SHAKE THE FUTURE.

CENTRALE NANTES

ENGINEERING PROGRAMME

SPECIALISATION

MATHEMATICS AND APPLICATIONS

SPRING SEMESTER

Établissement public sous tutelle du
ministère de l'Enseignement supérieur, de la Recherche et de l'Innovation

GROUPE CENTRALE

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UNCERTAINTY QUANTIFICATION

CORE COURSE

MATHEMATICS AND APPLICATIONS, ENGINEERING PROGRAMME SPECIALISATION

SPRING SEMESTER

Professor: Anthony NOUY

Objectives

The aim of the course is to introduce fundamental concepts and mathematical tools for the modeling and quantification of uncertainty in predictive science and engineering, and to provide students with a theoretical understanding of numerical methods for stochastic and parametric models.

Course contents

- Introduction to uncertainty quantification
- Uncertainty modelling
- Monte-Carlo methods, application to rare event estimation
- Sensitivity analysis and specific methods
- Approximation of models: interpolation methods, statistical learning, model order reduction

Course material

Keywords

Uncertainty quantification, Monte-Carlo methods, Rare events, Sensitivity analysis, Metamodels, Model order Reduction, Statistical learning

Links with other programmes

Probability, Stochastic processes, Functional analysis, Variational approximations for partial differential equations, Time series

LANGUAGE	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT
French	3	22,0 hrs	0,0 hrs	4,0 hrs	6 hrs

MODELLING FOR HEALTH AND BIOLOGY 1

NUMERICAL ANALYSIS & PROBABILITY TRACK

MATHEMATICS AND APPLICATIONS, ENGINEERING PROGRAMME SPECIALISATION

SPRING SEMESTER

Professor: Marie BILLAUD-FRIESS

Objectives

This lecture gives an introduction to numerical methods for solving stochastic differential equations (SDE). These methods will allow us to introduce the probabilistic point of view for numerical solutions to partial differential equations (PDE). These methods will be illustrated for solving simple problems coming from biology.

Course contents

1. Brownian motion: general process, brownian motion definition, simulation
2. Stochastic differential equations: stochastic integral, general information on SDEs, strong solutions, Ito process and formula, diffusion process
3. Numerical integration for SDEs: numerical schemes (Euler Maruyama, Milstein), weak and strong convergences, simulation
4. Probabilistic representation of PDEs: link between heat equation and brownian motion, Feynman Kac representation

Course material

[1] F. Comets, T. Meyre, Calcul stochastique et modèles de diffusion, Dunod, 2015

[2] E. Gobet, Méthodes de Monte-Carlo et processus stochastiques: du linéaire au non linéaire, Editions de l'école polytechnique, 2013

[3] P.E. Kloeden, E. Platen, Numerical Solution of Stochastic Differential Equations, Springer Verlag, 1999

[4] G. Lord, C. Powell, T. Shardlow, Introduction to computational stochastic PDEs, 2010

Keywords

Ito SDE, Brownian motion, Euler-Maruyama scheme, Milstein scheme, Feynman-Kac representation, Convergence, Biology models

Links with other programmes

Stochastic Modelling - Stochastic Processes - Partial Derived Equations - Numerical Analysis for Partial Derived Equations

LANGUAGE	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT
French	3	13,3 hrs	13,3 hrs	1,3 hrs	4 hrs

MODELLING FOR HEALTH AND BIOLOGY 2

NUMERICAL ANALYSIS & PROBABILITY TRACK

MATHEMATICS AND APPLICATIONS, ENGINEERING PROGRAMME SPECIALISATION

SPRING SEMESTER

Professor: Mazen SAAD

Objectives

This course covers the mathematical and numerical study of models arising from population dynamics. The models deal with the spread of epidemics like influenza, the Norovirus and the FIV (Feline Immunodeficiency Virus), interaction between species such as the predator-prey system, chemotaxis as in the Keller-Segel model, bone regeneration or breast cancer.

Chemotaxis is the movement of biological individuals towards a chemoattractant (or away from chemorepellent). A vital characteristic of living organisms is the ability to sense signals in the environment and adapt their movement accordingly. A typical model describing chemotaxis is the Keller-Segel system.

This model leads to a nonlinear parabolic system, which is the common thread throughout this course.

In this course, we first start with an introduction to functional spaces depending on time and space. Next, two major techniques are presented to handle the existence of solutions to linear and nonlinear connvection-diffusion equations. Then, a combined finite element/finite volume scheme is introduced to approximate the solutions to standard convective diffusive equations. Finally, the scheme is generalized to the Keller-Segel system and the convergence analysis is presented.

Course contents

1) Models in population dynamics
   - Epidemiology models (SIR, Influenza, Norovirus, FIV)
   - Chemotaxis Keller-Segel Model
   - Bone regeneration model
   - Breast cancer model
2) Functional spaces L^p((0,T);X) and compactness
3) Weak solutions for a convection-diffusion equation with Galerkin method
4) Mathematical study of Keller-Segel system (a nonlinear parabolic system)
5) Combined finite element/finite volume scheme for convection-diffusion equations
6) Combined finite element/finite volume scheme for Keller-Segel

Course material

J.D. Murray, Mathematical Biology I: An Introduction, Interdisciplinary Applied Mathematics; Springer

J.D. Murray, Mathematical Biology II: Spatial Models and Biomedical Applications, Interdisciplinary Applied Mathematics; Springer

A.M. Turing, The chemical basis of Morphogenesis. 1952

L.C. Evans, Partial Differential Equations. Graduate Studies in Mathematics, Volume19, AMS

L. Perko, Differential equations and Dynamical Systems, Texts in Applied Mathematics, 7

P.A. Raviart, J.M. Thomas, Introduction à l'analyse des équations aux dérivées partielles, Masson, 1988.

