies.
Understanding the complex challenges posed by digital technologies in their ethical, social, political and legal dimensions at the national and international levels.
Know how to collect and analyse information with logic and method to decipher situations of ethical and legal conflicts.

Description of the programme

This EU is deployed through a team study project and chosen in consultation with the teaching team.

- The ETHICS module is the central framework of the EU (23 h of TP). The work during the TP is guided by three axes:
- Research and analysis of the issues and issues raised by the theme. Identification of the actors (companies, institutions, associations, collectives...)
- Immersion in the work of the actors identified to understand their points of view, their actions and their effects
- Reflection, perspective/conclusion on the ethical issues highlighted by the two preceding

points- The module of SOCIOLOGY (4h CM, 5h TD: L. Piet) provides a general framework on digital society, its genesis and its contemporary dynamics. Three themes are covered:
- The genesis of the Internet and the web: cartography of actors, their values, and their ideals
- Political regulation of digital: Study of Internet and Web Issues for Democracy
- Digital Uses: analysis of forms of sociability and
digital inequalitiesThese general themes are refined according to the study subjects chosen by the students.

- The RIGHT module (6h CM, 4h TD: D. Roynard) provides general elements on the following topics:
- supervision of digital players: intellectual property, privacy, contract
regulation - legal settlement of issues related to
digital content and streamsThe teacher also provides specific understanding keys for the subjects dealt with by the student teams.

Target generic centrale-specific field-related skills and knowledge:

- C2: complexity (intermediate)
Understands and analyses the ethical issues and issues posed by digital in the political, economic, societal and legal spheres.
Offers scenarios of economic regulation, normative, ethical, balancing interests, conflict resolution and collaboration.

- C4: Ethical and responsible management (novice)
Positions itself as an actor (designer, user, citizen) in relation to the technical potentialities and societal impacts of digital technologies.

- C5: Strategic vision (novice)
Identifies the players, their respective motivations, values and proposals.
Evaluates the societal impacts of the forms of regulation prevalent in different areas of digital technologies.

Knowledge Control Procedures
100% continuous monitoring - group work on a theme chosen in the framework of the ethics module:
- delivery of written intermediate works (reading notes, synthesis)
- oral defence

Bibliography
Dominique Boullier, Sociologie du numérique, Armand Colin - U collection, 2016.

Teacher
- Edlira Nano
- Laetitia Piet
- Denis Roynard

Sustainable development objectives (SDO)
10-Reducing Inequality
11-Sustainable cities and communities
12-Responsible consumption and production

Distribution of hours
Total: 42
Magistrates: 10
Directed work: 9
Practical work: 23

Language(s) used during the course: French

Semester 8 - Alternate

Intercultural Management, CAD, leadership, project management, entrepreneurship