INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES TOULOUSE

3rd YEAR MIC_MA SPECIALITY SEMESTER 5

Introducing

Description

Évaluation

L'évaluation des acquis d'apprentissage est réalisée en continu tout le long du semestre. En fonction des enseignements, elle peut prendre différentes formes : examen écrit, oral, compte-rendu, rapport écrit, évaluation par les pairs...

Practical info

Location(s)

Toulouse

Optimization and linear programming

Introducing

Description

- Introduction to constrained optimization: definitions and generalities, existence of solutions, convexity and uniqueness
- Optimality conditions: first and second order conditions in unconstrained differentiable optimization, Karush-Kuhn-Tucker (KKT) conditions in constrained differentiable optimization, Lagrangian notion
- Algorithms for unconstrained optimization: gradient algorithm (fixed step, optimal step), Newton's algorithm, linear and nonlinear least squares problems
- Introduction to linear constrained optimization: modeling formalisms, characterization of the search space, geometric interpretation, graphical resolution, link with KKT conditions, simplex algorithm, method of dictionaries, complexity, duality of a PL problem, strong and weak duality theorems, complementary deviations theorems, Farkas lemma, alternatives theorem.

Detailed course handout provided.

Keywords : differentiable optimization, first and second order optimality conditions, gradient algorithms, Newton, least squares problems, linear programming and simplex algorithm.

Objectives

At the end of this module, the student will have understood and be able to explain (main concepts):

- The notions of local extremum and convexity
- Characterization of a local extremum by optimality conditions: first and second order conditions in unconstrained differentiable optimization, Karush-Kuhn-Tucker (KKT) conditions in constrained differentiable optimization
- The first algorithms for unconstrained optimization: gradient algorithm (fixed step, optimal step), Newton's algorithm, linear and nonlinear least squares problems
- Optimization under linear constraints (Linear Programming/PL): modeling in PL, characterization of the search space, geometric interpretation, solution principle, simplex algorithm, dictionary methods, complexity, duality.

The student will be able to:
Choose and implement a relevant and numerically efficient optimization method for an unconstrained differentiable optimization problem or for a linear programming problem.

Necessary prerequisites

Differential calculus: know how to calculate a gradient and a hessian. Link with differential.
Linear algebra: know how to diagonalize a matrix, calculate the eigenvalues, notion of semi-definite positivity.

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Operating system

Introducing

Description

The operating system is considered as resources managers: processors management (processes, scheduling) memory management (virtual memory, allocation), access to resources (synchronisation, mutual exclusion) and file system.

Objectives

At the end of this module, the student will have understood and be able to explain the operating system problems with a global overview of its functions and architecture.

Necessary prerequisites

Notions in computer's structure.

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Practical info

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Advanced algorithmics

Introducing

Description

Correction proofs
Asymptotic analysis
Devide and conquer
Greedy algorithms
Dynamic Programming
Branch and Bound
Problems tractability

Objectives

The objective of this course is to introduce the foundations of computational thinking, including complexity theory, proofs of correctness, advanced algorithmic design, and more. Throughout the course, students will learn to analyze the tractability of problems as well as the correctness and complexity of algorithms. They will be taught advanced algorithmic design techniques, such as divide and conquer, greedy algorithms, dynamic programming, and branch and bound.

Necessary prerequisites

Algorithms and Programming (1st and 2nd year)

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Databases 2

Introducing

Description

The aim of this course is to study relational databases. The fundamental concepts of the relational model are studied. The focus is then on relational algebra and the SQL language for manipulating and querying databases.

Objectives

At the end of this module, students should be able to understand and explain the main concepts.
- The relational model
- Data integrity constraints
- Languages for manipulating and querying relational databases, in particular relational algebra and the SQL language.

In practice, students should be able to :

- Implement a designed database while guaranteeing integrity constraints
- write queries in relational algebra, then implement them in SQL for manipulating and querying relational databases

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Practical info

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Toulouse

Markov chains

Introducing

Description

Markov chains and their classification: definition and class properties (irreducibility, recurrence, transience, aperiodicity), convergence to the stationary distribution, reversible Markov chain, absorbing time.

Objectives

Time-homogenous Markov chain over discrete state space, classification of states, stationary measure, reversible Markov chain, convergence to stationary distribution, ergodic theorem.

