# Courses

## Computer Science and System Engineering

### Academic Year 2018 – 2019

## Advanced Neuroimaging

**Abstract:** Early brain functional studies, based on MRI, PET or EEG, focused on univariate analyses, in which the activity of each region is processed independently from each other. Nowadays, multivariate machine learning techniques have been developed to model complex, sparse neuronal populations. This course will provide an introduction to new methods and cutting-edge machine-learning techniques in the neuroimaging field by exploring multivariate statistical modeling of brain-activity data and computational modeling of brain information processing. Specifically, the course focuses on machine learning decoding and encoding perspectives in fMRI and novel methods (e.g., Representational Similarity Analysis) to explore and analyze brain data. A comprehensive review of model validation and statistical inference is provided.
In addition, hardware and software implementation recently allowed to combine different neural measures with different spatial and temporal resolutions within the same experimental session. The course also discusses the transdisciplinary approach combining different neuroimaging techniques in unique methodological frameworks and the advent of ultrahigh field neuroimaging.
**Hours:** 30
**Professors/Lecturers:** Nicola Vanello (Università degli Studi di Pisa); Mauro Costagli (Fondazione IMAGO7 Pisa); Andrea Leo (IMT Lucca); Marcello Massimini (Università degli Studi di Milano)
**Available for:** Computer Science and System Engineering

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## Advanced Numerical Analysis

**Abstract:**

1. General considerations on matrices

Matrices:definitions and properties; norm of matrices
The condition number of a matrix
Sparse matrices and sparse formats (sparsity, structure, functionals)
The role of the PDE discretization (e.g., parameter dependence)

2.a Direct methods for general linear systems

Factorizations: definitions and properties
Factorization algorithms
Cost and numerical stability

2.b Direct methods for sparse linear systems

Factorizations of banded matrices
Ordering strategies to minimize the fill-in of a matrix
Solution of sparse triangular systems
Sparse matrices in Matlab: memorization and handling

Predefined functions for the direct solution of systems

3. Numerical solution of large-scale linear systems

Krylov subspace methods (CG, MINRES, GMRES, IDR family)
Structured problems
Preconditioning
Algebraic multigrid methods (hints)
Numerical experiments with Matlab and the IFISS package

4. Numerical solution of eigenvalue problems

Standard and generalized eigenproblems
Typical numerical methods
Equation of motion in structural dynamics: quadratic eigenproblems

**Hours:** 20
**Professors/Lecturers:** Valeria Simoncini (Università di Bologna); Benedetta Morini (Università degli Studi di Firenze)
**Available for:** Computer Science and System Engineering; Economics, Networks and Business Analytics

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## Advanced Topics in Network Theory: Algorithms and Applications

**Abstract:** Centrality metrics and spectral properties of graphs.
Community detection.
Bipartite and multilayer networks.
Applications: Worls Trade Web

Lecture 1: Centrality metrics
Lecture 2: Spectral properties
Lecture 3: Ranklings and reputation on graphs
Lecture 4: Community detection in networks I
Lecture 5: Community detection in networks II
Lecture 6: Bipartite networks
Lecture 7: Multilayer networks
Lecture 8: World Trade Web
Lecture 9: Infrastructural network I
Lecture 10: Infrastructural network II
**Hours:** 10
**Professors/Lecturers:** Guido Caldarelli (IMT Lucca); Fabio Saracco (IMT Lucca); Angelo Facchini (IMT Lucca)
**Compulsory for:** Economics, Networks and Business Analytics
**Also available for:** Computer Science and System Engineering

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## Advanced Topics in Network Theory: Brain Networks

**Abstract:** TBD
**Hours:** 10
**Professors/Lecturers:** Guido Caldarelli (IMT Lucca); Tommaso Gili (IMT Lucca)
**Available for:** Computer Science and System Engineering; Economics, Networks and Business Analytics

## Advanced Topics in Network Theory: Complex Networks and Python

**Abstract:** TBD
**Hours:** 10
**Professors/Lecturers:** Guido Caldarelli (IMT Lucca)
**Compulsory for:** Economics, Networks and Business Analytics
**Also available for:** Computer Science and System Engineering

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## Advanced Topics in Network Theory: Dynamical Processes of Networks

**Abstract:** Mean field and master equations.
Percolation and epidemic models.
Contagion: the case of financial networks.
Applications of network theory.

