MINORS FIELD_10 ECTS (=Electives/Optionals)

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

Finite Element Methods (optional choice)

Introducing

Description

Program (detailed contents)

Finite Elements Methods

FE BASES
* Recalls. Analysis of elliptic PDEs : weak solution vs classical solution, Sobolev spaces, Lax-Milgram theory, a-priori estimations. Boundary conditions. Energy minimization. (2 Lectures, 1Tutorial)
* Modelling with a FE software (FreeFEM++): classical models, one real-like problem.
1 Lab Work with FreeFEM++
* Finite Element Method (FEM) principles in multi-D: discretisation, approximation, Error analysis (a-priori). (1Lecture, 1Tutorial).
* In practice: data structures, implementation (assembly algorithm). Convergence curves (code validation from exact solutions). (2 Lectures, 1 Tutorial, 2 Lab Works with Python)

DISCONTINUOUS GALERKIN (DG) METHODS
* Discontinuous Galerkin Method for Diffusive and transport problem: Broken spaces, jumps and interior penalty techniques, stability, introduction to non-conforming analysis.
(3 Lectures, 1 Tutorial, 1 Lab Work)

ADVANCED FE METHODS
* The advection-diffusion equation:
- Analysis and naïve discretization. (1 Lecture, 1 Tutorial)
- Transport term: FE stabilisation (SD, SUPG). (1 Lecture, 1 Tutorial)

* Non-linear models: linearization (1 Lecture, 2 Tutorials, 3 Lab Works)
(Including: differential calculus / Riez-Frechet theorem)+ help to the marked practical).
* Unsteady models: semi-discretisation. 1 Lecture, 1 Lab Work

PDE MODEL REDUCTIONS
* Model Reduction for parametrized PDEs, offline-online strategies.
Linear PDEs: POD method. (1,5 Lecture, 1 Lab Work)
Non-linear PDEs: Hybrid approaches POD - Neural Networks. (1.5 Lecture, 1 Lab Work)

Objectives

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

- How to build up a FE scheme.
- How to elaborate an off-online strategy of resolution.

The student will be able to:

- Write weak forms of PDEs (and energy minimization in symmetric cases).
- Write and implement Finite Element schemes for linear and nonlinear scalar PDEs
- Employ Finite Element libraries: FEniCS - Python and FreeFem++.

- Set up an offline ¿ online strategy (real time computations):
 POD reduction for linear PDEs,
 Hybrid POD-ANN (Neural Networks) for non-linear PDEs.
- Simulate classical phenomena : linear/nonlinear advection-diffusion equations

Necessary prerequisites

Fundamentals of PDE models and math. analysis,
Numerical analysis.

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Practical info

Location(s)

Toulouse

Models and numerical methods for solid and fluid mechanics

Introducing

Description

Program (detailed contents):

Fundamental concepts of continuum mechanics:

- Physical properties of fluids and solids.
- Lagrangian and Eulerian formulations
- Tensor of deformations, strain rates and stresses
- Derivation of the general equations of continuum mechanics

Modeling and scientific computing in fluid mechanics:

- Dynamics of viscous incompressible fluids
- Dynamics of incompressible perfect fluids, potential flows
- Introduction to the finite volume method (FVM) for incompressible viscous fluids
- Implementation in PYTHON of the FVM on a simple problem
- Use of the industrial software FLUENT to model and compute the solution of some 2D problems (driven cavity, flow around a wing profile)

Modeling and scientific computing in structural mechanics

- Variational formulation and relation with the energy minimization for the elasticity problem.
- Numerical solution of elasticity with the finite element method.
- Modeling and computation of static as well as dynamic elastic problems through the use of an industrial software (ABAQUS)
- Multiscale model and code coupling.
- Development of python routines for the computation of stress concentration and local propagation of cracks within solids
- Data-Driven Computational Mechanics
- Introduction of the concept and application on a 2D example of lattice.

Objectives

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

The fundamentals of Mechanics for fluid and deformable solids, from a physical, mathematical and numerical point of view.

The student will be able to:
- Know the main models used in continuum mechanics for fluids and solids
- Calculate exact solutions of simple problems and know how to interpret them physically
- Evaluate orders of magnitude
- Formulate and solve the dynamics of an incompressible flow using the finite volume method.
- Formulate and solve the problem of elasticity using the finite element method.
- Use an industrial software to model and compute the elasticity problem in both static and dynamic modes, and some fluid mechanics problems, for incompressible and compressible flows
- Write and implement a mixed formulation to couple different elastic domains and different numerical codes used as black-boxes.
- Apprehend the data-driven (model-free) paradigm in computational mechanics.