Keywords

Chemotaxis, cancer, Keller-Segel, convection, diffusion, parabolic equations, approximation, existence of solutions

Links with other programmes

LANGUAGE	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT
French	**3**	**13,3 hrs**	**14,7 hrs**	**0,0 hrs**	**4 hrs**

STOCHASTIC MODELING

NUMERICAL ANALYSIS & PROBABILITY TRACK

MATHEMATICS AND APPLICATIONS, ENGINEERING PROGRAMME SPECIALISATION
SPRING SEMESTER

Professor: Antonio FALCO

Objectives

The goal of this course is to introduce the necessary tools to describe continuous time stochastic models and their relationship with partial differential equations. These concepts will be illustrated on models from physics and biology.

Course contents

Stochastic Processes, Brownian motion. Itô integral and Itô formulae. Itôs process. Stopping time. Girsanovs theorem. The theorem of Feynman and Kac.

Course material

D. Lamberton and B. Lapeyre. Introduction au calcul stochastique appliqué à la finance. Ellipses Marketing (2013).

H.C. Ötinger. Stochastic Processes in Polymeric Fluids: Tools and Examples for Developing Simulation Algorithms. Springer Verlag (1996)

C. Soize. Uncertainty Quantification: An Accelerated Course with Advanced Applications in Computational Engineering. Springer Verlag (2017)

Keywords

Brownian motion. Itô integral. Itô process. Girsanovs theorem. Theorem of Feyman-Kac.

Links with other programmes

Probability, Stochastic Processes

LANGUAGE	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT
French	3	16,0 hrs	10,0 hrs	0,0 hrs	6 hrs

STATISTICAL LEARNING

STATISTICS & DATA SCIENCE TRACK

MATHEMATICS AND APPLICATIONS, ENGINEERING PROGRAMME SPECIALISATION
SPRING SEMESTER

Professor: Bertrand MICHEL

Objectives

This course is an introduction to the theory and the methods of statistical learning

Course contents

- Statistical Learning: classification and regression
- Empirical Risk Minimization and Vapnik Chervonenkis theory
- Nearest Neighbour methods
- Kernel methods
- Tree based methods

Course material

S. Boucheron, O. Bousquet, and G. Lugosi. Theory of classification: a survey of some recent advances. ESSAIM; Probability and Statistics, 9:323-375, November 2005.

Devroye, L. P., Györ , L., and Lugosi, G. (1996). A Probabilistic Theory of Pattern Recognition, volume 31 of Applications of Mathematics (New York). Springer-Verlag, New York.

Hastie T., Tibshirani R. , Friedman J. (2009). The Elements of Statistical Learning: Data Mining, Inference, and Prediction.

Keywords

Statistical Learning, classification, regression

Links with other programmes

Computational Statistics-Statistical Inference and linear models-Advanced Statistical Learning

LANGUAGE	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT
French	3	13,3 hrs	14,7 hrs	0,0 hrs	4 hrs

ADVANCED STATISTICAL LEARNING

STATISTICS & DATA SCIENCE TRACK

MATHEMATICS AND APPLICATIONS, ENGINEERING PROGRAMME SPECIALISATION

SPRING SEMESTER

Professor: Bertrand MICHEL

Objectives

Practice of standard and more advanced algorithms in statistical learning

Course contents

- Practice of standard algorithms with Scikit-learn (SVM, random forest, lasso)
- Feature selection and dimension reduction
- Boosting
- Introduction to Big Data frameworks with Spark
- Introduction to Deep Learning

Course material

Hastie T., Tibshirani R. , Friedman J. (2009). The Elements of Statistical Learning: Data Mining, Inference, and Prediction.

Pedregosa, F. et al. Scikit-learn: Machine Learning in Python. Journal of Machine Learning Research, 2011.

Keywords

Machine Learning, Big Data, Deep Learning

Links with other programmes

Computational Statistics-Statistical Inference and linear models-Statistical Learning

LANGUAGE	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT
French	3	13,3 hrs	14,7 hrs	0,0 hrs	4 hrs

TIME SERIES

STATISTICS & DATA SCIENCE TRACK

MATHEMATICS AND APPLICATIONS, ENGINEERING PROGRAMME SPECIALISATION
SPRING SEMESTER

Professor: Anne PHILIPPE

Objectives

- Identification of Trends and Seasonal Components in time series
- Modeling with ARMA Processes
- Estimation for ARMA Processes

Course contents

- Time series analysis:

- Estimation and Elimination of Trend and Seasonal; Components
- The Sample Autocorrelation Function;

- Stationary Processes:

- Introduction to ARMA Processes;
- Estimation;
- Testing the Estimated Noise Sequence;
- Diagnostic Checking;

Course material

P. Brockwell and R. Davis : "Introduction to Time Series and Forecasting", 2016

Keywords

Time series, linear model, stationarity, estimation, model selection

Links with other programmes

LANGUAGE	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT
French	3	14,0 hrs	16,0 hrs	0,0 hrs	0 hrs