Lecture 1: Master equations for network models
Lecture 2: Fitness and relevance models
Lecture 3: Epidemic processes in mean fiels
Lecture 4: Epidemics on networks
Lecture 5: Scaling and percolation on networks
Lecture 6: Contagion in financial network I
Lecture 7: Contagion in financial network II
Lecture 8: Game theory on networks
Lecture 9: Evolutionary network games
lecture 10: Networks from time series and visibility graph
**Hours:** 10
**Professors/Lecturers:** Guido Caldarelli (IMT Lucca); Giulio Cimini (IMT Lucca)
**Compulsory for:** Economics, Networks and Business Analytics
**Also available for:** Computer Science and System Engineering

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## Advanced Topics of Computational Mechanics

**Abstract:** The course is organized as a set of seminars and lectures delivered by IMT Professors and by invited recognized international experts. It covers advanced topics of computational mechanics.
**Hours:** 20
**Professors/Lecturers:** Marco Paggi (IMT Lucca); Andrea Bacigalupo (IMT Lucca); Alessio Gizzi (Campus Bio-Medico Roma)
**Available for:** Computer Science and System Engineering

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## Advanced Topics of Computer Science

**Abstract:** This course will be organized as series of reading groups or specialized seminars by members or collaborators of the research unit on System Modelling and Analisys (SysMA).
**Hours:** 20
**Professors/Lecturers:** Hugo Filipe Mendes Torres Vieira (IMT Lucca); Max Tschaikowski (IMT Lucca); Claudio Mezzina (IMT Lucca)
**Available for:** Computer Science and System Engineering

## Advanced Topics of Control Systems: Numerical Methods for Optimal Control

**Abstract:** This course will cover a selected advanced topic in control, identification, or dynamical optimization.

Prerequisites: Linear algebra and matrix computation, calculus and mathematical analysis, control systems, numerical optimization.
**Hours:** 20
**Professors/Lecturers:** Mario Zanon (IMT Lucca)
**Available for:** Computer Science and System Engineering

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## Applications of Stochastic Processes

**Abstract:** This course offers an introduction to stochastic processes as a practical modelling tool for the quantitative analysis of systems. It covers the fundamentals of Markov chains, and presents algorithms and state-of-the-art software applications and libraries for their numerical solution and simulation. The class of Markov Population Processes is presented, with its most notable applications to as diverse disciplines as chemistry, ecology, systems biology, health care, computer networking, and electrical engineering. Finally, the course will examine the computational issues arising from the modelling of large-scale systems, reviewing effective approximation methods based ordinary differential equation (fluid) limits, moment-closure techniques, and hybrid models. Prerequisites: fundamentals of probability theory; knowledge of the topics of “Stochastic Processes and Stochastic Calculus” is useful but not necessary.
**Hours:** 20
**Professors/Lecturers:** Mirco Tribastone (IMT Lucca)
**Available for:** Computer Science and System Engineering

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## Behavioral Economics

**Abstract:** TBD
**Hours:** 20
**Professors/Lecturers:** Ennio Bilancini (IMT Lucca)
**Specializing course for:** Economics, Networks and Business Analytics
**Also available for:** Computer Science and System Engineering

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## Business Model for Emerging Markets

**Abstract:**

Teaching contents:

1. The economy of the intangibles
2. Manufacturing and robot
3. Strategy and business model
4. How to model a business
5. How to model a business in a complex scenario
6. What make market emerging? Not only new lands.
7. The Blockchain technology and the future
8. Initial Coins Offering (ICO) compressed between Business plan and White paper
9. Possible value of Blockchain technology for Small and medium Italian sized business
10. A global value chain approach to protect and foster strategic identity

Business case

Students will learn how to evaluate strategies, as well as how to locate sources of potential competitive advantage from a perspective that, for the purpose of this course, encompasses the internal and dynamic fit of a strategy. They will also learn how to identify organizational barriers and corporate behaviors that sustain or challenge the development and execution of strategies, and the competitive advantage of a company.

**Hours:** 20
**Professors/Lecturers:** Nicola Lattanzi (IMT Lucca)
**Available for:** Computer Science and System Engineering; Economics, Networks and Business Analytics

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## Computational Contact and Fracture Mechanics

**Abstract:** This course provides an overview on the theories of contact and fracture mechanics relevant for a wide range of disciplines ranging from materials science to engineering. Introducing their theoretical foundations, the physical aspects of the resulting nonlinearities induced by such phenomena are emphasized. Numerical methods (FEM, BEM) for their approximate solution are also presented together with a series of applications to real case studies. In detail, the course covers the following topics: Hertzian contact between smooth spheres; the Cattaneo-Mindlin theory for frictional contact; numerical methods for the treatment of the unilateral contact constraints; contact between rough surfaces; fundamentals of linear elastic fracture mechanics; the finite element method for crack propagation; nonlinear fracture mechanics and the cohesive zone model; interface finite elements; applications of fracture mechanics to materials science, retrofitting of civil/architectonic structures, composite materials.
**Hours:** 20
**Professors/Lecturers:** Marco Paggi (IMT Lucca)
**Available for:** Computer Science and System Engineering