Necessary prerequisites

Fundamentals in:
- Mechanics (forces, Newton's laws, kinetic energy, potential energy)
- PDE course (finite element method in 1D, finite volume method in 1D)
- Analysis and electrostatic courses: Differential and integral calculus for functions of several variables (gradient, Jacobian, Ostrogradsky's theorem ...)

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Practical info

Location(s)

Toulouse

Data analysis

Introducing

Description

Program (detailed contents):

- Introduction to exploratory data analysis
- Syntax and objects of R and Python languages, functions, object and functional programmation (Python).
- Factorial methods. Reminder on principal component analysis (PCA). Variants of PCA for qualitative data (correspondence analysis), classification (linear discriminant analysis), distance-based data (multidimensional scaling), non-linearities (kernel PCA)
- Clustering: reminder on basic techniques (k-means, hierarchical clustering). Mixture models and EM algorithm. Community slicing or graph clustering.
- Non-négative matrix factorization (NMF) and introduction to recommendation.

Objectives

At the end of this module, the student will have understood and be able to explain (main concepts):
- Data base organisation of R and Python data frames. Syntaxes R and Python languages. R and Python functions design, program and test.
- Statistical analyses of multidimensional data: dimension reduction and clustering with R and Python.
- Statistical interpretation of various graphical displays including the different kinds of factor analyses and clustering.

The student will be able to:

- Manage big data sets with R and Python.
- Lead exploratory data analyses of real big data. It includes univariate, bivariate and multivariate data analyses featuring PCA, MCA, FDA, NMF kmeans, mixture models, DBSCAN¿ depending on data structures and analysis purposes;
- Detect relevant structures within complex data sets and compile insightful interpretations.

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Practical info

Location(s)

Toulouse

Stochastic Processes:

Introducing

Description

Program (detailed contents):

Time series
- Introduction and Descriptive Analysis: Time series decomposition, Estimation and Elimination of Trend and Seasonal Components
- Random Modeling of Time Series: Stochastic process, stationnarity, Autocovariance Function
- Statistical Inference of Stationary processes of order 2: Moment Estimation, Best linear predictor, Partial autocorrelation, statistical tests
- ARMA and ARIMA Models: AR process, MA process, ARMA et ARIMA processes

The practical labworks will be performed with R software.

Poisson processes and application to reliability and actuarial science
1st part: Theoretical foundations
- Probability distributions in reliability theory, hazard rate, memoryless distributions
- Introduction to homogeneous Poisson processes: definitions, fundamental properties, and simulation methods
- Inferential statistics for the homogeneous Poisson process (likelihood, estimation of the rate, confidence intervals, statistical tests)
- Introduction to inhomogeneous Poisson processes: definition, fundamental properties, simulation methods, and likelihood

2nd part: Mini projects
Application and illustration of different aspects of the Poisson process on real and/or simulated data in reliability theory or actuarial science (e.g. Cramér-Lundberg model)

The practical labwork and the projects will also be performed with the R software.

Objectives

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

Time series
- Trend and seasonality of a time series
- Definitions and properties of stationary processes
- The autocovariogram and autocorrelograms (total and partial) of a stationary process
- The ARMA and ARIMA models

Poisson processes and application to reliability and actuarial science
- Homogeneous and inhomogeneous Poisson processes
- Statistical inference for homogeneous Poisson processes

The student will be able to:

Time series
- Estimate or eliminate the trend and/or the seasonality of a time series.
- Study the stationnarity of a time series.
- Calculate and estimate the autocorrelogram and the autocorrelograms (total and partial) of a stationary process.
- Study and/or adjust an ARMA (or ARIMA) model on a stationary time series.
- Carry an optimal linear forecast of an ARMA process.
- Apply these concepts using R software

Poisson processes and application to reliability and

actuarial science
- Know and understand the (homogeneous and inhomogeneous) Poisson process theory fundamentals.
- Estimate the rate of a homogeneous Poisson process and construct confidence intervals and statistical tests for such rate (theoretically and in practice with the R software)
- Draw at random (homogeneous and inhomogeneous) Poisson processes using different methods
- Model the recursive occurrences of the failures on a system, or the claim times in Insurance by Poisson processes

Necessary prerequisites

- Probability and Statistics (L2/2MIC)
- Probability and Data Analysis (L3/3MIC)
- Inferential Statistics (L3/3MIC)
- Statistics Modelling (M1/4MA)

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