Mathematics - Computer Science - Economics

ECTS credits
4 credits

Semester
Fall

In brief

Course langage: French

Presentation

Prerequisites

* Programs of the course units Mathematics 1A, Computer Science 1A and Economics-Business 1A from Ecole Centrale Méditerranée Engineering programme (see syllabus 1A)
* Basics of the Python language

Learning objectives

* Apply a field of applied mathematics (Probability-Statistics, Finite Elements, Optimal Transport) to applications
* Design a computer program by implementing the necessary steps with the adequate tools: modeling, algorithms, programming environment in Python
* Understand advanced concepts in economics about markets or strategic behavior or process data related to an economics problem.

Description of the programme

The major course unit Mathematics-Computer Science-Economics (MIE) is divided into 3 periods, each period is equal to 4 weeks (18h et 6h d'autonomie). For each period, the student must choose one subcourse offered in one of the following fields: Mathematics, Computer Science or Economics. There is one constraint for the student's choices (except for international credit mobility students such as Erasmus+ students): at the end of the semester the student must have studied subcourses in at least two different fields among Mathematics, Computer Science and Economics.

Choice of a course among Mathematics, Computer Science or Economics at each period

Mathematics - Computer Science - Economics

	Period 1 (Temps 1)	Period 2 (Temps 2)	Period 3 (Temps 3)
Mathematics	Probability & statistics	Variational methods and finite elements	Introduction to the theory of optimal transport
Computer Science	Algorithm design	Data driven programming	Scientific Python
Economics	Innovation and market power: monopoly and	Strategic behaviours: game theory	Inequalities: data and public policies

Mathématiques

1. M1 : Probability and statistics
    1. Conditional probability and conditional expectation: definition, conditional probability distribution, properties, Bayes formula, martingales
    2. Inferential statistics: parametric estimation (maximum likelihood, moment method, regular model and Fisher information, confidence interval, parametric tests (likelihood ratio test) and nonparametric tests (chi-square)
2. M2 : Variational methods and finite elements
    1. Distributions : definition, convergence, derivative
    2. Hilbert space, Sobolev spaces, inequalities (Cauchy-Schwarz, Minkowski), Green formula, semi-norm
    3. Variational methods: Lax-Milgram theorem, Galerkin methode (definition, convergence and order).
    4. Finite elements: definition, approximation space, convergences for the local approximation and for the global approximation, convergence theorem for the Lagrange finite-element method
3. M3 : Introduction to the theory of optimal transport
    1. Monge and Kantorovitc formulations,
    2. Kantorovitch duality, c-concave functions, applications in economics: matching equilibrium
    3. Wasserstein distance, generalized Wassertsein distance (unbalanced optimal transport)
    4. Computational methods: Sinkhorn algorithm, entropic regularization, Benamou-Brenier formulation

Computer Science

1. I1 : Algorithm design
    1. Algorithm divide & conquer
    2. *Sequence alignment* problem: sequence alignement problem, sequence alignement algorithm
    3. Dynamic programming and NP-completeness
    4. Greedy algorithms: principles and implementation
    5. Enumeration problem: branch-and-bound strategy and backtracking strategy
2. I2 : Data driven programming
    1. Event-driven programming and persistent objects. Python object. CRUD principle. MVC design template.
    2. Persistence managers: ORM, DAO. web servers. HTML/CSS. Django, pony ORM, Django ORM.
3. I3 : Scientific Python
    1. Data manipulation and data analysis with Python: libraries Numpy and Scipy
    2. Graphs in Python: library Matplotlib
    3. Dataframe manipulation and representation: libraries Pandas and Seaborn
    4. Image processing: library Scikit-image

Economics

1. E1 : Innovation and market power: monopoly and rents
    1. Market, market structures, competitive case
    2. Monopoly: simple monopoly, production of a sustainable good, price discrimination, product selection
    3. Strategic interactions: oligopoly, Cournot model, Bertrand model, industrial economic strategies
2. E2 : Strategic behaviours: game theory
    1. Dominated strategy and Iterated elimination of strictly dominated strategies (IESDS)
    2. Nash equilibrium: definition, best answers, connection between IESDS-Nash
    3. Mixed strategy: definition, investigation of mixed equilibrium, Nash theorem, interpretation of mixed Nash equilibrium
    4. Games with continuous action space
    5. Sequential games
    6. Matching
3. E3 : Economics : data and public policies
    1. inequalities in economics: definition, measure, inequality factors
    2. Public policies addressing inequalities
    3. Public policy evaluation: experimental and quasi-experimental evaluation methods

Generic central skills and knowledge targeted in the discipline

* M1: Model a statistical experiment for an i.i.d. sample and implement standard pointwise and interval estimation methods and testing procedures
* M2: Write and analyze a week formulation for a PDE. Implementation in Finite Element software.
* M3: Formulate the optimal transport problem and calculate Wasserstein distances
* I1: Understand the main categories of algorithms and how to implement them
* I2: Implement event-driven programming in Python and understand the notion of persistence
* I3: Program in Python with the Numpy, Scipy, Matplotlib, Pandas, Seaborn and Scikit-image libraries
* E1: Identify the different types of markets, understand the notions of monopoly and oligopoly
* E2: Classify strategies and understand Nash equilibrium
* E3: Understand inequalities in economics and implement tools to evaluate public policies addressing them

How knowledge is tested

Continuous assessment

Bibliography

A bibliography will be proposed at the beginning of each subcourse offered in the major course unit Mathematics-Computer Science-Economics.

Teaching team

1. **Mathematics**
    1. M1 : Christophe Pouet, Mitra Fouladirad, Frédéric Schwander

2. M2 : Guillaume Chiavassa
3. M3 : Magali Tournus

2. **Computer Science**
   1. I1 : François Brucker, Pascal Préa
   2. I2 : Emmanuel Daucé, Manon Philibert
   3. I3 : Muriel Roche, Manon Philibert
3. **Economics**
   1. E1 : Nicolas Clootens, Santiago Lopez-Cantor
   2. E2 : Nicolas Fournier (Aix-Marseille Université), Hajare El Hadri, Santiago Lopez-Cantor, Ayoub Salih
   3. E3 : Hajare El Hadri

Sustainable Development Goal

Climate action

Peace, justice and strong institutions

Reduced inequalities

Responsible consumption and production

Total des heures		**72h**
CM	Master class	54h
AA		18h

Useful info

Name responsible for EU

Lead Instructor

Christophe Pouet

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