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## Computer Programming and Methodology

**Abstract:** This course aims at introducing to students principles and methodologies of computer programming. Emphasis is on good programming style, techniques and tools that allow efficient design, development and maintenance of software systems. The course focuses on the design of computer applications drawing attention to modern software engineering principles and programming techniques, like object-oriented design, decomposition, encapsulation, abstraction, and testing. A significative case study is used to allow students to experiment with the principles and techniques considered in this course. Depending on the background of the class, Java, C++, and/or Python are considered in the course.
**Hours:** 20
**Professors/Lecturers:** Mirco Tribastone (IMT Lucca)
**Available for:** Computer Science and System Engineering; Economics, Networks and Business Analytics

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## Data Science Lab

**Abstract:** The aim of this class is to provide students with R language fundamentals and basic sintax. In particular, lessons will cover the following topics:

- Overview of R features
- The basics (vectors, matrices, objects, manipulation, basic statements)
- Reading data from files
- Probability distributions
- Basic statistical models

- Graphical procedures
- R packages overview

**Hours:** 15
**Professors/Lecturers:** Valentina Tortolini (IMT Lucca)
**Available for:** Computer Science and System Engineering; Economics, Networks and Business Analytics

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## Econometrics I

**Abstract:**

- Review of Asymptotic Theory
- Theory and Algebra of OLS
- Inference, non-spherical Errors and Clustering
- Structural Models, Identification and Causality
- Simultaneous Equation Models, 2SLS and 3SLS
- Introduction to M-Estimation
- Generalized Method of Moments
- Maximum Likelihood Estimation

**Hours:** 20
**Professors/Lecturers:** Paolo Zacchia (IMT Lucca)
**Compulsory for:** Economics, Networks and Business Analytics
**Also available for:** Computer Science and System Engineering

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## Econometrics II

**Abstract:**

- Microdata and Heterogeneity
- Potential Outcome Framework
- Difference-in-difference and treatment effects
- Linear and Static Panel Data Models
- Linear and Dynamic Panel Data Models
- Non-Linear Models
- Categorical variables and count data
- Multinomial models

**Hours:** 20
**Professors/Lecturers:** Armando Rungi (IMT Lucca)
**Compulsory for:** Economics, Networks and Business Analytics
**Also available for:** Computer Science and System Engineering

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## Finance

**Abstract:** This course introduces students to the basic concepts used in quantitative finance, which forms the basis for many applications such as derivatives pricing, financial engineering and asset pricing. Anyone interested in these areas will have to acquire a good grasp of the topics in this course. We will cover: the analysis of complete and incomplete markets in discrete and continuous time models; the discussion and extension of the assumptions of the Black-Scholes-Merton equation and the introduction of common numerical techniques that are widely applied in practice (along with practical lab sessions with real data); the introduction of structured finance products, their use in risk management and valuation techniques, most notably for mortgage-backed securities, credit default swaps and collateralized debt obligations.

Students require an adequate knowledge of mathematics, particularly in matrix algebra and analysis

along with stochastic processes and stochastic calculus to follow this course. Appropriate readings to refresh your knowledge are given on request.

Outline:

Part I – Pricing Models
- Hedging of securities;
- No-arbitrage pricing;
- Pricing in multi-period models (Binomial Model);
- Pricing in continuous time (Black-Scholes-Merton Model)

Part II - Numerical techniques
- Beyond Black-Scholes-Merton Model;
- Binomial lattices;
- Monte-Carlo simulation;
- Finite differences

Part III – Structured Finance
- Mortgage-backed securities;
- Modeling and pricing corporate default;
- Credit Default Swaps;
- Designing CDOs and exotic CDOs

Prerequisites: Stochastic Processes and Stochastic Calculus
**Hours:** 20
**Professors/Lecturers:** Tbd
**Available for:** Computer Science and System Engineering; Economics, Networks and Business Analytics

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## Firms, Business Analytics and Managerial Behavior

**Abstract:**

Teaching contents:

1. Theory of the Firm
2. The system of force in a business organization
3. The balance between efficiency of the production and effectiveness in results
4. Business performance and ways to represent
5. The financial statement
6. How to read and comprehend performances and results
7. Methodology and tools for Balance sheet analysis
8. Prevision versus prediction and business analytics
9. Entrepreneurship and management in complex scenario
10. Neuroscience, decision making process and managerial behavior

Business case

Students will learn how to evaluate strategies, as well as how to locate sources of potential competitive advantage from a perspective that, for the purpose of this course, encompasses the internal and dynamic fit of a strategy. They will also learn how to identify organizational barriers and corporate behaviors that sustain or challenge the development and execution of strategies, and the competitive advantage of a company.