Markov chains:
The description of a Markovian model to its formalization by a Markov chain
develop a analysis of Markov chains (description of its communication classes, conclusion on the existence of a stationary distribution and on the convergence of the chain distribution)

Necessary prerequisites

Basic notions in discrete probability theory

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Data analysis

Introducing

Description

• Unidimensional descriptive statistics
• Bidimensional descriptive statistics
• Principal component analysis
• Clustering: principle, hierarchical clustering, Kmean and DBSCAN
• Introduction to programming in R and Rmarkdown

Objectives

At the end of this module, the student will have understood and be able to explain (main concepts):

• the main definitions for the unidimensional and bi-dimensional descriptive statistics
• the main concepts and the interpretation of graphical results of the principal component analysis
• the main concepts of clustering (hierarchical clustering, kmeans method and DBSCAN) and the interpretation of graphical results

The student will be able to:

• develop a descriptive statistical analysis with the R software
• manipulate the concepts of the principal component analysis, know the main properties and comment the graphical results

Necessary prerequisites

Probability and Statistic course (L2/2MIC)

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Dynamical systems

Introducing

Description

- Definition of an autonomous ODE, definition of a Cauchy Problem, Theorem of Cauchy-Lipschitz
- Definition of a maximal solution and the maximum domain, analysis of the stability
- Qualitative properties: conservative systems, Lyapunov functions, introduction to bifurcations (+ limit cycles)
- Construction of the phase portrait of an ODE in dimension 1 and 2
- Numerical integration of an autonomous ODE (Euler, RK, Crank-Nicholson)
- Analysis of a numerical scheme: stability, consistency and convergence

The above-mentioned concepts will be introduced and applied to 4 dynamical systems used all along this class

Objectives

At the end of this module, the student will have understood and be able to

-Define a Cauchy problem and prove the well-posedness of an autonomous ordinary differential equation
-Obtain qualitative properties of the solution of an autonomous ordinary differential equation (maximal solution, maximum domain, stability)
-Draw the phase portrait of an autonomous ordinary differential equation in dimension 1 and 2
-Solve using numerical integration an autonomous ordinary differential equation
- Apply these notions to analyze a dynamical system used in physics, biology or population dynamics

Necessary prerequisites

Differential and integral calculus, linear algebra

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Complements of probabilities

Introducing

Description

Program (detailed contents):
- Sigma-algebra, sigma-algebra generated by one or many random variables.
- Conditional expectation with respect to a sigma-algebra generated by a partition and then with respect to a general sigma-algebra. Main properties of conditional expectation.
- Gaussian random vectors. Main properties, Gaussian miracle for the independence of coordinates, projection theorem for Gaussian random vectors, multidimensional central limit theorem.
- Classical inequalities arising in probability theory: Markov, Chebyshev, Cauchy-Schwarz and Hölder.
- Modes of convergence of random variables: almost sure, in probability, in distribution, in the Lp spaces, and links between them.

Objectives

At the end of this module, the student will have understood and be able to explain (main concepts):
- The notion of sigma-algebra generated by one or many random variables.
- The definition and main properties of a conditional expectation.
-The definition and main properties of a Gaussian vector.
-The various modes of convergence in probability theory and the links between them.

The student will be able to:
- Compute a conditional expectation with respect to a given sigma-algebra.
- Prove that a random vector is a Gaussian random vector and give the underlying parameters (expectation and covariance matrix); use the specific properties of Gaussian random vectors.
- Use classical inequalities appearing in probability theory.
- Prove that a given sequence of random variables converges (or not) almost surely, in probability, in distribution or in Lebesgue spaces (Lp spaces).

Necessary prerequisites

Course on Probability and Statistics (2MIC Semester 4).

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Ecological Transition, GHG Reduction, Responsibility and Environment (EARTH)

Introducing

Description

The teaching includes a "2 tonnes" workshop, which provides a fun way of understanding the orders of magnitude linked to the objectives of carbon neutrality in 2050. It also includes assignments on the following topics: housing; electricity production; inequalities and responsibilities; mobility; the climate inaction debate; agriculture and food; and aeronautics. Students also work on a complex problem linked to ecological issues, starting their reflections from an everyday object or service.

Objectives

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

- Be comfortable with the fundamental concepts related to greenhouse gas emissions, and be able to make simple calculations on this subject.
- Know the order of magnitude of important quantities.
- Be able to fetch emission values from the ADEME database and use them appropriately.
- Think about ecological issues in all their complexity and study a specific problem
- Have an understanding of life cycle analysis and how to apply it
- Be able to research scientific literature
- Be able to understand and analyse figures/data
- Draw political conclusions from scientific facts and one's own values
- Debate, discuss and confront points of view.

Necessary prerequisites

Basic knowledge on energy.

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Job Hunting Techniques

Introducing

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Humanities elective course

Introducing

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Physical Education

Introducing

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