**Hours:** 20
**Professors/Lecturers:** Nicola Lattanzi (IMT Lucca)
**Available for:** Computer Science and System Engineering; Economics, Networks and Business Analytics

## Foundations of Probability and Statistical Inference

**Abstract:**

This course aims at introducing, from an advanced point of view, the fundamental concepts of probability and statistical inference. Some proofs are sketched or omitted in order to have more time for examples, applications and exercises.
In particular, the course deals with the following topics:

- probability space, random variable, expectation, variance, cumulative distribution function, discrete and absolutely continuous distributions, random vector, joint and marginal distributions, joint cumulative distribution function, covariance,
- conditional probability, independent events, independent random variables, conditional probability density function, order statistics,
- multivariate Gaussian distribution,
- probability-generating function, Fourier transform/characteristic function,
- types of convergence and some related important results,
- point estimation, interval estimation, hypothesis testing, linear regression, introduction to Bayesian statistics.

Students may be exonerated up to a maximum of 10 hours according to their background.

**Hours:** 30
**Professors/Lecturers:** Irene Crimaldi (IMT Lucca)
**Compulsory for:** Economics, Networks and Business Analytics
**Also available for:** Computer Science and System Engineering

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## Funding and Management of Research and Intellectual Property (long seminar without exam)

**Abstract:** The long seminar aims at providing an overview on the management of intellectual property rights (copyright transfer agreements, open access, patents, etc.). Funding opportunities for PhD students, post-docs, and researchers are also presented (scholarships by the Alexander von Humboldt Foundation; initiatives by the Deutscher Akademischer Austausch Dienst; scholarships offered by the Royal Society in UK; bilateral Italy-France exchange programmes; Fulbright scholarships; Marie Curie actions; grants for researchers provided by the European Research Council). For each funding scheme, specific hints on how to write a proposal are given.
**Hours:** 10
**Professors/Lecturers:** Marco Paggi (IMT Lucca)
**Available for:** Computer Science and System Engineering; Economics, Networks and Business Analytics

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## Game Theory

**Abstract:** The course covers the basics of non-cooperative game theory and information economics. The goal is to equip students with an in-depth understanding of the main concepts and tools of game theory in order to enable them to successfully pursue research in applied areas of economics and related disciplines, and to provide a solid background for students who are planning to concentrate on economic theory.
The course starts with a detailed description of how to model strategic situations as a game. It proceeds by studying basic solution concepts and their main refinements (dominance and iterative dominance, Nash equilibrium, correlated equilibrium, subgame perfect equilibrium, weak perfect Bayesian equilibrium, sequential equilibrium), strategic interaction under incomplete information (Bayesian games, Bayesian Nash equilibrium), and asymmetric information (adverse selection, signaling, screening, moral

hazard, and the principal agent problem). The discussion of all theoretical concepts will be accompanied by representative applications from economics.
The course is mostly self-contained, but students should be familiar with basic concepts from calculus, linear algebra, and probability theory.
**Hours:** 20
**Professors/Lecturers:** Kenan Huremovic (IMT Lucca); Ennio Bilancini (IMT Lucca)
**Compulsory for:** Economics, Networks and Business Analytics
**Also available for:** Computer Science and System Engineering

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## Identification, Analysis and Control of Dynamical Systems

**Abstract:** The course provides an introduction to dynamical systems, with emphasis on linear systems in state-space form. After introducing the basic concepts of stability, controllability and observability, the course covers the main techniques for the synthesis of stabilizing controllers (state-feedback controllers and linear quadratic regulators) and of state estimators (Luenberger observer and Kalman filter). The course also briefly covers data-driven approaches of parametric identification to obtain models of dynamical systems from a set of data, with emphasis on the analysis of the robustness of the estimated models w.r.t. noise on data and on the numerical implementation of the algorithms.

Prerequisites: Linear algebra and matrix computation, calculus and mathematical analysis.
**Hours:** 20
**Professors/Lecturers:** Alberto Bemporad (IMT Lucca)
**Available for:** Computer Science and System Engineering; Economics, Networks and Business Analytics

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## Introduction to Cognitive and Social Psyschology

**Abstract:** This course will provide an introduction to general themes in Cognitive and Social Psychology. In the first part of the course, we will review seminal findings that had a major impact on our knowledge of cognitive processes and social interactions, as well as more recent studies that took advantage of neuroimaging, electrophysiology and brain stimulation methods to shed new light on decision-making and social behaviors. During the second part of the course, students will be asked to perform a brief presentation of a research article and to critically discuss positive aspects and limitations of the study. The course will include seminars and lectures by renowned researchers in the field and will educate PhD candidates about the influence of social aspects of the human nature on cognitive and brain functioning (and vice-versa) in an intellectually motivating manner.
**Hours:** 24
**Professors/Lecturers:** Pietro Pietrini (IMT Lucca); Emiliano Ricciardi (IMT Lucca)
**Available for:** Computer Science and System Engineering; Economics, Networks and Business Analytics

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## Introduction to Complex Systems and Networks

**Abstract:** Complexity, self-similarity, scaling, self-organised criticality.
Definition of graphs, real networks and their properties.
Models of static networks, models of network growth.

Lecture 01 Graph Theory Introduction
Lecture 02 Properties of Complex Networks
Lecture 03 Communities
Lecture 04 Different Kind of Graphs
Lecture 05 Ranking
Lecture 06 Static Models of Graphs
Lecture 07 Dynamical Models of Graphs

Lecture 08 Fitness Models
Lecture 09 World Trade Web
Lecture 10 Financial Networks
**Hours:** 10
**Professors/Lecturers:** Guido Caldarelli (IMT Lucca)
**Compulsory for:** Economics, Networks and Business Analytics
**Also available for:** Computer Science and System Engineering

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## Machine Learning

**Abstract:** The course provides an introduction to basic concepts in machine learning. Topics include: learning theory (bias/variance tradeoff; Vapnik-Chervonenkis dimension and Rademacher complexity, cross-validation, feature selection); supervised learning (linear regression, logistic regression, support vector machines); unsupervised learning (clustering, principal and independent component analysis); semisupervised learning (Laplacian support vector machines); online learning (perceptron algorithm); hidden Markov models.
**Hours:** 20
**Professors/Lecturers:** Giorgio Stefano Gnecco (IMT Lucca)
**Specializing course for:** Economics, Networks and Business Analytics
**Also available for:** Computer Science and System Engineering

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## Management of Complex Systems: Approaches to Problem Solving

**Abstract:** Methods and approach to problem solving. Problem analysis; analysis of complex systems (related to cultural heritage, such as a city of art organization, promotion, etc.). The course will include practical simulations. The course will be linked to a seminar on specific case studies.
**Hours:** 30
**Professors/Lecturers:** Andrea Zocchi
**Available for:** Computer Science and System Engineering; Economics, Networks and Business Analytics

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## Micromechanics

**Abstract:** The course covers the fundamentals on modelling heterogeneous materials with periodic, quasi-periodic or non-ordered microstructures. Metamaterials, auxetic materials, chiral and anti-chiral microstructures belong to this class and their design and optimization requires a deep knowledge of their mechanical behaviour. Topics addressed in the course concern the evaluation of the bounds to the effective elastic properties of heterogeneous materials, local (Cauchy continuum) and non-local (micromorphic and multipolar continuum) homogenization methods of materials with periodic and quasi-periodic microstructure using heuristic computational approaches or asymptotic techniques and multiscale modeling of materials with disordered microstructure based on computational and variational homogenization methods.
**Hours:** 10
**Professors/Lecturers:** Marco Paggi (IMT Lucca); Andrea Bacigalupo (IMT Lucca)
**Available for:** Computer Science and System Engineering

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## Model Predictive Control

**Abstract:** Model Predictive Control (MPC) is a well-established technique for controlling multivariable systems subject to constraints on manipulated variables and outputs in an optimized way. Following a long history of success in the process industries, in recent years MPC is rapidly expanding in several other domains, such as in the automotive and aerospace industries, smart energy grids, and financial

engineering. The course teaches the theory and practice of Model Predictive Control (MPC) of constrained linear, linear time-varying, nonlinear, stochastic, and hybrid dynamical systems, and numerical optimization methods for the implementation of MPC, including the use of the MPC Toolbox for MATLAB for basic linear MPC, and of the Hybrid Toolbox for explicit and hybrid MPC.

Topics covered in the course: General concepts of Model Predictive Control (MPC); MPC based on quadratic programming; General stability properties; MPC based on linear programming; Models of hybrid systems: discrete hybrid automata, mixed logical dynamical systems, piecewise affine systems; MPC for hybrid systems based on on-line mixed-integer optimization; Multiparametric programming and explicit linear MPC, explicit solutions of hybrid MPC; Stochastic MPC based on scenario enumeration; Linear parameter- and time-varying MPC and applications to nonlinear dynamical systems; Selected applications of MPC in various domains, with practical demonstration of the MATLAB toolboxes.

Prerequisites: Linear algebra and matrix computation, linear control systems, numerical optimization.
**Hours:** 20
**Professors/Lecturers:** Alberto Bemporad (IMT Lucca)
**Available for:** Computer Science and System Engineering

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## Modelling and Verification of Reactive Systems

**Abstract:** Computing systems are becoming increasingly sophisticated and control key aspects of our lives. In light of the increasing complexity of such computing devices, one of the key scientific challenges in computer science is to design and develop computing systems that do what they were expected to do, and do so reliably. The aim of this course is to introduce models for the formal description of computing systems, with emphasis on parallel, reactive and possibly real-time systems, and the techniques for system verification and validation that accompany them. As an important component of the course, we shall introduce industrial-strength software tools for modelling and analyzing the behaviour of (real-time) reactive systems.
**Hours:** 20
**Professors/Lecturers:** Rocco De Nicola (IMT Lucca)
**Available for:** Computer Science and System Engineering

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## Neuroscience in Bio-Engineering and Robotics

**Abstract:** TBD
**Hours:** 18
**Professors/Lecturers:** Tbd; Domenico Prattichizzo (Università degli Studi di Siena); Enzo Pasquale Scilingo (Università di Pisa)
**Available for:** Computer Science and System Engineering

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## Numerical Methods for the Solution of Partial Differential Equations

**Abstract:** The course introduces numerical methods for the approximate solution of initial and boundary value problems governed by linear partial differential equations (PDEs) ubiquitous in physics, engineering, and quantitative finance. The fundamentals of the finite difference method and of the finite element method are introduced step-by-step in reference to exemplary model problems related to heat conduction, linear elasticity, and pricing of stock options in finance. Notions on numerical differentiation, numerical integration, interpolation, and time integration schemes are provided. Special attention is given to the implementation of the numerical schemes in Matlab and in the finite element analysis program FEAP fast intensive computations.
**Hours:** 20
**Professors/Lecturers:** Marco Paggi (IMT Lucca)
**Available for:** Computer Science and System Engineering; Economics, Networks and Business Analytics

## Numerical Optimization

**Abstract:** Optimization plays a key role in solving a large variety of decision problems that arise in engineering (design, process operations, embedded systems), data science, machine learning, business analytics, finance, economics, and many others. This course focuses on formulating optimization models and on the most popular numerical methods to solve them.
The topics covered in the course include: modeling (linear programming models, convex optimization models), basic optimization theory (optimality conditions, sensitivity, duality), algorithms for constrained convex optimization (active-set methods for linear and quadratic programming, proximal methods and ADMM, stochastic gradient, interior-point methods), line-search methods for unconstrained nonlinear programming, sequential quadratic programming.

Prerequisites: Linear algebra and matrix computation, calculus and mathematical analysis.
**Hours:** 20
**Professors/Lecturers:** Alberto Bemporad (IMT Lucca)
**Available for:** Computer Science and System Engineering; Economics, Networks and Business Analytics

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## Optimal Control

**Abstract:** Discrete-time optimal control: dynamic programming for finite/infinite horizon and deterministic/stochastic optimization problems. LQ and LQG problems, Riccati equations, Kalman filter. Deterministic continuous-time optimal control: the Hamilton-Jacobi-Bellman equation and the Pontryagin's principle. Examples of optimal control problems in economics. An economic application of optimal control: a dynamic limit pricing model of the firm.
**Hours:** 20
**Professors/Lecturers:** Giorgio Stefano Gnecco (IMT Lucca)
**Compulsory for:** Economics, Networks and Business Analytics
**Also available for:** Computer Science and System Engineering

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## Philosophy of Science (long seminar without exam)

**Abstract:** This is an introduction to the basic concepts and problems in the analysis of scientific reasoning and inquiry. The course will focus on some central patterns of reasoning and argumentation which in science and critically discuss their features and limitations. Topics covered include the nature of theory and evidence, the logic of theory testing, and the debate about the aims of science and the trustworthiness of scientific results. Classical examples and case-studies from the history and practice of scientific inquiry will be employed to illustrate the relevant problems and theoretical positions. No previous knowledge of either logic or philosophy is required.
**Hours:** 10
**Professors/Lecturers:** Gustavo Cevolani (IMT Lucca)
**Available for:** Computer Science and System Engineering; Economics, Networks and Business Analytics

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## Principles of Concurrent and Distributed Programming

**Abstract:** The course objective is to introduce the basics of concurrent programming problems through an illustration of the concepts and techniques related to modeling systems in which there are more components that are simultaneously active and need to coordinate and compete for the use of shared resources. At the end of the course the student will have a good understanding of the constructs for concurrent programming and be able to use them to write and analyze concurrent programs.
**Hours:** 20

**Professors/Lecturers:** Rocco De Nicola (IMT Lucca)
**Available for:** Computer Science and System Engineering

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## Qualitative and Quantitative Formal Methods for Computer Science

**Abstract:** This course offers an introduction to core topics in formal methods for the specification and analysis of systems, both for functional and nonfunctional properties. Students will be exposed to basic models of computation such as labelled transition systems and process algebra, formal approaches to specifying the semantics of programming languages (such as operational and denotational semantics), and quantitative analysis methods based on Markov processes.
**Hours:** 20
**Professors/Lecturers:** Rocco De Nicola (IMT Lucca); Mirco Tribastone (IMT Lucca)
**Available for:** Computer Science and System Engineering

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## Research Topics in Computer Science

**Abstract:** The goal of this course is to get students acquainted with research methods in computer science, including publication strategies and a classification of its main outlets (workshops, conferences, and journals). Students will receive a broad perspective on the major sub-fields computer science (e.g., programming languages, verification, software engineering, security, …) by means of guest lectures delivered by leading experts in the respective areas.
**Hours:** 20
**Professors/Lecturers:** Rocco De Nicola (IMT Lucca); Mirco Tribastone (IMT Lucca)
**Available for:** Computer Science and System Engineering

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## Science Integrity and Misconduct

**Abstract:**

1. Introduction
a. The age of scientific fraud
b. FFP (Fabrication, Falsification, Plagiarism)
c. Error, misconduct, fraud

2. Great scientists, successful cheaters
a. Is scientific fraud a new phenomenon?
b. Accused: famous scientists were fraudsters?
c. Present vs past

3. Fraudulent images
a. Scientific images as data
b. Introduction to fraudulent image manipulation
c. Image manipulation detection
d. Large scale analysis of image manipulation

4. The numbers of scientific disguise
a. Lying with numbers
b. Detection of numerical manipulations
c. Large scale studies

5. Stealing into print
a. What is plagiarism
b. Plagiarism detection
c. Large scale studies

6. The aftermath of fraud
a. Damage to Science
b. Economic costs
c. Effects on our lives
d. Personal effects

7. Personal and systemic factors causing misconduct
a. Individual factors connected to scientific fraud
b. Systemic incentives to fraud
c. The social components of scientific fraud

8. What can be done?
a. Changing the weight of publications in academic's career: proposals
b. Education: do current efforts succeed?
c. Editorial Policies
• Open data policies: current status and perspectives
• COPE
• ORCID
d. International academic policies
• Declarations (S. Francisco, Singapore)
• The position of EU
e. Local academic policies
• Dedicated Institutions: ORI
• The German way: Ombudsmen and other systems
• Italy: CNR, Federico II and other guidelines
f. Lab policies
• Italian examples
g. Legal policies
• Administrative and internal (no judiciary intervention)
• Judiciary (with a review of international trials and sanctions)

9. Beyond scientific fraud: research ethics
a. Introducing Ethics in Science
b. 3 rules for responsible scientists
c. Experimenting with humans and animals
d. Unethical behaviours in publishing

**Hours:** 18
**Professors/Lecturers:** Enrico Bucci (Resis S.r.l.)
**Compulsory for:** Computer Science and System Engineering; Economics, Networks and Business Analytics

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## Scientific Writing, Dissemination and Evaluation (long seminar without exam)

**Abstract:** In order to ensure their widest possible dissemination, research results need to be presented in academic publications and in talks. The first goal of this course is to introduce students to basic principles of academic writing and on basic techniques to plan and deliver good academic talks. In addition, the course discusses the key principles of peer review, which is what makes science reliable knowledge. In particular, the course focuses on how to write a professional referee report.
**Hours:** 8
**Professors/Lecturers:** Luca Aceto (GSSI – L'Aquila)
**Available for:** Computer Science and System Engineering; Economics, Networks and Business Analytics

## Software Verification

**Abstract:** Software verification is the process by which a computer program is analysed in order to prove its correctness or to discover bugs. This course will introduce students to this topic with an overview of several techniques based on both testing and static verification, such as abstract interpretation, model checking, and satisfiability modulo theories. Students will be exposed to both theory and practice of software verification by means of practical sessions with state-of-the-art software tools.
**Hours:** 20
**Professors/Lecturers:** Gennaro Parlato (University of Southampton)
**Available for:** Computer Science and System Engineering

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## Stochastic Processes and Stochastic Calculus

**Abstract:** This course aims at introducing some important stochastic processes and Ito stochastic calculus. Some proofs are sketched or omitted in order to have more time for examples, applications and exercises.
In particular, the course deals with the following topics:

- Markov chains (definitions and basic properties, classification of states, invariant measure, stationary distribution, some convergence results and applications, passage problems, random walks, urn models, introduction to the Markov chain Monte Carlo method),
- conditional expectation and conditional variance,
- martingales (definitions and basic properties, Burkholder transform, stopping theorem and some applications, predictable compensator and Doob decomposition, some convergence results, game theory, random walks, urn models),
- Poisson process, Birth-Death processes,
- Wiener process (definitions, some properties, Donsker theorem, Kolmogorov-Smirnov test) and Ito calculus (Ito stochastic integral, Ito processes and stochastic differential, Ito formula, stochastic differential equations, Ornstein-Uhlenbeck process, Geometric Brownian motion, Feynman-Kac representation formula).

Prerequisites: Matrix Algebra + Foundations of Probability and Statistical Inference
**Hours:** 30
**Professors/Lecturers:** Irene Crimaldi (IMT Lucca)
**Specializing course for:** Economics, Networks and Business Analytics
**Also available for:** Computer Science and System Engineering

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## Strategies and Business Behavior

**Abstract:**

Teaching contents:

1. Market and strategy
2. Business and behavioral strategy
3. A new dimension for space and time in organization and strategy
4. Optimization and decision modeling on strategic decision making
5. Skills, competence and a new role of the human being
6. Business behavior as managerial evidence
7. Business plan: the role and function
8. Big data & decision-making process
9. Big data, machine learning for Management science
10. A multidisciplinary approach to business behavior

Business and Behavioral Strategy offers an essential view of the corporate decision-making

involved in orchestrating the strategy process - the key ideas, concepts, and tools - and answer to questions like why firms adopt different strategies and structures, why heterogeneity persists. The course will describe the decision-making in competitive markets at the business unit level in which many key strategic choices and actions are formulated and undertaken. The essential "tool-kit" that combines a broad understanding of competitive strategy analysis and the decision-making will be taught in a journey through the frameworks of the analytical and behavioral processes.

The course is divided into three parts.
1. The first focuses on the strategy problem. This part of the course starts by proposing vocabulary and models, which help understand how corporate behaviors influence corporate strategy and sustain (or tackle) competitive advantage depending on the size of the company.
Topic points:
- context and principles of strategic management;
- organizational behavior in entrepreneurial and family firms.

2. The second part focuses on how turning the data and judgment into a decision. It tackles the question of how an executive and business unit can locate opportunities to achieve sustained competitive advantage thanks to the contribution of management science framed within the strategy formulation analytical process.
Topic points:
- optimization and decision modeling;
- problem structuring;
- strategic decision making.

3. The third part focuses on how competency and behavior affect the development and execution of a successful strategy. This part of the course concludes with a discussion of why good analysis
in the hands of managers who have good judgment won't naturally yield good decisions. Strategic leaders should be not only competent to read market forces but also competent "practitioner psychologists," and what developing such competencies entails. This discussion will help surface the biases to which the decision process under review is particularly prone.
Topic points:
- cognitive biases, organization, entrepreneurial and family firm survival;
- the psychology of strategy, rational heuristics and cognitive biases.

Business case

Students will learn how to evaluate strategies, as well as how to locate sources of potential competitive advantage from a perspective that, for the purpose of this course, encompasses the internal and dynamic fit of a strategy. They will also learn how to identify organizational barriers and corporate behaviors that sustain or challenge the development and execution of strategies, and the competitive advantage of a company

**Hours:** 20
**Professors/Lecturers:** Nicola Lattanzi (IMT Lucca)
**Available for:** Computer Science and System Engineering; Economics, Networks and Business Analytics